Physical Activity, Nutrition and Health

Dephne Rowland

Physical Activity, Nutrition and Health

Physical Activity, Nutrition and Health

Editor: Dephne Rowland

Academic Pages,
5 Penn Plaza,
19th Floor,
New York, NY 10001, USA

ISBN: 978-1-9789-6170-8

The publisher's policy is to use permanent paper from mills that operate a sustainable forestry policy. Furthermore, the publisher ensures that the text paper and cover boards used have met acceptable environmental accreditation standards.

Cataloging-in-Publication Data

Physical activity, nutrition and health / edited by Dephne Rowland.
p. cm.
Includes bibliographical references and index.
ISBN 978-1-9789-6170-8
1. Exercise. 2. Physical education and training. 3. Nutrition. 4. Health.
I. Rowland, Dephne.

GV461 .P49 2021
612.044--dc23

Table of Contents

Preface ..... **IX**

Chapter 1 **Prevalence, trajectories, and determinants of television viewing time in an ethnically diverse sample of young children from the UK** **1**
Sally E. Barber, Brian Kelly, Paul J. Collings, Liana Nagy, Tracey Bywater and John Wright

Chapter 2 **Predictors of screen viewing time in young Singaporean children: the GUSTO cohort** **12**
Jonathan Y. Bernard, Natarajan Padmapriya, Bozhi Chen, Shirong Cai, Kok Hian Tan, Fabian Yap, Lynette Shek, Yap-Seng Chong, Peter D. Gluckman, Keith M. Godfrey, Michael S. Kramer, Seang Mei Saw and Falk Müller-Riemenschneider

Chapter 3 **Frequency of eating home cooked meals and potential benefits for diet and health: cross-sectional analysis of a population-based cohort study** **22**
Susanna Mills, Heather Brown, Wendy Wrieden, Martin White and Jean Adams

Chapter 4 **Children's everyday exposure to food marketing: an objective analysis using wearable cameras** **33**
L. N. Signal, J. Stanley, M. Smith, M. B. Barr, T. J. Chambers, J. Zhou, A. Duane, C. Gurrin, A. F. Smeaton, C. McKerchar, A. L. Pearson, J. Hoek, G. L. S. Jenkin and C. Ni Mhurchu

Chapter 5 **The development and validation of measures to assess cooking skills and food skills** **44**
Fiona Lavelle, Laura McGowan, Lynsey Hollywood, Dawn Surgenor, Amanda McCloat, Elaine Mooney, Martin Caraher, Monique Raats and Moira Dean

Chapter 6 **Perceived fussy eating in Australian children at 14 months of age and subsequent use of maternal feeding practices at 2 years** **57**
Rebecca Byrne, Elena Jansen and Lynne Daniels

Chapter 7 **The international food unit: a new measurement aid that can improve portion size estimation** **65**
T. Bucher, M. Weltert, M.E. Rollo, S.P. Smith, W. Jia, C.E. Collins and M. Sun

Chapter 8 **Item response modeling: a psychometric assessment of the children's fruit, vegetable, water, and physical activity self-efficacy scales among Chinese children** **76**
Jing-Jing Wang, Tzu-An Chen, Tom Baranowski and Patrick W.C. Lau

Chapter 9 **Appetitive traits associated with higher and lower body mass index: evaluating the validity of the adult eating behaviour questionnaire in an Australian sample** **90**
Kimberley M. Mallan, Alison Fildes, Xochitl de la Piedad Garcia, Jayne Drzezdzon, Matthew Sampson and Clare Llewellyn

Chapter 10 **Relationship between mean daily energy intake and frequency of consumption of out-of-home meals in the UK National Diet and Nutrition Survey....97**
Louis Goffe, Stephen Rushton, Martin White, Ashley Adamson and Jean Adams

Chapter 11 **Externalizing behavior is prospectively associated with intake of added sugar and sodium among low socioeconomic status preschoolers in a sex-specific manner....108**
Erica C. Jansen, Alison L. Miller, Julie C. Lumeng, Niko Kaciroti, Holly E. Brophy Herb, Mildred A. Horodynski, Dawn Contreras and Karen E. Peterson

Chapter 12 **Food parenting and child snacking....118**
Rachel E. Blaine, Alexandria Kachurak, Kirsten K. Davison, Rachel Klabunde and Jennifer Orlet Fisher

Chapter 13 **The impact of an innovative web-based school nutrition intervention to increase fruits and vegetables and milk and alternatives in adolescents: a clustered randomized trial....140**
Karine Chamberland, Marina Sanchez, Shirin Panahi, Véronique Provencher, Jocelyn Gagnon and Vicky Drapeau

Chapter 14 **Child and parent predictors of picky eating from preschool to school age....151**
Silje Steinsbekk, Arielle Bonneville-Roussy, Alison Fildes, Clare H. Llewellyn and Lars Wichstrøm

Chapter 15 **Effects of a physical activity and nutrition program in retirement villages: a cluster randomised controlled trial....159**
Jonine Jancey, Anne-Marie Holt, Andy Lee, Deborah Kerr, Suzanne Robinson, Li Tang, A.S. Anderson, Andrew P. Hills and Peter Howat

Chapter 16 **Disparities in dietary intake and physical activity patterns across the urbanization divide in the Peruvian Andes....169**
Morgan L. McCloskey, Carla E. Tarazona-Meza, Jessica C. Jones-Smith, Catherine H. Miele, Robert H. Gilman, Antonio Bernabe-Ortiz, J. Jaime Miranda and William Checkley

Chapter 17 **Determinants of diet and physical activity (DEDIPAC): a summary of findings....177**
Johannes Brug, Hidde P. van der Ploeg, Anne Loyen, Wolfgang Ahrens, Oliver Allais, Lene F. Andersen, Greet Cardon, Laura Capranica, Sebastien Chastin, Ilse De Bourdeaudhuij, Marieke De Craemer, Alan Donnelly, Ulf Ekelund, Paul Finglas, Marion Flechtner-Mors, Antje Hebestreit, Thomas Kubiak, Massimo Lanza, Nanna Lien, Ciaran MacDonncha, Mario Mazzocchi, Pablo Monsivais, Marie Murphy, Mary Nicolaou, Ute Nöthlings, Donal J. O'Gorman, Britta Renner, Gun Roos, Matthijs van den Berg, Matthias B. Schulze, Jürgen M. Steinacker, Karien Stronks, Dorothee Volkert and Jeroen Lakerveld

Permissions

List of Contributors

Index

Preface

The purpose of the book is to provide a glimpse into the dynamics and to present opinions and studies of some of the scientists engaged in the development of new ideas in the field from very different standpoints. This book will prove useful to students and researchers owing to its high content quality.

Nutrition is the study of nutrients in food and their influence in maintenance, growth and reproduction of an organism. It also studies the role of nutrients in disease prevention. A balanced diet replete with all essential nutrients is necessary for avoiding various deficiency syndromes and prevention of health-threatening conditions like obesity, cardiovascular diseases, diabetes, etc. This book is compiled to provide an in-depth knowledge of the different perspectives and standards of effective nutrition plans, physical activity and their effects on health. This book presents researches and studies performed by experts across the globe. Nutritionists, doctors, physical instructors and interested students will find this book to be a valuable source of information for furthering their knowledge of this field.

At the end, I would like to appreciate all the efforts made by the authors in completing their chapters professionally. I express my deepest gratitude to all of them for contributing to this book by sharing their valuable works. A special thanks to my family and friends for their constant support in this journey.

Editor

Prevalence, trajectories, and determinants of television viewing time in an ethnically diverse sample of young children from the UK

Sally E. Barber[1*], Brian Kelly[1], Paul J. Collings[1], Liana Nagy[1,2], Tracey Bywater[3] and John Wright[1]

Abstract

Background: Excessive screen viewing in early childhood is associated with poor physical and psycho-social health and poor cognitive development. This study aimed to understand the prevalence, trajectory and determinants of television viewing time in early childhood to inform intervention development.

Methods: In this prospective longitudinal study, mothers of 1558 children (589 white British, 757 Pakistani heritage, 212 other ethnicities) completed questionnaires when their children were approximately 6, 12, 18, 24 and 36 months old. Mothers answered questions about their own and their child's TV-time. TV-time trajectories were estimated by linear longitudinal multilevel modeling, potential determinants were considered in models.

Results: The modelled trajectory estimated that 75% of children aged 12 months exceeded guidelines of zero screen-time. At 12 months of age an accelerated increase in TV-time was observed (<1 h/day at 14 months, >2 h/day by 30 months old). For every hour of mothers' TV-time and every hour the TV was on in the home, children's TV-time was 8 min and 1 min higher respectively at 6 months old ($P < 0.05$), and 15 min and 3 min higher respectively at 36 months old ($P < 0.05$). Children whose mothers did not agree that it was important their child did not watch too much TV, had 17 min more TV-time than their counterparts ($P < 0.05$). Children of first time mothers had 6 min more TV-time ($P < 0.05$). At 12 months of age, children of mothers experiencing stress watched 8 min more TV ($P < 0.05$). By 36 months, children of Pakistani heritage mothers had 22 min more TV-time than those of white British mothers ($P < 0.05$), and an additional 35 min of TV-time if their mother was not born in the UK ($P < 0.05$).

Conclusions: High levels of TV-time were prevalent. Intervention developers should consider targeting interventions before 12 months of age. Modifiable determinants included mothers' own TV-time, the time the television is on in the home and mothers' attitude towards child TV-time. These behaviours may be key components to address in interventions for parents. Mothers experiencing stress, first time mothers, and Pakistani heritage mothers (particularly those born outside of the UK), may be priority groups for intervention.

Keywords: Sedentary behaviour, Screen-time, Television, Early childhood, Ethnic minority, Deprivation, Prospective longitudinal

* Correspondence: sally.barber@bthft.nhs.uk
[1]Bradford Institute for Health Research, Bradford Royal Infirmary, Duckworth Lane, Bradford BD9 6RJ, UK
Full list of author information is available at the end of the article

Background

The amount of screen time (i.e. using a device such as a TV, computer, games console, mobile phone or tablet) that children engage in is associated with a number of adverse health and educational outcomes including; higher risk of obesity [1–4], poor metabolic profile [5], poor fitness later in life [6], poor cognitive development (e.g. poor short term memory skills, poor reading, language and mathematics development) [7] and adverse psychosocial health [8]. Currently Canada and Australia recommend no screen time exposure in children under 2 years old and less than an hour a day for 2–5 year olds [9, 10]. In the US it is recommended that digital media use (except video-chatting) is avoided in children younger than 18 to 24 months, screen time of children aged 2–5 year old should be limited to 1 h/day which is high quality, co-viewed with, and re-taught by parents [11].

A recent systematic review [12] reported that the proportion of children aged under two years old meeting zero screen time recommendations ranged from 2.3% in a study from Thailand to 83% in a study from the US. The review concluded that by two years of age the majority of children were already engaging in high levels of screen time and were exceeding recommendations [12].

Children from ethnic minority groups (including South Asian children) and children with low socioeconomic status (SES) have a greater risk of obesity than their Caucasian or high SES counterparts [13]. Young children from ethnic minority groups (specifically Black and Hispanic children in the US) are consistently reported to have greater screen exposure (i.e. the amount of time the child was in the room with a screen on) than Caucasian children [14]. Outside the US, differences in screen time between young ethnic minority and ethnic majority children have not been investigated. In the US and the UK, older children and adolescents with a lower SES are consistently reported to engage in higher levels of screen time [15–17]. However, the association between indicators of SES and screen time in early childhood is inconsistent between studies [14]. Given that TV-time is associated with a small but significant increase in BMI in early childhood [4], reducing TV-time for ethnic minority children, and children from low SES families, could be targeted by interventions to address the inequalities seen in obesity levels.

Screen viewing behaviour is relatively stable over time, and tracks moderately through childhood and adolescence [18]. However, in early childhood the behaviour may be less stable and more malleable, thus early intervention may be most beneficial [19]. For young children, watching TV is the screen behaviour that contributes the most to daily screen time [20, 21]. Ascertaining determinants of TV-time in young children will help to identify at risk groups for intervention and inform the design of behaviour change interventions to reduce TV-time during early childhood. A recent systematic review found associations between screen time (mostly TV-time) and the following modifiable variables in children aged up to 3 years old: Child's BMI (4/4 studies), mother's screen time (3/3 studies) and mother's distress/depression (5/8 studies) [14]. Cognitive stimulation in the home environment was negatively associated with screen time (2/3 studies). However, none of these studies were conducted in the UK, or included children of South Asian ethnicity. The current study aimed to describe the prevalence, trajectories, and determinants of TV-time in an ethnically diverse (predominantly white British and Pakistani ethnicity) sample of children from 6 months through to 36 months old, living in the City of Bradford, West Yorkshire, UK.

Methods

Participants and setting

Born in Bradford (BiB) is a longitudinal multi-ethnic birth cohort study [22]. The study recruited pregnant women between 2007 and 2010 in Bradford, a city with high levels of socio-economic deprivation and ethnic diversity. Pregnant women were approached to take part whilst attending a routine hospital appointment at 26–28 weeks gestation. The full BiB cohort recruited 12,453 women during 13,776 pregnancies, at which time a baseline questionnaire was completed by interview with a trained study administrator. Women who were pregnant between August 2008 and March 2009 and who agreed to take part in the full cohort were also invited to take part in a sub-study named BiB1000 (n = 1735) at the same time. This study involved detailed follow-up appointments conducted in the home or clinic when children were aged approximately 6, 12, 18, 24, and 36 months [23]. A full description of the methods and data collected in BiB1000 is presented in the published protocol [23]. Informed consent was acquired prior to data collection and ethical approval for all aspects of the research was granted by Bradford Research Ethics Committee (Ref 07/H1302/112).

Of all children recruited to BiB1000, 1558 (90%) had at least one follow-up questionnaire completed; these children were included in the current study. Over half of the included children (n = 812) had questionnaires completed at all five follow-up time points, whereas 7% (n = 112) completed only one follow-up questionnaire. Four children died and 54 withdrew from the study, before the 36-month-old visit. Data for these children were excluded from the analysis. Eighty-two per cent of the sample completed the 6 and 12 and 18 month old visits; the children's mean age (standard deviation) at these time points were 6.7 (0.74) months, 12.7 (0.99) and 18.7 (0.98) respectively. At the 24 months and 36 month old

visits 79% completed questionnaires; the children's mean age at these visits were 25.3 (0.95) months and 37.0 (0.85) months respectively. Data were collected between 2008 and 2013.

TV-time, behaviours and attitudes

Information about child and mothers' daily TV-time (time spent watching TV or DVDs) was collected at each follow-up visit (when children were 6, 12, 18, and 24, and 36 months old) using questions from the EPIC Norfolk questionnaire [24] which has been validated for use in adults [24]. At the 24-month visit, mothers were additionally asked to report how long (in hours and minutes) the television was on in the home, on an average week and weekend day; it was stressed that this included time when the TV was on but not being watched. They were asked whether they think it is important their child does not watch too much TV (response options were agree/not agree), and how often they limited their child's TV/DVD viewing (questions were from the validated Southampton Women's Survey Questionnaire [25], (response options collapsed to: never or rarely/sometimes or often).

Socio-demographic variables

Mother's self-defined ethnicity at baseline was used to define the ethnicity of her offspring according to the ethnic group classification system used in the 2001 UK Census [26]; children were categorised as white British, Pakistani or Other (a group that comprised all other ethnic groups that were too small to analyse separately). Mothers' country of birth was collected from the baseline questionnaire (UK, Pakistan, Other) and mothers' age at delivery, child sex, and parity, were obtained from the hospital maternity system. Mothers' height and weight were recorded during pregnancy at registration in the maternity unit (around 10 weeks gestation) and extracted from hospital maternity systems; body mass index (BMI) was calculated. Child's length and weight at the 24-month-old visit was measured and BMI z-scores were calculated.

Mothers' SES was measured using a number of variables: self-reported financial situation, education level, housing tenure and neighbourhood material deprivation (using Index of Multiple Deprivation 2010; [27]). While it is the case that the participants were far more likely to be in a materially deprived neighbourhood (as shown in Table 1, only 1.5% were in the least deprived quintile score) the models used this deprivation score as a dichotomous variable. In the models the effect of being in the most deprived quintile (68%) was contrasted with not being in the most deprived quintile (32%), in order to maximise the variation – the most materially deprived neighbourhoods compared to the rest. Mothers' non-specific psychological stress was measured using a validated 6-item questionnaire [28] administered at the 12- and 24-month-old visits. Mothers who scored four or more (out of a possible score of 24) were considered to be experiencing non-specific psychological stress [28]. This score has been found to discriminate between Diagnostic and Statistical Manual of Mental Disorders edition 4 (DSM-IV) cases and non-cases [28].

Statistical analysis

Individual TV-time trajectories from 6 to 36 months of age were estimated using linear longitudinal multilevel models; with measurement visits at level one nested within children at level two. These models allow for the simultaneous measurement of within and between person differences, in conjunction with a number of time constant or time varying potential determinants. Time invariant (child level) and time variant (occasion level) measures can be incorporated into the model to assess their contribution to trajectories of child TV viewing. Multilevel models are able to accommodate data missing at random and unbalanced longitudinal designs, leading to more efficient estimates compared to methods that exclude cases to obtain balanced data [29]. The analysis strategy was to begin with a simple model, including only the age of the child to determine the average trajectory of TV-time. This model (model 1) contains polynomial terms for child age (age squared and age cubed) to allow for non-linear trajectories of child TV viewing. The second stage in the analysis then considers a range of covariates in isolation and then together in a multivariable model in order to determine whether socio-demographic, behavioural or attitudinal factors were associated with differences in the trajectories of child TV viewing. Time variant outcome and the determinants child age and mother TV-time are introduced into the model at the occasion level; all other determinants were time invariant or measured once and so were introduced into the model at the individual level. Results from these models are reported as model 2 and model 3 respectively. Covariates that are significant, and improve the model fit, are retained in the final model (model 4), and a number of interactions between significant covariates and child age were included. These interaction terms are used to determine whether the effect of socio-demographic, behavioural or attitudinal factors on child TV viewing change as the child becomes older. Analysis was carried out using Stata13. The predicted trajectories of child TV-time are given for particular groups of children, presented graphically in order to aid the interpretation of the model results. Trajectories of child TV-time are presented based on mother's ethnicity and country of birth, and also for different scenarios based on mother's attitude to TV viewing and the hours a TV is on in the house.

Table 1 Participant characteristics

	All	White British	Pakistani	Other
	n = 1558	*n* = 589	*n* = 757	*n* = 212
Mother				
Age at delivery: mean (Std. Dev.) (missing data, *n* = 15)	27.5 (5.74)	26.9 (6.11)	27.7 (5.15)	28.3 (5.78)
Country of Birth: n (%) (missing data, *n* = 0)				
UK	970 (62.3)	581 (98.6)	311 (41.1)	78 (36.8)
Pakistan	441 (28.3)	0	438 (57.9)	3 (1.4)
Other	147 (9.4)	8 (1.4)	8 (1.1)	131 (61.8)
BMI at registration (~10 weeks gestation): mean (Std. Dev.) (missing data, *n* = 60)	25.9 (5.74)	26.9 (6.18)	25.2 (5.41)	25.5 (5.22)
Neighbourhood material deprivation (IMD 2010): n (%) (missing data, *n* = 0)				
Quintile 1: Most deprived	1060 (68.0)	311 (52.8)	604 (79.8)	145 (68.4)
Quintile 2	286 (18.4)	133 (22.6)	111 (14.7)	42 (19.8)
Quintile 3	154 (9.9)	95 (16.1)	37 (4.9)	22 (10.4)
Quintile 4	34 (2.2)	30 (5.1)	2 (0.3)	2 (0.9)
Quintile 5: Least deprived	24 (1.5)	20 (3.4)	3 (0.4)	1 (0.5)
IMD Score: Mean (Std. Dev.)	42.9 (17.5)	37.2 (19.1)	46.7 (14.8)	45.2 (17.8)
Self-reported financial situation: n (%) (missing data, *n* = 8)				
Comfortable	409 (26.4)	137 (23.3)	209 (27.8)	63 (29.9)
All-right	648 (41.8)	254 (43.3)	304 (40.4)	90 (42.6)
Difficult	493 (31.8)	195 (33.3)	240 (31.9)	58 (27.5)
Mother non-specific psychological stress score when child was 12 months old (higher = greater stress; range 0–24) (missing data *n* = 285)	3.28 (3.89)	3.38 (3.90)	3.20 (3.89)	3.26 (3.82)
Percentage score 4 or more	35.6%	36.2%	35.1%	35.3%
Mother TV attitude when child was 24 months old: mother does not agree that it is important their child does not watch too much TV (missing data, *n* = 10)	23.3%	21.3%	25.2%	21.5%
Hours TV is on in house: Mean (Std. Dev.) (missing data, *n* = 364)	7.8 (4.0)	7.3 (3.9)	8.5 (4.0)	7.1 (4.1)
Whether mother restricts child TV viewing: n (%) (missing data, *n* = 377)				
Never	506 (42.8%)	147 (33.6%)	306 (51.8%)	53 (34.6%)
Occasionally	370 (31.3%)	145 (33.2%)	172 (29.1%)	53 (34.6%)
Everyday	305 (25.8%)	145 (33.2%)	113 (19.1%)	47 (30.7%)
No previous children (missing data, *n* = 35)	39.0%	47.3%	31.3%	43.5%
Child				
BMI 24 month: mean (Std. Dev.) (missing data, *n* = 10)	16.6 (1.22)	16.8 (1.05)	16.4 (1.28)	16.6 (1.34)
BMI 24 months Z-score: mean (Std. Dev.)	0.00 (1.00)	0.04 (0.55)	−0.05 (1.07)	0.07 (1.64)
Sex: n(%) (missing data, *n* = 0)				
Male	758 (48.6)	283 (48.0)	367 (48.5)	108 (50.9)
Female	800 (51.4)	306 (52.0)	390 (51.5)	104 (49.1)

BMI Body Mass Index, *IMD* Index of Multiple Deprivation

Results

Sample characteristics

Forty-nine per cent of mothers in the sample were of Pakistani ethnicity, of these 58% were born in Pakistan and 41% in the UK. Thirty-eight per cent of mothers were white British and nearly all were born in the UK. Table 1 describes the characteristics of the sample. Sixty-eight per cent of participants lived in the most materially deprived neighbourhoods of the UK (1st quintile in IMD 2010) and one third reported their financial situation to be difficult; only 1.5% lived in the least materially deprived neighbourhoods. On average, mothers were 27.5 ± 5.7 years old when their baby was born, and for 39% of mothers this was their first child. Just over a third of mothers were classified as experiencing psychological stress when their child was 12 months old. On

average mothers were overweight (BMI = 25.9) and children (at 24 months old) had an average BMI of 16.6 (BMI z-score: 0.0 ± 1.0). Attrition in the study was minimal; however drop out was higher in mothers with lower than A-level education (72% of the sample at the beginning of the study and 59% by 36 months) and in mothers who reported having a difficult financial situation (41% of the sample at the beginning of the study and to 33% by 36 months).

TV-time prevalence and trajectory

Model 1 (Table 2) represents the average trajectory of child TV-time, which is found to increase with age in a non-linear way. The estimated average trajectory is illustrated in Fig. 1.

On average, children's estimated TV-time was less than one hour a day up to the age of 14 months 0.92 h (95% CI: 0.89, 0.95) (55 min) per day at 6 months old and 0.94 h (95%CI: 0.91, 0.97) (56 min per day at 12 months old). This was followed by a period of accelerated increase 1.28 h (95%CI: 1.25, 1.31) (77 min) per day at 18 months old, 1.71 h (95%CI: 1.67, 1.75) (103 min) per day at 24 months old), where TV-time rose to above two hours per day by 30 months (Fig. 1). Between 30 and 36 months, the rate of increase in TV-time was slower, increasing by approximately 15 min during this six-month period to 2.08 h (95%CI: 2.04, 2.12) (125 min) per day at 36 months old).

By 18 months old, it was estimated that only 16% of children met guidelines of zero screen viewing and by 36 months of age it was estimated that 33% met the guideline of <1 h screen viewing/day [11–13] (Fig. 2).

Determinants of child TV-time

Mothers' TV-time, the time the TV was on in the home, and mothers' attitude towards child TV-time, all significantly predicted child's TV-time when considered in univariate models (Table 2, model 2).

The effect sizes reduced when considered alongside other variables in multivariable models (Table 2, models 3), but they remain statistically significant. There was no association between how much mothers limited their child's TV-time and the time the child spent in TV-time, this is therefore not reported in the models.

Model 4, which includes significant variables and interactions with age, predicted that there were already differences in child's TV-time, associated with mothers' TV-time, at the age of 6 months; and this association became stronger as the child grew older. For every extra hour that the mother watched TV, child TV-time was higher by 0.14 h (95%CI: 0.10–0.17) hours (8 min) at age 6 months and 0.26 h (95%CI: 0.30–0.37), (15 min) by age 36 months. For every hour the TV was on in the house children's TV-time was 0.02 h (95%CI: 0.01–0.03) (1.2 min) higher at 6 months old, and 0.05 h (95%CI: 0.03–0.06) (3 min) higher at 36 months old.

Mothers' attitudes to their child watching TV was associated with child TV-time. On average, children of mothers who did not agree that it was important that their child does not watch too much TV (23%), watched 0.28 h (95%CI: 0.17–0.39) hours (17 min) more TV-time daily compared to children of mothers who thought it was important that their child does not watch too much TV. There was no interaction between mothers' attitudes and child age, and the effect was constant over the trajectory.

At 12 months old, children whose mothers' had psychological stress had 0.13 h (95%CI:0.03–0.23), (8 min) more TV-time than children of mothers' who did not have psychological stress (Table 2, model 4). There was no statistically significant association between mothers' psychological stress and TV-time when children were 24 months old.

The modifiable factors that had a significant effect on the trajectories of child screen time were mother's behaviour, attitude and stress. Figure 3 illustrates the combined effect of these variables by comparing two situations where mothers' responses on all these variables are either not supportive (Scenario A, 'worst case' scenario) or supportive (Scenario B 'best case scenario) of child's TV-time. For comparative purposes the overall average trajectory of child TV-time is also shown in Fig. 3.

When ethnicity was considered in isolation in model 2, and with other covariates in model 3, it was found that the children of Pakistani ethnicity mothers had around 0.22 h (95%CI: 0.07–0.37) (13 min) more TV-time a day than children of white British mothers. The effect size remained similar in both models, such that ethnicity had an independent, separate effect after controlling for mothers' behaviour and attitudes (and all other covariates).

There was a similar relationship between country of birth and child TV-time, although the effect size decreased more when considered in a multivariable model. Model 3 suggested that at 6 months of age, children of mothers born in Pakistan had around 0.15 (95%CI: 0.01–0.29) (9 min) more TV-time a day than children of mothers born in the UK.

In Model 4 there was an interaction between both ethnicity and country of birth and the age of the child. This is illustrated in Fig. 3. Once child TV-time began to increase, at around 12 months, the rate of increase was greater for children of Pakistani mothers born in Pakistan, than for children of white British and Pakistani mothers born in the UK. By the age of 36 months, children of Pakistani heritage mothers who were born in the UK had 0.4 h (22 min) extra TV-time compared to

Table 2 Summary model results

	Model 1	Model 2	Model 3	Model 4
	Estimate (95% C.I.)	Estimate (95% C.I.)	Estimate (95% C.I.)	Estimate (95% C.I.)
Constant	0.921 (0.848, 0.995)		−0.578 (−0.862, −0.294)	0.099 (−0.085, 0.283)
Fixed Effects				
Age	−0.026 (−0.048, −0.004)		−0.015 (−0.042, 0.012)	−0.054 (−0.081, −-0.027)
Age^2	0.006 (0.004, 0.008)		0.006 (0.004, 0.008)	0.006 (0.004, −0.008)
Age^3	−0.00012 (−0.00016, −0.00008)		−0.00011 (−0.00015, −0.00008)	−0.00011 (−0.00015, −0.00008)
Hours TV on in the home		0.067 (0.055, 0.079)	0.041 (0.027, 0.055)	0.020 (0.004, 0.036)
Mother TV-time		0.205 (0.187, 0.223)	0.192 (0.168, 0.216)	0.135 (0.104, 0.167)
Mother TV attitude [a]		0.426 (0.314, 0.538)	0.249 (0.131, 0.367)	0.277 (0.167, 0.387)
Ethnicity (ref: White British)				
Pakistani		0.224 (0.129, 0.319)	0.219 (0.072, 0.366)	0.103 (−0.060, 0.266)
Other		0.155 (0.015, −0.295)	0.069 (−0.154, 0.292)	−0.007 (−0.262, 0.248)
Country Birth (ref: UK)				
Pakistan		0.247 (0.147, 0.346)	0.149 (0.008, 0.290)	−0.025 (−0.194, 0.144)
Other		0.148 (−0.006, 0.302)	0.170 (−0.083, 0.423)	0.137 (−0.153, 0.427)
In most deprived IMD quintile		0.166 (0.071, 0.260)	0.053 (−0.065, 0.171)	
No previous children		0.148 (0.056, 0.240)	0.072 (−0.042, 0.186)	0.098 (0.002, 0.194)
Child BMI at 24 months (z score)		−0.062 (−0.107, −0.018)	0.008 (−0.043, 0.059)	
Mother psychological stress (12 months) scored 4 or more.		0.06 (0.011, 0.109)	0.148 (0.042, 0.254)	0.133 (0.035, 0.231)
Interactions				
Age*Mother TV-time				0.004 (0.002, 0.006)
Age*TV on in the home				0.001 (0.001, 0.001)
Age*Pakistani ethnicity				0.012 (0.004, 0.020)
Age* Other ethnicity				0.005 (−0.009, 0.019)
Age*Pakistan born				0.014 (0.004, 0.024)
Age* Other non UK born				0.009 (−0.007, 0.026)
Random effects				
$U_{j(1)}$ Random slope	0.385	0.254	0.254	0.228
$U_{j(2)}$ Random intercept	0.001	0.0004	0.0004	0.0005
e_{ij} Between occasion	1.11	1.047	1.047	1.041
Total variance	1.496	1.3014	1.3014	1.269
Variance between children	26%	20%	20%	18%
Variance within children	74%	80%	80%	82%

Model 1: average trajectories of child TV viewing by age with a random effect for age along with age squared and age cubed to allow the modelling of non-linear trends
Model 2: reporting the coefficients from a series of univariate models considering each covariate independently
Model 3: as model 1 but with the inclusion of all covariates together in a multivariate model
Model 4: final model derived, as model 1 with all significant covariates and interaction terms in a multivariate model. This is the model used to estimate predicted child TV viewing
Variance between children is the percentage of variance in the outcome attributable to differences between children; variance within children is the percentage of variance attributable to change over time within children
All covariates are time invariant apart from mother TV time which was measured at each survey wave
BMI Body Mass Index, *IMD* Index of Multiple Deprivation
[a]Mother TV attitude: not agree that it is important that child not watch too much TV

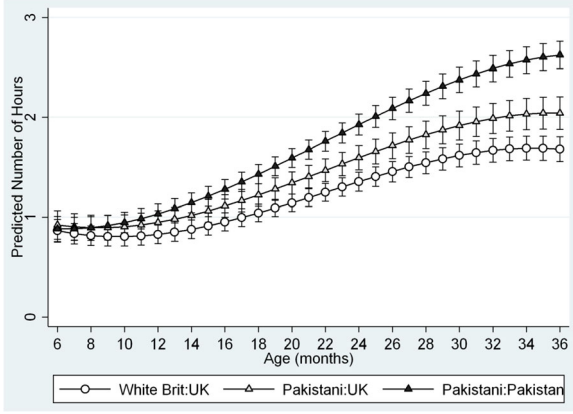

Fig. 1 Estimated child TV-time by age, mother ethnicity, and mother's country of birth

children of white British mothers; and children of Pakistani heritage mothers who were born in Pakistan, had 1.0 h (57 min) extra TV-time compared to children of white British mothers.

First-born children had more TV-time per day compared to those who were not (model 4, 0.1 ± 0.05 h; 6 min). A number of other variables were considered; these were not significant and so are not reported. These were mothers' education, household tenure, mother's BMI, child BMI, mother's general health and child's general health. Mother's age at delivery was significant when considered alone in a univariate model; younger age being associated with increased child TV-time. However, once considered alongside other variables in Model 3, mother's age was no longer significant (data not included in Table 2). Measures of self-reported financial situation and neighbourhood deprivation were significant when considered in isolation but not when considered in multivariable models (data not included in Table 2).

Discussion

This prospective longitudinal study aimed to describe the prevalence, trajectory and determinants of TV-time in an ethnically diverse (predominantly white British and Pakistani) sample of children from the UK as they aged from 6- to 36-months-old. The study found that high levels of TV-time were common with an average estimated daily TV-time of 55 min at 6 months increasing to 124 min at 36 months. Modifiable determinants of young children's screen time included mothers' own TV-time, the time the television is on in the home and mothers' attitude towards child TV-time. Mothers experiencing stress, first time mothers, and Pakistani heritage mothers, particularly those born outside of the UK, had children who had greater TV-time than their counterparts.

The high levels of TV-time reported in this study fall within the range reported in a systematic review of studies with children <2 years old from different countries (range: 36 to 197 min per day) [12]. In the same systematic review, [12] the proportion of children (aged <2 years old) meeting international recommendations (from Canada, Australia and the US [9–11]) of zero screen time was reported; results from the current study (27% at 6 months old, 16% at 18 months old) were similar to results from 9 out of 15 studies included in the review. By the age of 36 months, average TV-time of children in the current study was >2 h per day, which is higher than international guidelines (<1 h a day) [9–11]. Currently in the UK there are no specific guidelines for screen time, with guidance only stating that children under the age of five should minimise the amount of time spent being sedentary. Regardless, the amount of TV children in the study were watching is alarming given that the early years are critical for the development of health lifestyle behaviours [30]. The TV-time trajectory model showed that TV-time increased with age and a period of accelerated increase was observed between 12 and 30 months.

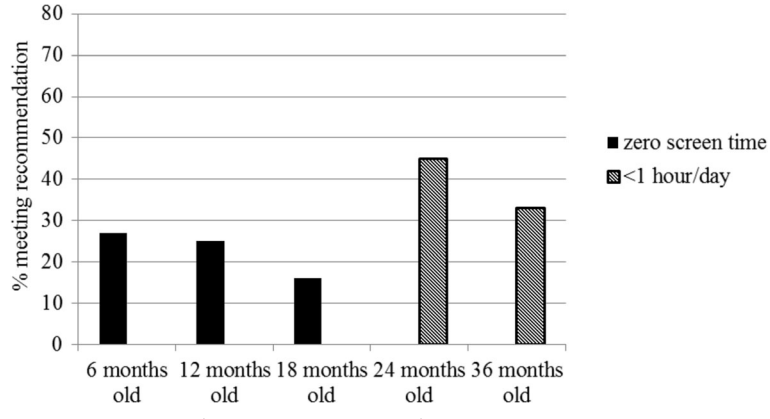

Fig. 2 Percentage of children meeting international screen time recommendations

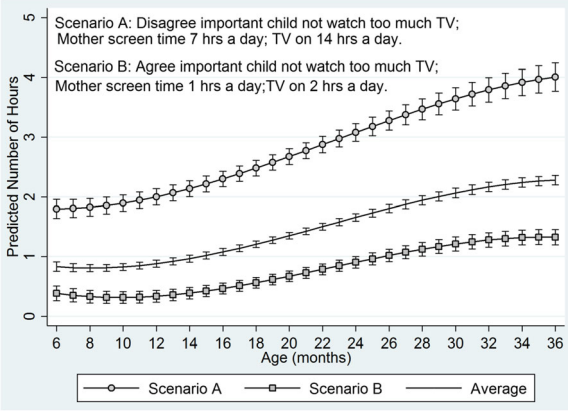

Fig. 3 Average TV-time trajectory and combined effect of mother's behaviour, attitude and stress on the trajectory

This finding suggests that to maximise the effectiveness of early interventions, they should begin before the observed acceleration in TV-time at 12 months old.

In the current study the combined effect of modifiable parental influences (attitude, mother's time spent watching TV, time TV on in the home) on child TV-time was predicted according to a 'worst case' scenario (scenario A) and a 'best case' scenario (scenario B). In the 'worst case' scenario children had almost 2 h of TV-time up to the age of 12 months old compared to less than half an hour a day in the 'best case' scenario. The rate of acceleration in TV-time after 12 months old was much greater in the 'worst case' compared to 'best case' and by age 36 months children in the 'worst case' had 4 h of TV-time a day (four times higher than international recommendations) compared to just over 1 h a day in the 'best case'. Although children in the 'best case' scenario were still exceeding international recommendations the behaviour and attitudes that make up the 'best case' scenario could be viewed as useful and realistic targets to aim for in interventions to reduce TV-time. As reported in the findings, the only parental influence found not to be associated with the outcome of child TV-time was whether the mother reported restricting TV viewing of the child. There may be a number of reasons why this was not associated with the outcome, perhaps this measure is not accurately capturing maternal behaviour in this area.

Previous literature has reported inconsistent associations between young children's screen viewing time and mother's depressive symptoms [14]. In the present study we found that mothers psychological stress when the child was 12 months old significantly and independently predicted child TV-time, with around 8 min more viewing a day for those children of mothers with higher levels of psychological stress, but this was not the case when children were older (24 months). These findings may go some way towards explaining the variability in the findings of previous studies and underline the important finding that up to 12 months old is a key period for intervention. The findings suggest that mothers who are suffering from psychological stress postnatally should be a focus for intervention.

Previous studies have been inconsistent in their findings regarding the association between indicators of SES and screen viewing in early childhood [14]. This study found that, after controlling for other factors, there was no significant effect of neighbourhood deprivation or mothers' self-reported financial situation upon TV-time when children are very young. However, older children and adolescents with a lower SES have consistently been reported to engage in higher levels of screen time [15–17] thus it is unclear when this socio-economic disparity begins; this requires further investigation.

Children from ethnic minority groups (Black and Hispanic) in the US have consistently been reported to have greater screen exposure in early childhood compared to their Caucasian counterparts [14]. The current study was the first to examine ethnic difference in young children's TV-time outside of the US focusing on differences between white British and Pakistani heritage children in the UK. In the current study 49% of mother were of Pakistani heritage and 38% white British. This is broadly representative of the childhood population in Bradford where 47% of babies born are of South Asian heritage [22] and similar to other large UK cities where over one third of the population are of non-white ethnicity; therefore findings are relevant to these multi-ethnic populations. We found that children of mothers with Pakistani ethnicity overall had on average 13 min more daily screen time than their white British counterparts. The effect was independent of mothers' behaviours and attitudes, and thus we cannot elucidate why these differences existed. Furthermore, we found an acculturation effect; children of mothers who were born in Pakistan had, on average, nine minutes greater TV-time at 6 months of age than children of mothers born in the UK. There was also an interaction between ethnicity, country of birth and the age of the child, such that the rate of increase in TV-time after 12 months of age was greater for children of Pakistani mothers born in Pakistan, than for children of mothers born in the UK. Our findings confirm those from the US and suggest that ethnic minority groups are particularly important targets for intervention. Qualitative explorations of TV-time behaviours in the different groups are required to begin to identify why differences exist between ethnic and cultural groups, and how behaviours can be modified.

Implications for the development of effective interventions

To date few interventions to reduce screen time have targeted young children and those that have, have all focused on children aged 2 and above [31–34]. A systematic review of interventions reporting the results of 13 studies targeting children aged 2–5 years old found that those that were effective had greater parental involvement (usually in the form of parent education and training), however none explicitly targeted parents TV behaviours [35]. The current study found that mothers' TV-time significantly and independently predicted their child's TV-time, which replicates findings from a systematic review [14]. Further, this study found that the strength of this association increased as the children aged; by the age of 36 months every hour of mothers TV viewing was associated with an increase of around 25 min in child TV viewing. This suggests that mothers' TV-time may be a key target for intervention. Furthermore, the strength of the association between mother and child TV-time increased as the children aged, thus supporting the idea that early intervention would reap greater effectiveness. The current study also found the time the TV was on in the house and mothers' attitude towards their child's TV-time were significant determinants of child TV-time. Figure 3 illustrates the size of the effect, and indicates how the size of this effect increases as the children get older; by the age of 36 months the differences in child TV-time can vary by over two hours a day. The strength of the association between time the TV was on and child TV-time also strengthened with age but this was not the case for mothers' attitude towards their child's TV viewing. A recent systematic review of interventions to reduce sedentary time in children and adolescents reported that encouraging a TV turn off week may be a promising strategy [36]. Since this would influence mother and child behaviours, testing the effectiveness of this for very young children would be worthwhile.

In a meta-analysis of interventions to reduce sedentary time in children and adolescents significant decreases in the amount of sedentary behaviour (post-intervention mean difference of −18 min/day) and BMI (post-intervention mean difference of $-0.25\ kg/m^2$) were found [35]. Thus, a reduction in sedentary time of 18 min/day could serve as a useful minimum threshold for interventions to aim for until sufficient evidence exist in younger children. In the current study, the effect size for each modifiable determinant alone was relatively small and unlikely to be clinically important in isolation. However, given their independence, changing these determinants in combination could lead to important changes in children's TV-time. Therefore, evidence from the current study suggests that interventions to prevent excessive TV-time in children should include components that support mothers to: reduce their own TV-time, reduce the time the TV is on in the household and understand the importance of preventing excessive TV viewing during early childhood. One third of mothers in the current study reported experiencing stress, and this was associated with greater child TV-time. Parent programmes have been shown to reduce parental stress and depression [37], therefore interventions to reduce TV-time could include strategies from such programmes. Mothers experiencing stress, first time mothers, Pakistani ethnicity mothers, and mothers born outside the UK all had children with higher TV-time and thus should be particular targets for intervention; interventions should be appropriate and tailored for these groups.

Strengths and limitations

The strengths of this study include its relatively large sample of children from a multiethnic, materially deprived population whose TV-time was measured at five time points over the first three years of life. The prospective longitudinal design enabled trajectories to be plotted and the identification of a potential key time point for intervention, 12 months of age, after which TV-time seemingly accelerates. It is the first study to report TV-time of young children from a South Asian ethnic minority group. Furthermore, the study examines acculturation in this ethnic minority group. The study is not without limitations, the questionnaire used to quantify child screen time has not been validated. It is a persisting problem that no valid or reliable tools are available for this age group [38]. The lack of variation in the neighbourhood material deprivation scores may have limited the ability to determine an association with the outcome. There was a systematic bias in missingness of data, mothers with lower educational attainment and those who reported having a difficult financial situation had higher rates of drop out. This may have affected the results; however, the number of participants in these groups who remained in the study was still high. The study only investigated the relationship between mother and child TV-time; the father/child relationship was not examined. Some literature suggests stronger relationships between sex matched parent/child dyads (mothers and daughters, fathers and sons), such that mothers have more influence on daughters and fathers on sons [39]. Whether this relationship exists when children are so young has not yet been investigated. The study did not explore whether mothers and children were watching TV together. Given the new American Academy of Pediatrics [11] recommendations that parents should co-view and re-teach screen content with their children, this would be interesting to investigate in future studies. We acknowledge that this study only measured TV-time

and did not encompass other screen behaviours (e.g. tablet/computer use). However, in early childhood the main contributor to screen time is TV-time. [14] A further limitation is that screen viewing data was self/proxy reported and this brings with it recall limitations and possible social desirability bias, which may occur in the reporting of determinants (e.g. attitude) as well as TV-time. Moreover, we assumed no differential reporting error of TV-time between ethnic groups.

Conclusion

High levels of TV-time were common amongst the children. A period of accelerated increase in TV-time was observed between 12 and 30 months, suggesting interventions should be targeted before this time. Modifiable determinants were identified and included mothers' own TV-time, the time the television is on in the home and mothers' attitude towards child TV-time. These behaviours may be key components to address in interventions for parents. Children of mothers experiencing stress, first time mothers, and mothers of Pakistani origin, particularly those born outside of the UK, had significantly greater TV-time than their counterparts and thus should be particular target groups for interventions to reduce TV-time during early childhood.

Abbreviations

SES: Socioeconomic status; TV-time: Television viewing time

Acknowledgements

We are grateful to all the mothers who took part in the study and to the Born in Bradford community team for assisting with recruitment and data collection.

Funding

The study was financially supported by the National Institute for Health Research (NIHR) programme grant for applied research (RP-PG-0407-10,044), the NIHR CLAHRC Yorkshire and the Humber and the Big Lottery Fund as part of the A Better Start programme. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR, the Department of Health or Big Lottery Fund.

Authors' contributions

The authors' responsibilities were as follows - SEB: designed the research, wrote the paper, and had primary responsibility for the final content of the manuscript; BK assisted with the design of the statistical analysis, conducted the data analysis, prepared the tables and figures and critiqued the manuscript; PJC assisted with design of the statistical analysis and critiqued the manuscript. LN and TB provided input and insight into the study rationale, interpretation of results and discussion, and they both critiqued the manuscript. JW assisted with the design of the study, organized and managed the data collection and critiqued the manuscript; all authors approved the final manuscript as submitted.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Bradford Institute for Health Research, Bradford Royal Infirmary, Duckworth Lane, Bradford BD9 6RJ, UK. [2]Faculty of Health Studies, University of Bradford, Richmond Rd, Bradford BD7 1DP, UK. [3]Department of Health Sciences, Faculty of Sciences, University of York, Area 2, Seebohm Rowntree Building, York YO10 5DD, UK.

References

1. Caroli M, Argentieri L, Cardone M, Masi A. Role of television in childhood obesity prevention. Int J Obes Relat Metab Disord. 2004;28(Suppl 3):104–8.
2. Marshall SJ, Biddle SJ, Gorley T, Cameron N, Murdy I. Relationship between media use, body fatness and physical activity in children and youth: a meta-analysis. Int J Obes Relat Metab Disord. 2004;28:1238–46.
3. Rey-Lopez JP, Vicente-Rodriguez G, Biosca M, Moreno LA. Sedentary behaviour and obesity development in children adolescents. Nurt Metab Cardiovas Dis. 2008;18:242–51.
4. Jackson DM, Djafarian K, Stewart J, Speakman JR. Increased television viewing is associated with elevated body fatness but not with lower total energy expenditure in children. Am J Clin Nutr. 2009;89:1031–6.
5. Ekelund U, Brarge S, Froberg K, Harro M, Aderssen SA, Sardinha LB, Riddoch C, Andersen LB. TV viewing and physical activity are independently associated with metabolic risk in children: the European Youth Heart Study. PLoS Med. 2006;3:e488.
6. Hancox RJ, Milne BJ, Poulton R. Associations between child and adolescent television viewing and adult health: a longitudinal birth cohort study. Lancet. 2004;364:257–62.
7. Le Blanc AG, Spence JC, Carson V, Connor Gorber S, Dillman C, Janssen I, Kho ME, Stearns JA, Timmons BW, Tremblay MS. Systematic review of sedentary behaviour and health indicators in the early years (aged 0–4 years). Appl Physiol Nutr Metab. 2012;37(4):753–72.
8. Hinkley T, Verbestel V, Aherns W, Lissner L, Molnár D, Moreno LA, et al. Early childhood electronic media use as a predictor of poorer well-being: a prospective cohort study. JAMA Pediatr. 2014;168(5):485–92.
9. Canadian Society for Exercise Physiology. Canadian sedentary behavior guidelines. OHowa: CSEP; 2011.
10. Australian Government Department of Health. Move and play every day: national physical activity recommendations for children 0–5 years. Canberra: Commonwealth of Australia; 2014.
11. AAP Council on Communications and Media. Media and young minds. Pediatrics. 2016;138(5):e20162591.
12. Downing KL, Hnatiuk J, Hesketh KD. Prevalence of sedentary behavior in children under 2 years: a systematic review. Prev Med. 2015;78:105–14.
13. The NHS Information Centre for Health and Social Care: National child measurement Programme 2010/2011; http://content.digital.nhs.uk/catalogue/PUB03034/nati-chi-meas-prog-eng-2010-2011-rep1.pdf. Accessed 1 Aug 2016.
14. Duch H, Fisher EM, Ensari I, Harrington A. Screen time use in children under 3 years old: a systematic review of correlates. IJBNPA. 2013;10:102.
15. Drenowatz C, Eisenmann JC, Pfeiffer KA, Welk G, Heelan K, Gentile D, Walsh D. Influence of socio-economic status on habitual physical activity and sedentary behavior in 8-to 11-year old children. BMC Public Health. 2010;10:214–24.
16. Brodersen NH, Steptoe A, Williamson S, Wardle J. Sociodemographic, developmental, environmental, and psychological correlates of physical activity and sedentary behavior at age 11 to 12. Ann Behav Med. 2005;29(1):2–11.
17. Fairclough SJ, Boddy LM, Hackett AF, Stratton G. Associations between children's socioeconomic status, weight status, and sex, with screen-based sedentary behaviours and sport participation. Int J Pediatr Obes. 2009;4(4):299–305.
18. Biddle SJH, Pearson N, Ross GM, Braithwaite R. Tracking of sedentary behaviour of young people: a systematic review. Prev Med. 2010;51(5):345–51.
19. Jones RA, Hinkley T, Okelty AD, Salmon J. Tracking physical activity and sedentary behaviour in childhood: a systematic review. Am J Prev Med. 2013;44(6):651–8.
20. Tomopoulos S, Dreyer BP, Valdez P, Flynn V, Foley G, Berkule SB, et al. Media content and externalizing behaviors in Latino toddlers. Ambul Pediatr. 2007;7(3):232–8.
21. Vandewater EA, Rideout VJ, Wartella EA, Huang X, Lee JH, Shim MS. Digital childhood: electronic media and technology use among infants, toddlers and preschoolers. Pediatrics. 2007;119(5):e1006–15.
22. Wright J, Small N, Raynor P, Tuffnell D, Bhopal R, Cameron N, et al. Cohort

profile: the born in Bradford multi-ethnic family cohort study. Int J Epidemiol. 2012;42(40):987–91.
23. Bryant M, Santorelli G, Fairley L, West J, Lawlor D, Bhopal R, et al. Design and characteristics of a new birth cohort to study the early origins and ethnic variation of child obesity: the BiB1000 study. Longitudinal Life Course Stud. 2013;4:119–35.
24. Wareham NJ, Jakes RW, Rennie KL, Mitchell J, Hennings S, Day NE. Validity and repeatability of the EPIC-Norfolk physical activity questionnaire. Int J Epidemiol. 2002;31:168–74.
25. McMinn AM, van Sluijs EMF, Cooper C, Inskip HM, Godfry KM, Griffin SJ. Validation of a maternal questionnaire on correlates of physical activity in pre-school children. IJBNPA. 2009;6:81.
26. Office for National Statistics. Ethnic group statistics: a guide for the collection and classification of ethnicity data. London: The Stationary Office; 2003.
27. English Indices' of Deprivation 2010: Overall. https://www.gov.uk/government/statistics/english-indices-of-deprivation-2010.
28. Kessler RC, Andrews G, Colpe LJ. Short screening scales to monitor population prevalence and trends in non-specific psychological distress. Psychol Med. 2002;32:959–76.
29. Plewis I. Longitudinal multilevel models. In: Davis A, Davies RB, editors. Analyzing social and political change: a casebook of methods. London: Sage; 1994. p. 118–35.
30. Reilly JJ. Physical activity, sedentary behaviour and energy balance in the preschool child: opportunities for early obesity prevention. Proc Nutr Soc. 2008;67:317–25.
31. Schmidt ME, Haines J, O'Brian A, McDonald J, Price S, Sherry B, et al. Systematic review of effective strategies for reducing screen time among young children. Obesity (Silver Spring). 2012;20:1338–54.
32. Hinkley T, Cliff DP, Okely AD. Reducing electronic media use in 2–3 year old children: feasibility and efficacy of the Family@play pilot randomised controlled trial. BMC Pub Heal. 2015;15:779.
33. Birken CS, Maguire J, Mekky M, Manlhiot C, Beck CE, Degroot J, et al. Office-based randomized controlled trial to reduce screen time in preschool children. Pediatrics. 2012;130:1110–5. doi:10.1542/peds.2011-3088.
34. Dennison BA, Russo TJ, Burdick PA, Jenkins PL. An intervention to reduce television viewing by preschool children. Arch Pediatr Adolesc Med. 2004;158:170–6.
35. van Grieken A, Ezendam NP, Paulis WD, van der Wouden JC, Raat H. Primary prevention of overweight in children and adolescents: a meta-analysis of the effectiveness of interventions aiming to decrease sedentary behaviour. Int J Behav Nutr Phys Act. 2012;9:61.
36. Altenburg TM, Kist-van Holthe J, Chinapaw MJ. Effectiveness of intervention strategies exclusively targeting reductions in children's sedentary time: a systematic review of the literature. Int J Behav Nutr Phys Act. 2016;13:65.
37. Furlong M, McGilloway S, Bywater T, Hutchings J, Smith SM, Donnelly M. Behavioral and cognitive-behavioural group-based parenting interventions for early-onset conduct problems in children age 3–12 years. Cochrane Database Syst Rev. 2012; Issue 2. Art. No.: CD008225.
38. Hidding LM, Altenburg TM, Mokkink LB, Terwee CB, Chinapaw MJ. Systematic review of childhood sedentary behavior questionnaires: what do we know and what is next? Sports Med. 2016.
39. Abbott G, Hnatiuk J, Timperio A, Salmon J, Best K, Hesketh KD. Cross sectional and longitudinal associations between parents and preschoolers physical activity and TV viewing: The HAPPY study. J Phys Act Health. 2016; 13(3):269–7.

Predictors of screen viewing time in young Singaporean children: the GUSTO cohort

Jonathan Y. Bernard[1,15*], Natarajan Padmapriya[2], Bozhi Chen[3], Shirong Cai[2], Kok Hian Tan[4,5], Fabian Yap[6], Lynette Shek[1,7,8], Yap-Seng Chong[1,2], Peter D. Gluckman[1,9], Keith M. Godfrey[10,11], Michael S. Kramer[12], Seang Mei Saw[3,5,13] and Falk Müller-Riemenschneider[3,14]

Abstract

Background: Higher screen viewing time (SVT) in childhood has been associated with adverse health outcomes, but the predictors of SVT in early childhood are poorly understood. We examined the sociodemographic and behavioral predictors of total and device-specific SVT in a Singaporean cohort.

Methods: At ages 2 and 3 years, SVT of 910 children was reported by their parents. Interviewer-administered questionnaires assessed SVT on weekdays and weekends for television, computer, and hand-held devices. Multivariable linear mixed-effect models were used to examine the associations of total and device-specific SVT at ages 2 and 3 with predictors, including children's sex, ethnicity, birth order, family income, and parental age, education, BMI, and television viewing time.

Results: At age 2, children's total SVT averaged 2.4 ± 2.2 (mean ± SD) hours/day, including 1.6 ± 1.6 and 0.7 ± 1.0 h/day for television and hand-held devices, respectively. At age 3, hand-held device SVT was 0.3 (95% CI: 0.2, 0.4) hours/day higher, while no increases were observed for other devices. SVT tracked moderately from 2 to 3 years ($r = 0.49$, $p < 0.0001$). Compared to Chinese children, Malay and Indian children spent 1.04 (0.66, 1.41) and 0.54 (0.15, 0.94) more hours/day watching screens, respectively. Other predictors of longer SVT were younger maternal age, lower maternal education, and longer parental television time.

Conclusions: In our cohort, the main predictors of longer children's SVT were Malay and Indian ethnicity, younger maternal age, lower education and longer parental television viewing time. Our study may help target populations for future interventions in Asia, but also in other technology-centered societies.

Trial registration: This ongoing study was first registered on July 1, 2010 on NCT01174875 as. Retrospectively registered.

Keywords: Television, Computer, Hand-held device, Sedentary lifestyle, Childhood, Cohort studies

Background

In the 1960's, television became widely introduced into homes of high-income countries and rapidly occupied a substantial fraction of individuals' leisure time. In 2013, watching television reached an average of 3.5 h daily in US adults, i.e., about 10 years total accumulated over the life course [1]. Since the 1980's, office-based workers have spent increasing part of their work day facing computer monitors, and more recently, playing video games has become a popular home activity for many Western adults and children [2–4]. Screens have now evolved to pocket, mobile, and personal devices, such as tablets and smartphones, which broaden the opportunities to use such devices in different locations and times. Importantly, hand-held devices have become increasingly accessible to young children and to individuals from lower socioeconomic strata and those from low- and middle-income countries.

Lack of physical activity is now recognized as a leading cause of preventable morbidity and mortality globally

* Correspondence: jonathan_bernard@sics.a-star.edu.sg
[1]Singapore Institute for Clinical Sciences, Agency for Science, Technology and Research (A*STAR), Singapore, Singapore
[15]Singapore Institute for Clinical Sciences (SICS), Agency for Sciences, Technology and Research (A*STAR). MD1 Tahir Foundation Building, #12-02/03, 21 Lower Kent Ridge Rd, Singapore 119077, Singapore
Full list of author information is available at the end of the article

[5–7]. Less evidence is available, however, regarding high levels of sedentary behavior, which differs from inactivity [5, 8]. In adults, a sedentary lifestyle is an independent risk factor for cardiovascular and metabolic diseases [9]. In childhood, sedentary lifestyle has been independently associated with obesity, higher blood pressure and poorer mental health [9]. This level of evidence remains fragile, however, owing to cross-sectional designs, the complexity of accurately measuring sedentary behavior in young children, and the potential for residual confounding. Screen use is a waking activity involving low energy expenditure and is therefore considered a form of sedentary behavior [8, 10]. Screen viewing time (SVT) in preschool children is associated with eating disorders, reduced sleep duration, development delays, attention deficit and myopia [11–13]. As early as age 2, SVT has been associated with childhood obesity [14]. Based on this evidence, the American Academy of Pediatrics (AAP) now recommends that children below 18 months avoid any digital media use but suggests the gradual introduction of family-shared, high-quality content between 18 months and 2 years, while limiting screen time to a maximum of 1 h/day between 2 and 5 years of age [15].

Populations living in high-income Asian countries have become among the top users of all kinds of screen devices. According to the Google Consumer Barometer survey, in 2015 only 6% of persons ≥16 years living in South Korea or Singapore owned no devices (vs 13% in the U.S.) [16]. This survey also reported that 91% of Singaporeans owned a smartphone, 41% a tablet, and 60% at least 3 screen devices. The above statistics on prevalence of SVT have remained fairly stable in Singapore over recent years but are rising rapidly in Western countries [16]. In some ways, observations from "high-tech" Asian countries may presage a similar situation in Western populations. A multiscreen environment may encourage screen use in early childhood. To date, predictors of screen viewing behavior in Asian children are not well known; they may differ from those reported in other populations [17, 18]. As an illustration, a recent Singaporean cross-sectional study focusing on device-specific screen use in children less than 2 years of age reported a median number of 2 televisions, 2 computers, and 4 hand-held devices in their homes, while half of their parents had a total SVT ≥8 h daily [19]. Parents of less than half the sample of children aged <2 years reported no screen viewing, while 16% reported ≥2 h daily. Ethnicity, parental screen viewing and rule setting practices were identified as independent predictors of total SVT [19]. Longitudinal data are needed to establish the temporal precedence of potential predictors of SVT and changes in SVT over time. We thus aimed to describe total and device-specific SVT and assess its predictors, both cross-sectionally and longitudinally, among children aged 2 and 3 years enrolled in a tri-ethnic Singaporean cohort.

Methods

Study design and population

Between June 2009 and September 2010, the Growing Up in Singapore Towards healthy Outcomes (GUSTO) study recruited pregnant women of Chinese, Malay and Indian ethnicities who visited two public maternity units (KK Hospital and National University Hospital) in Singapore for their first ultrasound scan before the 15th week of pregnancy. The main exclusion criteria were non-homogeneous ethnic background (up to the four grandparents of the offspring), intention not to deliver in the study centers or not to remain in Singapore for the following 5 years. From the 1247 pregnant women recruited, 1171 singleton newborns were included and followed regularly. The recruitment and follow-up protocol has been detailed previously [20]. All participants signed written informed consent at enrolment. The study received ethical approval from the National Healthcare Group Domain Specific Review Board and the SingHealth Centralised Institutional Review Board.

Data collection

Sociodemographic and health information was obtained at enrolment as part of an interviewer-administered questionnaire: ethnicity (Chinese/Malay/Indian), maternal and paternal age, maternal highest education level (secondary or less/post-secondary/university), marital status (single/married), maternal place of birth (Singapore/other), accommodation type (public/private housing), monthly household income (<2000/2000-3999/4000-5999/≥6000 Singapore dollars), and maternal pre-pregnancy weight (kg). During the clinic visit at 26-28 weeks' gestation, maternal height (cm) was measured, and pre-pregnancy and pregnancy behavioral information was obtained through an interviewer-administered questionnaire: tobacco (yes/no) and alcohol consumption (yes/no), television viewing time (6 categories from <1 h to >5 h daily) and physical activity (frequency and duration of light-moderate, moderate and vigorous intensity activities). Information on the offspring's date of birth, sex and birth order was extracted from medical records. Paternal data were obtained from the fathers when they attended (80% of them did) postnatal visits with their child at 24 or 36 months: highest education level and television viewing time (same categories as for mothers) via interviewer-administered questionnaires, while weight (kg) and height (cm) were both measured. Time point and measurement method of the collected data are summarized in Additional file 1: Table S1.

Maternal and paternal age were categorized into 4 groups: <25, 25-29, 30-34 and ≥35 years for mothers and <30, 30-34, 35-39, and ≥40 years for fathers. Maternal pre-pregnancy and paternal BMI was derived from weight divided by height squared (m^2), then categorized according to WHO criteria (<18.5, 18.5-24.9, 25.0-29.9, and ≥30.0 kg/m^2). Maternal and paternal television viewing times were categorized as <1 h, 1-2 h, 2-3 h or ≥3 h/day. Maternal physical activity before pregnancy was categorized as insufficiently, sufficiently or highly active, as detailed previously [21].

Screen viewing time (SVT)

Screen use data were assessed at the 2- and 3-year clinic visits as part of a questionnaire on quantitating children's time spent in indoor and outdoor activities. Trained interviewers asked the parents how much time, in 5-min increments, their child spent on average using screens on weekdays and weekend days. Three types of devices (with examples enunciated to the participants) were considered: 1) television and television games (e.g., PlayStation®, Wii™, Xbox™), further referred to as 'television,' 2) computers, and 3) hand-held video games and hand phones (e.g., Game Boy®, hand-phone games), including tablets, hereinafter referred to as hand-held devices. Although the item 'computer' was enunciated without example, the interviewers were trained to clarify, if necessary, that it includes both desktop and laptop computers. For each type, weekday and weekend day times were averaged to obtain device-specific SVT in hours/day ([weekday × 5 + weekend day × 2]/7). Total SVT was calculated as the sum of the times for the three types of device.

Statistical analyses

Total and device-specific SVT at 2 and 3 years, and the changes between those ages, are described as mean ± standard deviation (SD) and median and interquartile range (IQR), while categorical variables are summarized using frequencies and percentages. Spearman's correlation was used to assess the degree of SVT tracking between 2 and 3 years.

Potential predictors of SVT at 2 and 3 years were examined in several steps. First, parental and child predictors were screened by linear regression to identify those associated with SVT in unadjusted models. Second, multivariable linear regression models were built using a forward selection approach and $p \leq 0.25$ as an entering criterion. To maximize statistical power, multivariable analyses were restricted to the sample with complete data for both the offspring and the mother ($n = 910$), but not necessarily with complete paternal data (since they were missing for $n = 270$). Multivariable models with the paternal variables were built afterwards on the sample with complete data for the three family members ($n = 640$). We also carried out a sensitivity analysis using multiple imputation for missing paternal data. Third, repeated measures linear regression model with an unstructured variance-covariance matrix was used to account for non-independence among the repeated outcomes for each individual assessed at both time points. This also permitted us to use a single model for children whose SVT was estimated at one time point only (see Fig. 1). Interactions between the predictors and time points were tested to evaluate whether predictors were associated differentially with SVT at 2 and 3 years. Significant interaction denotes an association between the predictor and the change in SVT from 2 to 3 years [22], but has the additional advantage of including all children assessed at either age; p-interaction was considered significant when <0.10, since tests of interaction tend to be statistically under-powered. Interactions between child sex and ethnicity, and child sex and parental television time were also examined. Finally, we used multivariable logistic regression to examine whether the predictors of total SVT also predicted the odds of ≥2 and ≥4 h/day. All statistical analyses were carried out with SAS 9.4 (SAS Institute Inc., Cary, NC, USA) during the second half of 2016.

Results

Overall, 910 parents reported their child's SVT, including 812 reporting SVT at both ages ($n = 812$) and those who reported at 2 years only ($n = 49$) or 3 years only ($n = 49$) (Fig. 1). At age 2 years, the children spent an average of 2.4 ± 2.2 h of total SVT, mainly contributed by 1.6 ± 1.7 h of television and 0.7 ± 1.0 of hand-held devices (Table 1). Fewer children engaged in any computer use: 21 and 18% at 2 and 3 years, respectively. Thus, computer use was not examined further separately. At age 3 years, total SVT increased on average by 0.33 ± 2.42 h/day, mainly owing to an increase in hand-held device viewing time. SVTs at 2 and 3 years were moderately correlated ($r = 0.45$ for television, $r = 0.42$ hand-held devices, $r = 0.49$ for total SVT, all $p < 0.0001$, not shown).

The study sample at 2 and 3 years of age is described in Table 2. Predictors of child SVT that passed the multivariable model selection criteria were ethnicity, household income, parental age and education, and higher maternal television viewing time (all $p < 0.001$). Marital status, maternal place of birth, accommodation type, maternal tobacco and alcohol consumption, and parental BMI did not reach the model selection criteria ($p > 0.25$, not shown) and were therefore excluded from the subsequent multivariable models. Although not associated with SVT, child sex and exact age were forced into the models.

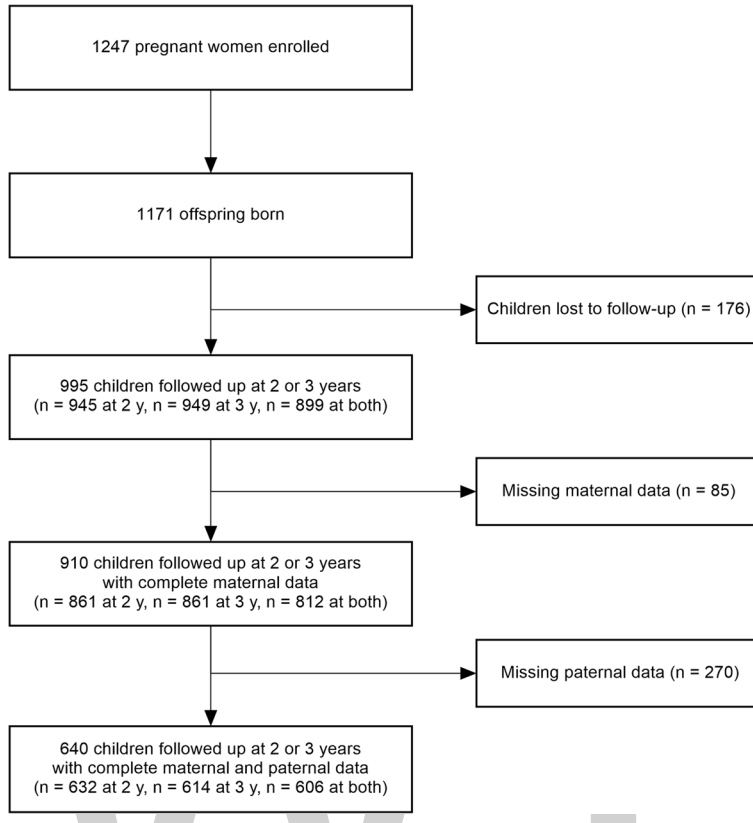

Fig. 1 Flow diagram of the GUSTO study participants followed up to 2 and 3 years

Results of linear mixed-effect regression models adjusted for maternal data (model 1) and both parents' data (model 2) are shown in Table 3. Compared to Chinese children, Malay and Indian children spent 0.94 (0.64, 1.25) and 0.60 (0.28, 0.92) more hours/day, respectively, in total SVT. Other sociodemographic variables independently associated with total or device-specific SVT were birth order, low household income, maternal education less than university level and paternal age < 35 years. Longer maternal and paternal television viewing times were associated with longer total SVT.

Interactions were observed between maternal age and child age (time point) and both television ($p = 0.07$) and hand-held device ($p = 0.05$) viewing time as outcomes (Additional file 2: Figure S1). Television viewing time at 2 years was longer in children of mothers aged <30 years than those of mothers ≥30 years, whereas no differences were observed at 3 years. The interaction pattern was opposite for hand-held device viewing time; no differences by maternal age were observed at age 2 years, whereas viewing time at age 3 years was longest in children of mothers <25 years. No other factors were significantly associated with the change in SVT between ages 2 and 3 years.

No interaction was found between child sex and ethnicity, nor between child sex and parental television viewing time. In logistic regression models, the predictors of total SVT ≥2 and ≥4 h/day were similar to those observed in the linear mixed-effect regressions (not shown). Finally, sensitivity analyses using multiple imputation for missing paternal viewing time showed comparable results (not shown).

Discussion

In our tri-ethnic Singaporean mother-offspring cohort, we found a substantial amount of reported total SVT in early childhood, mainly attributable to television and hand-held devices, whereas computers were used by few children. An increase in total SVT was seen from age 2 to 3 years, largely owing to an increase in hand-held device viewing time. SVT tracked moderately from age 2 to 3 years for all types of screen devices. We identified several predictors of SVT; Malay and Indian ethnicity, maternal education less than university level, and higher parental television viewing time were significantly and independently associated with longer total SVT. Predictors of device-specific viewing time differed somewhat. Low household income and high maternal daily television viewing time were associated with longer television

Table 1 Daily total and device-specific SVT in 2- and 3-year-old children from the GUSTO cohort study

	n (%)	Mean ± SD	Median (IQR)
Screen viewing time at 2 years	861[a]		
Television and video game, *hour/day*		1.6 ± 1.7	1.0 (0.5 – 2.3)
Computer, *hour/day*		0.1 ± 0.4	0.0 (0.0 – 0.0)
Hand-held devices, *hour/day*		0.7 ± 1.0	0.3 (0.1 – 0.9)
Total, hour/day		2.4 ± 2.2	1.9 (0.9 – 3.3)
<2 h/day	439 (51.0)		
2-4 h/day	257 (29.9)		
≥4 h/day	165 (19.2)		
Screen viewing time at 3 years	861[a]		
Television and video game, *hour/day*		1.6 ± 1.5	1.0 (0.5 – 2.3)
Computer, *hour/day*		0.1 ± 0.4	0.0 (0.0 – 0.0)
Hand-held devices, *hour/day*		0.9 ± 1.2	0.5 (0.2 – 1.0)
Total, *hour/day*		2.7 ± 2.2	2.1 (1.1 – 3.6)
<2 h/day	387 (45.0)		
2-4 h/day	274 (31.8)		
≥4 h/day	200 (23.2)		
Change between 2 and 3 years	812		
Television and video game, *hour/day*		0.03 ± 1.82	0.0 (−1.0 – 1.0)
Computer, *hour/day*		0.01 ± 0.56	0.0 (0.0 – 0.0)
Hand-held devices, *hour/day*		0.29 ± 1.45	0.0 (0.0 – 1.0)
Total, *hour/day*		0.33 ± 2.42	0.0 (−1.0 – 1.0)

[a]Maximum sample size with data at each age (sample overlapping both ages = 812)

viewing time, whereas being a first-born was associated with longer hand-held device viewing time. Finally, younger maternal age was a significant predictor of an increase in SVT between 2 and 3 years.

To the best of our knowledge, this is the first study to use a longitudinal design to assess SVT and its predictors in Asians children. The GUSTO cohort is based in Singapore, a high-income country where screen use is among the highest globally [16]. At 2 years of age, about 75% of our study children exceeded the recent AAP recommendations for 2 and 3 year old children [15]. Similarly to previous reports in older children, we found that SVT tracks moderately between 2 and 3 years [23]. An increase in SVT between 2 and 3 years was mostly due to an increase in hand-held device SVT, consistent with findings from a cross-sectional study among Singaporean children aged 2 years and below. In that study, Goh et al. also reported that greater SVT at older ages was mainly attributable to use of hand-held devices [19]. Our study also corroborates their finding that young Malay and Indian children engage in longer SVT than Chinese children, even after controlling for other sociodemographic variables. Although the relationship between ethnicity and childhood SVT may be country- and context-specific, the available literature suggests that children from ethnic majorities spend less time on screen devices [18, 24–26].

Consistent with other studies on children of the same age, we did not observe a sex difference in SVT [14, 19, 24, 27–29]. However, it has been reported that boys spend more time on screen devices after age 4-5 years, suggesting that a difference by sex may emerge with age [30–32]. Among the studies that have examined birth order or number of siblings, most were conducted before 2010, when tablets and smartphones were not widely available [24, 28, 33–36]. Other sociodemographic factors associated with longer total or device-specific SVT in our study were low household income, maternal education less than university level, and paternal age less than 35 years. Paternal education was, however, not associated with SVT. Other studies have found similar associations, although the findings remain mixed and likely population-specific [18, 37]. Interestingly, we found that maternal age was associated with change in total and device-specific SVT between 2 and 3 years. Children of mothers younger than 25 years engaged in longer television watching at 2 years than did their counterparts, but from 2 to 3 years, they had a larger increase in hand-held device use. This finding may reflect changing parenting patterns of the so-called

Table 2 Sample description in 2- and 3-year-old children

	Subsample assessed at 2 years ($n = 861$)	Subsample assessed at 3 years ($n = 861$)
Child age, months	24.4 ± 0.9	36.5 ± 1.1
Study centre		
KKH	654 (76.0)	651 (75.6)
NUH	207 (24.0)	210 (24.4)
Ethnicity		
Chinese	490 (56.9)	492 (57.1)
Malay	220 (25.6)	219 (25.4)
Indian	151 (17.5)	150 (17.4)
Child sex		
Male	457 (53.1)	461 (43.5)
Female	404 (46.9)	400 (46.5)
Birth order		
First-born	383 (44.5)	387 (45.0)
Second- or later-born	478 (55.5)	474 (55.1)
Monthly household incomes		
< 2000 SGD	123 (14.3)	126 (14.6)
2000-3999 SGD	262 (30.4)	253 (29.4)
4000-5999 SGD	218 (25.3)	212 (24.6)
≥ 6000 SGD	258 (30.0)	270 (31.4)
Accommodation type		
Public housing	786 (91.3)	787 (91.4)
Private	75 (8.7)	74 (8.6)
Maternal place of birth		
Singapore	539 (62.6)	542 (63.0)
Abroad	322 (37.4)	319 (37.1)
Maternal age		
< 25 years	83 (9.6)	82 (9.5)
25-29 years	263 (30.6)	259 (30.1)
30-34 years	279 (32.4)	283 (32.9)
≥ 35 years	236 (27.4)	237 (27.5)
Maternal education		
University	300 (34.8)	309 (35.9)
Post-secondary	302 (35.1)	294 (34.2)
Primary or Secondary	259 (30.1)	258 (30.0)
Maternal BMI before pregnancy, kg/m^2	22.8 ± 4.4	22.8 ± 4.4
Maternal tobacco consumption before pregnancy		
Yes	92 (10.7)	89 (10.3)
No	769 (89.3)	772 (89.7)
Maternal alcohol consumption before pregnancy		
Yes	295 (34.3)	297 (34.5)
No	566 (65.7)	564 (65.5)

Table 2 Sample description in 2- and 3-year-old children *(Continued)*

Maternal physical activity level before pregnancy		
Insufficiently active	281 (32.9)	286 (33.5)
Sufficiently active	419 (49.1)	418 (48.9)
Highly active	153 (17.9)	151 (17.7)
Missing, *n*	8	6
Maternal daily television-viewing time		
< 1 h	152 (17.7)	154 (17.9)
1-2 h	237 (27.5)	235 (27.3)
2-3 h	187 (21.7)	195 (22.7)
≥ 3 h	285 (33.1)	277 (32.2)
Maternal marital status		
Married	829 (97.1)	828 (97.1)
Single/divorced	25 (2.9)	25 (2.9)
Missing, *n*	7	8
Paternal age		
< 30 years	164 (22.0)	156 (21.5)
30-34 years	243 (32.6)	235 (32.3)
35-39 years	209 (28.0)	207 (28.5)
≥ 40 years	130 (17.4)	129 (17.7)
Missing, *n*	115	134
Paternal education		
University	279 (39.0)	277 (39.6)
Post-secondary	157 (22.0)	151 (21.6)
Primary or Secondary	279 (39.0)	272 (38.9)
Missing, *n*	146	161
Paternal BMI[a], kg/m^2	25.7 ± 4.5	25.9 ± 4.8
Paternal daily television-viewing time		
< 1 h	235 (32.9)	236 (33.7)
1-2 h	268 (37.5)	256 (36.6)
2-3 h	102 (14.3)	103 (14.7)
≥ 3 h	110 (15.4)	105 (15.0)
Missing, *n*	146	161

Values are Mean ± SD or % (n) for continuous and categorical variables, respectively
[a]Missing data: 63 and 61 at in 2-year and 3-year samples, respectively

Generation Y, who grew up with television and now have switched to more recent digital technologies like tablets and smartphones.

Several parental behavioral predictors were also observed. Maternal television viewing time ≥ 3 h/day was among the strongest predictors of children's total SVT and television viewing time, but not of hand-held device viewing time. Paternal television viewing time ≥ 2 h/day was associated, although less strongly, with total and device-specific SVT. Previous studies have reported that the presence of frequent screen users in the household is associated with children's screen behavior [18, 36, 37]. Altogether, the evidence suggests that children's screen use behavior is strongly influenced by parental behavior. Targeting parental behavior in early childhood may be a potentially effective avenue for interventions aimed at reducing children's SVT.

Strengths of our study include its longitudinal design, wide range of sociodemographic and behavioral predictors measured a priori and assessment of SVT at two ages, a clear advantage over cross-sectional studies. We also assessed exposure to different types of screen devices, including hand-held devices, which has been uncommon in previous studies. We treated SVT as a continuous variable, thus providing greater statistical power vis-à-vis categorized variables. Study limitations

Table 3 Adjusted associations between predictors and total and device-specific SVT (h/day) in 2- and 3-year-old children

	Total screen viewing time		TV viewing time		Hand-held device viewing time	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
	B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)	B (95% CI)
Intercept	1.22 (0.80, 1.64)	0.95 (0.39, 1.51)	0.75 (0.44, 1.05)	0.61 (0.19, 1.03)	0.37 (0.16, 0.58)	0.24 (−0.04, 0.51)
Age (ref: 2-year)						
3-year	0.29 (0.13, 0.46)	0.29 (0.10, 0.48)	0.03 (−0.09, 0.15)	0.00 (−0.13, 0.14)	0.27 (0.18, 0.36)	0.30 (0.20, 0.41)
Centre (ref: KKH)						
NUH	0.22 (−0.05, 0.50)	0.06 (−0.28, 0.39)	0.27 (0.07, 0.47)	0.18 (−0.07, 0.43)	−0.06 (−0.20, 0.08)	−0.12 (−0.29, 0.04)
Ethnicity (ref: Chinese)						
Malay	0.94 (0.64, 1.25)	1.04 (0.66, 1.41)	0.42 (0.20, 0.64)	0.42 (0.14, 0.70)	0.44 (0.29, 0.60)	0.51 (0.33, 0.70)
Indian	0.60 (0.28, 0.92)	0.54 (0.15, 0.94)	0.39 (0.16, 0.62)	0.39 (0.10, 0.69)	0.14 (−0.03, 0.30)	0.09 (−0.11, 0.28)
Child sex (ref: Female)						
Male	−0.05 (−0.27, 0.18)	0.00 (−0.27, 0.27)	−0.06 (−0.22, 0.11)	0.01 (−0.19, 0.21)	−0.05 (−0.16, 0.06)	−0.08 (−0.21, 0.05)
Birth order (ref: Second born)						
First born	0.16 (−0.08, 0.41)	0.17 (−0.12, 0.47)	−0.01 (−0.19, 0.17)	−0.03 (−0.24, 0.19)	0.14 (0.02, 0.27)	0.18 (0.04, 0.32)
Monthly household incomes (ref: ≥6000 SGD)						
< 2000 SGD	0.28 (−0.17, 0.73)	0.15 (−0.43, 0.72)	0.41 (0.08, 0.74)	0.38 (−0.04, 0.81)	−0.17 (−0.40, 0.06)	−0.26 (−0.54, 0.01)
2000-3999 SGD	0.20 (−0.16, 0.57)	−0.04 (−0.48, 0.41)	0.22 (−0.05, 0.49)	0.04 (−0.29, 0.37)	−0.05 (−0.24, 0.13)	−0.11 (−0.33, 0.10)
4000-5999 SGD	0.11 (−0.22, 0.44)	0.01 (−0.38, 0.40)	0.10 (−0.14, 0.35)	0.00 (−0.29, 0.29)	0.00 (−0.16, 0.17)	−0.01 (−0.20, 0.18)
Maternal age (ref: ≥35 years)						
< 25 years	0.43 (−0.02, 0.89)	0.28 (−0.37, 0.93)	0.19 (−0.14, 0.53)	0.05 (−0.43, 0.53)	0.23 (0.00, 0.46)	0.19 (−0.12, 0.51)
25-29 years	0.14 (−0.17, 0.45)	−0.12 (−0.58, 0.34)	0.10 (−0.13, 0.33)	−0.03 (−0.37, 0.31)	0.06 (−0.10, 0.22)	−0.05 (−0.28, 0.17)
30-34 years	−0.04 (−0.33, 0.26)	−0.28 (−0.68, 0.12)	−0.04 (−0.26, 0.17)	−0.2 (−0.49, 0.10)	0.03 (−0.12, 0.18)	−0.06 (−0.25, 0.14)
Maternal education (ref: University)						
Post-secondary	0.41 (0.10, 0.73)	0.42 (0.03, 0.81)	0.30 (0.07, 0.53)	0.22 (−0.07, 0.51)	0.15 (−0.01, 0.31)	0.24 (0.05, 0.43)
Primary or Secondary	0.34 (−0.03, 0.72)	0.59 (0.12, 1.05)	0.21 (−0.07, 0.48)	0.30 (−0.05, 0.64)	0.14 (−0.05, 0.33)	0.29 (0.06, 0.52)
Maternal daily television viewing time (ref: <1 h)						
1-2 h	0.04 (−0.31, 0.39)	−0.04 (−0.46, 0.38)	0.17 (−0.08, 0.43)	0.09 (−0.22, 0.40)	−0.09 (−0.27, 0.08)	−0.14 (−0.34, 0.06)
2-3 h	0.19 (−0.18, 0.56)	0.04 (−0.41, 0.50)	0.24 (−0.02, 0.51)	0.16 (−0.17, 0.50)	0.01 (−0.18, 0.20)	−0.10 (−0.32, 0.12)
≥ 3 h	0.77 (0.42, 1.12)	0.70 (0.28, 1.13)	0.65 (0.39, 0.90)	0.63 (0.32, 0.95)	0.16 (−0.02, 0.34)	0.06 (−0.15, 0.26)
Paternal age (ref: ≥40 years)						
< 30 years	-	0.52 (−0.05, 1.08)	-	0.42 (0.01, 0.84)	-	0.06 (−0.22, 0.33)
30-34 years	-	>0.62 (0.14, 1.11)	-	0.40 (0.04, 0.76)	-	0.27 (0.03, 0.50)
35-39 years	-	0.32 (−0.12, 0.75)	-	0.27 (−0.05, 0.6)	-	0.03 (−0.18, 0.24)
Paternal education (ref: University)						
Primary or Secondary	-	0.10 (−0.35, 0.55)	-	0.11 (−0.23, 0.44)	-	0.02 (−0.19, 0.24)
Post-secondary	-	−0.01 (−0.41, 0.4)	-	−0.01 (−0.31, 0.29)	-	0.05 (−0.15, 0.25)
Paternal daily television viewing time (ref: <1 h)						
1-2 h	-	0.04 (−0.29, 0.36)	-	−0.08 (−0.32, 0.16)	-	0.12 (−0.04, 0.28)
2-3 h	-	0.46 (0.03, 0.89)	-	0.29 (−0.03, 0.61)	-	0.25 (0.04, 0.46)
≥ 3 h	-	0.40 (−0.03, 0.83)	-	0.29 (−0.03, 0.60)	-	0.14 (−0.06, 0.35)

Values are regression coefficients (95% CI) of multivariable linear mixed-effect models. Models were adjusted for all the variables displayed in the table

include reliance on SVT reported by parents, who may overlook the child's screen use when the parents are not at home or during daycare. Whilst the questionnaire we administered has been used in other studies [38], its validity and reliability are unknown. Moreover, it includes no information about the context of screen use (number

of screens, parental knowledge on the recommendations, and rule-setting practices), nor on the viewing content. Contextual information is of importance when developing and testing interventions, as highlighted by the recent AAP guidelines that now included media content as an additional target. However, assessing both objective and qualitative SVT measures is challenging and costly in large epidemiological studies. We assessed maternal television viewing time during pregnancy, but it may have changed after birth. Finally, the GUSTO cohort is not representative of the entire Singaporean population. Malay and Indian families were overrepresented purposely at inclusion. GUSTO mothers were also less likely to hold a university degree than the women from the general population of the same age range [39]. The SVT figures observed in our study may therefore differ somewhat from those at the national level.

Conclusions

In conclusion, we observed a substantial total SVT in Singaporean children at ages 2 and 3 years. Significant predictors of total SVT included ethnicity, maternal education and parental television viewing, suggesting potential targets for health promotion activities. We observed stable television viewing time between 2 and 3 years, whereas hand-held device viewing time increased over time, particularly in children of young mothers. Intervention studies targeting parental screen behavior in early childhood may be warranted: for example, by testing the impact of recommending that parents who watch screens frequently limit their own SVT while their toddler is present. Future interventions should also take into account the evolution of screen usage, which tends to move from television to smartphones and tablets [40].

Additional files

Additional file 1: Table S1. Summary of the measurement method and time point of assessment of the variables examined as predictors of screen viewing time in 2- and 3-year-old children from the GUSTO cohort study.

Additional file 2: Figure S1. Television and hand-held devices viewing time (h/day) at ages 2 and 3 years according to maternal age in children from the GUSTO cohort study. Values are means ± SE, and *p*-values are for the interaction term between maternal age and child age, with viewing time as outcome.

Abbreviations

AAP: American Academy of Pediatrics; GUSTO: Growing Up in Singapore Towards healthy Outcomes; SVT: Screen viewing time

Acknowledgements

We thank the members of the GUSTO study group: Allan Sheppard, Amutha Chinnadurai, Anne Eng Neo Goh, Anne Rifkin-Graboi, Anqi Qiu, Arijit Biswas, Bee Wah Lee, Birit F.P. Broekman, Boon Long Quah, Borys Shuter, Chai Kiat Chng, Cheryl Ngo, Choon Looi Bong, Christiani Jeyakumar Henry, Cornelia Yin Ing Chee, Yam Thiam Daniel Goh, Doris Fok, Fabian Yap, George Seow Heong Yeo, Helen Chen, Hugo P S van Bever, Iliana Magiati, Inez Bik Yun Wong, Ivy Yee-Man Lau, Jeevesh Kapur, Jenny L. Richmond, Jerry Kok Yen Chan, Joanna D. Holbrook, Joshua J. Gooley, Keith M. Godfrey, Kenneth Kwek, Kok Hian Tan, Krishnamoorthy Niduvaje, Leher Singh, Lin Lin Su, Lourdes Mary Daniel, Lynette Pei-Chi Shek, Marielle V. Fortier, Mark Hanson, Mary Foong-Fong Chong, Mary Rauff, Mei Chien Chua, Michael Meaney, Mya Thway Tint, Neerja Karnani, Ngee Lek, Oon Hoe Teoh, P. C. Wong, Peter D. Gluckman, Pratibha Agarwal, Rob M. van Dam, Salome A. Rebello, Seang-Mei Saw, Shang Chee Chong, Shirong Cai, Shu-E Soh, Sok Bee Lim, Chin-Ying Stephen Hsu, Victor Samuel Rajadurai, Walter Stunkel, Wee Meng Han, Wei Wei Pang, Yap-Seng Chong, Yin Bun Cheung, Yiong Huak Chan and Yung Seng Lee.

Funding

This research was supported by the Singapore National Research Foundation under its Translational and Clinical Research (TCR) Flagship Programme and administered by the Singapore Ministry of Health's National Medical Research Council (NMRC), Singapore- NMRC/TCR/004-NUS/2008; NMRC/TCR/012-NUHS/2014. Additional funding of the present study was provided by the Singapore Institute for Clinical Sciences, A*STAR and Nestec. The study sponsors were not involved in study design, data collection, analysis and interpretation of data, manuscript writing, and the decision to submit the article for publication. KMG is supported by the National Institute for Health Research through the NIHR Southampton Biomedical Research Centre and by the European Union's Seventh Framework Programme (FP7/2007-2013), project EarlyNutrition under grant agreement number 289346.

Authors' contributions

KHT, FY, LS, YSC, PDG, KMG and SMS conceived and designed the cohort study; JYB, MSK and FMR designed the present work; NP and SC contributed to data collection; NP, BC, MSK and FMR contributed to data analysis and interpretation led by JYB; JYB and NP drafted the manuscript, and MSK and FMR added important intellectual content; all authors read and approved the final manuscript.

Competing interests

LS, YSC and KMG have received reimbursement for speaking at conferences sponsored by companies selling nutritional products. They are part of an academic consortium that has received research funding from Abbott Nutrition, Nestle, and Danone. All other authors declare that they have no competing interests.

Author details

[1]Singapore Institute for Clinical Sciences, Agency for Science, Technology and Research (A*STAR), Singapore, Singapore. [2]Department of Obstetrics and Gynaecology, Yong Loo Lin School of Medicine, National University of Singapore, Singapore, Singapore. [3]Saw Swee Hock School of Public Health, National University of Singapore, Singapore, Singapore. [4]Department of Maternal Fetal Medicine, KK Women's and Children's Hospital, Singapore, Singapore. [5]Duke-NUS Medical School, Singapore, Singapore. [6]Department of Paediatrics, KK Women's and Children's Hospital, Singapore, Singapore. [7]Department of Paediatrics, Yong Loo Lin School of Medicine, National University of Singapore, Singapore, Singapore. [8]Division of Paediatric Allergy, Immunology and Rheumatology, Khoo Teck Puat - National University Children's Medical Institute, National University Health System, Singapore, Singapore. [9]Liggins Institute, University of Auckland, Auckland, New Zealand. [10]Medical Research Council Lifecourse Epidemiology Unit, University of Southampton, Southampton, UK. [11]NIHR Southampton Biomedical Research Centre, University of Southampton and University Hospital Southampton NHS Foundation Trust, Southampton, UK. [12]Departments of Pediatrics and of Epidemiology and Biostatistics, McGill University Faculty of Medicine, Montreal, Quebec, Canada. [13]Singapore Eye Research Institute, Singapore, Singapore. [14]Institute for Social Medicine, Epidemiology and Health Economics, Charite University Medical Centre, Berlin, Germany. [15]Singapore Institute for Clinical Sciences (SICS), Agency for Sciences, Technology and Research (A*STAR). MD1 Tahir Foundation Building, #12-02/03, 21 Lower Kent Ridge Rd, Singapore 119077, Singapore.

References

1. Bureau of Labor Statistics, U.S. Department of Labor. American time use survey - 2013 results. Washington; 2014. https://www.bls.gov/news.release/archives/atus_06182014.pdf.
2. Interactive Software Federation Of Europe. Videogames In Europe. Brussels: Consumer Study; 2012.
3. NPD Group. Kids and gaming 2013. Port Washington, NY: The NPD Group, Inc.; 2013.
4. Verloigne M, Loyen A, Van Hecke L, Lakerveld J, Hendriksen I, De Bourdheaudhuij I, et al. Variation in population levels of sedentary time in European children and adolescents according to cross-European studies: a systematic literature review within DEDIPAC. Int J Behav Nutr Phys Act. 2016;13:69.
5. World Health Organization: Global recommendations on physical activity for health. http://whqlibdoc.who.int/publications/2010/9789241599979_eng.pdf?ua=1; 2010.
6. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the global burden of disease study 2010. Lancet. 2012;380:2224–60.
7. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet. 2012;380:219–29.
8. Sedentary Behaviour Research N. Letter to the editor: standardized use of the terms "sedentary" and "sedentary behaviours". Appl Physiol Nutr Metab. 2012;37:540–2.
9. de Rezende LF, Rodrigues Lopes M, Rey-Lopez JP, Matsudo VK, Luiz OC. Sedentary behavior and health outcomes: an overview of systematic reviews. PLoS One. 2014;9:e105620.
10. Pate RR, Mitchell JA, Byun W, Dowda M. Sedentary behaviour in youth. Br J Sports Med. 2011;45:906–13.
11. Christakis DA, Garrison MM. Preschool-aged children's television viewing in child care settings. Pediatrics. 2009;124:1627–32.
12. Dennison BA, Erb TA, Jenkins PL. Television viewing and Television in Bedroom Associated with Overweight Risk among low-Income Preschool Children. Pediatrics. 2002;109:1028–35.
13. Reid Chassiakos Y, Radesky J, Christakis D, Moreno MA, Cross C. Children and adolescents and digital media. Pediatrics. 2016;138:e20162593-e.
14. Saldanha-Gomes C, Heude B, Charles MA, de Lauzon-Guillain B, Botton J, Carles S, et al. Prospective associations between energy balance-related behaviors at 2 years of age and subsequent adiposity: the EDEN mother-child cohort. Int J Obes. 2017;41:38–45.
15. Council On Communications Media. Media and young minds. Pediatrics. 2016;138:e20162591-e.
16. 2015 Google Consumer Barometer [https://www.consumerbarometer.com].
17. Hildebrand M, Øglund GP, Wells JC, Ekelund U. Prenatal, birth and early life predictors of sedentary behavior in young people: a systematic review. Int J Behav Nutr Phys Activ. 2016;13
18. Duch H, Fisher EM, Ensari I, Harrington A. Screen time use in children under 3 years old: a systematic review of correlates. Int J Behav Nutr Phys Act. 2013;10:102.
19. Goh SN, Teh LH, Tay WR, Anantharaman S, Dam RM, Tan CS, et al. Sociodemographic, home environment and parental influences on total and device-specific screen viewing in children aged 2 years and below: an observational study. BMJ Open. 2016;6:e009113.
20. Soh SE, Tint MT, Gluckman PD, Godfrey KM, Rifkin-Graboi A, Chan YH, et al. Cohort profile: growing up in Singapore towards healthy outcomes (GUSTO) birth cohort study. Int J Epidemiol. 2014;43:1401–9.
21. Padmapriya N, Shen L, Soh SE, Shen Z, Kwek K, Godfrey KM, et al. Physical activity and sedentary behavior patterns before and during pregnancy in a multi-ethnic sample of Asian women in Singapore. Matern Child Health J. 2015;19:2523–35.
22. Tu Y-K, Gilthorpe MS. Statistical thinking in epidemiology. Boca Raton: CRC Press; 2011.
23. Biddle SJ, Pearson N, Ross GM, Braithwaite R. Tracking of sedentary behaviours of young people: a systematic review. Prev Med. 2010;51:345–51.
24. Certain LK, Kahn RS. Prevalence, correlates, and trajectory of television viewing among infants and toddlers. Pediatrics. 2002;109:634–42.
25. Flores G, Tomany-Korman SC, Olson L. Does disadvantage start at home? Racial and ethnic disparities in health-related early childhood home routines and safety practices. Arch Pediatr Adolesc Med. 2005;159:158–65.
26. Schmidt ME, Rich M, Rifas-Shiman SL, Oken E, Taveras EM. Television viewing in infancy and child cognition at 3 years of age in a US cohort. Pediatrics. 2009;123:e370–5.
27. Carson V, Janssen I. Associations between factors within the home setting and screen time among children aged 0-5 years: a cross-sectional study. BMC Public Health. 2012;12:539.
28. Chandra M, Jalaludin B, Woolfenden S, Descallar J, Nicholls L, Dissanayake C, et al. Screen time of infants in Sydney. Australia: a birth cohort study BMJ Open. 2016;6:e012342.
29. Dong S, Song Y, Jiang Y, Sun W, Wang Y, Jiang F. Multi-center study on the effects of television viewing on sleep quality among children under 4 years of age in China. Zhonghua Er Ke Za Zhi. 2015;53:907–12.
30. Cui Z, Hardy LL, Dibley MJ, Bauman A. Temporal trends and recent correlates in sedentary behaviours in Chinese children. Int J Behav Nutr Phys Act. 2011;8:93.
31. Huang WY, Wong SH, Salmon J. Correlates of physical activity and screen-based behaviors in Chinese children. J Sci Med Sport. 2013;16:509–14.
32. Atkin AJ, Sharp SJ, Corder K, van Sluijs EM, International Children's Accelerometry Database C. Prevalence and correlates of screen time in youth: an international perspective. Am J Prev Med. 2014;47:803–7.
33. Zimmerman FJ, Christakis DA, Meltzoff AN. Television and DVD/video viewing in children younger than 2 years. Arch Pediatr Adolesc Med. 2007;161:473–9.
34. Songul Yalcin S, Tugrul B, Nacar N, Tuncer M, Yurdakok K. Factors that affect television viewing time in preschool and primary schoolchildren. Pediatr Int. 2002;44:622–7.
35. Tomopoulos S, Dreyer BP, Valdez P, Flynn V, Foley G, Berkule SB, et al. Media content and externalizing behaviors in Latino toddlers. Ambul Pediatr. 2007;7:232–8.
36. Kourlaba G, Kondaki K, Liarigkovinos T, Manios Y. Factors associated with television viewing time in toddlers and preschoolers in Greece: the GENESIS study. J Public Health (Oxf). 2009;31:222–30.
37. Hoyos Cillero I, Jago R. Systematic review of correlates of screen-viewing among young children. Prev Med. 2010;51:3–10.
38. Gopinath B, Baur LA, Hardy LL, Kifley A, Rose KA, Wong TY, et al. Relationship between a range of sedentary behaviours and blood pressure during early adolescence. J Hum Hypertens. 2012;26:350–6.
39. Singapore Department of Statistics, Ministry of Trade and Industry. Census of population 2010 statistical release 1: demographic characteristics, education, language and religion, vol. 2011. http://www.singstat.gov.sg/publications/publications-and-papers/cop2010/census10_stat_release1.
40. Hinkley T, Cliff DP, Okely AD. Reducing electronic media use in 2-3 year-old children: feasibility and efficacy of the family@play pilot randomised controlled trial. BMC Public Health. 2015;15:779.

Frequency of eating home cooked meals and potential benefits for diet and health: cross-sectional analysis of a population-based cohort study

Susanna Mills[1*], Heather Brown[1], Wendy Wrieden[2], Martin White[1,3] and Jean Adams[3]

Abstract

Background: Reported associations between preparing and eating home cooked food, and both diet and health, are inconsistent. Most previous research has focused on preparing, rather than eating, home cooked food; used small, non-population based samples; and studied markers of nutrient intake, rather than overall diet quality or health. We aimed to assess whether frequency of consuming home cooked meals was cross-sectionally associated with diet quality and cardio-metabolic health.

Methods: We used baseline data from a United Kingdom population-based cohort study of adults aged 29 to 64 years (n = 11,396). Participants self-reported frequency of consuming home cooked main meals. Diet quality was assessed using the Mediterranean Diet Score, Dietary Approaches to Stop Hypertension (DASH) score, fruit and vegetable intake calculated from a 130-item food frequency questionnaire, and plasma vitamin C. Markers of cardio-metabolic health were researcher-measured body mass index (BMI), percentage body fat, haemoglobin A_{1c} (HbA_{1c}), cholesterol and hypertension. Differences across the three exposure categories were assessed using linear regression (diet variables) and logistic regression (health variables).

Results: Eating home cooked meals more frequently was associated with greater adherence to DASH and Mediterranean diets, greater fruit and vegetable intakes and higher plasma vitamin C, in adjusted models. Those eating home cooked meals more than five times, compared with less than three times per week, consumed 62.3 g more fruit (99% CI 43.2 to 81.5) and 97.8 g more vegetables (99% CI 84.4 to 111.2) daily. More frequent consumption of home cooked meals was associated with greater likelihood of having normal range BMI and normal percentage body fat. Associations with HbA_{1c}, cholesterol and hypertension were not significant in adjusted models. Those consuming home cooked meals more than five times, compared with less than three times per week, were 28% less likely to have overweight BMI (99% CI 8 to 43%), and 24% less likely to have excess percentage body fat (99% CI 5 to 40%).

Conclusions: In a large population-based cohort study, eating home cooked meals more frequently was associated with better dietary quality and lower adiposity. Further prospective research is required to identify whether consumption of home cooked meals has causal effects on diet and health.

Keywords: Home cooking, Diet, Cardio-metabolic health

* Correspondence: susanna.mills@newcastle.ac.uk
[1]Institute of Health & Society, Newcastle University, Baddiley-Clark Building, Richardson Road, Newcastle upon Tyne NE2 4AX, UK
Full list of author information is available at the end of the article

Background

The prevalence of obesity and diet-related non-communicable diseases (NCDs), such as type II diabetes, hypertension, and certain cancers, have been increasing steadily worldwide [1]. These changes have been accompanied by a decrease in the time spent cooking at home in the majority of developed countries [2, 3]. Concern has been expressed by policy makers, practitioners and researchers in the field of food and nutrition regarding a perceived decline in cooking skills, which has been hypothesised to be linked to the increase in diet-related NCDs [4–6].

Certain studies, primarily cross-sectional in design, have indicated that a higher frequency of cooking and preparing food at home may be associated with consuming a healthier diet [7–9] and benefits to health and longevity [10–12]. In contrast, other cross-sectional research has suggested that home food preparation and cooking may be associated with diets lower in fibre and higher in fat, saturated fat, sugar, and salt [13, 14] and could potentially be detrimental to health [15, 16]. Adding to this confusion, the majority of research to date has used cooking and food preparation practices as an exposure, rather than the consumption of home cooked food itself. Since eating food is more proximal to potential diet and health outcomes, focusing on behaviour upstream may be more likely to introduce confounding, for example regarding gender – given that more women than men engage in food preparation [3], and women tend to have healthier diets [17]. Of key primary interest therefore is establishing whether consuming home cooked meals is associated with benefits to diet and health, and subsequently investigating who eats home cooked meals, and then who prepares these meals and why.

To date, research investigating the potential advantages and disadvantages for diet and health of cooking and preparing food at home has generally focused on specific dietary indicators, rather than overall diet quality or health, and assessed measures cross-sectionally or after a brief follow-up period [18]. Most studies have been small in size, with associated limited scope to identify significant associations [8]; limited to a specific geographical area [19]; and/or restricted to population subgroups by for example age [10, 20] or ethnicity [11].

Despite the fact that the evidence base for relationships between cooking and both diet and NCDs is mixed and inconclusive, the promotion of home cooking forms part of public health strategies to improve diets and reduce obesity and diet-related NCDs internationally [21]. Further research is therefore crucial, to investigate on a large scale the potential associations between consumption of home cooked meals and diet and health outcomes.

In this study we aimed to assess whether the consumption frequency of home cooked meals was cross-sectionally associated with indicators of diet and cardio-metabolic status. In view of the current evidence base, we hypothesised that eating home cooked meals more frequently would be associated with markers of a healthier diet and improved cardio-metabolic health.

Methods

Data source

The Fenland Study is a population-based cohort study investigating interactions between genetic and lifestyle factors in determining obesity and diabetes. The study recruited adults born between 1950 and 1975 from general practice lists in Cambridgeshire, United Kingdom (UK), between 2005 and 2015 [22]. Participants were invited to attend one of three clinical sites in Cambridgeshire to take part in a detailed assessment. A total of 12,434 participants undertook baseline assessment (approximate response rate 27%), which involved a range of clinical, biological and anthropometric measurements, and completion of questionnaires. The data collection tools are available online [23].

Study exclusion criteria included previously diagnosed diabetes, psychosis, terminal illness, pregnancy, and inability to walk unaided. The Fenland study was approved by the Health Research Authority National Research Ethics Service Committee – East of England Cambridge Central – and performed in accordance with the Declaration of Helsinki. All participants provided written informed consent to participate in the study.

Frequency of consumption of home cooked meals

Exposure was derived from an item in the participant questionnaire: 'When eating your main meal at home, how often do you usually eat home cooked meals?' Response categories were: never or rarely; one to two times per week; three to five times per week; or more than five times per week. The first two response categories were collapsed to yield appropriate numbers for statistical analysis, as previously [24], giving a three category variable: less than three times per week, three to five times per week, and more than five times per week.

Indicators of diet quality

We assessed a range of dietary outcome variables, namely Mediterranean Diet Score (MDS) [25], Dietary Approaches to Stop Hypertension (DASH) score [26], plasma vitamin C, and fruit and vegetable intakes. Participants completed a 130-item, semi-quantitative food frequency questionnaire (FFQ) for their food intake over the previous year [27], which has been shown to yield valid and reproducible food intake assessments, and has been validated previously in dietary data collection in the European Prospective Investigation into Cancer and Nutrition (EPIC) studies [28]. The FFQ EPIC Tool for Analysis was used to convert food intake frequency to energy, nutrient and food intakes [29]. Total daily intake was provided in grams for carbohydrate,

fibre, fat, saturated fat, sugar, protein, fruit, vegetables and alcohol. Total daily sodium intake was measured in milligrams, and total daily energy intake in kilojoules. Dietary intake values were winsorized at 1st and 99th percentiles, by replacing the smallest and largest percentage values in the distribution with the observations closest to them [30]. This was undertaken to account for their positively skewed distribution, and the limitations of the FFQ as a tool to collect precise data on dietary intake [31, 32]. Data on dietary supplements were not collected.

The consumption of a more DASH accordant diet is associated with positive health indicators and lowered cardio-metabolic risk [33–35]. The DASH diet assumes that beneficial impact is derived from the overall diet, rather than individual foods or nutrients playing important roles [36]. A DASH score was computed from each participant's dietary intake using the method developed by Fung et al. [26]. This index includes eight components (one nutrient and seven food groups) based on eating guidance from the United States (US) National Heart, Lung and Blood Institute [37]. Scoring is established through quintile rankings, on the basis of relative comparisons to the rest of the sample, with men and women classified separately. Participants are allocated a score from one (lowest quintile) to five (highest quintile) for energy-adjusted intake of: low-fat dairy products; whole grains; nuts, seeds and legumes; fruit (includes fruit juice); and vegetables (excludes potatoes). In contrast, for intakes of red and processed meat; sodium; and sugar-sweetened beverages, participants are allocated a score from one (highest quintile) to five (lowest quintile). Scores are then combined to give a total DASH score, ranging from a minimum of eight to a maximum of 40 points. In this study, DASH scores were standardised using the z-score, to yield a semi-continuous measure of participants' relative standing.

The Mediterranean diet is generally considered to be low in consumption of red meats, moderate in consumption of fish, poultry, fermented dairy products and wine, and high in consumption of fruits, legumes, cereals and olive oil [38, 39]. Concordance with the Mediterranean diet has been linked with positive health outcomes, in particular the primary prevention of cardiovascular disease [40]. A Mediterranean diet score (MDS) was calculated from each participant's dietary intake using sex-specific tertiles, according to relative comparisons with the rest of the sample. Scores of zero, one or two were allocated for each of nine dietary components, including legumes; fruit and nuts; vegetables; ratio of monounsaturated and polyunsaturated fatty acids to saturated fatty acids; fish; meat products; dairy products; cereals; and alcohol [25]. In order to appraise quality of diet independent of quantity, dietary intakes were adjusted to a 2000 kcal/day diet using the residual method. This also aimed to help reduce measurement errors, since energy intake is partially associated with over-reporting and under-reporting of dietary intake [41]. MDS scores were then standardised using the z-score.

Plasma vitamin C (μmol/l) provides an objective biomarker of fruit and vegetable consumption [42] and fruit and vegetable intake is promoted in dietary guidelines [43, 44]. Fasting venous blood samples drawn into heparin-containing tubes and stabilised using metaphosphoric acid (10%) were measured for plasma vitamin C levels by fluorometric assay within two months, as undertaken previously [45].

Markers of cardio-metabolic health

We used body mass index (BMI), percentage body fat, haemoglobin A_{1c} (HbA_{1c}), cholesterol and hypertension as indicators of cardio-metabolic health. Elevated total cholesterol and low levels of high density lipoprotein cholesterol (HDL) are associated with increased risk of cardiovascular disease [46], and the derived ratio of total cholesterol to HDL is used in the QRISK2 model to estimate risk of cardiovascular disease over the next ten years [47]. HDL and total cholesterol were measured in mmol/l in fasting venous blood samples, and the ratio of total cholesterol to HDL calculated for analysis. In line with UK guidance, a ratio of 4.0 or greater was used to indicate higher risks to cardio-metabolic health [48].

Excess body fat and raised BMI have been associated with increased risk of various NCDs [49]. Height and weight were measured at the clinical sites by trained observers, with participants wearing light clothing and barefoot. Height was measured to the nearest 0.1 cm using a wall-mounted calibrated stadiometer (SECA 240, Birmingham, UK). Weight was measured to the nearest 0.1 kg with a calibrated electronic scale (TANITA, BC-418MA, Tokyo, Japan). BMI was derived as weight (kg) divided by height (m^2). Dual-energy X-ray absorptiometry (DEXA; Lunar prodigy advanced fan beam scanner (GE Healthcare)) was used to assess body composition, and has been described in detail elsewhere [22]. A three-compartment model (fat mass, fat-free mass and bone mineral mass) was used to estimate percentage total body fat. In line with international guidance, overweight was defined as BMI 25 kg/m^2 and above [50] and excess percentage body fat as 25% and over for males and 38% and over for females [51].

Haemoglobin A_{1c} (HbA_{1c}) has previously been used to assess risk of developing type II diabetes [52]. Participants' HbA_{1c} was measured on entry to the study from fasting venous blood samples, in either mmol/mol or as a percentage. A conversion algorithm was used to convert all measurements to mmol/mol, and in accordance with international guidance [52], a level of 42.00 mmol/mol (6.0%) or higher was used to indicate increased risk of type II diabetes.

Hypertension is associated with an elevated risk of developing cardiovascular disease [53]. Using an upper arm cuff and automated oscillometric device, three sets of diastolic and systolic blood pressure measurements were performed on each participant. The first readings were discarded and the lowest systolic and lowest diastolic readings from the last two readings were used for assessment. In adherence to UK guidance [54], readings of at least 90 mmHg diastolic and 140 mmHg systolic were considered indicative of hypertension. Participants currently taking hypotensive medication, or self-reporting a diagnosis of hypertension from a clinician, were also classified as hypertensive.

Covariates

In view of the current evidence base regarding factors influencing dietary intake [55], a self-administered questionnaire was used to collect demographic and behavioural variables including sex, age, smoking status (current/ex-smoker or never smoker), and first degree family history of relevant diseases such as type II diabetes. Participants were asked whether or not they had been employed in the past four weeks, and those answering yes were identified as currently working. Participants reporting more than 48 h working in any one week were identified as working overtime. Socioeconomic status was assessed using age at leaving full time education, which was divided into three categories: education up to age 16 years (compulsory education); over 16 and up to 18 years (post-compulsory school education); and over 18 years (higher education).

Physical activity was measured objectively using an integrated movement and heart rate sensor (Actiheart; CamNtech, Cambridge, UK) attached to the chest via two standard ECG electrodes and worn during free-living over six days [56]. A ramped treadmill protocol test was used to individually calibrate heart rate, as undertaken previously [57]. Monitoring data were cleaned for measurement issues and sensor wear time was specified as at least 48 h, although data were not necessarily spread over a full 24 period. Periods of non-wear were inferred from the combination of non-physiological heart rate and prolonged periods of inactivity, which were taken into account to minimise diurnal information bias when summarising the intensity time-series. Data were processed [58] and a branched equation framework [59] used for modelling to estimate intensity time series. These were collated over time to yield daily physical activity energy expenditure (kJ/kg per day).

Statistical analysis

All analyses were on a complete case basis. Thus, participants with missing data on any of the variables described were excluded (n = 1038), leaving 11,396 participants (91.7% total cohort) in the analysis. The outcome variable with the greatest missingness was vitamin C (missing for 350 participants) and the covariate with the greatest missingness was physical activity (missing for 227 participants). Differences in the characteristics of Fenland study participants included and excluded from the analytic sample were tested using the Mann–Whitney test for continuous variables and Pearson Chi squared test for categorical variables.

Differences in covariates and markers of diet and cardiometabolic health across the three frequency categories of consuming home cooked meals were assessed using descriptive statistics (Kruskal-Wallis test and Pearson Chi squared test). Separate analyses were then run for each outcome variable, using linear regression for continuous diet variables and logistic regression for binary health variables. Analyses were adjusted for covariates: sex, age, alcohol intake, smoking status, age at leaving full-time education, physical activity, working status, and overtime working, with supplementary adjustment for family history of diabetes for the outcome of HbA_{1c}. The analyses for markers of cardio-metabolic status were additionally adjusted for dietary variables (MDS, DASH score, plasma vitamin C, fruit and vegetable intakes) to assess the potential health benefits of consuming home cooked meals independent of dietary improvements.

All analyses were conducted using Stata (version 14; Stata Corp.) and in view of the large number of comparisons, 99% confidence intervals were used to determine if variables were statistically significant (see Additional file 1 for details of the participant sample).

Results

Participant distribution is summarised in Additional file 2. A slight majority of the included sample was female (53.3%), with median age 48.9 years. Most participants were non-smoking (88.2%), with no family history of diabetes (76.1%), median alcohol intake of 5.47 g/day and physical activity expenditure of 51.0 kJ/kg/day. Most participants had left full time education by 18 years of age (62.2%), were currently in work (82.8%), and did not work overtime (88.8%). There were significant differences between the included and excluded participants in terms of sex, age, smoking status, physical activity expenditure, working status, and frequency of consuming home cooked meals.

Table 1 shows that 6.2% of included participants consumed home cooked meals as their main meal less than three times per week, 32.4% consumed these three to five times per week, and 61.5% consumed these more than five times per week. Participants who ate home cooked meals more frequently tended to be female, older, non-smokers, not currently in work, working fewer hours and not working overtime, older at leaving full time education, with greater daily alcohol intake. These associations were all statistically significant at $p < 0.01$. Participants who consumed home cooked meals more frequently generally had higher plasma vitamin C, higher fruit and vegetable intakes, and higher MDS and DASH score. They were also less likely to

Table 1 Characteristics of participants overall and by frequency of consuming home cooked meals

Covariate[a]		Consumption of home cooked main meals			
		Total	<3×/week	3-5×/week	>5×/week
		n = 11,396 (100.00%)	*n* = 704 (6.18%)	*n* = 3688 (32.36%)	*n* = 7004 (61.46%)
Sex	Male	5321	389 (7.31)	1914 (35.97)	3018 (56.72)
	Female	6075	315 (5.19)	1774 (29.20)	3986 (65.61)
Age (years)	Median (IQR)	48.9 (42.7, 54.8)	47.1 (41.7, 53.3)	48.3 (42.2, 53.9)	49.5 (43.1, 55.3)
Alcohol (grams/day)	Median (IQR)	5.47 (1.27, 10.72)	3.90 (0.76, 9.56)	5.47 (1.30, 10.56)	5.47 (1.27, 10.88)
Age at leaving full-time education (years)	≤16	4570	351 (7.68)	1709 (37.40)	2510 (54.92)
	>16 to ≤18	2521	148 (5.87)	839 (33.28)	1534 (60.85)
	>18	4305	205 (4.76)	1140 (26.48)	2960 (68.76)
Smoker	No	10,045	569 (5.66)	3133 (31.19)	6343 (63.15)
	Yes	1351	135 (9.99)	555 (41.08)	661 (48.93)
Family History of diabetes[b]	No	8677	535 (6.17)	2796 (32.22)	5346 (61.61)
	Yes	2719	169 (6.22)	892 (32.81)	1658 (60.98)
Physical activity (kJ[c]/kg[d]/day)	Median (IQR)	51.00 (37.84, 66.75)	49.64 (35.82, 65.82)	51.57 (38.22, 67.64)	50.89 (37.88, 66.27)
Working in past 4 weeks	No	1959	118 (6.02)	563 (28.74)	1278 (65.24)
	Yes	9437	586 (6.21)	3125 (33.11)	5726 (60.68)
Working hours	Median (IQR)	33.0 (14.0, 40.0)	37.0 (20.0, 43.7)	35.0 (17.5, 41.0)	30.0 (12.0, 40.0)
Overtime work (>48 h/week)	No	10,116	592 (5.85)	3243 (32.06)	6281 (62.09)
	Yes	1280	112 (8.75)	445 (34.77)	723 (56.48)
Outcome[i]					
Vitamin C (umol/l[e])	Median (IQR)	69.40 (56.00, 82.00)	63.15 (44.73, 77.38)	66.80 (52.70, 80.10)	71.1 (58.5, 83.4)
Fruit intake (grams/day)	Median (IQR)	207.10 (111.61, 329.50)	142.53 (60.08, 264.19)	180.53 (93.10, 293.10)	226.83 (131.16, 353.04)
Vegetable intake (grams/day)	Median (IQR)	258.95 (188.89, 348.56)	174.41 (111.92, 257.26)	234.59 (172.55, 310.33)	280.56 (209.53, 375.83)
DASH score[f]	Median (IQR)	24 (21, 27)	22 (19, 25)	23 (20, 26)	25 (22, 28)
MDS[g]	Median (IQR)	9 (7,11)	7 (6, 10)	8 (6, 10)	10 (7, 11)
Excess body fat (≥25% men; ≥38% women)	No	4831	246 (5.09)	1399 (28.96)	3186 (65.95)
	Yes	6565	458 (6.98)	2289 (34.87)	3818 (58.16)
Overweight BMI[h] (≥25.0)	No	4384	211 (4.81)	1290 (29.43)	2883 (65.76)
	Yes	7012	493 (7.03)	2398 (34.20)	4121 (58.77)
High cholesterol ratio (≥4.0)	No	7234	400 (5.53)	2209 (30.54)	4625 (63.93)
	Yes	4162	304 (7.30)	1479 (35.54)	2379 (57.16)
High HbA^{i}_{1c}(≥42.00)	No	10,207	608 (5.96)	3265 (31.99)	6334 (62.06)
	Yes	1189	96 (8.07)	423 (35.58)	670 (56.35)
Hypertension	No	8561	516 (6.03)	2761 (32.25)	5283 (61.72)
	Yes	2836	188 (6.63)	927 (32.69)	1721 (60.68)

[a]Results shown as number (row percentage). Median (inter-quartile range) shown for: age, alcohol, physical activity, average working hours, vitamin C, fruit intake, vegetable intake, DASH score, MDS
[b]History of diabetes in first degree relative
[c]kj = kilojoules
[d]kg = kilograms
[e]umol/l = micromole/l
[f]DASH = Dietary Approaches to Stop Hypertension
[g]MDS = Mediterranean Diet Score
[h]BMI = body mass index
[i]HbA_{1c} = Haemoglobin A_{1c}

have an overweight BMI, excess percentage body fat, high risk cholesterol ratio, or to be at risk of developing diabetes according to HbA_{1c} level.

Multivariate associations between the frequency of consuming home cooked meals and indicators of diet quality and cardio-metabolic status are shown in Table 2. In all cases, consuming home cooked meals more frequently was significantly associated with indicators of a healthier diet, as measured by higher MDS, DASH score, plasma vitamin C, and fruit and vegetable intakes. These associations were present for both consuming home cooked meals three to five times per week, and more than five times per week, compared with the reference of less than three times per week, and remained robust to adjustment for sociodemographic and behavioural covariates. In particular, those who consumed home cooked meals more than five times per week consumed 62.3 g more fruit (99% CI 43.2 to 81.5) and 97.8 g more vegetables (99% CI 84.4 to 111.2) daily than those who consumed home cooked meals less than three times per week. This equates to more than three-quarters of a portion of fruit, and almost one and a quarter portions of vegetables, or approximately two extra portions of fruit and vegetables per day.

In terms of cardio-metabolic status, consuming home cooked meals more than five times per week compared with the reference of less than three times per week was significantly associated with all markers except hypertension in the unadjusted models. After adjustment for sociodemographic and behavioural covariates (model 1), the association between consuming home cooked meals more than five times per week and high risk cholesterol ratio was extinguished. After further adjustment for dietary variables

Table 2 Associations between frequency of consuming home cooked meals and markers of diet and cardio-metabolic status

Outcomes	Home cooked meals[a]	Unadjusted value (99% CI[b])	Adjusted value, model 1[c] (99% CI[b])	Adjusted value, model 2[d] (99% CI[b])
Regression coefficients for dietary indicators				
DASH score[e]	3-5×/week	0.23 (0.13, 0.34)	0.18 (0.08, 0.28)	NA
	>5×/week	0.61 (0.51, 0.71)	0.44 (0.35, 0.54)	NA
MDS[f]	3-5×/week	0.27 (0.17, 0.38)	0.23 (0.13, 0.33)	NA
	>5×/week	0.64 (0.54, 0.74)	0.52 (0.42, 0.61)	NA
Vitamin C (μmol/l[g])	3-5×/week	4.50 (2.28, 6.73)	3.29 (1.18, 5.39)	NA
	>5×/week	8.95 (6.81, 11.09)	5.35 (3.31, 7.39)	NA
Fruit intake (grams/day)	3-5×/week	32.29 (12.14, 52.44)	27.17 (7.43, 46.92)	NA
	>5×/week	79.06 (59.69, 98.43)	62.33 (43.19, 81.46)	NA
Vegetable intake (grams/day)	3-5×/week	54.22 (40.06, 68.39)	50.54 (36.61, 64.29)	NA
	>5×/week	107.43 (93.81, 121.05)	97.83 (84.42, 111.24)	NA
Odds ratios for markers of cardio-metabolic status				
Cholesterol binary (high vs low risk)	3-5×/week	0.88 (0.71, 1.09)	0.96 (0.76, 1.21)	0.99 (0.78, 1.25)
	>5×/week	0.68 (0.55, 0.83)	0.87 (0.70, 1.09)	0.93 (0.74, 1.17)
BMI[h] binary (over- vs normal weight)	3-5×/week	0.80 (0.63, 1.00)	0.81 (0.64, 1.02)	0.82 (0.65, 1.05)
	>5×/week	0.61 (0.49, 0.76)	0.70 (0.55, 0.88)	0.72 (0.57, 0.92)
Body fat binary (excess vs normal)	3-5×/week	0.88 (0.70, 1.10)	0.89 (0.71, 1.13)	0.92 (0.73, 1.17)
	>5×/week	0.64 (0.52, 0.80)	0.71 (0.57, 0.89)	0.76 (0.60, 0.95)
HbA_{1c}[i] binary (high vs low risk)	3-5×/week	0.82 (0.60, 1.12)	0.83 (0.60, 1.15)	0.86 (0.62, 1.19)
	>5×/week	0.67 (0.50, 0.91)	0.68 (0.49, 0.93)	0.73 (0.53, 1.01)
Hypertension binary (yes vs no)	3-5×/week	0.92 (0.72, 1.17)	0.88 (0.69, 1.13)	0.89 (0.69, 1.14)
	>5×/week	0.89 (0.71, 1.13)	0.84 (0.67, 1.07)	0.86 (0.67, 1.09)

[a]Consumption of home cooked meals as main meal at home: comparisons with low consumption (<3×/week, reference), for medium consumption (3-5×/week), and high consumption (>5×/week)
[b]CI = 99% confidence interval
[c]Adjusted for age, sex, alcohol intake, smoking, physical activity, working status, working overtime, years of full time education (+ family history diabetes for HbA_{1c} outcome)
[d]Adjusted for age, sex, alcohol intake, smoking, physical activity, working status, working overtime, years of full time education, DASH score, MDS, vitamin C, fruit intake, vegetable intake (+ family history diabetes for HbA_{1c} outcome)
[e]DASH = Dietary Approaches to Stop Hypertension
[f]MDS = Mediterranean Diet Score
[g]umol/l = micromole/l
[h]BMI = Body Mass Index
[i]HbA_{1c} = Haemoglobin A_{1c}

(model 2), only the associations with having a normal range BMI and lower percentage body fat remained significant. Such associations indicated that consuming home cooked meals more than five times per week compared with the reference was associated with improved adiposity, independent of the effects due to diet. Those consuming home cooked meals more than five times per week were 28% less likely to have a BMI in the overweight range (99% CI 8 to 43%), and 24% less likely to have excess percentage body fat (99% CI 5 to 40%), compared with those who consumed home cooked meals less than three times per week. Overall, a higher frequency of consuming home cooked meals was associated with markers of improved cardio-metabolic health, including lower risk cholesterol ratio, normal range BMI, lower percentage body fat, and lower risk of diabetes according to HbA_{1c} level.

Discussion

Statement of principal findings

In accordance with our hypothesis, a higher frequency of consuming home cooked main meals was significantly associated with indicators of a healthier diet, namely DASH score, MDS, plasma vitamin C, fruit intake and vegetable intake. Similarly, eating home cooked meals more frequently was significantly associated with several markers of cardio-metabolic health, including lower likelihood of having an overweight BMI, and lower likelihood of excess percentage body fat. Associations between frequency of home cooked meal consumption and markers of cardio-metabolic health were strongest at the highest consumption frequency of eating meals more than five times per week.

To our knowledge, this is the first large scale, population-based study to address associations between the frequency of consuming home cooked meals and indicators of both diet quality and cardio-metabolic status. The study has been reported according to the STROBE-nut guidelines [60] (see Additional file 3).

Strengths and weaknesses of the study

The Fenland study is a large cohort, with detailed sociodemographic data, objective physical measurements and samples, and comprehensive dietary measures. Participants in this study were from the county of Cambridgeshire, which is representative of the wider population in England in terms of adult obesity and several lifestyle variables, such as smoking and levels of physical activity [61].

Overall diet quality was assessed using two composite diet scores, DASH and MDS. Using two composite scores provided robust evidence in support of potential associations between consuming home cooked meals more frequently and higher diet quality. These results were supported by similar associations with higher fruit and vegetable intakes, measured by both FFQ, and plasma vitamin C as a biomarker. We used consumption, rather than preparation, of home cooked meals as our exposure, which is likely to be closer on the potential causal pathway to diet and health outcomes. The use of objective measurements for determining cholesterol ratio, BMI, percentage body fat, HbA_{1c} level and hypertension is likely to increase the validity of these markers of cardio-metabolic status, and the confidence in conclusions drawn from resultant analyses.

This research is also subject to some limitations. The cross-sectional nature of the data means that direction of cause and effect cannot be established, although follow-up data collection in the Fenland study is currently underway, which will enable future longitudinal analysis. Participants were recruited between the ages of 29 and 64 years, and are therefore not representative of the full UK population age range. Given that food preparation practices vary with age [62], our results may not be generalizable to younger populations. We excluded participants with missing data on any of the analytic variables, and excluded participants were systematically different from the rest of the cohort in terms of certain characteristics (see Additional file 2). Furthermore, differences in cooking and food culture internationally may mean that the relationships between consuming home cooked meals, diet quality, and cardio-metabolic health, vary between countries. Therefore, our findings may not necessarily be generalizable to other populations.

The fruit and vegetable intakes and DASH and MDS dietary scores were derived from FFQ data, which although validated, may be subject to error and biases [31, 32]. The composite scores assessed diet quality relative to other participants, rather than establishing absolute values, and ranking groups may constitute a broad range. The exposure variable for consumption of home cooked meals was derived from a questionnaire item, and given the absence of consensus on home cooking terminology [63, 64], participants may have interpreted this question differently. We collected data specifically on home cooked meals eaten at home and not those eaten elsewhere, such as packed lunches taken to work or place of study. The self-reported nature of several sociodemographic and behavioural variables, such as smoking, may have led to variables being correlated with each other, with associated risk of type II analytical errors.

Although we adjusted for a number of relevant potential confounders in our analyses, residual confounding remains possible. If people who consume home cooked meals more frequently are also more likely to engage in other health promoting behaviours, this could artificially strengthen associations between increased consumption of home cooked meals and markers of cardio-metabolic health.

Interpretation of findings in the context of existing research

Our findings reflect those of others that found associations between home food preparation and cooking and

higher quality diets. A recent systematic review [18] identified that potential benefits included intake from healthier food groups [19, 65, 66]; greater fruit and vegetable preference and healthy eating self-efficacy [67]; enhanced nutrient intake [7, 68]; higher Diet Quality Index-International score and intake from healthier food groups [20]; trend towards higher Healthy Eating Index score [69]; consumption of a healthful dietary pattern [70]; and improved adherence to: Healthy People 2010 dietary intake objectives [8], Balance of Good Health (now Eatwell Guide) criteria [71], and a Mediterranean diet using the KIDMED index [72]. A greater frequency of home cooked meals has also been associated with higher Healthy Eating Index scores [24]. However, the majority of this research has been cross-sectional and therefore unable to conclusively indicate direction of causation. Most studies have also employed self-reported measures, which are vulnerable to bias [73], and have used food preparation practices as an exposure, rather than the consumption of home cooked food itself.

Our results also support previous studies that identified associations between home food preparation and cooking and potential advantages to health. Greater home cooking frequency has been linked with longer lifespan [10] and more frequent consumption of meals prepared at home has been associated with reduced risk of developing type II diabetes [12]. Amongst adolescents, healthier home cooking by a caregiver was linked with lowered risk of having an overweight or obese BMI [11]. However, our findings conflict with a US study that reported more time spent on home food preparation and associated clean-up at baseline, or increased involvement over time, was linked with an adverse cardio-metabolic profile [16]. Possible reasons for this discrepancy include that the US study used time spent preparing meals, rather than meal consumption, as the exposure, and the exposure included clean-up time, which may have a differential impact on cardio-metabolic health. Since food preparation activities are strongly patterned by gender [18, 74], this may also confound observed associations with health.

Meaning of the study: possible mechanisms and implications for clinicians and policymakers

Our findings indicate that an increased frequency of consuming home cooked meals is associated cross-sectionally with markers of a healthier diet, and indicators of improved cardio-metabolic health, particularly in terms of adiposity, cholesterol and diabetes risk. Links between more frequent consumption of home cooked meals and dietary benefits could be attributable to healthier food preparation methods, increased dietary variety and/or consumption of healthier food groups. Such links may also be due to decreased intake of convenience foods, which tend to prioritise ingredients such as fat, sugar and salt to increase palatability and preservation, over those for optimising health [75].

The association between a higher frequency of consuming home cooked meals and potential benefits for health in terms of hypertension was not significant in the unadjusted model, and in terms of cholesterol was no longer significant after adjustment for sociodemographic and behavioural variables. This may be because the hypertension variable was poorly ascertained, since in addition to blood pressure measurement, participants were required to report on any previous diagnoses of hypertension, and receipt of hypotensive medication. However, we conducted a sensitivity analysis for the relationship between frequency of consuming home cooked meals and hypertension, with the inclusion and the exclusion of participants diagnosed with hypertension by a doctor and/or receiving hypotensive medication. Regardless of whether or not these participants were excluded, the relationship was not significant. Cholesterol is strongly genetically determined [76], and the impact of home cooked meal consumption may not have been sufficient to result in statistically significant changes.

The cross-sectional association between higher frequency of consuming home cooked meals and lower adiposity was robust to adjustment for sociodemographic, lifestyle, and dietary covariates, whilst the association with lower likelihood of being classified as at risk of diabetes according to HbA_{1c} level was borderline significant. Although the direction of causation cannot be established, this indicates that home cooking potentially confers benefits to health, beyond those mediated through dietary changes. Such benefits from eating home cooked meals might be attributable to consumption of smaller portion sizes [77]; moderated snacking behaviour [78]; more structured mealtimes and the time of day at which meals are consumed [79]. Increased social cohesion has been linked with potential health benefits [80], and it is plausible that higher social capital may be associated with more sociable eating patterns. Given the potential time and effort involved in home cooking, home cooked meals may be more likely to be shared together than meals from other sources, and a range of benefits to diet, health and wellbeing derived from shared mealtimes have been identified [81, 82].

Our results support previous research indicating putative benefits from home cooked meals, suggesting that public health promotional messages should advocate for cooking at home as a positive approach for improving diet and health. Strategies could also be considered for supporting people to learn to cook healthy meals, and to use their skills often, for example using digital technology and social media to provide shopping list generators, food preparation teaching videos, and nutritional information. Regularity is particularly important, given that our findings indicated the greatest potential advantages from consuming home cooked meals were experienced at the highest frequencies of consumption. Infrequent home cooking, such as a weekly Sunday lunch, is unlikely to be of benefit to population health, and cooking habits should be adopted as part of the daily routine. This is

in accordance with research suggesting that routinized home cooking behaviour is more likely to be maintained and prioritised over time [83].

Unanswered questions and future research

The evidence base for associations between home cooking, dietary indicators and cardio-metabolic status requires further longitudinal studies to establish causal relationships. This could be facilitated by incorporating questions on home cooking into current large scale national longitudinal surveys, particularly those with more detailed existing dietary components. Additional analyses, for example using structural equation modelling, could be employed to explore causal pathways more fully in future. It will also be insightful to identify who eats home cooked meals and why, and then who prepares these meals and why. Other questions include exploring further the potential benefits of home cooking beyond those mediated through diet, and determining the most effective approaches to encourage home cooking, which may require a combination of tailored interventions.

Conclusion

In a cross-sectional population-based study, consuming home cooked main meals more frequently was associated with a range of indicators of a healthier diet, and several markers of cardio-metabolic health including adiposity, cholesterol and diabetes risk. Strongest associations were observed for the highest frequency of consuming home cooked meals, more than five times per week. These findings suggest that regularly eating home cooked meals may confer benefits to diet and health, and that home cooking promotion and skill development should form part of future public health initiatives. Further research regarding causal relationships between home cooking, diet and health; the wider social aspects of home food preparation; and evaluation of interventions to promote home cooking, is required.

Additional files

Additional file 1: This file provides requested information regarding how the sample was recruited, how representative the sample was of the target group, how the analysed sample differed from the recruited sample, and how missing data were handled.

Additional file 2: Characteristics of Fenland study participants included and excluded from the analytic sample. This table compares the characteristics of participants in the Fenland study who were included in the current study analytic sample, and those who were excluded.

Additional file 3: STROBE-nut: An extension of the STROBE statement for nutritional epidemiology. This table provides a checklist, reporting adherence of the current study to the STROBE-nut guidelines.

Abbreviations

BMI: Body mass index; DASH: Dietary Approaches to Stop Hypertension; EPIC: European Prospective Investigation into Cancer and Nutrition; FFQ: Food Frequency Questionnaire; HbA_{1c}: Haemoglobin A_{1c}; HDL: High density lipoprotein; MDS: Mediterranean Diet Score; NCDs: Non-communicable diseases; UK: United Kingdom; US: United States

Acknowledgements

The authors would like to thank all the volunteers who participated in the Fenland study, as well as the Fenland Study Coordination, Field Epidemiology, and Data Cleaning teams.

Funding

The Fenland Study is funded by the Wellcome Trust and the Medical Research Council. Support from Medical Research Council programmes MC_UU_12015/1 and MC_UU_12015/5 is acknowledged. This report is independent research arising from a Doctoral Research Fellowship Grant DRF-2014-07-020 for the lead author (SM), supported by the National Institute for Health Research. JA and MW received funding from the Centre for Diet and Activity Research (CEDAR), a UK Clinical Research Collaboration (UKCRC) Public Health Research Centre of Excellence. HB and SM are members of Fuse, also a UKCRC Public Health Research Centre of Excellence. Grant reference number is MR/K02325X/1. Funding for CEDAR and for Fuse from the British Heart Foundation, Cancer Research UK, Economic and Social Research Council, Medical Research Council, the National Institute for Health Research and the Wellcome Trust, under the auspices of the UKCRC, is gratefully acknowledged. The views expressed in this publication are those of the authors and not necessarily those of the National Health Service, the Department of Health, the funders or UKCRC. The funders had no role in the study design; in the collection, analysis and interpretation of data; nor in the writing of the report and the decision to submit for publication.

Authors' contributions

SM, HB, WW, MW and JA designed the study. SM led the data analyses, supported by JA and HB. SM drafted the manuscript. All authors contributed to the interpretation of results and critically reviewed the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Institute of Health & Society, Newcastle University, Baddiley-Clark Building, Richardson Road, Newcastle upon Tyne NE2 4AX, UK. [2]Human Nutrition Research Centre, Institute of Health & Society, Newcastle University, M1.151 William Leech Building, Medical School, Framlington Place, Newcastle upon Tyne NE2 4HH, UK. [3]Centre for Diet and Activity Research (CEDAR), MRC Epidemiology Unit, School of Clinical Medicine, University of Cambridge, Box 285 Biomedical Campus, Cambridge CB2 0QQ, UK.

References

1. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2012;380:2224–60.
2. Möser A. Food preparation patterns in German family households. An econometric approach with time budget data. Appetite. 2010;55:99–107.
3. Smith L, Ng S, Popkin B. Trends in US home food preparation and consumption: analysis of national nutrition surveys and time use studies from 1965–1966 to 2007–2008. Nutr J. 2013;12:45.
4. Michaud P, Condrasky M, Griffin S. Review and application of current literature related to culinary programmes for nutrition educators. Top Clin Nutr. 2007;22:336–48.
5. Short F. Domestic cooking skills: what are they? J Home Econ Inst Aust. 2003;10:13–22.
6. Condrasky MD, Hegler M. How culinary nutrition can save the health of a nation. J Ext. 2010;48:1–6.
7. Wolfson JA, Bleich SN. Is cooking at home associated with better diet quality or weight-loss intention? Public Health Nutr. 2015;18:1397–406.
8. Larson N, Perry C, Story M, Neumark-Sztainer D. Food preparation by young adults is associated with better diet quality. J Am Diet Assoc. 2006;106:2001–7.

9. Smith K, McNaughton S, Gall S, Blizzard L, Dwyer T, Venn A. Involvement of young Australian adults in meal preparation: cross-sectional associations with sociodemographic factors and diet quality. J Am Diet Assoc. 2010;110:1363–7.
10. Chen R, Lee M, Chang Y, Wahlqvist M. Cooking frequency may enhance survival in Taiwanese elderly. Public Health Nutr. 2012;15:1142–9.
11. Kramer RF, Coutinho AJ, Vaeth E, Christiansen K, Suratkar S, Gittelsohn J. Healthier home food preparation methods and youth and caregiver psychosocial factors are associated with lower BMI in African American youth. J Nutr. 2012;142:948–54.
12. Zong G, Eisenberg DM, Hu FB, Sun Q. Consumption of Meals Prepared at Home and Risk of Type 2 Diabetes: An Analysis of Two Prospective Cohort Studies. PLoS Med. 2016;13.
13. Jones M, Freeth EC, Hennessy-Priest K, Costa RJ. A systematic cross-sectional analysis of British based celebrity chefs' recipes: is there cause for public health concern? Food Public Health. 2013;3:100–10.
14. Howard S, Adams J, White M. Nutritional content of supermarket ready meals and recipes by television chefs in the United Kingdom: cross-sectional study. BMJ. 2012;345:e7607.
15. Pope L, Latimer L, Wansink B. Viewers vs. Doers. The relationship between watching food television and BMI. Appetite. 2015;90:131–5.
16. Appelhans BM, Segawa E, Janssen I, Nackers LM, Kazlauskaite R, Baylin A, et al. Meal preparation and cleanup time and cardiometabolic risk over 14 years in the Study of Women's Health Across the Nation (SWAN). Prev Med. 2015;71:1–6.
17. Imamura F, Micha R, Khatibzadeh S, Fahimi S, Shi P, Powles J, et al. Dietary quality among men and women in 187 countries in 1990 and 2010: a systematic assessment. Lancet Glob Health. 2015;3:e132–42.
18. Mills S, White M, Brown H, Wrieden W, Kwasnicka D, Halligan J, et al. Health and social determinants and outcomes of home cooking: A systematic review of observational studies. Appetite. 2017;111:116–34.
19. Monsivais P, Aggarwal A, Drewnowski A. Time spent on home food preparation and indicators of healthy eating. Am J Prev Med. 2014;47:796–802.
20. Chu YL, Storey KE, Veugelers PJ. Involvement in meal preparation at home is associated with better diet quality among Canadian children. J Nutr Educ Behav. 2014;46:304–8.
21. World Health Organization. Report of the commission on ending childhood obesity. Geneva: World Health Organization; 2016. http://www.who.int/end-childhood-obesity/en/. Accessed 13 Aug 2017.
22. de Lucia RE, Loos RJF, Druet C, Stolk RP, Ekelund U, Griffin SJ, et al. Association between birth weight and visceral fat in adults. Am J Clin Nutr. 2010;92:347–52.
23. MRC Epidemiology Unit. Fenland Study. 2014. http://epi-meta.medschl.cam.ac.uk/includes/fenland/fenland.html. Accessed 13 Aug 2017.
24. Tiwari A, Aggarwal A, Tang W, Drewnowski A. Cooking at Home: A Strategy to Comply With U.S. Dietary Guidelines at No Extra Cost. Am J Prev Med. 2017;52:616–24.
25. InterAct Consortium. Mediterranean Diet and Type 2 Diabetes Risk in the European Prospective Investigation Into Cancer and Nutrition (EPIC) Study. Diabetes Care. 2011;34:1913–8.
26. Fung TT, Chiuve SE, McCullough ML, Rexrode KM, Logroscino G, Hu FB. Adherence to a dash-style diet and risk of coronary heart disease and stroke in women. Arch Intern Med. 2008;168:713–20.
27. Bingham S, Welch A, McTaggart A, Mulligan A, Runswick S, Luben R, et al. Nutritional methods in the European Prospective Investigation of Cancer in Norfolk. Public Health Nutr. 2001;4:847–58.
28. Bingham SA, Gill C, Welch A, Cassidy A, Runswick SA, Oakes S, et al. Validation of dietary assessment methods in the UK arm of EPIC using weighed records, and 24-hour urinary nitrogen and potassium and serum vitamin C and carotenoids as biomarkers. Int J Epidemiol. 1997;26:S137.
29. Mulligan AA, Luben RN, Bhaniani A, Parry-Smith DJ, O'Connor L, Khawaja AP, et al. A new tool for converting food frequency questionnaire data into nutrient and food group values: FETA research methods and availability. BMJ Open. 2014;4.
30. Hastings C, Mosteller F, Tukey JW, Winsor CP. Low Moments for Small Samples: A Comparative Study of Order Statistics. Ann Math Statist. 1947; 8(3): 413–26. doi:10.1214/aoms/1177730388.
31. Drewnowski A. Diet image: A new perspective on the food-frequency questionnaire. Nutr Rev. 2001;59:370–2.
32. Willett W. Nutritional Epidemiology. 3rd ed. New York: Oxford University Press; 1998.
33. de Koning L, Chiuve SE, Fung TT, Willett WC, Rimm EB, Hu FB. Diet-Quality Scores and the Risk of Type 2 Diabetes in Men. Diabetes Care. 2011;34:1150–6.
34. Berz JB, Singer MR, Guo X, Daniels SR, Moore LL. Use of a dash food group score to predict excess weight gain in adolescent girls in the national growth and health study. Arch Pediatr Adolesc Med. 2011;165:540–6.
35. Folsom AR, Parker ED, Harnack LJ. Degree of Concordance With DASH Diet Guidelines and Incidence of Hypertension and Fatal Cardiovascular Disease. Am J Hypertens. 2007;20:225–32.
36. Karanja N, Erlinger T, Pao-Hwa L, Miller E, Bray G. The DASH diet for high blood pressure: from clinical trial to dinner table. Cleve Clin J Med. 2004;71:745–53.
37. United States Department of Health and Human Services, National Heart Lung and Blood Institute. Healthy Eating Plan. https://www.nhlbi.nih.gov/health/educational/lose_wt/eat/calories.htm. Accessed 13 Aug 2017.
38. Willett WC, Sacks F, Trichopoulou A, Drescher G, Ferro-Luzzi A, Helsing E, et al. Mediterranean diet pyramid: a cultural model for healthy eating. Am J Clin Nutr. 1995;61:1402S–6S.
39. Bach-Faig A, Berry EM, Lairon D, Reguant J, Trichopoulou A, Dernini S, et al. Mediterranean diet pyramid today. Science and cultural updates. Public Health Nutr. 2011;14:2274–84.
40. Estruch R, Ros E, Salas-Salvadó J, Covas M-I, Corella D, Arós F, et al. Primary Prevention of Cardiovascular Disease with a Mediterranean Diet. N Engl J Med. 2013;368:1279–90.
41. Hu FB, Stampfer MJ, Rimm E, Ascherio A, Rosner BA, Spiegelman D, et al. Dietary Fat and Coronary Heart Disease: A Comparison of Approaches for Adjusting for Total Energy Intake and Modeling Repeated Dietary Measurements. Am J Epidemiol. 1999;149:531–40.
42. Dehghan M, Akhtar-Danesh N, McMillan CR, Thabane L. Is plasma vitamin C an appropriate biomarker of vitamin C intake? A systematic review and meta-analysis. Nutr J. 2007;6:41–1.
43. World Health Organization, Food and Agriculture Organization. Diet, nutrition and the prevention of chronic diseases: Report of the joint WHO/FAO expert consultation. Geneva: World Health Organization; 2003.
44. Public Health England. The Eatwell Guide. 2016. https://www.gov.uk/government/publications/the-eatwell-guide. Accessed 13 Aug 2017.
45. O'Connor L, Brage S, Griffin SJ, Wareham NJ, Forouhi NG. The cross-sectional association between snacking behaviour and measures of adiposity: the Fenland Study, UK. Br J Nutr. 2015;114:1286–93.
46. Pencina MJ, D'Agostino RB, Larson MG, Massaro JM, Vasan RS. Predicting the Thirty-year Risk of Cardiovascular Disease: The Framingham Heart Study. Circulation. 2009;119:3078–84.
47. Collins GS, Altman DG. Predicting the 10 year risk of cardiovascular disease in the United Kingdom: independent and external validation of an updated version of QRISK2. Br Med J. 2012;344.
48. NHS Choices. High cholesterol. 2015. http://www.nhs.uk/conditions/cholesterol/Pages/Introduction.aspx. Accessed 13 Aug 2017.
49. Baumgartner RN, Heymsfield SB, Roche AF. Human Body Composition and the Epidemiology of Chronic Disease. Obes Res. 1995;3:73–95.
50. World Health Organization. Body mass index - BMI. 2017. http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi. Accessed 13 Aug 2017.
51. Gallagher D, Heymsfield SB, Heo M, Jebb SA, Murgatroyd PR, Sakamoto Y. Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. Am J Clin Nutr. 2000;72:694–701.
52. John WG, on behalf of the UKDoHACoD. Use of HbA1c in the diagnosis of diabetes mellitus in the UK. The implementation of World Health Organization guidance 2011. Diabet Med. 2012;29:1350–7.
53. Franklin SS, Wong ND. Hypertension and Cardiovascular Disease: Contributions of the Framingham Heart Study. Glob Heart. 2013;8;49–57.
54. National Institute for Health and Care Excellence. Hypertension in adults: diagnosis and management. 2016. https://www.nice.org.uk/guidance/CG127/chapter/1-Guidance#diagnosing-hypertension-2. Accessed 13 Aug 2017.
55. McGowan L, Pot GK, Stephen AM, Lavelle F, Spence M, Raats M, et al. The influence of socio-demographic, psychological and knowledge-related variables alongside perceived cooking and food skills abilities in the prediction of diet quality in adults: a nationally representative cross-sectional study. Int J Behav Nutr Phys Act. 2016;13:111.
56. Brage S, Brage N, Franks PW, Ekelund U, Wareham NJ. Reliability and validity of the combined heart rate and movement sensor Actiheart. Eur J Clin Nutr. 2005;59:561–70.
57. Brage S, Ekelund U, Brage N, Hennings MA, Froberg K, Franks PW, et al. Hierarchy of individual calibration levels for heart rate and accelerometry to measure physical activity. J Appl Physiol. 2007;103:682–92.

58. Stegle O, Fallert S, MacKay D, Brage S. Gaussian Process Robust Regression for Noisy Heart Rate Data. IEEE Trans Biomed Eng. 2008;55:2143–51.
59. Brage S, Brage N, Franks PW, Ekelund U, Wong M-Y, Andersen LB, et al. Branched equation modeling of simultaneous accelerometry and heart rate monitoring improves estimate of directly measured physical activity energy expenditure. J Appl Physiol. 2004;96:343–51.
60. Lachat C, Hawwash D, Ocké MC, Berg C, Forsum E, Hörnell A, et al. Strengthening the Reporting of Observational Studies in Epidemiology—Nutritional Epidemiology (STROBE-nut): An Extension of the STROBE Statement. PLoS Med. 2016;13:e1002036.
61. Public Health England. Health Profile Cambridgeshire. 2016. http://fingertipsreports.phe.org.uk/health-profiles/2016/e10000003.pdf&time_period=2016. Accessed 13 Aug 2017.
62. Lavelle F, Spence M, Hollywood L, McGowan L, Surgenor D, McCloat A, et al. Learning cooking skills at different ages: a cross-sectional study. Int J Behav Nutr Phys Act. 2016;13:119.
63. Short F. Kitchen secrets: the meaning of cookery in everyday life. Oxford: Berg; 2006.
64. Wolfson JA, Bleich SN, Smith KC, Frattaroli S. What does cooking mean to you?: Perceptions of cooking and factors related to cooking behavior. Appetite. 2016;97:146–54.
65. Laska MN, Larson NI, Neumark-Sztainer D, Story M. Does involvement in food preparation track from adolescence to young adulthood and is it associated with better dietary quality? Findings from a 10-year longitudinal study. Public Health Nutr. 2012;15:1150–8.
66. Smith KJ, McNaughton SA, Gall SL, Blizzard L, Dwyer T, Venn AJ. Involvement of young Australian adults in meal preparation: cross-sectional associations with sociodemographic factors and diet quality. J Am Diet Assoc. 2010;110:1363–7.
67. Chu YL, Farmer A, Fung C, Kuhle S, Storey KE, Veugelers PJ. Involvement in home meal preparation is associated with food preference and self-efficacy among Canadian children. Public Health Nutr. 2012;16:108–12.
68. Larson NI, Story M, Eisenberg ME, Neumark-Sztainer D. Food preparation and purchasing roles among adolescents: associations with sociodemographic characteristics and diet quality. J Am Diet Assoc. 2006;106:211–8.
69. Blake CE, Wethington E, Farrell TJ, Bisogni CA, Devine CM. Behavioral contexts, food-choice coping strategies, and dietary quality of a multiethnic sample of employed parents. J Am Diet Assoc. 2011;111:401–7.
70. Leech RM, McNaughton SA, Crawford DA, Campbell KJ, Pearson N, Timperio A. Family food involvement and frequency of family dinner meals among Australian children aged 10-12years. Cross-sectional and longitudinal associations with dietary patterns. Appetite. 2014;75:64–70.
71. Swanson V, Power KG, Crombie IK, Irvine L, Kiezebrink K, Wrieden W, et al. Maternal feeding behaviour and young children's dietary quality: A cross-sectional study of socially disadvantaged mothers of two-year old children using the Theory of Planned Behaviour. Int J Behav Nutr Phys Act. 2011;8.
72. Da Rocha Leal FM, De Oliveira BMPM, Pereira SSR. Relationship between cooking habits and skills and Mediterranean diet in a sample of Portuguese adolescents. Perspect Public Health. 2011;131:283–7.
73. Black AE, Cole TJ. Biased Over- Or Under-Reporting is Characteristic of Individuals Whether Over Time or by Different Assessment Methods. J Am Diet Assoc. 2001;101:70–80.
74. Adams J, Goffe L, Adamson AJ, Halligan J, O'Brien N, Purves R, et al. Prevalence and socio-demographic correlates of cooking skills in UK adults: cross-sectional analysis of data from the UK National Diet and Nutrition Survey. Int J Behav Nutr Phys Act. 2015;12:1–13.
75. Jaworowska A, Blackham T, Stevenson L, Davies IG. Determination of salt content in hot takeaway meals in the United Kingdom. Appetite. 2012;59:517–22.
76. Humphries SE, Peacock RE, Talmud PJ. The genetic determinants of plasma cholesterol and response to diet. Bailliere Clin Endocrinol Metab. 1995;9:797–823.
77. Benton D. Portion Size: What We Know and What We Need to Know. Crit Rev Food Sci Nutr. 2015;55:988–1004.
78. Miller R, Benelam B, Stanner SA, Buttriss JL. Is snacking good or bad for health: An overview. Nutr Bull. 2013;38:302–22.
79. St-Onge MP, Ard J, Baskin ML, Chiuve SE, Johnson HM, Kris-Etherton P, et al. Meal Timing and Frequency: Implications for Cardiovascular Disease Prevention: A Scientific Statement From the American Heart Association. Circulation. 2017. doi:10.1161/cir.0000000000000476.
80. Walsh D, McCartney G, McCullough S, van der Pol M, Buchanan D, Jones R. Comparing levels of social capital in three northern post-industrial UK cities. Public Health. 2015;129:629–38.
81. Hammons AJ, Fiese BH. Is Frequency of Shared Family Meals Related to the Nutritional Health of Children and Adolescents? Pediatrics. 2011;127:e1565–74.
82. Fiese BH, Schwartz M. Reclaiming the family table: mealtimes and child health and wellbeing. Soc Policy Rep. 2008;22.
83. Gatley A, Caraher M, Lang T. A qualitative, cross cultural examination of attitudes and behaviour in relation to cooking habits in France and Britain. Appetite. 2014;75:71–81.

Children's everyday exposure to food marketing: an objective analysis using wearable cameras

L. N. Signal[1*], J. Stanley[1], M. Smith[1], M. B. Barr[1], T. J. Chambers[1], J. Zhou[2], A. Duane[2], C. Gurrin[2], A. F. Smeaton[2], C. McKerchar[1], A. L. Pearson[3], J. Hoek[4], G. L. S. Jenkin[1] and C. Ni Mhurchu[5]

Abstract

Background: Over the past three decades the global prevalence of childhood overweight and obesity has increased by 47%. Marketing of energy-dense nutrient-poor foods and beverages contributes to this worldwide increase. Previous research on food marketing to children largely uses self-report, reporting by parents, or third-party observation of children's environments, with the focus mostly on single settings and/or media. This paper reports on innovative research, Kids'Cam, in which children wore cameras to examine the frequency and nature of everyday exposure to food marketing across multiple media and settings.

Methods: Kids'Cam was a cross-sectional study of 168 children (mean age 12.6 years, SD = 0.5) in Wellington, New Zealand. Each child wore a wearable camera on four consecutive days, capturing images automatically every seven seconds. Images were manually coded as either recommended (core) or not recommended (non-core) to be marketed to children by setting, marketing medium, and product category. Images in convenience stores and supermarkets were excluded as marketing examples were considered too numerous to count.

Results: On average, children were exposed to non-core food marketing 27.3 times a day (95% CI 24.8, 30.1) across all settings. This was more than twice their average exposure to core food marketing (12.3 per day, 95% CI 8.7, 17.4). Most non-core exposures occurred at home (33%), in public spaces (30%) and at school (19%). Food packaging was the predominant marketing medium (74% and 64% for core and non-core foods) followed by signs (21% and 28% for core and non-core). Sugary drinks, fast food, confectionary and snack foods were the most commonly encountered non-core foods marketed. Rates were calculated using Poisson regression.

Conclusions: Children in this study were frequently exposed, across multiple settings, to marketing of non-core foods not recommended to be marketed to children. The study provides further evidence of the need for urgent action to reduce children's exposure to marketing of unhealthy foods, and suggests the settings and media in which to act. Such action is necessary if the Commission on Ending Childhood Obesity's vision is to be achieved.

Keywords: Food marketing, Childhood obesity, Obesogenic environments, Wearable cameras

* Correspondence: louise.signal@otago.ac.nz
[1]Department of Public Health, Health Promotion & Policy Research Unit, University of Otago, PO Box 7343, Wellington South, Wellington 6242, New Zealand
Full list of author information is available at the end of the article

Background

Over the past three decades the global prevalence of childhood overweight and obesity has increased by 47% [1]. Excess adiposity during childhood and adolescence is associated with an increased risk of many serious health conditions and has lifetime consequences for children's health, well-being, and productivity [2–4].

Marketing of energy-dense nutrient-poor (EDNP) foods and beverages contributes to the worldwide increase in childhood obesity [5] by encouraging the repeat purchase and consumption of foods that do not meet nutritional guidelines [6–8]. Internationally, it is estimated that 60% to 90% of food marketing to children is for pre-sugared breakfast cereals, soft drinks, savoury snacks, confectionery and fast foods [8]. The World Health Organization (WHO) Commission on Ending Childhood Obesity (ECHO) recommends reducing children's exposure to, and the power of, marketing of unhealthy foods [5]. ECHO states that "settings where children and adolescents gather (such as schools and sports facilities or events) and the screen-based offerings they watch or participate in, should be free of marketing of unhealthy food and sugar-sweetened beverages" [5, p.18]. According to the WHO Regional Office for Europe Nutrient Profiling Model [9], foods not recommended to be marketed to children include confectionery, sweet snack food, ice-cream, iced confectionery and sugar-sweetened and artificially-sweetened beverages. In New Zealand, the industry self-regulating Children's Code for Advertising Food states that "food advertisements should not undermine the food and nutrition policies of Government, the Ministry of Health Food and Nutrition Guidelines nor the health and well-being of children" ([10], p.21.)

Previous studies quantifying children's exposure to food and beverage marketing have concluded that promotions encouraging the consumption of EDNP products are ubiquitous in children's environments [6, 11–15]. Yet, despite this important work, little is known about children's actual daily exposure to food marketing. This knowledge gap exists because previous research has largely used self-report, reporting by parents, or third-party observation of children's environments. Further, it often focuses on single settings [16–18] (outdoors) and/or media (television) [11, 14, 19, 20]. This paper reports on innovative research, Kids'Cam, which used wearable cameras to examine the frequency and nature of New Zealand (NZ) children's everyday exposure to food and non-alcoholic beverage marketing (hereafter food marketing) across multiple media and settings [21]. Marketing exposure was examined by socioeconomic status and ethnicity (including whether the magnitude of any ethnic differences varied with socioeconomic status), as childhood obesity is strongly patterned by these factors [21].

Methods

Study design

Kids'Cam was a cross-sectional study of 168 Year 8 children (typical age range 11 to 13 years) in the Wellington region of NZ. Children were asked to wear a camera around their neck from when they got up in the morning until going to bed for four consecutive days (Thursday to Sunday, to capture both weekday and weekend exposures). They were advised to remove the camera in situations where privacy could be expected (e.g. toilet or shower facilities), if they felt uncomfortable, when swimming or playing vigorous sport, or if requested. The camera automatically captured a 136° image of the front-facing scene approximately every seven seconds. Data were collected over a 12-month period from July 2014 to June 2015 to allow for seasonal variations. Full details of the study methods (including sample size calculations) are published elsewhere [22]. The study protocol is available at https://diet.auckland.ac.nz/content/kidscam

Sampling and recruitment

Sampling and recruitment were conducted in two stages, first at school level and then child level. The number of Year 8 children enrolled across all schools in the Wellington region was collated using aggregate school enrolment data from the Ministry of Education, and schools were sampled with probability-proportional-to-size stratified random sampling by school decile[1] (low decile = 1–3, medium decile = 4–7, high decile = 8–10) and student ethnicity Māori (indigenous population), Pacific (mostly second generation migrants from Pacific Islands), and NZ European (NZE). This sampling strategy facilitated comparisons of marketing exposure by socioeconomic status and ethnicity, and gave a total of nine sampling strata. Randomly selected schools were invited to participate.

In consenting schools, a maximum of 20 Year 8 children were randomly selected from the class list, stratified by ethnicity, using R 3.2.4 (R Institute, Vienna). The school principal or lead teacher reviewed the list of students to identify children who did not meet the study criteria (n = 5 over the study period). The first 15 eligible children were invited to participate, and the first six children on the list who returned signed consent forms (including parental consent) were selected to participate. The number of children invited exceeded the number of participants required in order to achieve recruitment of four to six children per school (as per the sampling strategy), and reduce the burden on the schools from multiple rounds of invitation.

Data collection and management

Written consent was gained from children and their parents and basic demographic data were collected via

parental questionnaire. A briefing session was held with participating children the day before the cameras were first worn to explain the project. Following data collection, cameras were collected and images downloaded, with children given the opportunity to review and delete any photos before the researchers viewed them. At this review, height and weight were measured to determine age- and gender-specific BMI, using the extended international body mass index cut-offs [22]. Approved images were downloaded to a password-protected server, saved in secure cloud storage, and backed up to a password-protected external hard drive. Approximately 1.3 million images were recorded that could be coded for the presence of food marketing.

Coding of image data

Image coding was performed using a coding protocol to guide content analysis [23]. Customised software enabled manual coding of each image. Marketing was defined as "any form of commercial communication or message that is designed to, or has the effect of, increasing recognition, appeal and/or consumption of particular products and services" ([24], p.9). A three-tiered framework was used to code each relevant image for setting, marketing medium and food product category, based on the WHO food marketing framework [9]. Key settings codes were home, school, food venues, recreation venues and other public spaces. Key marketing media codes were product packaging, signs, in-store marketing, print media, screen and merchandise.

MB, TC and four other health science students undertook the coding. A half day training workshop was held with all coders and coders were then given access to the dataset for a number of days to become familiar with it. Once coders felt comfortable, reliability testing was conducted, with each coder achieving 90% concurrence with model answers on a test dataset of 115 images before coding commenced. Coders were supervised by MS, MB and TC to ensure consistency. Uncertain codes were noted as such and checked by MB or TC.

All foods were classified as either recommended (core) or not recommended (non-core) to be marketed to children based on the WHO Regional Office for Europe Nutrient Profiling Model [9], with some modifications (e.g. a 'fast food' category was added which included all commercially prepared food products sold at quick service restaurants). All fast food was classified as not recommended to be marketed to children as it is typically high in saturated fat and sodium and low in fiber [25]. Marketing in convenience stores and supermarkets was too extensive to code individually and was therefore excluded from this analysis. Codes were only assigned to an image where 50% or more of a brand name or logo could be clearly seen by the coder. Individual images could be coded for multiple marketing media and product categories.

Further processing of the coded data included determining the number of marketing exposures for each unique exposure code (defined as the combination of setting, medium and product type for that code). A marketing exposure was defined as starting on the first instance of an image with a particular setting/medium/product code; subsequent images were counted as part of the same exposure. An exposure was considered to have ended when 30 s had elapsed since the last recorded code of that setting/medium/product code (defined using the image timestamps). Any subsequent code for that same combination after this 30 s limit was counted as the start of a new exposure sequence.

The number of exposures was summed for each unique exposure code by child; aggregate counts were determined for each child to estimate total exposures to core and non-core foods, and exposure by setting, medium, and product type. Cleaning and aggregation of coded data was completed in R version 3.2.3 (R Institute, Vienna).

Data analysis

All statistical analysis was conducted in Stata 12 (StataCorp, College Station, TX, USA). Data analysis for study outcomes accounted for the complex sampling by using inverse sampling weights to account for over- and under-sampling of groups by ethnicity and school decile relative to their share of the Year 8 population in the Wellington region, and inferential statistics incorporated elements to handle sample stratification and clustering of children within schools (95% confidence intervals, *p*-values) [26] using Stata's svy prefix commands and associated weighting options.

Descriptive analysis of the overall cohort was undertaken to describe children by ethnicity, school decile group, age, gender, individual deprivation (NZiDep) [27] and BMI status. Schools participating in the study were described by sub-region within the greater Wellington area and school decile group.

Descriptive analysis of rates of core and non-core food marketing exposures for each child was undertaken by taking the total number of exposures (by core and non-core foods) and dividing by the total number of photos for that child, with this number subsequently re-scaled as an exposure rate for a ten hour day. These were summarised within the major sampling groups (ethnicity and school decile stratum) as median and interquartile ranges of the daily rates, weighted for the sampling design.

Subsequent analysis of rates of marketing exposures used Poisson regression methods, as appropriate for count-based numerator data, analysed separately for core and non-core food marketing exposures. Rates and rate ratios were presented with 95% confidence intervals

(95% CI). Results were reported as rates per day of photos (i.e. per 10 h of photographs). Each photo was specified as contributing seven seconds of exposure time (seven seconds being the median interval between images) for the Poisson regression.

Rates of core and non-core exposures per day were analysed using Poisson regression models. Separate models were constructed for core and non-core food exposures. For each, an initial model looked at differences by ethnicity, adjusted for child gender and age (treated as a linear covariate); a second model added school decile group (area level socioeconomic position) to this first model. A third model examined our primary research question of whether ethnic group differences in overall rates of marketing exposures differed across school decile group, by including interaction terms between these two variables. *P*-values are reported for hypothesis tests of these interaction terms and fully stratified results are presented when these hypothesis tests were significant. These results are presented in the additional files as rates within each ethnicity/school decile stratum, and as rate ratios comparing exposure rates between ethnic groups, as calculated separately within each school decile stratum.

Results

Participating schools and children

Sampling and recruitment of schools and children are summarised in Fig. 1. All 93 schools with Year 8 students in the Wellington region were eligible to be sampled. Twenty-eight schools were approached across the nine sampling strata and 16 consented to participate (57%). Of the 443 children invited to participate, 192 gave consent (43%) and 168 participated (38%). Sociodemographic information for participating children is presented in Table 1. Most children were 12 years old (75%: mean = 12.6 years, SD = 0.5) with approximately equal numbers of girls and boys (52.7% female). Just over half the children were of normal weight or underweight (57.5%); with the remainder overweight or obese (42.5%). The lower part of Table 1 shows location and school decile for participating schools. The number of children in each sampling stratum is reported in

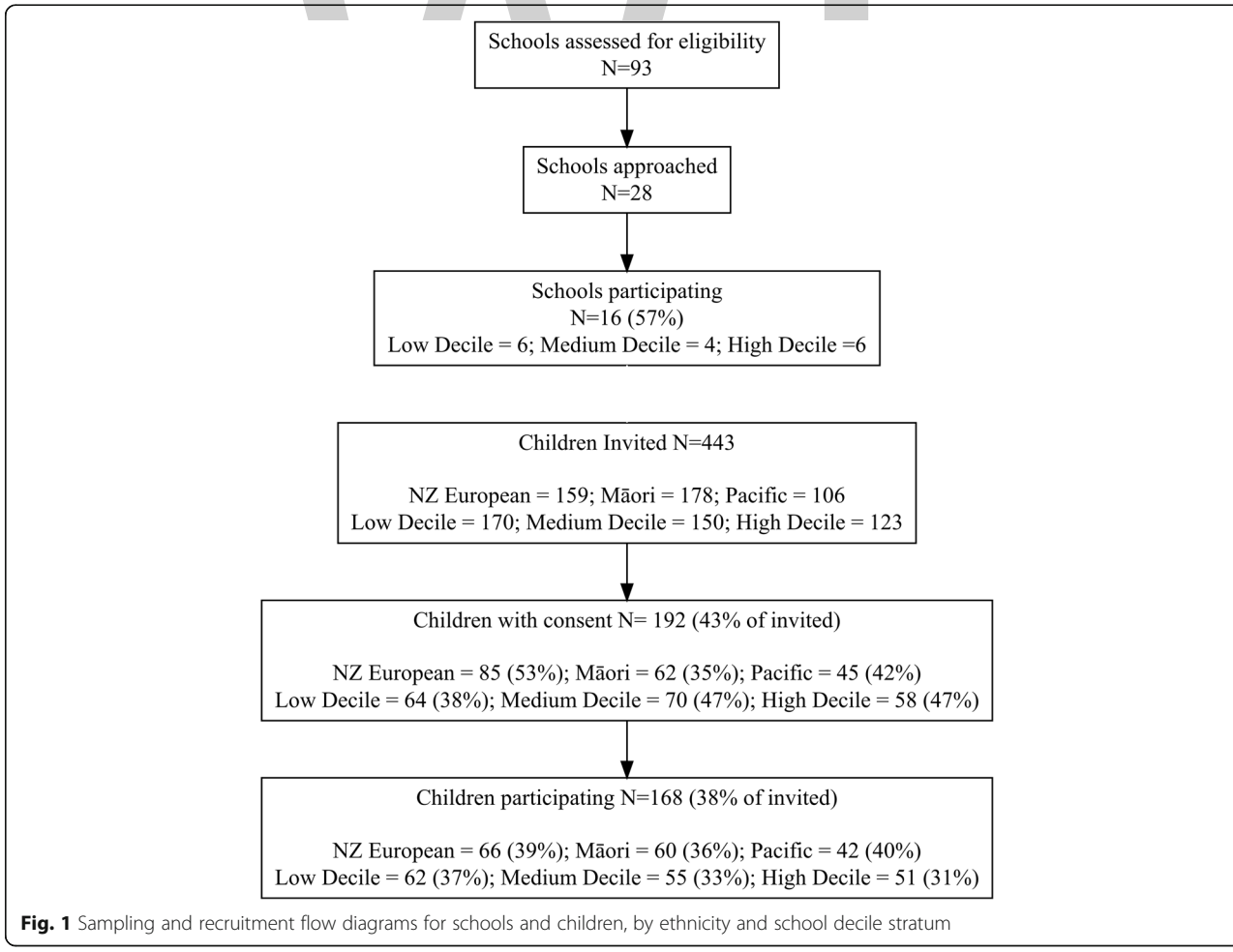

Fig. 1 Sampling and recruitment flow diagrams for schools and children, by ethnicity and school decile stratum

Table 1 Sociodemographic and other characteristics of Kids'Cam participants and schools

Sociodemographic variable	Group	N (%)
Child participants (total *n* = 168)		
Ethnicity	NZ European	66 (39.3)
	Māori	60 (35.7)
	Pacific	42 (25.0)
School decile	Low (1–3)	62 (36.9)
	Medium (4–7)	55 (32.7)
	High (8–10)	51 (30.2)
Age (years)*	11	13 (8.0)
	12	122 (75.3)
	13	26 (16.1)
	14	1 (0.6)
Gender	Female	88 (52.7)
	Male	80 (47.3)
NZiDep *	1	52 (32.1)
	2	33 (20.4)
	3	25 (15.4)
	4	26 (16.1)
	5	26 (16.1)
BMI**	Underweight	9 (5.4)
	Healthy	87 (52.1)
	Overweight	46 (27.5)
	Obese	25 (15.0)
School details (*n* = 16)		
Location		
	Wellington	6 (37.5)
	Porirua	6 (37.5)
	Hutt Valley	4 (25.0)
School decile***		
	Low (1–3)	7 (43.8)
	Medium (4–7)	3 (18.8)
	High (8–10)	6 (37.5)

* Age and NZiDep missing for 6 participants (questionnaire not completed)
** BMI missing for 1 participant as child declined to be measured
*** Some schools were sampled multiple times for a particular ethnicity/school decile stratum in accordance with sampling probability-proportional-to-size

Additional file 1, along with a summary of the number of photos available for analysis within each stratum.

Rates of marketing exposures

Rates of marketing exposures per day for core and non-core foods are presented in Table 2. The mean rate for core food was 12.3 marketing exposures per day; for non-core foods, the mean rate was 27.3 marketing exposures per day, more than twice that for core foods. Additional file 2 reports the median and interquartile range of daily exposure to core and non-core food marketing: the interquartile range spread from 15 to 34 non-core exposures per day.

Most core food marketing exposures occurred at home or school (5.5 and 5.3 exposures per day, making up 45% and 43% of all core exposures respectively) (see Table 2 and Fig. 2, top panel); for non-core food marketing exposures, the majority happened either at home (33% of all non-core exposures) or in public spaces other than food or recreation venues (30% of all non-core exposures). One-fifth of non-core food marketing exposures occurred at school (19%). Additional file 3 gives further detail regarding the settings in which marketing exposures occurred: for example, most exposures in other public spaces were on the street or on shop fronts.

The majority of marketing exposures were in the form of food packaging (see Table 2 and Fig. 2, bottom panel), at a mean rate of 9.1 exposures per day for core foods (74% of core exposures) and 17.4 exposures for non-core foods (64% of non-core exposures). The remaining marketing exposures were mostly signs (21% and 28% of core and non-core food marketing exposures, respectively) (see Fig. 3 for images of marketing).

Types of non-core food product marketing exposures

Marketing exposure rates for specific non-core food product categories are presented in Table 2. The largest share was for sugary drinks (mean rate of 9.1 exposures per day, 33% of non-core exposures) followed by fast food (22% of non-core exposures), confectionery (11% of non-core exposures) and snack foods (10% of non-core exposures). Foods making up the remainder of non-core marketing exposures (24% of exposures) are listed in Table 2.

Rates of marketing exposures by child ethnicity and school decile stratum

The mean exposure rates for core and non-core foods are presented in Additional file 4, stratified by ethnicity and school decile stratum. The rate of exposure for non-core foods was higher than for core foods in all strata.

Initial analysis for core foods compared exposure by ethnicity, adjusted for gender and age (Table 3, model 1). Māori children had non-significantly higher rates of exposure compared to NZE (RR = 1.55, 95% CI 0.68, 3.56); and Pacific children had similar rates of exposure to NZE (RR = 0.98, 95% CI 0.59, 1.61). Adding school decile group into the model did not appreciably change ethnic differences (Table 3, model 2). Compared to middle-decile children, children at higher decile schools had higher exposure to core foods (RR = 1.60, 95% CI 1.03, 2.48); while children at lower decile schools had non-significantly higher rates of such exposure (RR = 1.18; 95% CI 0.80, 1.73; reference is middle decile group). The third model incorporated a formal

Table 2 Mean rate of core and non-core food marketing exposures (per day, with 95% CI, from Poisson regression) for total exposures (across all settings/media) and by setting, medium, and product category (with percentage share of all exposures by setting/medium/product category)

	Core Foods		Non-core Foods	
Total/Setting/Medium/Product category	Rate per day* (95% CI)	% of total	Rate per day* (95% CI)	% of total
Total (any setting/ marketing medium)	12.3 (8.7, 17.4)	100	27.3 (24.8, 30.1)	100
Setting**				
Home	5.5 (4.6, 6.6)	44.9	8.9 (7.9, 10.1)	32.8
School	5.3 (2.9, 9.5)	42.9	5.3 (4.2, 6.8)	19.5
Food venues***	0.2 (0.1, 0.4)	1.7	2.7 (1.5, 4.7)	9.7
Recreation venues****	0.4 (0.3, 0.7)	3.5	2.1 (1.1, 3.8)	7.6
Other public spaces*****	0.9 (0.5, 1.5)	7.0	8.3 (6.0, 11.4)	30.4
Marketing medium				
Product packaging	9.1 (7.2, 11.4)	73.5	17.4 (15.7, 19.4)	63.9
Sign	2.6 (1.0, 6.8)	21.2	7.6 (5.3, 10.9)	27.9
Instore marketing	0.1 (0.0, 0.2)	0.6	1.0 (0.7, 1.4)	3.6
Print media	0.0 (0.0, 0.1)	0.2	0.6 (0.2, 1.8)	2.2
Screen	0.1 (0.0, 0.2)	0.5	0.2 (0.1, 0.4)	0.6
Merchandise	0.5 (0.2, 1.2)	3.9	0.5 (0.2, 1.2)	1.9
Product category				
Core	12.3 (8.7, 17.4)	100		
Sugary drinks			9.1 (8.3, 10.0)	33.4
Fast food			6.0 (4.7, 7.6)	22.1
Confectionery			3.0 (2.3, 4.0)	11.1
Snack foods			2.9 (2.4, 3.5)	10.5
Ice cream			1.9 (1.3, 2.7)	7.0
Diet soft drinks			1.4 (0.9, 1.9)	4.9
Cookies/cakes/pastries			1.3 (0.9, 2.0)	4.8
Milk product (unhealthy)			0.8 (0.4, 1.3)	2.8
Cereal (unhealthy)			0.7 (0.4, 1.1)	2.5
Other			0.2 (0.1, 0.4)	0.9

* Rate of marketing exposures per day (calculated as rate per 10 h of photographs)
** Details for aggregated settings are presented in Additional file 2
*** Includes fast food indoor, full service restaurant, and fresh food market
**** Includes sport, outdoor recreation, and community venue
***** Includes street, shop front, shopping mall, private transport, public transport facility, onboard public transport, and other retail

interaction test between ethnicity and school decile group, which was non-significant, suggesting that ethnic patterns were similar across school decile groups (F 4, 15 = 1.99; p = 0.1481).

Analysis of ethnic differences in non-core exposures (adjusted for child gender and age; Table 3, right hand column, model 1) showed non-significantly higher rates of exposure to non-core foods for Māori children relative to NZE (RR = 1.18, 95% CI 0.90, 1.55) but not for Pacific children (RR = 0.99, 95% CI 0.84, 1.16). Differences in exposure by school decile group appeared minimal (Table 3) and adjustment of ethnic differences for school decile group did not appreciably change estimates from those in the initial model. A third model, incorporating interaction terms, suggested that ethnic differences in non-core exposures differed across the three school decile groups (F 4, 15 = 4.58, p = 0.013). These results are presented in Additional files 4 and 5. In brief, there was reasonably strong evidence for ethnic differences in the lowest school decile group (Māori RR = 1.20, 95% CI 0.97, 1.47; Pacific RR = 1.50, 95% CI 1.19, 1.89; both relative to NZE).

Discussion

Children in this study were exposed to non-core food marketing, food not recommended to be marketed to children, 27.3 times a day on average across all settings, excluding convenience stores and supermarkets.

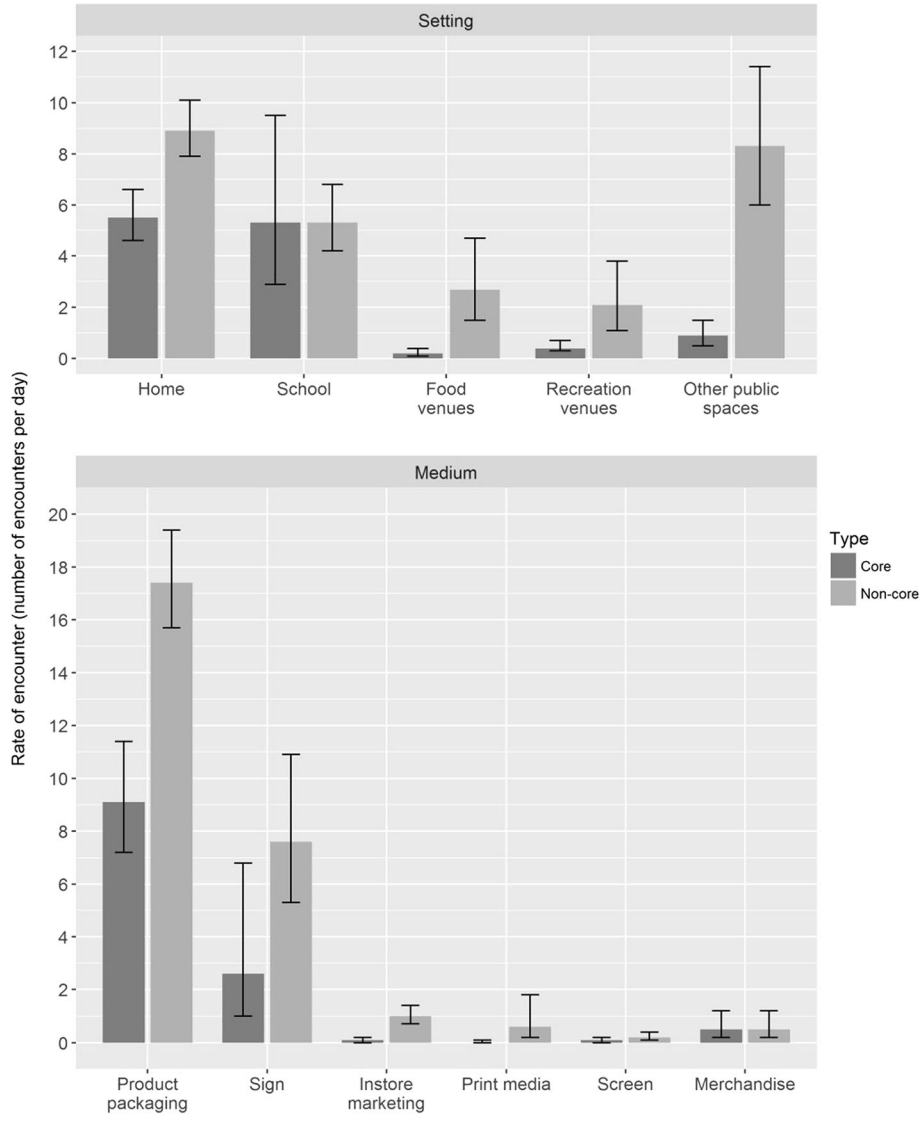

Fig. 2 Mean rate (and 95% CI) of core and non-core food marketing exposures per day (10 h of photographs) by setting (top panel) and medium (bottom panel)

Exposure to non-core food marketing was more than twice that of exposure to core food marketing (12.3 times a day). Most non-core exposures occurred at home, in public spaces and at school. Food packaging was the predominant marketing medium, followed by signs. Product packaging is commonly used to attract attention, provide information about product attributes and encourage purchase at point-of-sale [16]. Product packaging is particularly salient as children are the population group most vulnerable to such food marketing [20].

Children were most exposed to non-core marketing for sugary drinks, fast food, confectionary and snack foods, a finding consistent with previous research [11, 14, 28–31]. A notable exception is exposure to marketing for high-sugar, low-fibre breakfast cereals which comprised only 2.5% of all non-core marketing. Research in the UK and Australia found high rates of such marketing on television [11, 30].

Although televisions, smart phones, tablets and computers often appeared in the images, screen-based marketing is likely under-reported in the current study as content on screens was often not clear enough to meet coding criteria in the images. Research across 11 countries in 2010 reported five food advertisements per hour of television. A 2014 national survey of NZ children aged 6–14 found 88% watch television each day, 44% of whom watch more than an hour a day [32] thus potentially seeing five food advertisements daily on television alone, considerably more than the 0.2 exposures per day

Fig. 3 Sign for sugary drink in public space, sign for sugary drink in public place, product packaging for snack food at school, product packaging for sugary drink at home

Table 3 Rate ratios (with 95% confidence intervals) from Poisson regression models for core and non-core food exposures, from models accounting for ethnicity, gender, and age (model 1) and extended model including school decile group (model 2)

	Core Foods	Non-core Foods
Variable	Rate ratio (95% CI)	Rate ratio (95% CI)
MODEL 1. Ethnicity, Gender, Age		
Ethnicity		
NZE	1 (reference)	1 (reference)
Māori	1.55 (0.68, 3.56)	1.18 (0.90, 1.55)
Pacific	0.98 (0.59, 1.61)	0.99 (0.84, 1.16)
Gender		
Female	1 (reference)	1 (reference)
Male	0.84 (0.62, 1.15)	1.03 (0.83, 1.27)
Age (per year*)	1.28 (0.98, 1.69)	0.97 (0.78, 1.21)
MODEL 2. Model 1 + School decile group		
Ethnicity		
NZE	1 (reference)	1 (reference)
Māori	1.70 (0.78, 3.69)	1.23 (0.94, 1.62)
Pacific	1.15 (0.70, 1.88)	1.06 (0.91, 1.23)
Gender		
Female	1 (reference)	1 (reference)
Male	0.88 (0.61, 1.28)	1.03 (0.81, 1.30)
Age (per year*)	1.19 (0.90, 1.58)	0.97 (0.79, 1.21)
School decile group		
Low (1–3)	1.18 (0.80, 1.73)	0.90 (0.77, 1.06)
Middle (4–7)	1 (reference)	1 (reference)
High (8–10)	1.60 (1.03, 2.48)	1.05 (0.87, 1.27)

* Rate ratio for a one year difference in age

identified across all screen types in the current study. Food marketing on new media is also of concern (e.g. websites, social media and apps) and may have even greater impact than traditional media e.g. television [33]. NZ children engage with the internet frequently, with 66% accessing it daily [32].

Exposure to non-core food marketing was higher than for core foods in all school decile strata. Core exposures were more common in the high school decile groups; while for non-core exposures, there were no significant differences in exposure by these school decile groups. Similarly, while Māori children had higher exposure to both core and non-core marketing than NZE children, these results were not statistically significant in the adjusted models. The more complex model incorporating interaction terms suggested that ethnic group differences were somewhat varied across school decile group, with stronger evidence in the lowest school decile group for Pacific and Māori children.

To our knowledge, this is the first study to objectively measure children's exposure to food marketing in their everyday environments across multiple settings and in multiple media. The use of automated wearable cameras enabled unprecedented access to children's worlds, recording their exposures with food marketing as they occurred. This methodology overcomes many of the limitations inherent in using self-report or proxy report data [34]. Further, it comprehensively documented children's actual exposure to marketing, with the important exceptions of marketing on screens, and in convenience stores and supermarkets. This is a major advantage of the Kids'Cam methodology: documenting actual exposure is challenging in third-party

environmental observation studies, particularly in private contexts such as the home.

While this research provides some of the most robust data yet analysed on children's exposure to food marketing, it does have limitations. First, the images do not determine if a child actually sees the marketing in the image. For example, the child could be looking away, although given the extent of food marketing in children's environments they may still see marketing. Secondly, the decision to only code an image if 50% or more of a brand name or logo could be clearly seen is likely to underestimate the exposure to marketing, as does the exclusion of marketing in convenience stores and supermarkets, where marketing is likely to be extensive [35]. Further, the use of still photography may have missed some exposures. However, excluding screens, convenience stores and supermarkets, the ratio of more than two non-core food marketing exposures for every one core exposure is likely to be consistent, despite these limitations. The participation rate (n = 192 or 43% of invited children consenting to participate; with space for 168 participants, or 38% of the full invitation list participating) was reasonable for a study that required ongoing engagement by the children over several days. It remains possible that those children and families consenting to participate were systematically different from children who did not participate. Finally, while the sample size was determined prior to the study commencing, the number of participants was limited by the study budget and timeframe. This meant that some analyses (e.g. comparisons of exposure rates by ethnic group) might have had sub-optimal power to detect differences between groups, which is reflected in the relatively wide confidence intervals for these estimates. These specific estimates should be interpreted with caution.

Further real time research is needed on children's exposure to marketing in convenience stores and supermarkets and on screens to complement this research. Further exploration of potential ethnic differences appears warranted, but will require a substantially larger sample size to improve statistical precision and power. Use of photo elicitation [36] with children who wore cameras would likely elicit valuable data on the meaning of food marketing and enable exploration of effective means for intervention from children's perspective. Manual data coding was resource intensive, taking a total of 1440 person-hours. While this was an extensive undertaking, the richness of the resulting dataset made it worthwhile: the children collected 2553 h of image data from their perspective, giving insight into settings that would have been difficult to study as a participant observer. Ancillary studies also benefitted from this initial coding, as settings and other image characteristics were already available to researchers, which reduces processing times in these subsequent studies [37, 38]. Further, automated image recognition has the potential to aid analysis and reduce manual coding time requirements [39, 40]. The Kids'Cam method has the potential to validate other methods, e.g. surveys of school food policies, with in-depth analysis of the actual food environment [41]. Comparative research of children's exposure to food marketing in other jurisdictions would further strengthen the global body of evidence.

This research suggests that children live in an obesogenic food marketing environment that promotes obesity as a normal response to their everyday environment [42]. Children are more than twice as likely to be exposed to non-core food marketing, not recommended to be marketed to children [9], than core food marketing, and to be exposed multiple times a day across various settings and via multiple media. All children, regardless of socio-economic position, were exposed to more non-core than core food marketing, and there appears to be some ethnic patterning.

Particularly concerning is the amount of exposure in school, an environment where children's health is required to be protected under NZ law [43], and which the ECHO Commission states should be free of such marketing [5]. Exposure in public places is an arena for central and local governments globally. Given that over two-thirds of marketing is in the form of food packaging, consideration should be given to plain packaging in some specific cases (e.g. sugar sweetened beverages) as a highly effective intervention in this arena [44].

Conclusions

The ECHO Commission is right to call for the reduction of children's exposure to marketing of unhealthy foods [5]. This research provides further evidence of the need for action and suggests both settings and media in which to act. Urgent action is required if the vision of the Commission on Ending Childhood Obesity is to be achieved.

Endnotes

[1]Publically-funded schools in NZ are ranked by decile for funding purposes. Schools in decile 1 have the largest proportion of students from low socio-economic backgrounds. Schools in decile 10 have the smallest proportion of these students. Each decile contains approximately 10% of schools. http://www.education.govt.nz/school/running-a-school/resourcing/operational-funding/school-decile-ratings/

Additional files

Additional file 1: Number of children and photos by ethnicity/school decile sampling stratum, and mean number of photos per child in each stratum.

Additional file 2: Median and interquartile range of per-child rates of exposure per day to core and non-core items, by school. (DOCX 15 kb)

Additional file 3: Mean rate of core and non-core food marketing exposures (per day, with 95% CI, from Poisson regression) by setting with aggregated and detailed setting information (with percentage share of all exposures by setting).

Additional file 4: Mean rate (and 95% CI) of core and non-core marketing exposures per day (10 h of photographs), by school decile stratum and ethnicity of child.

Additional file 5: Rate ratios for differences in non-core food marketing exposures (from Poisson regression, with 95% CI) by interaction school decile group and ethnicity, adjusted for gender and age.

Acknowledgements
We gratefully thank the children, parents, caregivers and schools who let us into their lives. We also thank Ryan Gage and the fourth year medical students who assisted with the coding, especially Saskia Campbell, Ryan Cullen and Richard Kennedy.

Funding
This research was funded by a Health Research Council of New Zealand Programme Grant (13/724), and supported by Science Foundation Ireland (grant 12/RC/2289), a European Commission FP7 International Research Staff Exchange Scheme (IRSES) funding award (2011-IRSES-295157-PANAMA) and a University of Otago Wellington Equipment Grant.

Authors' contributions
LS, MS, MB, JS, GJ, ALP, JH, CG, AFS, and CNM conceived the idea and developed the study design. JZ, AD, CG, and AS developed the coding software. LS, MS, MB, TC, and GJ collected the data. JS led the data management and analysis. LS, MS, MB, TC, CM, JH and CNM participated in the data analysis. LS provided overall leadership of the research. All authors contributed to this manuscript and approved the final version.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Department of Public Health, Health Promotion & Policy Research Unit, University of Otago, PO Box 7343, Wellington South, Wellington 6242, New Zealand. [2]Insight Centre for Data Analytics, Dublin City University, Belfield, Dublin, Ireland. [3]Department of Geography, Environment and Spatial Sciences, Michigan State University, 673 Auditorium Rd, East Lansing, MI 48825, USA. [4]Department of Marketing, University of Otago, Level 4, Business School, Clyde St, North Dunedin, Dunedin 9016, New Zealand. [5]National Institute for Health Innovation, University of Auckland, 261 Morrin Road, Glen Innes, Auckland 1072, New Zealand.

References

1. Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the global burden of disease study 2013. Lancet. 2014;384(9945):766–81.
2. Han JC, Lawlor DA, Kimm SYS. Childhood obesity. Lancet. 2010;375:1737–48.
3. Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. Int J Obes. 2011;35(7):891–8.
4. Franks PW, Hanson RL, Knowler WC, Sievers ML, Bennett PH, Looker HC. Childhood obesity, other cardiovascular risk factors and premature death. N Engl J Med. 2010;362(6):485–93.
5. World Health Organization Commission on Ending Childhood Obesity. Report of the commission on ending childhood obesity. Geneva: World Health Organization; 2016.
6. Hastings G, Stead M, Mcdermott L, Forsyth A, Mackintosh AM, Rayner M, et al. Review of research on the effects of food promotion to children. Glasgow: Centre for Social Marketing, University of Strathclyde; 2003. p. 1–218.
7. Cairns G, Angus K, Hastings G. The extent, nature and effects of food promotion to children: a review of the evidence to. Geneva: World Health Organization. December 2008:2009.
8. Cairns G, Angus K, Hastings G, Caraher M. Systematic reviews of the evidence of the nature, extent and effects of food marketing to children. A retrospective summary Appetite. 2013;62:209–15. 10.1016/j.appet.2012.04.017
9. World Health Organization Regional Office for Europe. WHO Regional Office for Europe Nutrient Profile Model. Copenhagen: World Health Organization Regional Office for Europe; 2015.
10. Advertising Standards Authority. Advertising codes of practice 2014. Wellington: Advertising Standards Authority; 2014.
11. Kelly B, Smith B, King L, Flood V, Bauman A. Television food advertising to children: the extent and nature of exposure. Public Health Nutr. 2007;10(11):1234–40.
12. Kelly B, Baur LA, Bauman AE, King L, Chapman K, Smith BJ. Food and drink sponsorship of children's sport in Australia: Who pays? Health Promot Int. 2010;26(2). 10.1093/heapro/daq061.
13. Kelly B, Cretikos M, Rogers K, King L. The commercial food landscape: outdoor food advertising around primary schools in Australia. Aust N Z J Public Health. 2008;32(6):522–8.
14. Jones SC, Gregory P. Kervin L. Branded food references in magazines: 'advertisements' are the tip of the iceberg. Pediatric Obesity. 2012;7(3):220.
15. Montgomery KC, Chester J. Interactive food and beverage marketing: targeting adolescents in the digital age. J Adolesc Health. 2009;45:S18–29.
16. Chapman K, Nicholas P, Banovic D, Supramaniam R. The extent and nature of food promotion directed to children in Australian supermarkets. Health Promot Int. 2006;21(4):331–9.
17. Molnar A, Garcia DR, Boninger F, Merrill B. Marketing of foods of minimal nutritional value to children in schools. Prev Med. 2008;47(5):504–7.
18. Adams J, Ganiti E, White M. Socio-economic differences in outdoor food advertising in a city in northern England. Public Health Nutr. 2011;14(6):945–50.
19. Vandevijvere S, Sagar K, Kelly B, Swinburn B. Unhealthy food marketing to New Zealand children and adolescents through the internet. NZMJ. 2017; 130(1449):32–43.
20. Mehta K, Phillips C, Ward P, Coveney J, Handsley E, Carter P. Marketing foods to children through product packaging: Prolific, unhealthy and misleading. Public Health Nutr. 2012;*FirstView* Article:1–8. 10.1017/S1368980012001231.
21. Signal LN, Smith MB, Barr M, Stanley J, Chambers TJ, Zhou J, et al. Kids'Cam: an objective methodology to study the world in which children live. Am J Prev Med. 2017. http://doi.org/10.1016/j.amepre.2017.02.016.
22. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatric Obesity. 2012;7:284–94.
23. Rose G. Visual methodologies: an introduction to researching with visual materials: sage; 2012.
24. World Health Organization. A framework for implementing the set of recommendations on the marketing of foods and non-alcoholic beverages to children. World Health Organization; 2012.
25. Lin BH, Guthrie J, Frazao E. Quality of children's diets at and away from home: 1994-96. FoodReview. 1999;22(1):2–10.
26. Lumley T. Complex surveys: a guide to analysis using R. Hoboken, NJ: Wiley; 2011.
27. Salmond C, Crampton P, King P, Waldegrave C. NZiDep: a New Zealand index of socioeconmic deprivation for individuals. Soc Sci Med. 2006;62(6): 1474–85.
28. Kelly B, Halford JCG, Boyland EJ, Chapman K. Bautista-Castañ˜O I, Berg C, et al. Television advertising to children: a global perspective. American Journal of Public Health. 2010;100(9):1730–6.
29. Wilson N, Signal L, Nicholls S, Thomson G. Marketing fat and sugar to children on New Zealand television. Prev Med. 2006;42(2):96–101.
30. Boyland EJ, Harrold JA, Kirkham TC, Halford JCG. The extent of food advertising to children on UK television in 2008. Int J Pediatr Obes. 2011;6(5–6):455–61.
31. Maher A, Wilson N, Signal L. Advertising and availability of 'obesogenic' foods around New Zealand secondary schools: a pilot study. NZMJ. 2005; 118(1218).
32. Broadcast Standards Authority. Children's Media Use Study. Wellington, New Zealand Broadcast Standards Authority 2015.

33. Kelly B, Vandevijvere S, Freeman B, Jenkin G. New media but same old tricks: food marketing to children in the digital age. Curr Obes Rep. 2015;4(1):37–45. http://doi.org/10.1007/s13679-014-0128-5
34. Doherty AR, Hodges SE, King AC, Smeaton AF, Berry E. Moulin CJA, et al. Wearable cameras in health the state of the art and future possibilities. American Journal of Preventive Medicine. 2013;44(3):320–3.
35. Grigsby-Toussaint DS, Moise IK, Geiger SD. Observations of marketing on food packaging targeted to youth in retail food stores. Obesity. 2011;19(9):1898–900. http://doi.org/10.1038/oby.2011.120
36. Clark-Ibáñez M. Framing the social world with photo-elicitation interviews. Am Behav Sci. 2016;47(12):1507–27. http://doi.org/10.1177/0002764204266236
37. Gage R, Leung W, Stanley J, Reeder A, Barr M, Chambers T, et al. Clothing protection from UVR: a new method for assessment. Photochem Photobiol. 2017; https://doi.org/10.1111/php.12803
38. Chambers T, Pearson AL, Stanley J, Smith M, Barr M, Ni Mhurchu C, et al. Children's exposure to alcohol marketing within supermarkets: an objective analysis using GPS technology and wearable cameras. Health & Place. 2017; 46:274–80. https://doi.org/10.1016/j.healthplace.2017.06.003
39. Krizhevsky A, Sutskever I, Hinton GE, editors. Imagenet classification with deep convolutional neural networks. Advances in neural information processing systems. Paper presented at the Advances in Neural Information Processing Systems; 2012.
40. Smeaton AF, McGuinness K, Gurrin C, Zhou J, O'Connor NE, Wang P, et al. Semantic indexing of wearable camera images: Kids'Cam concepts. Proceedings of the 2016 ACM Workshop on Vision and Language Integration Meets Multimedia Fusion; Amsterdam, The Netherlands. 2983566: ACM; 2016. p. 27–34.
41. Puloka V, Smith M, Chambers T, Signal L. An evaluation of Tonga School Food Policy 2012-2015: A Pathway to a Healthier Life. Unpublished report. Health Promotion & Policy Research Unit. Wellington: University of Otago; 2017.
42. Swinburn B, Egger G. Raza F. Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions of obesity. Prev Med. 1999;29:563–70.
43. Ministry of Education. National Administrative Guidelines Wellington. Ministry of Education; 2013 [cited. 17 April. 2017; Available from: https://education.govt.nz/framework/main.php/legislation/nags/?url=/ministry-of-education/legislation/nags/#NAG5.
44. Bollard T, Maubach N, Walker N, Ni Mhurchu C. Effects of plain packaging, warning labels, and taxes on young people's predicted sugar-sweetened beverage preferences: an experimental study. Int J Behav Nutr Phys Act. 2016;13(1):95. doi:10.1186/s12966-016-0421-7.

The development and validation of measures to assess cooking skills and food skills

Fiona Lavelle[1], Laura McGowan[2], Lynsey Hollywood[3], Dawn Surgenor[3], Amanda McCloat[4], Elaine Mooney[4], Martin Caraher[5], Monique Raats[6] and Moira Dean[1*]

Abstract

Background: With the increase use of convenience food and eating outside the home environment being linked to the obesity epidemic, the need to assess and monitor individuals cooking and food skills is key to help intervene where necessary to promote the usage of these skills. Therefore, this research aimed to develop and validate a measure for cooking skills and one for food skills, that are clearly described, relatable, user-friendly, suitable for different types of studies, and applicable across all sociodemographic levels.

Methods: Two measures were developed in light of the literature and expert opinion and piloted for clarity and ease of use. Following this, four studies were undertaken across different cohorts (including a sample of students, both 'Food preparation novices' and 'Experienced food preparers', and a nationally representative sample) to assess temporal stability, psychometrics, internal consistency reliability and construct validity of both measures. Analysis included T-tests, Pearson's correlations, factor analysis, and Cronbach's alphas, with a significance level of 0.05.

Results: Both measures were found to have a significant level of temporal stability ($P < 0.001$). Factor analysis revealed three factors with eigenvalues over 1, with two items in a third factor outside the two suggested measures. The internal consistency reliability for the cooking skills confidence measure ranged from 0.78 to 0.93 across all cohorts. The food skills confidence measure's Cronbach's alpha's ranged from 0.85 to 0.94. The two measures also showed a high discriminate validity as there were significant differences ($P < 0.05$ for cooking skills confidence and $P < 0.01$ for food skills confidence) between Food preparation novices' and 'Experienced food preparers.'

Conclusions: The cooking skills confidence measure and the food skills confidence measure have been shown to have a very satisfactory reliability, validity and are consistent over time. Their user-friendly applicability make both measures highly suitable for large scale cross-sectional, longitudinal and intervention studies to assess or monitor cooking and food skills levels and confidence.

Keywords: Cooking skills, Food skills, Development, Validation, Cross-sectional, Intervention, Measure, Obesity

* Correspondence: moira.dean@qub.ac.uk
[1]Institute for Global Food Security, School of Biological Sciences, Queen's University Belfast, Belfast BT9 5AG, UK
Full list of author information is available at the end of the article

Background

The consumption of food prepared in the home environment has been associated with an improved diet quality and better weight control [1, 2]. As obesity is increasingly becoming a worldwide epidemic, any methods that can contribute to its reduction must be considered and all measures should be taken to help their implementation. The promotion and increase of home meal preparation is one strategy in a multidisciplinary approach to tackling this issue [3], however, a culinary transition has been reported within the literature [4]. This transition explores the possibility that individuals may not have the necessary skill level to prepare a meal [5, 6]. In addition, numerous other barriers have been proposed for home meal preparation and cooking from scratch including; lack of time (real and perceived), perceived affordability of healthy foods versus convenience products, longer working hours, a dislike for cooking or the effect of negative previous experiences, enjoying eating out and take-away foods, accessibility and considering it too much effort [7–10]. In a possible attempt to overcome this lack of skills or as a means to facilitate the consumption of food without cooking, the use of convenience and processed food has increased, thereby reducing the need for cooking skills. The increase in the use of these products may in fact contribute to the obesity epidemic as these products are typically high in fats and sugars [11–14]. In light of this, there is a need to assess the level of cooking skills within the population, and intervene where necessary.

Cooking skills have been defined as a set of physical or mechanical skills used in the production of a meal encompassing cooking methods (e.g. boiling) and food preparation techniques (e.g. peeling a vegetable), in addition to this they are also said to include conceptual and perceptual skills such as understanding the transformation food undergoes when heat is applied, i.e. knowing that chicken is fully cooked from its colour [15, 16]. Aside from the cooking skills needed to prepare a meal, there is a wider set of skills involved in the entirety of the meal preparation process known as Food skills [17, 18]. Food skills include the knowledge and skills to be able to select and prepare food with the available resources, to produce a nutritionally balanced, age appropriate and satisfying meals for those that are consuming it, this includes meal planning, shopping, budgeting, resourcefulness, and label reading [17, 19]. These skills are essential to prepare a meal in the home environment [17].

While some measures for cooking and food skills currently exist, they have some limitations. A key issue is that food skills tend to be encompassed in existing measures and not considered as a stand-alone set of skills and therefore all necessary elements may not be included [20]. Other limitations of previous measures include: the specific mention of certain foods which may not be transferable to all cultures, developed for specific intervention groups, and not having succinct definitions of the skills being measured [20, 21]. Some of the measures also had issues with their validations including using mainly female samples, small sample sizes, test-retest biased sample, self-selection bias and highly educated samples [21, 22].

In recognition of these limitations, the current research aimed to develop and validate two separate measures (one for cooking skills and one for food skills) that are clearly described, relatable, user-friendly, suitable for different types of studies, and applicable across all sociodemographic levels.

Methods

Tool construction

A review of cooking related literature was undertaken prior to tool development. This focused on the relationships between cooking and food skills and their impact on the healthiness of diets (for more details see [23]). The results of the critical appraisal of these articles in combination with the results from Safefood's publication regarding food skills [24] underpinned the development of the measures. In addition, four semi-structured qualitative interviews with experts working in the area of health promotion including cooking and food skills interventions and education were conducted to validate the literature findings and to investigate whether anything missing from the literature that needed to be included. All experts had an undergraduate degree in Home Economics with either a masters or PhD in Home Economics, Nutrition, Food Science or related discipline. The interviews questioned areas such as diet quality influencers, the role of cooking and food skills on diet and their perceptions on what encompasses cooking and food skills. A template analysis (a form of thematic analysis used in qualitative research, emphasising the use of hierarchical coding and the development of a coding template that is continuously refined [25]) was used to assess the relevant information for the measures and the overall survey, including the need for clear terminology.

Two measures were developed - the cooking skills confidence measure, consisting of 14 items; and the food skills confidence measure, consisting of 19 items (see Table 1 for items and corresponding sources). The two measures were tested using two different presentation methods: Computer Assisted Personal Interviewing (CAPI) and the traditional paper and pen (P/P) styled format. For the CAPI method, the question: *"Please tell us which of the following you do (or use):"* is asked. The skills that are used are recorded. Following this, the question *"On a scale from 1 to 7 where 1 means very*

Table 1 Cooking skills and food skills items

Cooking skills[a]

Cooking Method

1. 'Chop, mix and stir foods, for example chopping vegetables, dicing an onion, cubing meat, mixing and stirring food together in a pot/bowl'
2. 'Blend foods to make them smooth, like soups or sauces' (using a whisk/blender/food processor etc.)
3. Steam food (where the food doesn't touch the water but gets cooked by the steam)
4. Boil or simmer food (cooking it in a pan of hot, boiling/bubbling water)
5. Stew food (cooking it for a long time (usually more than an hour) in a liquid or sauce at a medium heat, not boiling) e.g. beef stew
6. Roast food in the oven, for example raw meat/chicken, fish, vegetables etc.
7. Fry/stir-fry food in a frying pan/wok with oil or fat using the hob/gas rings/hot plates
8. Microwave food (not drinks/liquid) including heating ready-meals

Food Preparation Techniques

9. Bake goods such as cakes, buns, cupcakes, scones, bread etc., using basic/raw ingredients or mixes
10. Peel and chop vegetables (including potatoes, carrots, onions, broccoli)
11. Prepare and cook raw meat/poultry
12. Prepare and cook raw fish
13. Make sauces and gravy from scratch (no ready-made jars, pastes or granules)
14. Use herbs and spices to flavour dishes

Food skills[b]

Meal Planning and Preparing

1…plan meals ahead? (e.g. for the day/week ahead)

2…prepare meals in advance? e.g. packed lunch, partly preparing a meal in advance

3…follow recipes when cooking?

Shopping

4…shop with a grocery list?

5…shop with specific meals in mind?

6…plan how much food to buy?

Budgeting

7…compare prices before you buy food?

8…know what budget you have to spend on food?

9…buy food in season to save money?

10…buy cheaper cuts of meat to save money?

Resourcefulness

11…cook more or double recipes which can be used for another meal?

12…prepare or cook a healthy meal with only few ingredients on hand?

13…prepare or cook a meal with limited time?

14…use leftovers to create another meal?

15… keep basic items in your cupboard for putting meals together? e.g. herbs/spices, dried/tinned goods?

Label reading/consumer awareness

16…read the best-before date on food?

17…read the storage and use-by information on food packets?

18…read the nutrition information on food labels?

19…balance meals based on nutrition advice on what is healthy?

Source:
[a]Devised from National Diet and Nutrition Survey (NDNS) Year 1 [35], Barton et al. [20], Condrasky et al. [21], Chun & Worsley [36] and by the research team. Participants asked to rate how good they are at each skill, on a scale of 1–7, where 1 is very poor and 7 is very good. If a skill is not used, an option of 'never/rarely do it' is available for participants to tick.
[b]Devised from National Diet and Nutrition Survey (NDNS) Year 1 cooking items [35], Barton et al. [20], Condrasky et al. [21], and by the research team Participants asked to rate how good they are at each skill, on a scale of 1–7, where 1 is very poor and 7 is very good. If a skill is not used, an option of 'never/rarely do it' is available for participants to tick

poor and 7 means very good, please say how good you are at... [substitute each one they stated they used in previous question]," and only the skills that were previously stated as in use are rated and this creates the confidence measure. The confidence score is the sum of the 1 to 7 ratings for the skills that were stated as used. This process is repeated for both the cooking skills and food skills measures. If a skill is not used, it is scored a zero for that skill. There is also no classification of the confidence measures. For the paper and pen presentation, the participant is asked to *"say how good you are at each task on a scale of 1-7, where 1 is very poor and 7 very good,"* with a *'Never/rarely do it'* option also given. The scoring of the measure is the same as the CAPI, where the confidence measure is a sum of the ratings of the items and a zero if a participant ticked that they 'Never/rarely did it.'

The data for the present research was collected as part of the *'Impact of cooking and related food skills on the healthiness of diets'* project, a research project carried out on the island of Ireland (IOI) and funded by Safefood Ireland, The Food Safety Promotion Board. Ethical approval for this research was received from Queen's University Belfast Research Ethics Committee and each study was conducted in line with the guidance given in the Declaration of Helsinki. Participants consented to partake in the research and were aware they could remove themselves at any point. The measures were included in a larger survey assessing diet quality, psychological components, and demographic details (further information on other elements assessed in the overall survey can be seen in Lavelle et al. [26] and McGowan et al. [27]). Approximately 40 internal pilot surveys (convenience sampling of contacts of the research team across the collaborating universities on the IOI) took place; and 14 pilot survey field based interviews took place with SMR (data collection sub-contractors) during the

refinement of the survey tool. These pilots assessed the clarity of the questions and how easy participants found the measures to complete and resulted in minor amendments to the wording of questions in the survey. The pilot data collected was not used in the statistical validation of the measures, however, readability and usability was assessed in these pilots. At this piloting phase, after minor amendments to language, participants at the various stages of piloting, verbally reported that they found the measures clear in meaning and not time consuming. After piloting, there were four studies which together assed the reliability and validity of the two measures. As missing data was scattered randomly through the datasets (assessed by creating dummy variables and running independent t-tests), missing data was handled using listwise deletion [28]. All data were analysed using SPSS version 22 (IBM Corporation, 2013) and a significance level was set at 0.05 for all analysis.

Study 1

Study 1 was conducted to assess whether the skills were appropriately classified into 'cooking skills' and 'food skills,' as the skills included in the measures were derived both from previous literature and expert opinion. In addition, this study investigated the convergent validity of the measures, to assess whether the two measures of cooking skills and food skills are related but not a single factor, as they theoretically should be related yet distinct.

A nationally representative sample of 1049 adults between the ages of 20–60 years, responsible for preparing a main meal at least once per week was collected. All sampling was completed by SMR, a market research company (in line with their sampling procedures). An overview of demographic characteristics can be seen in Table 2. Further details on sampling and procedure can be found in previous publications [26, 27]. Briefly, the measures were completed in this sample as part of the larger survey by Computer Assisted Personal Interviewing and were conducted by fully trained interviewers in participants' homes between October and December 2014. In total, 1172 potential participants were approached to partake in the survey. One hundred and twenty-three participants did not participate in the survey (this represents 10.50% of potential participants approached) due to ineligibility or for other reported reasons including no interest, no time, did not feel comfortable having the interviewer in their home, etc.

Results from this sample were used to conduct factor analysis using oblique rotation (direct oblimin) to assess the item classification into the two measures, interpreting both the Pattern Matrix and the Structure Matrix. Correlations were used for the investigation of the convergent validity. In addition, the internal consistency reliability of the measures was tested using Cronbach's alpha.

Table 2 Sociodemographic characteristics of nationally representative sample in Study 1

Characteristic	M	SD
Age	39.72	11.84
	N	%
Jurisdiction of Residence		
Northern Ireland	312	29.7
Republic of Ireland	737	70.3
Gender		
Female	590	56.2
Male	459	43.8
Level of Education		
None	3	0.3
Primary School	11	1.0
Secondary School (Junior Cert/GCSE – age 15/16)	121	11.5
Secondary School (Leaving Cert/A Level – age 17/18)	351	33.5
Additional Training (e.g. NVQ, BTEC, FETAC, FAS)	305	29.1
University Undergraduate	153	14.6
University Postgraduate	105	10.0
Perceived Weight Status		
Very underweight	5	0.5
Slightly underweight	58	5.5
About the right weight	601	57.3
Slightly overweight	334	31.8
Very overweight	51	4.9

Study 2

This study measured the test-retest reliability of the measures to assess their temporal stability. This sample was also used to examine the internal consistency reliability of the measures in the P/P format. Study 2 consisted of a sample of 23 'Food preparation novices' students from Ulster University, recruited by the research team. Students were classified as 'Food preparation novices' if they were enrolled on a course that consisted of no nutrition, hospitality, food marketing or food product and innovation orientated modules. The participants were made aware that they could withdraw at any time and that their details would remain confidential. The students were aged 18–27. Their demographic characteristics can be seen in Table 3. These participants completed a pen and paper version of the two measures and two weeks later completed the measures again. Of the students recruited; 56.5% (13 students) completed both measures at both time points, 30.4% (7 students) had partial completion of both measures

Table 3 Sociodemographic characteristics of student sample in Study 2

Characteristic	M	SD
Age	19.22	1.91
	N	%
Jurisdiction of Residence		
Northern Ireland	23	100
Gender		
Female	17	73.90
Male	6	26.10
Level of Education		
Secondary School (Leaving Cert/A Level – age 17/18)	19	82.6
Additional Training (e.g. NVQ, BTEC, FETAC, FAS)	2	8.7
University Undergraduate	2	8.7
Perceived Weight Status		
Slightly underweight	1	4.3
About the right weight	15	65.2
Slightly overweight	5	21.7
Very overweight	1	4.3

at both time points (some element was missing, for example a section of one of the measures) and 13% (3 students) completed both measures at only one time point. Mean differences and Pearson correlations were used to verify the consistency of the results over time. Again, Cronbach's Alpha's were used to assess the internal consistency reliability of the P/P measures.

Study 3

Study 3 was used to test the discriminate validity of the measures between those with high levels of cooking and food skills, and those with low levels. In addition, this sample was used to further assess the internal consistency reliability of the P/P measures. This study consisted of a sample of 57 students. This sample completed a modified version of the larger survey (some questions regarding dietary intake, sources of learning etc. were removed to reduce the time needed for completion) as the overall aim was to test the discriminant validity of the two measures.

The student sample consisted of students from the Ulster University, Northern Ireland and St. Angela's College Sligo, Ireland, recruited by the researchers. All students were made aware that they could withdraw at any time and that their confidentiality would be kept intact. The students were either studying a Business-related degree or were studying Home Economics in their second year and were classified as 'Food preparation novices' (same classification as Study 2) and 'Experienced food preparers' (each year required to complete a minimum of 80 h of practical cooking externally to any completed within class time, in addition to studying food science and nutrition). The 'Experienced food preparers' sample were aged 18–26 and the 'Food preparation novices' were aged 19–24. Their characteristics can be seen in Table 4. This sample also completed a pen and paper version of the survey.

The discriminate validity was tested between the 'Experienced food preparers' and the 'Food preparation novices' students using T-tests. Internal consistency reliability was investigated using Cronbach's Alpha.

Table 4 Sociodemographic Characteristics of Student sample in Study 3

Characteristic	M	SD
Experienced Food Preparers		
Age	19.70	1.27
	N	%
Jurisdiction of Residence		
Republic of Ireland	40	100
Gender		
Female	39	97.5
Male	1	2.5
Level of Education		
Secondary School (Leaving Cert/A Level – age 17/18)	34	85.0
Additional Training (e.g. NVQ, BTEC, FETAC, FAS)	1	2.5
University Undergraduate	4	10.0
University Postgraduate	1	2.5
Perceived Weight Status		
About the right weight	19	47.5
Slightly overweight	16	40.0
Very overweight	2	5.0
Characteristic	M	SD
Food preparation novices		
Age	21.35	1.41
	N	%
Jurisdiction of Residence		
Northern Ireland	17	100
Gender		
Female	11	64.7
Male	6	35.3
Level of Education		
Secondary School (Leaving Cert/A Level – age 17/18)	4	23.0
Additional Training (e.g. NVQ, BTEC, FETAC, FAS)	1	6.0
University Undergraduate	11	65.0
Perceived Weight Status		
Slightly underweight	1	5.9
About the right weight	6	35.3
Slightly overweight	10	58.8

Study 4

Study 4 was conducted to assess differences between the CAPI and the P/P method in relation to the confidence scores of the measures. This study sample consisted of a combination of the samples in study 2 and study 3 (keeping the Home Economics students as a separate group as they have greater skills and this could inflate the scores and introduce bias), representing the P/P method, and due to sample size differences, a randomly selected 38 participants from the IOI sample in Study 1, representing the CAPI method. Here three groups were compared two P/P method groups (Home Economic students and a combination of the non-Home Economics students from studies 2 and 3) and one CAPI method group (random selection from the IOI cohort). As the scoring is the same for both methods, one-way ANOVAs were conducted with Bonferroni post hoc analysis, to investigate differences in the cooking skills confidence measure and the food skills confidence measure between the two methods of presentation.

Results

Psychometrics and internal consistency reliability

Participants' cooking and food skills confidence were measured using the following 14 items and 19 items respectively in Table 5 and their mean scores on each item can be seen. For the psychometric testing, three factors with eigenvalues over 1 were found - one main component accounts for 65.26% variance, then the second one 8.2% of the variance and component 3 just 3.2% of the variance. All factor loadings were above the minimum criterion. The pattern matrix indicated the original cooking skills and food skills measures with some minor exceptions (see Table 6). The items falling into this third component consisted of the items: '*Bake goods such as cakes, buns, cupcakes, scones, bread etc., using basic/raw ingredients or mixes'* and *'Microwave food (not drinks/liquid) including heating ready-meals.'* In the Structure Matrix both the microwaving (Factor 1 = 0.656, Factor 2 = 0.557, Factor 3 = −0.537) and Baking (Factor 1 = 0.677, Factor 2 = 0.477) had highest loading in Factor 1 (Cooking skills). Four 'food skill' items had higher loadings in Factor 1 (Cooking Skills); Buying in Season, using leftovers to create another meal, Keeping Basics in the cupboard and Reading the best before date. In the Structure Matrix, Buying in Season had higher loading onto Factor 2 (Factor 1 = 0.758, Factor 2 = 0.764) and using leftovers to create another meal had the same loading on both Factors (Factor 1 and 2 = 0.798). Keeping basics in a cupboard and reading the best before date had higher loadings on Factor 1 in the Structure Matrix (Factor 1 = 0.789, Factor 2 = 0.731 and Factor 1 = 0.793 and Factor 2 = 0.758, respectively). The internal consistency reliability measured by Cronbach's Alpha for the cooking skills confidence measure ranged from 0.78 (Study 3 Food preparation novices/Experienced food preparer students) to 0.93 (Study 1 IOI cohort), please see Table 7 for each cohorts Cronbach alpha. The food skills confidence measure's Cronbach's alpha's ranged from 0.89 (Study 2 student cohort) to 0.94 (Study 1 IOI cohort) (see Table 7).

Temporal stability

The temporal stability of the measures was assessed using the test re-test approach in study 2. As there was a large number of missing cases in the food skills confidence measure test re-test scores, a dummy variable was created and showed there was no significant differences (P = .902) between those that reported on both time points and those that were missing data on food skills confidence on the initial time. The results show (see Table 8) that both measures have acceptable temporal stability as there were no significant differences between the two mean confidence scores from the first time (T1) and the two weeks repeated measure (T2). In addition, a further assessment of temporal stability was conducted using correlations between the cooking skills confidence measure and the food skills confidence measure scores at T1 and T2. A significant correlation was found between cooking skills measures at T1 and T2 (r = .815, P < 0.001) and food skills measures (r = .872, P < 0.001) again illustrating the consistency of the measures over time.

Construct validity

A strong positive correlation was found between cooking skills confidence and food skills confidence (r = 0.76, p < 0.001) which indicates that the measures are measuring highly related components. In addition, there was a significant difference between the mean scores on both the cooking and food skills confidence measures between 'Food preparation novices' and 'Experienced food preparers' from study 3. Table 5 shows that the 'Experienced food preparers' home economics students scored had consistently higher mean confidence scores on the individual items than the 'Food preparation novices' students, with the exception of 3 items (stewing, making sauces, and comparing prices before buying). 'Experienced food preparers' had significantly better cooking skills confidence (F = 4.63, P < 0.05) and food skills confidence (F = 7.95, P < 0.01) scores than 'Food preparation novices' (see Table 9). Therefore, the measures were found to have a high convergent validity as they were highly related. In addition, as the measures were found to discriminate between those with high and low skills they also had notable discriminant validity.

Table 5 Cooking skills and food skills measures use, mean and standard deviations

Cohort	Study 1: Nationally Representative (CAPI)				Study 2: Students (P/P)				Study 3: Food Preparation Novices (P/P)				Study 3: Experienced Food Preparers (P/P)			
N	1049				23				17				40			
Cooking Skills	**Usage**		**Confidence (rated 1–7)**		**Usage**		**Confidence (rated 1–7)**		**Usage**		**Confidence (rated 1–7)**		**Usage**		**Confidence (rated 1–7)**	
	N	**%**	**Mean**	**SD**	***N***	**%**	**Mean**	**SD**	***N***	**%**	**Mean**	**SD**	***N***	**%**	**Mean**	**SD**
1. Chop, mix and stir foods	401	38.2	5.88	1.112	22	95.7	5.65	1.70	17	100	5.88	1.22	40	100	6.65	0.70
2. Blend foods to make them smooth, like soups or sauces	140	13.3	6.01	1.158	17	73.9	3.70	2.67	14	82.4	4.50	2.25	40	100	6.45	1.04
3. Steam food	186	17.7	5.90	1.153	17	73.9	2.61	2.27	16	94.1	3.88	2.06	34	85.0	4.62	2.26
4. Boil or simmer food	427	40.7	5.75	1.141	22	95.7	5.91	1.54	17	100	5.47	1.28	40	100	6.47	0.75
5. Stew food	369	35.2	5.91	1.074	15	65.2	2.65	2.48	16	94.1	4.76	1.86	33	82.5	4.05	2.33
6. Roast food in the oven	404	38.5	5.86	1.089	20	87.0	4.57	2.39	17	100	5.18	1.51	40	100	6.35	0.83
7. Fry/stir-fry food in a frying pan/wok with oil or fat	407	38.8	5.71	1.169	21	91.3	5.26	2.12	17	100	6.35	1.00	40	100	6.48	0.91
8. Microwave food	189	18.0	5.98	1.266	22	95.7	5.87	1.79	14	82.4	4.82	2.72	34	85.0	4.95	2.53
9. Bake goods	110	10.5	5.55	1.310	19	82.6	3.96	2.40	14	82.4	3.88	2.06	39	97.5	6.40	1.41
10. Peel and chop vegetables	479	45.7	5.81	1.085	21	91.3	5.43	2.23	16	94.1	6.00	1.00	40	100	6.80	0.46
11. Prepare and cook raw meat/poultry	517	49.3	5.69	1.136	19	82.6	4.61	2.59	15	88.2	5.56	1.71	39	97.5	6.48	1.20
12. Prepare and cook raw fish	231	22.0	5.69	1.231	10	43.5	2.00	2.65	13	76.5	4.13	2.63	34	85.0	4.79	2.26
13. Make sauces and gravy from scratch	153	14.6	5.75	1.256	11	47.8	2.17	2.67	14	82.4	3.94	2.29	33	82.5	3.45	2.04
14. Use herbs and spices	273	26.0	5.71	1.173	21	91.3	4.48	2.21	15	88.2	5.50	2.16	39	97.5	5.83	1.62
Overall Cooking skills scores			47.78	29.32			58.83	16.45			71.07	15.32			79.67	10.42
Cohort	**Study 1: Nationally Representative (CAPI)**				**Study 2: Students (P/P)**				**Study 3: Food Preparation Novices (P/P)**				**Study 3: Experienced Food Preparers (P/P)**			
N	1049				21				17				40			
	Usage		**Confidence**		**Usage**		**Confidence**		**Usage**		**Confidence**		**Usage**		**Confidence**	
Food Skills	***N***	**%**	**Mean**	**SD**	***N***	**%**	**Mean**	**SD**	***N***	**%**	**Mean**	**SD**	***N***	**%**	**Mean**	**SD**
1.Plan meals ahead?	283	27.0	5.83	1.138	20	95.2	4.29	1.93	12	70.6	3.47	2.72	39	97.5	5.44	1.48
2…prepare meals in advance?	183	17.4	5.82	1.242	18	85.7	3.52	2.18	12	70.6	3.35	2.55	36	90.0	4.95	1.93
3…follow recipes when cooking?	237	22.6	5.77	1.233	21	100	4.71	1.90	12	70.6	3.88	2.76	36	90.0	6.05	1.53
4…shop with a grocery list?	299	28.5	5.94	1.221	19	90.5	4.48	2.29	13	76.5	3.76	2.59	37	92.5	5.46	1.85
5…shop with specific meals in mind?	481	45.9	5.80	1.103	19	90.5	4.14	2.27	15	88.2	4.35	2.37	39	97.5	6.05	1.15
6…plan how much food to buy?	326	31.1	5.78	1.159	19	90.5	4.38	2.42	14	82.4	3.76	2.51	39	97.5	5.95	1.19
7…compare prices before you buy food?	238	22.7	5.82	1.230	17	81.0	4.14	2.69	15	88.2	5.24	2.56	38	95.0	5.21	1.87
8…know what budget you have to spend on food?	248	23.6	6.03	1.112	18	85.7	4.43	2.80	15	88.2	5.12	2.45	37	92.5	5.47	1.64
9…buy food in season to save money?	150	14.3	5.89	1.191	13	61.9	2.29	2.24	13	76.5	2.65	1.97	38	95.0	4.62	1.79
10…buy cheaper cuts of meat to save money?	101	9.6	5.82	1.328	12	57.1	2.38	2.31	10	58.8	2.59	2.55	37	92.5	4.73	1.96
11…cook more or double recipes which can be used for another meal?	139	13.3	5.94	1.205	15	71.4	2.81	2.44	15	88.2	3.53	2.15	38	95.0	5.54	1.60
12…prepare or cook a healthy meal with only few ingredients on hand?	313	29.8	5.80	1.100	18	85.7	3.57	2.38	16	94.1	4.47	1.77	39	97.5	5.20	1.51
13…prepare or cook a meal with limited time?	300	28.6	5.83	1.087	19	90.5	4.24	2.05	15	88.2	5.00	2.00	40	100	5.95	1.26
14…use leftovers to create another meal?	303	28.9	5.79	1.205	18	85.7	3.76	2.49	16	94.1	3.88	2.06	39	97.5	5.25	1.79

Table 5 Cooking skills and food skills measures use, mean and standard deviations *(Continued)*

15… keep basic items in your cupboard for putting meals together?	493	47.0	5.74	1.243	20	95.2	4.52	1.89	17	100	5.35	1.50	39	97.5	6.26	1.29
16…read the best-before date on food?	431	41.1	5.95	1.109	20	95.2	5.62	2.01	16	94.1	5.44	2.00	40	100	6.58	0.75
17…read the storage and use-by information on food packets?	280	26.7	5.90	1.158	16	76.2	4.10	2.86	17	100	5.24	2.17	39	97.5	5.95	1.52
18…read the nutrition information on food labels?	135	12.9	5.89	1.196	19	90.5	3.29	1.93	16	94.1	3.88	2.57	39	97.5	5.75	1.61
19…balance meals based on nutrition advice on what is healthy?	119	11.3	6.06	1.033	18	85.7	2.62	1.91	15	88.2	3.53	2.43	39	97.5	5.37	1.66
Overall food skills scores			45.82	38.64			74.76	27.64			81.31	29.15			105.64	17.78

Differences between CAPI and P/P methods of presentation of measures

Results show that on both the cooking skills confidence and the food skills confidence measures there is a significant difference in scores between the two different methods ($P < 0.005$) (see Table 10). As seen in usage and confidence rating in Table 5 and discriminate validity in Table 9, Experienced Food preparers are consistently higher for their scoring, this difference is also seen in the comparison of the three groups in Table 10.

Frequency of usage of skills

Table 5 shows an overview of the reported frequency of usage and mean confidence score of all items for each group and following is the top reported used skills in each group. For the study 1 cohort, Preparing and cooking raw meat/poultry was the top reported skill (49.3%), followed by Peel and chopping vegetables (45.7%), Boiling or simmering food (40.7%), Frying/Stir-frying (38.8%), and Roasting/Baking food in the oven (38.5%). The Study 2 sample reported using Microwaving, Chopping, and Boiling (95.7%) and Frying/stir-frying, Peeling and chopping vegetables/using herbs and spices (91.3%). In Study 3, the 'Food preparation Novices' reported using Chopping, Boiling, Roasting, and frying/stir-frying (100%). In comparison to the 'Experienced Food Preparers' who reported using Peeling, Frying/stir-frying, Roasting, Boiling, Blending and chopping (100%) and Baking, preparing and cooking raw meat/poultry, and using herbs and spices (97.5%). In addition, for this groups reported usages for any cooking skill was not below 82.5%.

For the food skills Study 1 reported usage of keeping basics in the cupboard (47.0%), shopping with specific meals in mind (45.9%), and reading the best before (41.1%) as the top three. Study 2's sample stated their usage of following a recipe (100%), keeping basics in the cupboard, reading the best before, and planning ahead (all 95.2%). In Study 3, the 'Food Preparation Novices' reported keeping basics in the cupboard and reading the use-by (100%) and reading the nutrition information, reading the best before, using leftovers to create another meal, and creating a meal from few ingredients (94.1%). Comparatively, the 'Experienced Food Preparers' had no reported usage below 90%, all of the sample reported reading the best before and being able to create a meal with limited time. 97.5% of this sample reported the usage of Planning ahead, shopping with specific meals in mind, planning how much to buy, preparing a meal with few ingredients, creating a meal using leftovers, keeping basic ingredients in the cupboard, reading the use-by date, reading the nutrition information and balancing meals based on nutrition advice.

Discussion

This paper describes the development and validation of two measurements to assess cooking skills confidence and food skills confidence. The measures were developed to include a full range of skills for both cooking (cooking method and food preparation techniques) and wider food skills (meal planning, shopping, budgeting, resourcefulness and label reading) through a literature review, expert interviews and piloting. The results indicate that both measures have substantial internal consistency reliability, construct and convergent validity and temporal stability, as well as being easy to complete and user-friendly measures.

Both measures were highly correlated with each other which showed that they are related but also psychometric testing indicated that they were two distinct measures. The psychometric testing showed that two items did not only fit into the two factors (cooking skills and food skills) but also into a third factor, however they were left in the cooking skills measure as the third factor consisted of only these two items and explained a small variance. In addition, in the Structure Matrix both these items had higher loadings in the Cooking skills Factor (Factor 1). Furthermore, as Nunnally and Bernstein [29] argue the intention of factor analysis is to reduce variables to 'more substantive' underlying factors and the use of a cut-off point of an eigenvalue of 1 for factor extraction (as recommended by Kaiser [30])

Table 6 Study 1: Summary of Exploratory Factor Analysis for cooking and food skills measures using direct oblimin oblique rotation and the pattern matrix (N = 1049)

	Factor Loadings		
Item	Factor 1: Cooking Skills	Factor 2: Food Skills	Factor 3: Other
1) Chopping, mixing, stirring	0.82		
2) Blending	0.80		
3) Steaming	0.90		
4) Boiling	0.95		
5) Stewing	0.89		
6) Roasting	0.84		
7) Frying/Stir-frying	0.86		
8) Microwaving	0.55		−0.48
9) Baking	0.61		0.46
10) Peeling	0.92		
11) Preparing/cooking raw meat/poultry	0.83		
12) Preparing/cooking raw fish	0.83		
13) Making sauces	0.88		
14) Using herbs/spices	0.82		
1) Planning ahead		0.74	
2) Preparing in advance		0.61	
3) Following recipes		0.76	
4) Grocery List		1.01	
5) Specific meals		0.76	
6) Planning how much to buy		0.78	
7) Comparing prices		1.07	
8) Knowing food budget		0.88	
9) Buying in season	0.46	0.43	
10) Buying cheaper cuts		0.89	
11) Doubling recipes		0.75	
12) Cooking healthy with a few ingredients		0.57	
13) Cooking with limited time	0.47	0.49	
14) Using leftovers	0.50	0.43	
15) Keeping basics in cupboard	0.56		
16) Reading best before	0.53		
17) Reading storage/use-by	0.42	0.45	
18) Reading nutrition information on labels		0.70	
19) Balancing meals based on nutrition advice		0.67	
Eigenvalues	21.54	2.72	1.07
% of Variance	65.26	8.23	3.24

*All factor loadings were greater than 0.162, the criterion for the sample size [37], the factor loadings are regression coefficients as they are from the pattern matrix [38]

is over simplified and fundamentally flawed. Therefore, as recommended in Field [31], a scree plot was used to assess factors for extraction and only the initial two factors were to the left of the point of inflection. The two items that fell into the third factor were microwaving food and baking goods such as cakes. It is suggested that although microwaving may be used in meal preparation, for example microwaving a ready meal, it is not seen as a cooking skill and therefore participants did not rate this as they did not use it in cooking a meal. However, as a wide range of cooking abilities were recruited for, including those with very limited skill, participants had to be

Table 7 Internal Consistency reliability of the cooking skills and food skills confidence measures

Cohort	No. of items	Range	Mean Score[a]	SD	*n*	α
Cooking Skills						
Study 1: Island of Ireland (*N* = 1049, CAPI)	14	0–98	47.78	29.32	1049	.93
Study 2: Test/Re-test Students (*N* = 23, P/P)	14	27–89	58.83	16.45	23	.79
Study 3: Experienced/Novice food preparers (*N* = 57, P/P)	14	46–98	71.1	15.3	15	.78
Food Skills						
Study 1: Island of Ireland (*N* = 1049, CAPI)	19	0–133	45.82	38.64	1049	.94
Study 2: Test/Re-test Students (*N* = 23, P/P)	19	18–134	74.76	27.64	21	.89
Study 3: Experienced/Novice Food Preparers (*N* = 57, P/P)	19	32–127	81.3	29.2	16	.93

[a]NB the paper and pencil version meant that participants rated their ability on almost all CS and FS items. The national survey means are lower as participants were first asked to highlight the CS and FS they used and only rated their confidence of those items

responsible for preparing a main meal at least once a week which could include heating a ready meal. By removing microwaving as a skill it may have excluded some participants that potentially use microwaving as their only skill or in combination with one or two others and therefore it was decided to keep microwaving as part of the scale. The other item that was questionable but that was kept was baking. Baking may be seen as different to cooking in itself, with its own separate skills, however, there is a certain amount of overlap and there are elements of baking that may be used in meal preparation including making fresh bread or making pastry for pies. Therefore, the item was included in the cooking skills confidence measure, however, future studies may consider developing and validating a baking skills confidence measure in itself. Additionally, the two items 'Keeping basic ingredients in the cupboards,' and 'Reading the best before date' had higher loadings on the Cooking Skills Factor. As the two measures are correlated, it is understandable that some items would load on both measures, however, as conceptually these items are not considered 'cooking skills' and have been identified as food skills in previous literature [17], they were left in the food skills measure and further testing of these items is needed.

The temporal stability of the measures, assessed using a test-retest approach, was found to be highly correlated with both measures having no differences in their mean scores between both time points and with the correlations between the time points for both measures being significant. This highlights that scores remain consistent over time in a non-biased sample as the sample consisted of 'Food preparation novices' that had no previous experience of the measures or cooking/food education. Previous research has had problems with test re-test samples being biased due to their involvement in the development and testing of the measures [21].

Table 8 Study 2 (P/P): Temporal Stability of both cooking and food skills confidence measures

Measure	N	Time point	Mean	SD	T	df	Sig
Cooking Skills Confidence	20	T1	58.25	17.26			
		T2	59.00	19.75	−0.292	19	0.774
Food Skills Confidence	13	T1	74.15	28.34			
		T2	71.77	27.06	0.610	12	0.553

The internal consistency reliability of both measures was >0.70 in all cohorts. Cronbach's alpha's > 0.70 have been established as satisfactory for non-clinical measures [32, 33]. Therefore, both the cooking skills confidence measure and the food skills confidence measure can be seen as highly reliable and they are measuring coherent concepts.

The two measures also showed a high discriminate validity as there were significant differences ($P < 0.05$ for cooking skills confidence and $P < 0.01$ for food skills confidence) between 'Experienced food preparers' (Home Economics students), proposed as high skilled students, and 'Food preparation novices', proposed as lower skilled students. Therefore, these measures would be able to distinguish between higher and lower skilled individuals and could potentially be used for pre-screening for cooking interventions aimed at low skilled individuals. This supports the overall high construct validity of both measures [33].

A difference in both the cooking skills confidence measure and food skills confidence measure scores were seen between the different methods of presenting the questions to the participants. This is an important factor to consider when choosing the method of presenting the measures to participants in future studies, as those that complete a P/P version of the scale may report inflated scores. If possible it is recommended using a tablet/computer to replicate the system used in CAPI where participants are presented with all the skills and choose which they use and then after completing this, they are then asked to rate their confidence on only the skills they stated they used. When presented with the question of usage and rating confidence at the same time, participants were more likely to give a rating for a skill even if they did not use it. Therefore, if using the P/P version of the measures this inflation

Table 9 Study 3 (P/P): Discriminant validity of both cooking and food skills confidence measures

Measure	Student Type	*N*	Mean	SD	F	Sig
Cooking Skills Confidence	Food Preparation Novices	15	71.07	15.32		
	Experienced Food Preparers	39	79.67	10.42	4.63	.036
Food Skills Confidence	Food Preparation Novices	16	81.31	29.15		
	Experienced Food Preparers	34	105.64	17.78	7.95	.007

of scores must be taken into account. Further when studying change in cooking skills the method used must be the same. In addition, the representativeness of the measures may be considered to be accurate considering the reported usage. For the cooking skills items, the top reported cooking skills may be considered reflective of the eating patterns of that group, the Study 1 group top skills could be considered to correspond with a traditional diet on the IOI, meat and vegetables, roasts, casseroles (that are still reported as the most common main meals on the IOI – data not reported here). The student samples report chopping, frying/stir-fry, boiling, peeling, microwaving, roasting in the oven, these skills could be considered fundamental to the quick, easy meals associated with a student diet. In addition, the top reported food skills across the different cohorts show a number of consistencies, such as keeping basic ingredients in cupboards and reading best before dates. This shows learned behaviours across the different groups or perhaps adherence to consistent health messages (checking the best before date).

Additionally, some interesting differences between the 'Food preparation novices' and the 'Experienced food preparers' can be seen. Experienced food preparers tended to use a higher number of skills more frequently than the food preparation novices. The high frequency use of skills such as peeling, blending and preparing or cooking raw meat/poultry may indicate a greater use of basic ingredients in this group. Future interventions should focus on increasing the number of skills used by lower skilled individuals to enable the use of more basic ingredients. Additionally, future research could investigate correlations between the use of different skills and the type of ingredients used in meal preparation. Furthermore, differences can be seen between usage of food skills among these groups. Experienced food preparers had a greater use of preparing a meal with limited time, as time has been identified as key barrier to home meal preparation [8], future research should investigate whether their use of more skills more frequently or that they have a greater confidence in a range of skills enables meal preparation in a limited time.

Strengths and limitations

The new measures were developed in light of the literature and expert opinion and were found to be highly reliable and valid. In addition, the items do not revolve around specific foods, which increases the generalisability of the measures outside UK and Irish populations, although further studies to assess the validity of these measures in other populations are needed. In addition, although there were a large number of male respondents completing the measures, the majority were female. This may be reflective that women remain responsible for the meal preparation of most households [34]. However, this must be taken into consideration when generalising the results to men. A limitation of the test re-test study was the format in which the measures were presented, the question was split over two pages and some participants did not turn the page to complete the second half of the measure and therefore those measures could not be included in the analysis resulting in the lower response rate for the food skills confidence measure. Due to different answering formats, P/P versions of the measures were found to inflate the scores on both measures. Thus, interviewer led or computer based applications (where participants are only provided the opportunity to rate the skills they said they use) may provide the most accurate scores for these measures. However, to use as part of a paper based large scale cross-sectional survey, longitudinal research or as screeners/measures for interventions, rearranging the question to put "if you don't do a skill" tick 'Never/rarely do it' first followed by confidence rating may help to make this version similar to the CAPI version.

Table 10 Study 4: Differences between the different methods of presentation of the measures

	Range	F (df)	Significance	Non-Home Ec Students (P/P, *N* = 38)	Home Ec Students (P/P, *N* = 39)	Random Selection from IOI (CAPI, *N* = 38)
			P	M (SD)	M (SD)	M (SD)
Cooking skills Confidence	0–98	28.63 (2112)	.000	63.66 (16.93)[a]	79.67 (10.42)[b]	45.29 (28.38)[c]
				N = 37	*N* = 37	*N* = 38
Food skills Confidence	0–134	52.50 (2109)	.000	77.60 (28.10)[a]	106.16 (17.82)[b]	39.74 (35.52)[c]

Superscript letters depict where significant differences (P < 0.05) are found

Conclusions

The developed cooking skills confidence measure and the food skills confidence measure have been shown to have a very satisfactory internal consistency reliability and validity. In addition, they have been shown to remain consistent over time. They are able to accurately distinguish between high and low skilled individuals and are user-friendly. While the choice of presentation of the measures must be considered, both measures are highly suitable for large scale cross-sectional research, longitudinal studies and interventions alike to assess or monitor cooking and food skills levels and confidence.

Abbreviations

CAPI: Computer Assisted Personal Interviewing; IOI: Island of Ireland; P/P: Paper Pen; UK: United Kingdom

Acknowledgments

The authors would like to acknowledge the contribution made by Aileen McGloin and Marian Faughnan from Safefood, particularly with regard to their input on the development of the survey.

Funding

This material is based upon work supported by safefood, The Food Safety Promotion Board, under Grant No. 11/2013 for the period May 2014 – October 2015.

Authors' contributions

FL, LM and MD conceived the manuscript. FL conducted the data analysis. FL drafted the manuscript and MD and LH edited. All authors were involved in the design of the study, read, commented and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Institute for Global Food Security, School of Biological Sciences, Queen's University Belfast, Belfast BT9 5AG, UK. [2]Centre for Public Health, School of Medicine, Dentistry and Biomedical Sciences, Queen's University Belfast, Belfast, UK. [3]Department of Hospitality and Tourism Management, Ulster University Business School, Ulster University, Coleraine, UK. [4]Department of Home Economics, St. Angela's College, Sligo, Ireland. [5]Centre for Food Policy, Department of Sociology, School of Arts and Social Sciences, City University London, London, UK. [6]Food, Consumer Behaviour and Health Research Centre, School of Psychology, University of Surrey, England, UK.

References

1. Wolfson JA, Bleich SN. Is cooking at home associated with better diet quality or weight-loss intention? Public Health Nutr. 2015;18(08):1397–406.
2. Van der Horst K, Brunner TA, Siegrist M. Ready-meal consumption: associations with weight status and cooking skills. Public Health Nutr. 2011; 14(02):239–45.
3. Nelson SA, Corbin MA, Nickols-Richardson SM. A call for culinary skills education in childhood obesity-prevention interventions: current status and peer influences. J Acad Nutr Diet. 2013;113(8):1031–6.
4. Lang T, Caraher M. Is there a culinary skills transition? Data and debate from the UK about changes in cooking culture. J HEIA. 2001;8(2):2–14.
5. Beck ME. Dinner preparation in the modern United States. Br Food J. 2007; 109(7):531–47.
6. Worsley T, Wang WC, Wijeratne P, Ismail S, Ridley S. Who cooks from scratch and how do they prepare food? Br Food J. 2015;117(2):664–76.
7. Lavelle F, McGowan L, Spence M, Caraher M, Raats MM, Hollywood L, McDowell D, McCloat A, Mooney E, Dean M. Barriers and facilitators to cooking from 'scratch'using basic or raw ingredients: a qualitative interview study. Appetite. 2016;107:383–91.
8. Wolfson JA, Bleich SN, Smith KC, Frattaroli S. What does cooking mean to you?: perceptions of cooking and factors related to cooking behavior. Appetite. 2016;97:146–54.
9. Deliens T, Clarys P, De Bourdeaudhuij I, Deforche B. Determinants of eating behaviour in university students: a qualitative study using focus group discussions. BMC Public Health. 2014;14(1):53.
10. Chang MW, Nitzke S, Buist D, Cain D, Horning S, Eghtedary K. I am pregnant and want to do better but i can't: focus groups with low-income overweight and obese pregnant women. Matern Child Health J. 2015;19(5): 1060–70.
11. Monteiro CA, Moubarac JC, Cannon G, Ng SW, Popkin B. Ultra-processed products are becoming dominant in the global food system. Obes Rev. 2013;14(S2):21–8.
12. Moodie R, Stuckler D, Monteiro C, Sheron N, Neal B, Thamarangsi T, Lincoln P, Casswell S, Lancet NCD. Action group. Profits and pandemics: prevention of harmful effects of tobacco, alcohol, and ultra-processed food and drink industries. Lancet. 2013;381(9867):670–9.
13. Monteiro CA, Levy RB, Claro RM, de Castro IR, Cannon G. Increasing consumption of ultra-processed foods and likely impact on human health: evidence from Brazil. Public Health Nutr. 2011;14(01):5–13.
14. Stuckler D, McKee M, Ebrahim S, Basu S. Manufacturing epidemics: the role of global producers in increased consumption of unhealthy commodities including processed foods, alcohol, and tobacco. PLoS Med. 2012;9(6): e1001235.
15. Short F. Domestic cooking skills - what are they? J HEIA. 2003;10(3):13–22.
16. Short F. Domestic cooking practices and cooking skills: findings from an English study. Food Service Tech. 2003;3:177–85.
17. Fordyce-Voorham S. Essential food skills required in a skill-based healthy eating program. J HEIA. 2009;16(2):16–20.
18. Vrhovnik, L. A pilot study for the development of a food skills survey tool. Dissertation.Accessed at: https://qspace.library.queensu.ca/bitstream/1974/7323/3/Vrhovnik_Lydia_201207_MSc.pdf on 10th May 2014.
19. Porter J, Capra S, Watson G. An individualized food-skills programme: development, implementation and evaluation. Aust Occup Therap J. 2000; 47(2):51–61.
20. Barton KL, Wrieden WL, Anderson AS. Validity and reliability of a short questionnaire for assessing the impact of cooking skills interventions. J Human Nutr Diet. 2011;24(6):588–95.
21. Condrasky MD, Williams JE, Catalano PM, Griffin SF. Development of psychosocial scales for evaluating the impact of a culinary nutrition education program on cooking and healthful eating. J Nutr Educ Behav. 2011;43(6):511–6.
22. Morin P, Demers K, Turcotte S, Mongeau L. Association between perceived self-efficacy related to meal management and food coping strategies among working parents with preschool children. Appetite. 2013;65:43–50.
23. McGowan L, Caraher M, Raats M, Lavelle F, Hollywood L, McDowell D, Spence M, McCloat A, Mooney E, Dean M. Domestic Cooking and Food Skills: A Review. Crit Rev Food Sci Nutr. 2015; (just-accepted):00-
24. Safefood. Food Skills: Definitions, Influences and Relationships with Health. 2014. http://www.safefood.eu/SafeFood/media/SafeFoodLibrary/Documents/Publications/Research%20Reports/Food-Skills-Edited-Final-Report.pdf . Accessed 1 Dec 2016.
25. Brooks J, McCluskey S, Turley E, King N. The utility of template analysis in qualitative psychology research. Qual Res Psychol. 2015;12(2):202–22.
26. Lavelle F, Spence M, Hollywood L, McGowan L, Surgenor D, McCloat A, Mooney E, Caraher M, Raats M, Dean M. Learning cooking skills at different ages: a cross-sectional study. Int J Behav Nutr Phys Act. 2016;13(1):119.
27. McGowan L, Pot GK, Stephen AM, Lavelle F, Spence M, Raats M, Hollywood L, McDowell D, McCloat A, Mooney E, Caraher M. The influence of socio-demographic, psychological and knowledge-related variables alongside perceived cooking and food skills abilities in the prediction of diet quality in adults: a nationally representative cross-sectional study. Int J Behav Nutr Phys Act. 2016;13(1):111.
28. Tabachnick BG, Fidell LS, Osterlind SJ. (2001). Using multivariate statistics.

29. Nunnally JC, Bernstein IH. Psychometric theory. 3rd ed. New York: McGraw-Hill; 1994.
30. Kaiser HF. The application of electronic computers to factor analysis. Educ Psychol Meas. 1960;20(1):141–51.
31. Field A. Discovering statistics using SPSS. London: Sage publications; 2009.
32. Bland JM, Altman DG. Statistics notes: Cronbach's alpha. Brit Med J. 1997; 314(7080):572.
33. Rattray J, Jones MC. Essential elements of questionnaire design and development. J Clin Nurs. 2007;16(2):234–43.
34. Smith KJ, McNaughton SA, Gall SL, Blizzard L, Dwyer T, Venn AJ. Involvement of young Australian adults in meal preparation: cross-sectional associations with sociodemographic factors and diet quality. J Amer Diet Ass. 2010;110(9):1363–7.
35. National Diet and Nutrition Survey (NDNS) Year 1 questionnaire items. http://doc.ukdataservice.ac.uk/doc/6533/mrdoc/pdf/6533_ndns_yr1_interviewing_documents.pdf. Accessed 2 May 2015.
36. Chun Wang W, Worsley A. Who uses herbs and spices? Nutr Food Sci. 2014; 44(4):363–74.
37. Stevens J. Applied multivariate statistics for the social sciences. Lawrence Erlbaum. Mahwah, NJ. 2002:510–1.
38. Jöreskog, K. G. (1999). How large can a standardized coefficient be. *Unpublished Technical Report. Retrieved from:* http://www.ssicentral.com/lisrel/techdocs/HowLargeCanaStandardizedCoefficientbe.pdf.

Perceived fussy eating in Australian children at 14 months of age and subsequent use of maternal feeding practices at 2 years

Rebecca Byrne[1*], Elena Jansen[1] and Lynne Daniels[2]

Abstract

Background: Concerns about fussy eating are common amongst parents of young children. However, studies of the long-term impact of fussy eating show mixed results with regard to adequacy of dietary intake and child growth. This may be in part because there is no accepted definition of fussy eating and studies measure the construct in different ways, commonly relying on parent perception. This longitudinal analysis explores maternal and child characteristics associated with maternal perception of her toddler as a fussy eater in early toddlerhood and subsequent use of feeding practices at 2 years.

Methods: Mothers completed a self-administered questionnaire at child age 14 months, describing perception of their child as fussy/not fussy and child behaviour. Intake was assessed using a single 24-h recall and weight was measured by research staff. At child age 2 years mothers completed the validated 28-item Feeding Practices and Structure Questionnaire (FPSQ-28).
Weight-for-age z-score (WAZ) was derived from WHO standards. Gram daily intake of fruit, vegetables and meat/alternative and a dietary diversity score were determined. Maternal/child characteristics independently associated ($p \leq 0.05$) with perception of child as a fussy eater were determined using logistic regression. Variables were combined in a structural equation model assessing the longitudinal relationship between child/maternal characteristics, perception of child as a fussy eater and eight FPSQ factors.

Results: Mothers' ($n = 330$) perception of her child as a fussy eater at age 14 months, was associated with higher frequency of food refusal and lower WAZ ($R^2 = 0.41$) but not dietary intake. Maternal perception as fussy (age 14 months) was associated with four FPSQ factors at 2 years ($n = 279$) - Reward for Eating, Reward for Behaviour, Persuasive Feeding and Overt Restriction, $x^2/df = 1.42$, TLI = 0.95, CFI = 0.95, RMSEA = 0.04(0.03–0.05), PCLOSE = 0.99.

Conclusions: Lower relative child weight and food refusal prompted mothers to perceive their child as fussy. These behaviours in healthy weight children most likely reflect self-regulation of energy intake and neophobia. This perception was prospectively associated with use of non-responsive feeding practices, which may increase obesity risk. Future interventions could directly address perceptions of growth and fussiness, supporting parents to understand food refusal as developmentally appropriate behaviour in healthy young children.

Trial registration: ACTRN12608000056392. Registered 29 January 2008.

Keywords: Dietary intake, Food refusal, Fussy eating, Maternal feeding practices, Maternal perception, Obesity, Overweight, Picky eating, Structural equation modelling, Toddlers

* Correspondence: ra.byrne@qut.edu.au
[1]Centre for Children's Health Research, School of Exercise and Nutrition Sciences, Queensland University of Technology, 62 Graham St, South Brisbane, QLD 4101, Australia
Full list of author information is available at the end of the article

Background

Anecdotally, parents have a strong desire to raise a child who is a 'good eater' and children are routinely praised for 'eating all the food on their plate' [1]. Concerns about fussy eating and underweight are common amongst parents in developed countries [2, 3] with fussy (or picky) eating reported to occur in 25–40% of toddlers [3]. This is in stark contrast to public health priorities which overwhelmingly relate to consumption of too much food and prevalence of childhood obesity [4]. The relationship between fussy eating and child outcomes, such as adequacy of dietary intake and growth trajectory is unclear [5–10]. This is perhaps because the construct of fussy eating is measured in a myriad of different ways [11].

From a theoretical perspective, fussy eating is defined as the rejection of a substantial amount of familiar and unfamiliar foods, potentially resulting in limited dietary variety and food intake [12, 13] However, studies rarely use objective measure of dietary intake (most likely because of the complexity and labour-intensive nature of this type of data collection) and instead rely on parent report/perception of fussiness [3, 10, 14, 15]. However, it is important to explicitly examine the criteria that parents use to label their child as a fussy eater. Parents, health professionals and researchers may not necessarily define fussy eating in the same way [16] and hence interpret study-specific questions such as 'is your child a fussy/picky eater' [5, 7] quite differently. Perception may also differ between mothers, fathers and non-parental carers. Children could be labelled as fussy because they do not consume the type and/or amount of *food* perceived as appropriate [17] and parents may differ in the type, frequency and extent of *behaviours* they consider to be problematic. The Food Fussiness (FF) scale of the Child Eating Behaviour Questionnaire (CEBQ) [18] is frequently used to characterise fussiness according to child behaviour, with five items related to food refusal, tasting new foods and enjoying variety. In a cross-sectional analysis of 3-year-old twin children (n = 1330 pairs) from the Gemini cohort in the United Kingdom, FF was inversely correlated with liking of both fruit and vegetables [19] but we are unaware of any examination of the relationship with food intake amongst toddlers.

Our underlying premise is that a mother pieces together information (consciously or not) about her child's behaviour, physical appearance and amount/type of dietary intake, which inform her perception and her subsequent feeding practices. Non-responsive feeding practices are actions which a parent employs during feeding which may interfere with a child's ability to recognise and attend to internal hunger and satiety cues and increase obesity risk [20, 21]. Examples of these practices include pressuring a child to eat more than they want to, and using food as a reward to encourage eating or to encourage desired behaviour. In another analysis of the Gemini cohort, this time of when the twins were 16-month-old (n = 2026) [22], between-family analyses indicated that 'pressure to eat' and 'instrumental feeding' i.e. using food to encourage healthy food consumption/good behaviour were positively associated with Food Fussiness on CEBQ [23]. An analysis of a subset of 274 Gemini twin pairs that were most discordant on food fussiness, found that mothers used more 'pressure to eat' and 'instrumental feeding' with the twin perceived as fussier. Similarly a cross-sectional survey of 413 parents of Australian children aged 1–10 years found that 'persuasive feeding' and 'reward for eating' (constructs which correspond to 'pressure to eat' and 'instrumental feeding' respectively) were both positively associated with Food Fussiness on CEBQ [23]. Overall, there is evidence that parent perception of fussiness is, at least cross-sectionally, associated with non-responsive feeding practices which may in turn be counterproductive in our obesogenic environment and contribute to obesity risk.

The aims of this analysis were to 1. Identify what maternal and child characteristics – demographics, behaviour, measured dietary intake - were associated with maternal perception of her child as a fussy eater in early toddlerhood (12–16 months), and 2. Explore the prospective relationship between child/maternal characteristics and maternal perception of child as a fussy eater at 12–16 months, with maternal feeding practices at age 2 years.

Methods

Design and participants

This is a secondary analysis of data from mother-child dyads who participated in the control group of NOURISH, a randomised controlled trial that evaluated an intervention promoting positive feeding practices in very young children [24], and an additional sample of mothers recruited for the South Australian Infants Dietary Intake (SAIDI) Study [25]. SAIDI participants were recruited simultaneously and using the same protocol as NOURISH. Recruitment has been described in detail [24, 26]. Briefly, a consecutive sample of mothers (aged ≥18 years) delivering healthy term infants (≥ 37 weeks gestation and birthweight ≥2500 g) at maternity hospitals in Brisbane, Queensland (n = 3) and metropolitan (n = 5) and regional (n = 7) South Australia were approached within 72 h post-delivery. Eligible mothers were asked to provide consent to be contacted when infants were 4- to 7-months-of-age, for full enrolment in the study. Approval was gained from a total of 11 human research ethics committees including Queensland University of Technology and Flinders University (QUT HREC 00171 Protocol 0700000752).

Measurements

Maternal and child demographic data were collected during initial recruitment in hospital including gender,

maternal age at birth of child (years), and maternal university education.

Participants attended study-specific outcome assessment clinics when children were 12–16 months of age (June 2009 to June 2010). Child weight was measured by trained staff using a standard protocol. Weight was measured twice, lying or sitting on electronic infant scales with no nappy or clothes (except a singlet), to the nearest 10 g. A third measurement was taken if the first two differed by more than 50 g. In regional areas, participants were measured at their local child health or general practitioner clinic. Mothers completed a self-administered questionnaire containing five questions regarding fussy eating and child behaviour (Table 1).

Within two weeks of this assessment, child dietary intake was assessed via telephone by a dietitian using a single three-pass 24-h recall [27]. Recalls were collected on week days and weekends. The mother was asked to recall everything her child ate or drank in the previous 24 h, starting from midnight on the previous day, with quantities estimated using household measures (metric cup, tablespoon and teaspoon). A visual aide designed to improve estimation, which showed actual size illustrations of these measures, was provided at assessment. Items from the recall were entered into FoodWorks Professional version 9 using the AUSNUT 2007 database from the 2007 Australian National Children's Nutrition and Physical Activity Survey [28]. An additional database containing commercial infant products was created by study staff. Mixed dishes prepared at home were added to FoodWorks as a recipe or if there were ≤three ingredients, entered into FoodWorks as separate items. A study-wide data checking protocol meant that any children with very high or very low estimates of energy intake - <3000kj or >6000kj had their FoodWorks file checked against the original recall, to correct any possible errors. Food recall data were exported from FoodWorks into an Access database and merged with an eight digit food group code which allows identification of each unique food [29]. Study staff allocated additional eight digit codes to infant foods and mixed dishes/recipes with codes allocated based on the predominant ingredient. A comprehensive analysis of dietary intake data for this cohort has been published elsewhere [27].

When the child was aged 2 years, mother-child dyads attended a second assessment at which time mothers completed another questionnaire containing 28 items of the Feeding Practices and Structure Questionnaire (FPSQ-28) [30] and an item regarding Family Meal Setting (Additional file 1).

Derived variables

Weight-for-age z-scores were derived from measured weight using WHO standards [30] and all data was exported into SPSS 22.0 for analysis.

Maternal perception of child as a fussy eater at 12–16 months and child behaviour

Responses to the question 'Do you think your child is a picky or fussy eater?' were dichotomised to form the variable 'perception of child as a fussy eater': *fussy* / *not fussy* as per the methodology of Carruth et al. [5] (Table 1). Table 1 also shows the four questionnaire items chosen to characterise child behaviour regarding refusal of familiar and unfamiliar food.

Dietary intake

Intake (grams/day) of three food groups were derived based on their unique eight digit food group code – i. fruit (excluding 100% fruit juice), ii. vegetables (including beans and lentils) and iii. Meat/alternatives (including fish, poultry, and eggs). Australian and international studies indicate that dairy and cereal groups contribute the highest proportion of daily energy intake amongst young children with these food groups tending to be consumed in excess of dietary recommendations [27, 31, 32]. The most recent representative study of Australian children aged 2–3 years indicated 95% consumed dairy and 97% cereals, with each

Table 1 Items on self-administered questionnaire at child age 12–16 months used to characterise maternal perception of fussy eating and child behaviour

Question	Response	Dichotomised variable used in regression model
Maternal perception of her child as a fussy eater:		
Do you think your child is a picky or fussy eater?	*Very picky, Somewhat picky, Not picky, Not sure*	Fussy (*very picky*, *somewhat picky* combined), Not fussy (*not picky*, *not sure* combined)
Child behaviour**:**		
How often does your child refuse food?	*Very often, Often, Sometimes, Hardly ever*	Often (*Very often, Often*), Not often (*Sometimes, Hardly ever)*
Does your child ever refuse food they usually eat?	*Hardly ever, Yes*	
How willing is your child to eat unfamiliar foods?	*Very willing, Willing, Neutral, Unwilling, Very unwilling*	Willing (*Very willing, Willing*), Not willing (*Neutral, Unwilling, Very unwilling*)
Who decides how much food your child eats – you or your child?	*You only, Mostly you, You and your child equally, Mostly your child, Your child only*	Mother (*You only, Mostly you, You and your child equally*), Child (*Mostly your child, Your child only*)

food group contributing 21% and 27% of daily estimated energy intake, respectively [31]. Therefore they were not considered an 'at risk' food groups requiring further investigation in this analysis.

A dietary diversity score was calculated for each child i.e. number food groups consumed on 24-h recall with a potential score of 0–9 [33] (vitamin A-rich fruits and vegetables [34], other fruit; other vegetables; legumes and nuts; meat, poultry and fish; breads, cereals, roots and tubers; eggs; dairy/alternatives; fats and oils). Australia's second dietary guideline states that by 12 months of age children should "*enjoy a wide variety of nutritious foods… each day*" [35].

Analyses

Bivariate analyses were conducted using independent t-test or Mann-Whitney test for continuous variables and Pearson's chi-squared test for categorical variables to determine differences between children perceived as *fussy* or *not fussy* for thirteen independent variables that described maternal and child demographics; child food refusal and dietary intake. Variables with a significant bivariate association ($p \leq 0.05$) with perceived fussiness were entered into a logistic regression model to determine characteristics independently associated with perception of child as a fussy eater (dependant variable), with results expressed as odds ratios and 95% CI. Using Mplus (v7.4), these variables were combined in a structural equation model with maternal perception of child as a fussy eater and 28 items of the FPSQ-28 [30] and the additional single item measuring family meal setting (Additional file 1). The weighted least squares estimator (WLSMV) was used to determine standardised regression weights for the pathways in the model since items were treated as ordinal categorical variables [36]. Model fit was determined using normed chi-square (x^2/df), Tucker-Lewis index (TLI), comparative fit index (CFI) and root mean square error of approximation (RMSEA) with 90% CI and probability (PCLOSE).

Results

Characteristics of mother-child dyads completing an assessment at age 12–16 months (n = 330) are shown in Table 2. Notably, no children were underweight [30].

Thirty-one percent of mothers defined their child as a fussy eater - not fussy, n = 232; fussy, n = 98 ('very picky' n = 10 and 'somewhat picky' n = 88 combined). Bivariate analyses comparing children perceived as 'fussy' versus 'not fussy' revealed group differences for nine (highlighted by *italics*) of the 13 variables considered: maternal age, *maternal education*, *child age*, gender, *WAZ*, *fruit intake*, *vegetable intake*, meat/alt intake; diversity; *child decides amount of food eaten; how willing is your child to eat unfamiliar foods?; how often does your child refuse food?*; and *does your child ever refuse food they usually eat?* (additional file 2). However, only five variables remained significantly associated with maternal perception in the adjusted cross sectional analysis (Table 3): weight-for-age z-score and the four measures of child behaviour. Mothers' perception of her child as a fussy eater was associated with higher frequency of refusal of familiar and unfamiliar food, the child choosing amount eaten and lower WAZ; but not intake of fruit, vegetables, meat or dietary diversity; $x^2(9) = 109.36$, $p < 0.001$, –2 Log likelihood = 287.56, $R^2 = 0.41$(Nagelkerke).

Longitudinal data was available for 279 mother-child dyads. The model showing the relationship between child variables, maternal perception and the FPSQ-28 is shown in Fig. 1 and was a good fit, x^2/df = 1.42, TLI = 0.95, CFI = 0.95, RMSEA = 0.04 (0.03–0.05), PLCOSE = 0.99. Maternal perception of her child as a fussy eater at age 12–16 months was directly associated with four factors of the FPSQ-28 at 2 years - Reward for Eating ($\beta = 0.34$, $p < 0.001$), Reward for Behaviour ($\beta = 0.27$, $p < 0.01$), Persuasive Feeding ($\beta = 0.37$, $p < 0.001$), and Overt Restriction ($\beta = 0.31$, $p < 0.001$). The relationships between WAZ, child decides amount of food eaten, or does your child ever refuse food they usually eat and maternal perception were no longer significant.

Discussion

In everyday lexicon young children tend to be categorised as either a 'good' eater or a 'fussy' eater. Amongst this sample of healthy children, a third were perceived as fussy and this perception was associated with maternal feeding practices that may be counterproductive in our obesogenic environment.

The finding that approximately 30% of mothers perceived their child as a fussy eater is consistent with published prevalence data [5, 37], and the analysis identified factors that explain 40% of the variance in maternal perception. However, instead of aligning with the theoretical definition of fussy eating which is largely focussed on limited intake - there was no difference in the amount of fruit, vegetables or meat/alternatives eaten, or dietary diversity, between those children perceived as fussy and those that were not - perception was related to child behaviour not food intake. This supports previous qualitative analysis indicating "*parents believe that picky eating is not only defined by the food the child eats, but also by the child's overall behaviours and attitudes toward mealtimes*" [38].

The relevant behaviours - child refused food often or unwilling to eat unfamiliar foods – do support the definition of fussy eating as the rejection of both novel and familiar foods [12]. However, these behaviours could also be indicative of normal toddler development i.e. self-regulation of energy intake (refusal of familiar foods), neophobia (refusal of unfamiliar foods) and emerging autonomy [39]. Rate of growth in toddlers slows in comparison to infancy [40] with a relative decline in energy requirements, which may result in refusal of familiar foods in response to intrinsic cues of

Table 2 Characteristics of mothers and toddlers (N = 330)

Characteristic	Mean (SD)	n (%)
Child age (months)	13.8 (1.3)	
Birthweight (kg)	3.5 (0.4)	
Weight-for-age z-score[a] at 12–16 months of age	0.58 (0.86) Range: −1.6 to 2.9	
Male gender		165 (49)
Maternal age at birth of child (years)	30.3 (5.0)	
Maternal university education		193 (58)
Family income[b] ≥ 70,001 $AUD		199 (60)
Child Dietary intake	Median (IQR)	
Fruit intake (g) on 24-h recall[c]	118 (60–192)	
Vegetable intake (g) on 24-h recall[c]	80 (21–152)	
Meat/alternatives intake (g) on 24-h recall[c]	49 (15–108)	
Dietary diversity score[d]	6 (5–7)	

[a]Weight-for-age z-score calculated using WHO Anthro (2008); 92% weight measured vs 8% self-reported based on measure with GP/nurse in rural areas
[b]n = 321; Median Australian gross income, 2008 - all household types = 67,000 $AUD [56]
[c] Intake on single 24-h recall of whole sample; Fruit: fresh, canned, dried, cooked, infant food or mixed dish where fruit is the predominant ingredient; Vegetables: fresh, canned, cooked, beans and lentils, infant food or mixed dish where vegetable is the predominant ingredient; Meat/alternatives: fish, poultry, beef, lamb, pork, game meats, egg, nuts and seeds, infant food or mixed dish where meat/alternative is the predominant ingredient
[d] Diversity score from 0 to 9 representing number of different food groups (vitamin A-rich fruits and vegetables; other fruit; other vegetables; legumes and nuts; meat, poultry and fish; breads, cereals, roots and tubers; eggs; dairy/alternatives; fats and oils) consumed on 24-h recall

satiety. Food neophobia, the rejection of foods that are novel or unfamiliar, also increases markedly at this age [12]. This heritable trait [41, 42] is thought to play a protective function, discouraging children from ingesting toxic substances as they become more mobile [43]. The age group 12–16 months coincides with the development of autonomy and independence [39] and meal times are perhaps one of the few areas that toddlers can exert their growing autonomy – by refusing to eat when they are not hungry. It is unknown whether mothers distinguish between (and respond differently to) refusal of familiar versus unfamiliar foods.

Kerzner et al. [44], in their 'Pyramidal Representation of Young Children's Feeding Behaviors' identify four child behaviour categories – normal, misperceived feeding problems, milder feeding difficulties and feeding disorders. Their paper urges clinicians to take parent concerns seriously, even if misperceived, given the potential for parents in response to these concerns to "*adopt inappropriate feeding practices*". This is consistent with our findings. We postulated that a mother pieces together information about her toddler which informs (consciously or unconsciously) her perception and subsequent feeding responses/practices. In our study, the child who refused familiar and unfamiliar food more frequently was perceived as a fussy eater at age 12–16 months, which was associated with use of non-responsive maternal feeding practices at 2 years. These included specific practices such as using favourite foods in

Table 3 Variables independently associated with maternal perception of child as a fussy eater (N = 330)

Independent variables	Dependant variable: perception of child as a fussy eater (not fussy[a], n = 232; fussy, n = 98); OR (95% CI)
Child weight-for-age z-score	0.69 (0.48–0.99)*
Child age (months)	1.17 (0.92–1.48)
Maternal university education; yes, n = 191	1.58 (0.85–2.96)
Fruit intake (g) on 24-h recall[b]	0.99 (0.99–1.00)
Vegetable intake (g) on 24-h recall[b]	0.99 (0.99–1.00)
Who decides amount of food eaten; child, n = 144	1.94 (1.07–3.51)*
How willing is your child to eat unfamiliar foods?; unwilling, n = 76	4.52 (2.33–8.75)***
How often does your child refuse food?; often, n = 47	6.12 (2.62–14.30)***
Does your child ever refuse food they usually eat?; yes, n = 158	2.31 (1.23–4.34)*

*$p \leq 0.05$; ***$p \leq 0.001$, $x^2(9) = 109.36$, $p < 0.001$, −2 Log likelihood = 287.56, 0.41 (Nagelkerke)
Mean(sd) child age 13.8 (1.3) months; 49% male; WAZ using WHO standards [55]
[a]Referent group
[b]Intake on single 24-h recall of whole sample; Fruit: fresh, canned, dried, cooked, infant food or mixed dish where fruit is the predominant ingredient; Vegetables: fresh, canned, cooked, beans and lentils, infant food or mixed dish where vegetable is the predominant ingredient

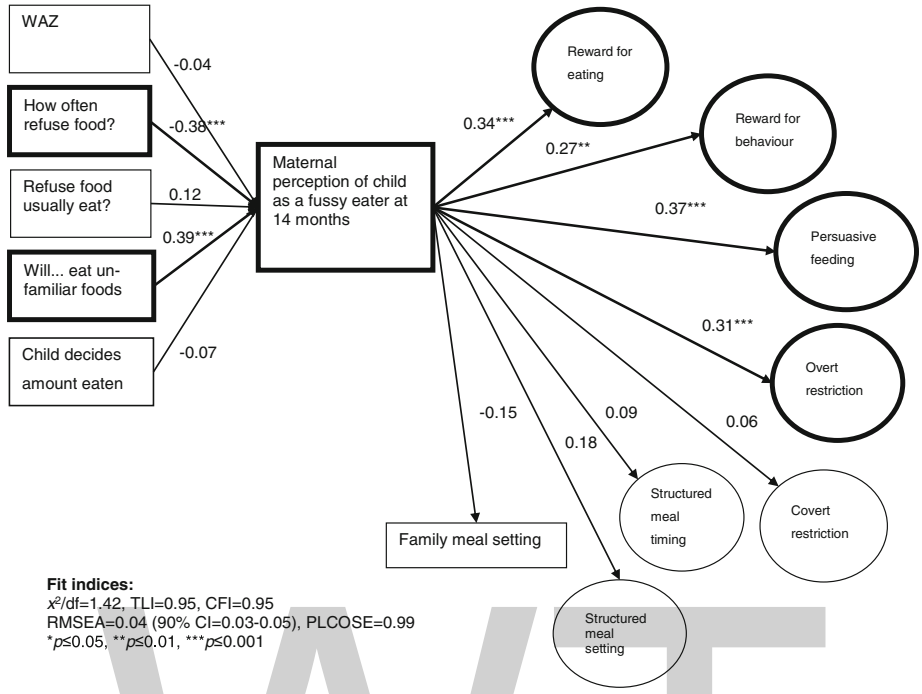

Fig. 1 Relationships between child characteristics and maternal perception of child as a fussy eater at 14 months, and use of feeding practices at 2 years (n = 279). For ease of reading figure, error terms associated with variables or measurement component of FPSQ-28 are not shown. WAZ: Weight-for-age z-score using WHO Standards [55]. How often does your child refuse food? Very often, often, sometimes, hardly ever. Does your child ever refuse food they usually eat? Hardly ever, yes. How willing is your child to eat unfamiliar foods? Very willing, willing, neutral, unwilling, very unwilling. Child decides amount of food eaten. Mother only, mostly mother, mother and child equally, mostly child, child only

exchange for good behaviour or offering children food when they are upset (Reward for behaviour), and insisting children eat food despite not being hungry or showing disapproval when a child does not eat (Persuasive feeding). All of these practices may prompt a child to eat for reasons other than hunger and may interfere with self-regulatory ability [43, 45, 46]. In a longitudinal study of 222 Australian children, food fussiness at age two years (measured within a 'food approach' construct using items from the CEBQ) was correlated with use of instrumental feeding practices i.e. use of food as a reward, a year later [47]. Our findings also support the suggestion of Walton et al. that labelling a child as fussy may contribute to sub-optimal feeding interactions and endorse their call to reconceptualise fussy/picky eating i.e. resistance during eating can be considered children's agency in communicating eating preferences instead of deviant behaviour [48].

The finding that maternal perception of fussy eating was not associated with objectively assessed dietary intake in the NOURISH/SAIDI sample highlights the importance of accurately assessing the child variables informing maternal perception. Perception of fussiness defined according to actual inadequate dietary intake, might prompt use of different feeding practices than those identified in this analysis. This research could also be extended by considering whether particular feeding practices have differential outcomes. For example is persuasive feeding associated with adverse growth trajectory? Does offering preferred foods effectively reduce exposure to a wide range of foods, resulting in a narrow range of food preferences in later life [49, 50]? Understanding different 'types' of fussy eating, differential feeding practices employed in response to these, and subsequent effects on a range of child eating behaviour, dietary intake and growth outcomes may facilitate the development of targeted interventions to address the unique needs of parent-child dyads at each stage in this continuum. Use of non-responsive practices could be reduced by explicitly designing interventions to assist mothers (and other carers) to understand developmentally appropriate eating behaviour.

Limitations of the current analysis include not measuring and adjusting for feeding practices used at 12–16 months. When NOURISH and SAIDI were designed, there were no tools validated to measure feeding practices at both 12–16 months and 2 years. The FPSQ-28 is validated for use at 2 years, but not yet at younger ages. The relationship between dietary variety and maternal perception was not assessed. While use of a single 24-h recall is valid for group level estimates of food intake [51] and a simple measure of diversity [33, 52], it is not suitable to assess micronutrient intake. It is also not appropriate to assess dietary variety, which may also inform a mother's

perception of her child as fussy. Also, the premise that child behaviour informs maternal perception is limited by using maternal report of child behaviour. If a mother is concerned or frustrated about a child refusing food, then it is possible she could systematically overestimate the frequency of this behaviour [53]. This bias would strengthen the positive statistical relationship between frequency of food refusal and perception of fussiness, but highlights that a mother's perception of her child may be more influential in determining what she does, than the child's actual intake or behaviour. The analysis may have been strengthened by comparing variables of interest across children perceived as 'very picky' versus 'somewhat picky' versus 'not picky' however given only 3% (n = 10) of the total sample were characterised as 'very picky' there is inadequate power to investigate differences between these groups. The analyses reported here do not enable consideration of important questions related to potential prospective impact of maternal feeding practices on child weight outcomes and hence the hypothesised role of feeding practices as a mediator of reported associations between fussy eating and child weight. During an additional analysis that added child WAZ at 2 years to the model, fit became unacceptable (data not shown) and hence no conclusions could be drawn.

The sample comprised first-time mothers who were slightly older with a higher level of education compared to the Australian average [54] and hence generalisability is unclear. It is unknown whether the prevalence of perceived fussy eating differs according to socioeconomic status (SES) and it is feasible that the characteristics which mothers use to inform their perception vary according to SES. The contribution of fathers to feeding and family life generally is acknowledged, but was outside the scope of this study.

Strength of this study lies in the use of SEM to simultaneously assess the relationship between child characteristics, maternal perception and maternal feeding practices. Many studies rely on parent report only, to investigate the relationship between the 'fussy child' and maternal practice. However, this analysis was able to take into account multiple factors mothers used to inform their perception, delineating between refusal of familiar and unfamiliar foods and objective measures of dietary intake and weight.

Conclusion

Overall, there was no difference in food intake between children perceived as fussy versus not. Mothers appear to be interpreting developmentally appropriate feeding behaviour as fussiness in the leaner but healthy weight child. Importantly, this perception of typical child eating behaviour as fussiness was prospectively associated with use of non-responsive feeding practices, which may teach children to eat in response to cues other than hunger or satiety, disrupting self-regulation of energy intake and increasing obesity risk. Interventions to modify feeding practices should support parents and clinicians to interpret food refusal as normal behaviour in healthy young children and directly address perceptions of healthy child growth and developmentally appropriate behaviour.

Additional files

Additional file 1: Factors and corresponding items of the Feeding Practices and Structure Questionnaire (FPSQ-28) with an additional item measuring family meal setting.

Additional file 2: Results of bivariate analysis comparing children perceived as 'fussy' versus 'not fussy'.

Abbreviations

FPSQ: Feeding Practices and Structure Questionnaire„; SEM: Structural Equation Modelling; WAZ: weight-for-age z-score; WHO: World Health Organisation

Acknowledgements

The authors thank the families participating in NOURISH and SAIDI and our research team in Brisbane and Adelaide.

Funding

NOURISH was funded 2008–2010 by the Australian National Health and Medical Research Council (grant 426,704). Additional funding was provided by HJ Heinz, Meat & Livestock Australia (MLA), Food Standards Australia New Zealand (FSANZ), and Queensland University of Technology.

Authors' contributions

LD conceptualised and led the NOURISH study. RB and EJ participated in data collection. RB conceptualised and conducted this data analysis and drafted this manuscript, while EJ completed the analysis in Mplus. All authors were involved in writing the paper and had final approval of the submitted and published versions.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Centre for Children's Health Research, School of Exercise and Nutrition Sciences, Queensland University of Technology, 62 Graham St, South Brisbane, QLD 4101, Australia. [2]School of Exercise and Nutrition Sciences, Queensland University of Technology, Kelvin Grove, QLD 4069, Australia.

References

1. Ramsay SA, Branen LJ, Fletcher J, Price E, Johnson SL, Sigman-Grant M. Are you done? Child Care Providers' Verbal Communication at Mealtimes That Reinforce or Hinder Children's Internal Cues of Hunger and Satiation. J Nutr Educ Behav. 2010;42:265–70.
2. Chan L, Magarey AM, Daniels L. Maternal feeding practices and feeding behaviours of Australian children aged 12-36 months. Matern Child Health J. 2011;15:1363–71.
3. Mitchell GL, Farrow C, Haycraft E, Meyer C. Parental influences on children's eating behaviour and characteristics of successful parent-focussed interventions. Appetite. 2013;60:85–94.
4. Birch LL, Doub AE. Learning to eat: birth to age 2 y. Am J Clin Nutr. 2014; 993:723S–8S.
5. Carruth BR, Ziegler PJ, Gordon A, Barr SI. Prevalence of picky eaters among infants and toddlers and their caregivers decisions about offering a new food. JADA. 2004;104:S57–64.

6. Jacobi C, Schmitz G, Stewart AW. Is picky eating an eating disorder? Int J Eat Disord. 2008;417:626–34.
7. Mascola A, Bryson S, Agras WS. Picky eating during childhood: a longitundinal study to age 11 years. Eat Behav. 2010;11:253–7.
8. Wright CM, Parkinson KN, Shipton D, Drewett RF. How do toddler eating problems relate to their eating behaviour, food preferences and growth? Pedatrics. 2007;120:e1069–e75.
9. Dubois L, Farmer AP, Girard M, Peterson K. Preschool children's eating behaviours are related to dietary adequacy and body weight. Eur J Clin Nutr. 2007;617:846–55.
10. Taylor CM, Northstone K, Wernimont SM, Emmett PM. Macro- and micronutrient intakes in picky eaters: a cause for concern? Am J Clin Nutr. 2016;1046:1647–56.
11. Taylor CM, Wernimont SM, Northstone K, Emmett PM. Picky/fussy eating in children: review of definitions, assessment, prevalence and dietary intakes. Appetite. 2015;95:349–59.
12. Dovey TM, Staples PA, Gibson EL, Halford JCG. Food neophobia and 'picky/fussy' eating in children: a review. Appetite. 2008;50:181–93.
13. Lafraire J, Rioux C, Giboreau A, Picard D. Food rejections in children: cognitive and social/environmental factors involved in food neophobia and picky/fussy eating behavior. Appetite. 2016;96:347–57.
14. Goh DYT, Jacob A. Perception of picky eating among children in Singapore and its impact on caregivers: a questionnaire survey. Asia Pac Fam Med. 2012;115
15. Hafstad GS, Abebe DS, Torgersen L, von Soest T. Picky eating in preschool children: the predictive role of the child's temperament and mother's negative affectivity. Eat Behav. 2013;143:274–7.
16. Mayeaux M, Donovan S, Lee Y. Defining perceptions of picky eater children by cojoint analysis. J Nutr Educ Behav. 2010;424S:S77.
17. Carruth BR, Skinner JD, Houck KS, Moran J, Coletta F, Ott D. The phenomenon of "picky eater": a behavioural marker in eating patterns of toddlers. J Am Coll Nutr. 1998;172:180–6.
18. Wardle J, Guthrie CA, Sanderson S, Rapoport L. Development of the Children's eating behaviour questionnaire. J Child Psychol Psych. 2001;427:963–70.
19. Fildes A, van Jaarsveld CHM, Cooke L, Wardle J, Llewellyn CH. Common genetic architecture underlying young children's food fussiness and liking for vegetables and fruit. Am J Clin Nutr. 2016;1034:1099–104.
20. DiSantis KI, Hodges EA, Johnson SL, Fisher JO. The role of responsive feeding in overweight during infancy and toddlerhood: a systematic review. Int J Obes. 2011;35:480–92.
21. Jansen E, Mallan KM, Nicholson JM, Daniels LA. The feeding practices and structure questionnaire: construction and initial validation in a sample of Australian first-time mothers and their 2-year olds. Int J Behav Nutr Phys Act. 2013;111:72.
22. Harris HA, Fildes A, Mallan KM, Llewellyn CH. Maternal feeding practices and fussy eating in toddlerhood: a discordant twin analysis. Int J Behav Nutr Phys Act. 2016;13
23. Finnane JM, Jansen E, Mallan KM, Daniels LA. Mealtime structure and responsive feeding practices are associated with less food fussiness and more food enjoyment in children. J Nutr Ed Behav. 2017;49(1):11–8.
24. Daniels L, Magarey AM, Battistutta D, Nicholson JM, Farrell A, Davidson G, et al. The NOURISH randomised controlled trial: positive feeding practices and food preferences in early childhood - a primary prevention program for childhood obesity. BMC Public Health. 2009;9:387–96.
25. Koh GA, Scott JA, Woodman RJ, Kim SW, Daniels LA, Magarey AM. Maternal feeding self-efficacy and fruit and vegetable intakes in infants. Results from the SAIDI study. Appetite. 2014;81:44–51.
26. Daniels LA, Wilson JL, Mallan KM, Mihrshahi S, Perry R, Nicholson JM, et al. Recruiting and engaging new mothers in nutrition research studies: lessons from the Australian NOURISH randomised controlled trial. Int J Behav Nutr Phys Act. 2012;9:129.
27. Byrne R, Magarey A, Daniels L. Food and beverage intake in Australian children aged 12–16 months participating in the NOURISH and SAIDI studies. Aust N Z J Public Health. 2014;384:326–31.
28. CSIRO, University of South Australia. 2007 Australian National Children's Nutrition and Physical Activity Survey - Main Findings. Australian Government Department of Health and Ageing, Australian Food and Grocery Council, Australian Government Department of Agriculture. Australian Government 2008.
29. Food Standards Australia New Zealand. AUSNUT 2007__ Australian Food Supplement and Nutrient Database for Estimation of Population Nutrient Intakes. In: Australian Government Publishing Service, editor. Canberra, ACT: Australian Government Publishing Service, Canberra, ACT; 2008.
30. Jansen E, Williams KE, Mallan KM, Nicholson JM, Daniels L. The feeding practices and structure questionnaire (FPSQ-28): a parsimonious version validated for longitudinal use from 2-5 years. Appetite. 2016;100:172–80.
31. Australian Bureau of Statistics. 4364.0.55.007 - Australian Health Survey: Nutrition First Results – Food and Nutrients, 2011–12. In: Australia Co, editor. 2014.
32. Fox MK, Reidy K, Novak T, Ziegler P. Sources of energy and nutrients in the diets of infants and toddlers. J Am Diet Assoc. 2006;1061(Suppl 1):S28–42.
33. Steyn NP, Nel JH, Nantel G, Kennedy G, Labadarios D. Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? Public Health Nutr. 2005;95:644–50.
34. Kennedy G, Ballard T, Dop M. Guidelines for measuring household and individual dietary diversity. Nutrition and Consumer Protection Division, FAO, UN. Italy: In; 2011.
35. National Health and Medical Research Council. Australian Dietary Guidelines. Australian Government, 2013.
36. Brown TA. Confirmatory Factor Analysis for Applied Research. New York, NY: 404 Guilford Press; 2006.
37. Reau NR, Senturia YD, Lebailly SA, Christoffel KK. Infant and toddler feeding patterns and problems: normative data and a new direction. J Dev Behav Ped. 1996;173:149–53.
38. Boquin M, Moskowitz H, Donovan S, Lee S. Defining perceptions of picky eating obtained through focus groups and conjoint analysis. J Sens Stud. 2014;292:126–38.
39. Forman DR. Autonomy, compliance, and internalization. In: Brownell CA, Kopp CB, editors. Socioemotional development in the toddler years: transitions and transformations. New York, NY, US: Guilford Press; 2007. p. 285–319.
40. Colson ER, Dworkin PH. Toddler development. Pediatr Rev. 1997;188:255–9.
41. Cooke LJ, Haworth CMA, Wardle J. Genetic and environmental influences on children's food neophobia. Amer J Clin Nutr. 2007;862:428–33.
42. Faith MS, Heo M, Keller KL, Pietrobelli A. Child food neophobia is heritable, associated with less compliant eating, and moderates familial resemblance for BMI. Obesity. 2013;218:1650–5.
43. Tan C, Holub SC. Maternal feeding practices associated with food neophobia. Appetite. 2012;592:483–7.
44. Kerzner B, Milano K, MacLean WC, Berall G, Stuart S, Chatoor I. A practical approach to classifying and managing feeding difficulties. Pediatrics. 2015;1352:344–53.
45. Adamo KB, Brett KE. Parental perceptions and childhood dietary quality. Matern Child Health J. 2014;18:978–95.
46. Sherry B, McDivitt J, Birch LL, Cook FH, Sanders S, Prish JL, et al. Attitudes, practices, and concerns about child feeding and child weight status among socioeconomically diverse white, Hispanic and African-American mothers. J Am Diet Assoc. 2004;104:215–21.
47. Rodgers RF, Paxton SJ, Massey R, Campbell KJ, Wertheim EH, Skouteris H, et al. Maternal feeding practices predict weight gain and obesogenic eating behaviors in young children: a prospective study. Int J Behav Nutr Phys Act. 2013;10:24.
48. Walton K, Kuczynski L, Haycraft E, Breen A, Haines J. Time to re-think picky eating?: a relational approach to understanding picky eating. Int J Behav Nutr Phys Act. 2017;141:62.
49. Shim JE, Kim J, Mathai RA. Associations of infant feeding practices and picky eating behaviors of preschool children. J Am Diet Assoc. 2011;111:1363–8.
50. Birch LL, Ventura AK. Preventing childhood obesity: what works? Int J Obes. 2009;33(Suppl 1):S74–81.
51. Briefel RR, Kalb LM, Condon E, Deming DM, Clusen NA, Fox MK, et al. The feeding infants and toddlers study 2008: study design and methods. J Am Diet Assoc. 2010;11012(Suppl):S16–26.
52. Ruel MT. Operationalizing dietary diversity: a review of measurement issues and research priorities. J Nutrition. 2003;13311(Suppl 2):3911S–26S.
53. Nederkoorn C, Jansen A, Havermans RC. Feel your food. The influence of tactile sensitivity on picky eating in children. Appetite. 2015;840:7–10.
54. Australian Bureau of Statistics. 4102.0 - Australian Social Trends December 2010. One for the country: recent trends in fertility 2010.
55. World Health Organisation. The WHO child growth standards. Geneva; World Health Organisation; 2006.
56. Australian Bureau of Statistics. 6523.0 - Household income and income distribution, Australia, 2007–08. 2009.

The international food unit: a new measurement aid that can improve portion size estimation

T. Bucher[1,2*], M. Weltert[1,2], M.E. Rollo[2], S.P. Smith[3], W. Jia[4], C.E. Collins[2] and M. Sun[4]

Abstract

Background: Portion size education tools, aids and interventions can be effective in helping prevent weight gain. However consumers have difficulties in estimating food portion sizes and are confused by inconsistencies in measurement units and terminologies currently used. Visual cues are an important mediator of portion size estimation, but standardized measurement units are required.
In the current study, we present a new food volume estimation tool and test the ability of young adults to accurately quantify food volumes. The International Food Unit™ (IFU™) is a 4x4x4 cm cube (64cm^3), subdivided into eight 2 cm sub-cubes for estimating smaller food volumes. Compared with currently used measures such as cups and spoons, the IFU™ standardizes estimation of food volumes with metric measures. The IFU™ design is based on binary dimensional increments and the cubic shape facilitates portion size education and training, memory and recall, and computer processing which is binary in nature.

Methods: The performance of the IFU™ was tested in a randomized between-subject experiment (n = 128 adults, 66 men) that estimated volumes of 17 foods using four methods; the IFU™ cube, a deformable modelling clay cube, a household measuring cup or no aid (weight estimation). Estimation errors were compared between groups using Kruskall-Wallis tests and post-hoc comparisons.

Results: Estimation errors differed significantly between groups (H(3) = 28.48, $p < .001$). The volume estimations were most accurate in the group using the IFU™ cube (Mdn = 18.9%, IQR = 50.2) and least accurate using the measuring cup (Mdn = 87.7%, IQR = 56.1). The modelling clay cube led to a median error of 44.8% (IQR = 41.9). Compared with the measuring cup, the estimation errors using the IFU™ were significantly smaller for 12 food portions and similar for 5 food portions. Weight estimation was associated with a median error of 23.5% (IQR = 79.8).

Conclusions: The IFU™ improves volume estimation accuracy compared to other methods. The cubic shape was perceived as favourable, with subdivision and multiplication facilitating volume estimation. Further studies should investigate whether the IFU™ can facilitate portion size training and whether portion size education using the IFU™ is effective and sustainable without the aid. A 3-dimensional IFU™ could serve as a reference object for estimating food volume.

Keywords: Portion size measurement aid, PSMA, PSEM, Volume and capacity training, Standardisation, Dietary assessment, Food shape, Automated food volume recognition, Food intake reporting

* Correspondence: tbucher@ethz.ch
[1]Department of Health Sciences and Technology, ETH Zurich, Universitätsrasse 16, 8092 Zurich, Switzerland
[2]Priority Research Centre for Physical Activity and Nutrition, Faculty of Health and medicine, The University of Newcastle, Newcastle, Australia
Full list of author information is available at the end of the article

Background

Larger portion sizes increase energy intake in children and adults [1–3], a phenomenon termed the portion size effect [4]. Choosing appropriate portion sizes and being aware of amounts consumed is a critical skill to assist with weight control, improve health and lower chronic disease risk [5]. Not being able to accurately estimate food portions makes it problematic for implementing dietary recommendations. In addition, health care professionals cannot generate an accurate assessment of a patient's food and nutrient intake [5].

People generally have difficulties assessing food portion sizes [6–8] and consumers are confused as measurement units and terminologies are used inconsistently and differ internationally [9].

Dietary recommendations are often communicated in cup measures. For example, in Australia a standard serve of cooked vegetable is half a cup, with five standard servings recommended daily [10]. However, cup measures differ internationally. One cup in Japan is 200 ml, a traditional Japanese cup is 180 ml (the gō), a Canadian cup is 227.3 ml (8 imperial oz), a U.S. Customary cup is 236.6 ml (8 oz), a US legal cup is 240 ml, the Imperial cup (UK) is 285 ml and the metric cup (Commonwealth countries) is 250 ml. Conversely, many European countries such as Switzerland, Germany or the Netherlands do not use cups, but refer to grams and milliliters (for liquids) in recipes, on food labels and within dietary recommendations.

Spence et al. found consumers mentioned that household measurements were open to interpretation, with poor recognition of actual serving quantities specified in metric (e.g. grams) or imperial (e.g. ounces) measurements [9]. In their study, participants recalled inconsistent serving size information for specific foods and food groups provided by the public, private and voluntary sectors (e.g. dietitians, weight loss communities, food labels) [9]. Variation in terminologies, measurement units and recommendations cause confusion and lack of clarity on recommended serving sizes was the major barrier to appropriate food portion size selection in adults [9, 11].

To assist with countering the obesity epidemic, portion size interventions and education are acknowledged strategies to improve dietary habits and reduce overall energy intake at the population level [12]. A systematic review of the impact of portion education and training interventions on dietary intake concluded that interventions can improve adults' ability to estimate portion sizes [13]. Visual cues are an important mediator of portion size estimation and education [4, 14]. However, standardized international terminologies, food measures and aids are needed to avoid confusion and facilitate education strategies related to dietary recommendations [11]. Rather than 'cup' measures, new consumer-focussed methods that standardize food volume estimation using SI units (e.g. cubic metres = m^3) or the Centimetre-Gramm-Second (CGS) system (e.g. cubic centimetres = cm^3) should be considered [11]. Standardised aids for food volume measurement based on SI units may facilitate international food portion measurement and surveillance and portion control strategies [11]. There is an urgent need to develop a standardised food volume unit, which is accepted across cultures with unique intakes [11]. Here we propose a 4x4x4 cm cube with a volume of 64 cm^3 (64 ml) that can be subdivided into eight 2 cm sub-cubes for estimating smaller portions, as a potential International Food Unit IFU™ and food volume measurement aid (Fig. 1).

The IFU™ was developed by an international team of dietitians, nutrition scientists, bioengineers and computer scientists. The dyadic division scheme of the cube size follows the use of the binary system in computer systems since binary dimensional increments facilitate portion size education and training, memory and recall, and computer processing, which is binary in nature. The cubic shape is important for understanding of the mathematical volume concept by allowing people to visually

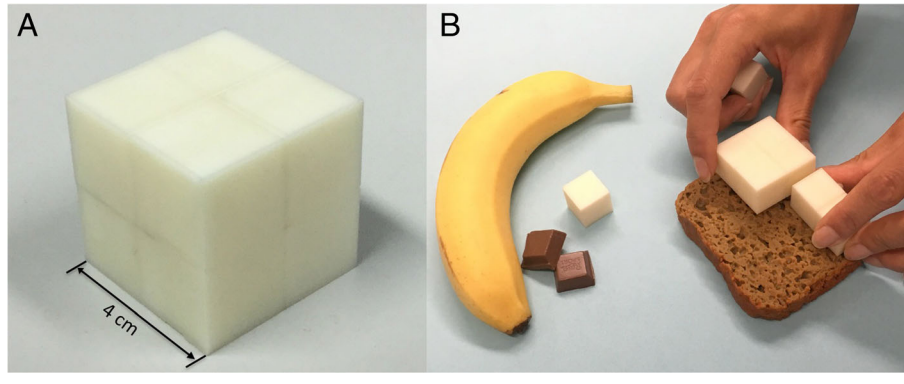

Fig. 1 a The International Food Unit™ (IFU™): A 4x4x4 cm cube with a volume of 64cm3 (64 ml), which can be subdivided into 8 smaller cubes (2x2x2cm = 8 cm3 (8 ml)) to estimate smaller volumes **b**. The present study tested the performance of the IFU™ as a measurement aid

correlate a cube of defined volume with an irregularly shaped object (here a food object). Another important feature of the IFU™ as a reference object is that it is smaller than a standard measuring cup and more similar to actual consumption units, such as a portion of meat recommended for usual consumption. The IFU™ can easily be converted into volumes of existing household measurement cups by multiplication (e.g. 4 IFUs™ are similar to the US and the metric cup, and 3 IFUs™ are similar to the Japanese cup). In addition, subdivision and multiplication of the cube have a straightforward visual correspondence hence the IFU™ facilitates both volume estimation and observation from the screen of a computer or a mobile device. A cube, which can be subdivided into smaller cubes, further allows easier measurement of foods with different shapes and volumes since it is already in volumetric units. This could be useful for food volume and portion size education and training. Moreover, the cubic shape is strategic, as it can serve as a 3D reference object on food photographs or within smartphone applications.

The aim of the current study was to test the performance of the IFU™ for food volume estimation.

Methods

Study sample

Written informed consent was obtained from all subjects prior to participation. Participants were recruited between June and September 2016 via flyers, handouts and social media in Newcastle, NSW, Australia. People were included if they were aged ≥18 years, did not have a university degree major in nutrition or dietetics and did not have food allergies or intolerances.

Experimental procedure

Participants were invited to estimate 23 specific food portions, 17 different foods, three with three differing portions sizes (Additional file 1: Figure S1 and Additional file 1: Table S1). A team of nutritionists and dietitians selected foods commonly consumed in Australia. A range of food shapes and sizes were included as these were considered to potentially influence estimation errors. To minimise food preparation and food waste, authentic and validated food replicas [15] previously used for portion size and serving studies [16–19] were used (Döring GmbH, Germany). The exception was for nuts and dried fruit mix, which was purchased at a local retailer (Woolworths Limited, Australia), as no good quality replicas existed. Foods were classified into Australian Guide to Healthy Eating (AGHE) food groups (National Health and Medical Research Council (NHMRC), 2016). For rice, chicken and French fries, three different portion sizes to test the impact on estimation accuracy [20–22] were included. These three foods were selected as they do not come in predefined portions but have different shapes. Portion sizes for continuous (uncountable) foods were informed by a previous study on adult perceptions of small, medium and large portion sizes [23], one piece or slice was used for fruit and bread. For French fries, the small, medium and large portions served in McDonald's were used [24].

Subjects were manually randomised to one of four experimental conditions, which differed in the portion size estimation aid provided (Additional file 1: Table S2). Therefore, a number was drawn from a box containing cards with numbers for the four conditions. Two different boxes were used for males and females to balance gender between conditions. Group 1 used one IFU™ (64 mL) to estimate food volumes. Group 2 used a modelling clay cube of the same volume. Group 3 used an Australian cup (250 mL), while group 4 estimated food weights with no aid. Weight instead of volume estimation was chosen in group 4 as estimation aids generally improve portion size estimation and we would have expected large errors in volume estimation without a reference object. However, consumers might be more familiar with food weight given this is usually presented in the information on food labels and from grocery shopping for foods sold by weight.

Food portions were presented on the same size plates (IKEA Australia, Australia). Milk was presented in a glass on the plate. Participants received one plate at a time to assess, with no direct comparison between items allowed. Foods were presented in random order to control for fatigue and learning effects [21, 25]. Subjects were not allowed to touch the foods, but were allowed to handle the estimation aids, e.g. they could subdivide the IFU™ into smaller cubes or reshape the modelling clay cube.

Volume estimates had to be reported relative to the estimation aid and participants were free to report estimates in decimals, fractions or percentages. For data analysis, all values were converted into decimals. In the condition with no aid, estimates were reported in grams or ounces based on individual choice.

Survey

After participants estimated all food portions, they were asked to complete a questionnaire (Qualtrics, LLC, Utah, USA) assessing potential confounding variables (numeracy, cooking frequency, use of measuring aids at home, knowledge of dietary guidelines (AGHE), consumption frequency of experimental foods and hunger), which could influence the accuracy of portion size estimates. Participants' subjective numeracy was assessed using the Subjective Numeracy Scale (SNS) [26]. They were asked how often they cook from scratch, bake, or consume ready-made meals. Further, they were asked how often they use measuring cups, scales or other estimation aids.

These questions were answered using a five-point scale (1 = Daily; 2 = Several times per week; 3 = Several times per month; 4 = Once a month or less; 5 = Never).

Knowledge of dietary guidelines was assessed with one question 'Are you familiar with the Australian Guide to Healthy Eating (AGHE) standard serve sizes? (No; I have heard about them; Yes, I know them). Consumption frequency of each experimental food (n = 17) was measured on a six-point scale (1 = ≥5 per week; 2 = 2-4 per week; 3 = Once per week; 4 = 1-3 per month; 5 = < 1 per month; 6 = Never). Hunger level was measured on a six-point scale (1 = Not hungry at all; 6 = Very hungry). Data on sex, age, self-reported weight and height, education and country of birth was collected. Usability of the estimation aids was evaluated by asking whether the aid helped them to estimate portion sizes and if it was easy to use (1 = strongly disagree; 5 = strongly agree), which food they found the easiest to estimate and which the most difficult. The reasons for their choice were assessed with an open question.

Statistical analysis and measures

Estimation errors

Estimates with the IFU™, the modelling clay and the measuring cup were compared to the actual food volume relative to the aid and weight estimates made without an aid to the weight of the corresponding real food in grams. The relative estimation error was calculated as follows: ([estimated amount or volume– actual amount or volume]/actual amount or volume) * 100. Relative estimation errors were calculated for each food as well as a group mean across all 17 foods in order to assess estimation accuracy across the four experimental conditions. For the foods presented in three different portion sizes, the relative estimation error of the medium portion was used to calculate the mean relative error. Here, the term estimation error refers to the relative estimation error, unless stated otherwise. For the purpose of comparison with specific studies in literature, absolute errors were calculated (| (estimated amount or volume– actual amount or volume) |/actual amount or volume) * 100) and classified into within 25% and within 75% range.

Statistical analysis was performed using IBM SPSS Statistics Version 23 (SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was used to test whether data was normally distributed; the Levene's test to test for homogeneity of variance. Normally distributed data was summarised as mean (M) and standard deviation (SD); non-normal data as median (Mdn) and interquartile range (IQR). The significance level was set at $P < .05$. Distribution of continuous variables was compared between the four experimental conditions using the Kruskal-Wallis test (H) and categorical variable distribution using Pearson's chi-square (χ^2) test. Differences between portion sizes were investigated using Friedman's ANOVA, as each individual estimated all portions and the data is dependent. Post-hoc comparisons were performed for independent conditions using the Mann-Whitney test and for related groups using the Wilcoxon signed-rank test. The Bonferroni correction was applied to adjust for multiple comparisons and distribution of estimation errors across the experimental conditions visually explored using boxplots.

Body mass index (BMI)

Participants' BMI was calculated by dividing weight in kilograms by height squared in metres (kg/m^2) using self-reported weight and height.

Results

Characteristics of the 128 participants (51.6% male) are summarised in Table 1. Subjects were predominantly students (71.1%) and born in Australia (60.9%), with a mean age of 29.2 ± 9.3 years and a BMI of 24.0 ± 4.0 kg/m^2. Foods that were on average consumed at least 2-4 times a week were vegetables M = 1.6, SD =0.8), milk (M = 1.7, SD = 1.3), bread (M = 1.9, SD = 1.1) and cheese (M = 2, SD = 1.1). Cake (M = 4.0, SD = 1.1) and nectarines (M = 4.4, SD = 1.1) were consumed less frequently. Participant characteristics and potential confounders (numeracy, cooking frequency, use of measuring aids at home, knowledge of dietary guidelines (AGHE), consumption frequency of experimental foods and hunger) did not significantly differ between the four experimental conditions.

Comparison of errors depending on aid

Relative estimation errors significantly differed between study groups ($H(3) = 28.48$, $P < .01$) (Table 2). The smallest estimation error was in the group using the IFU™ (Mdn = 18.9%, IQR = 50.2%) and largest for the measuring cup (Mdn = 87.7%, IQR = 56.1%). The median error for the group without a portion size estimation aid (PSEA) was 23.5% (IQR = 79.8%) and 44.8% (IQR = 41.9%) for the modelling clay. Estimation errors were significantly larger with the measuring cup compared to the IFU™ (U = 183.00, $P < .01$), the modelling clay (U = 278.00, $P < .01$) and the group with no estimation aid (U = 258.00, $P < .01$). The later three experimental conditions did not have significantly different estimation errors ($P > .05$).

Comparison of errors depending on food

All foods were on average overestimated with the measuring cup, whereas there was both over- and underestimation for the IFU™, the modelling clay and the group with no PSEA. Overestimation in all four study groups was found for six foods (pasta, mixed vegetables, chicken, French fries, strawberry and steak). The remaining 11

Table 1 Participant characteristics

		Total (*N* = 128)		Measuring cup (*N* = 36)		IFU (*N* = 31)		Modelling clay (*N* = 31)		No aid (*N* = 30)	
		Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Age [years]		29.2	9.3	28.2	7.4	29.7	11.5	29.1	8.2	29.8	10.4
BMI [kg/m^2][a]		24.0	4.0	23.4	3.4	23.4	3.5	23.9	3.9	25.4	3.1
Subjective numeracy score[b]		4.8	0.8	5.0	0.7	4.8	0.8	4.6	0.9	4.7	0.7
Hunger level[c]		3.2	1.3	3.2	1.3	3.3	1.4	2.9	1.2	3.2	1.4
Cooking skills[d]	Cooking from scratch	1.8	1.0	1.9	1.1	1.8	0.8	1.8	1.0	1.8	1.0
	Baking	3.6	0.8	3.8	0.7	3.5	0.9	3.5	1.0	3.7	0.7
	Cooking ready meals	3.4	1.1	3.3	1.1	3.4	1.2	3.4	1.2	3.5	1.0
Use of measure-ment aids[d]	Measuring cup	2.7	1.1	2.8	1.2	2.6	1.1	2.6	1.1	2.6	1.2
	Scale	3.8	1.3	3.7	1.4	4.0	1.4	3.7	1.3	3.7	1.3
	Other aids	3.6	1.6	3.8	1.6	3.6	1.6	3.0	1.7	4.0	1.5
		N	%	*N*	%	*N*	%	*N*	%	*N*	%
Gender	Female	62	48.4	17	47.2	15	48.4	15	48.4	15	50.0
	Male	66	51.6	19	52.8	16	51.6	16	51.6	15	50.0
Country of birth	Australia	78	60.9	22	61.1	16	51.6	18	58.1	22	73.3
	Other countries	50	39.1	14	38.9	15	48.4	13	41.9	8	26.7
Student	Yes[e]	91	71.1	25	69.4	25	80.6	23	74.2	18	60.0
	No	37	28.9	11	30.6	6	19.4	8	25.8	12	40.0

[a]Body Mass Index (BMI) = Weight / Height2 [kg/m^2]. Weight and height were self-reported by participants
[b]The subjective numeracy score is the average score of the eight questions of the Subjective Numeracy Scale (Fagerlin et al., [26])
[c]Hunger level was measured on a six-point scale (1 = Not hungry at all; 6 = Very hungry)
[d]Cooking skills and use of measurement aids were measured on a five-point scale (1 = Daily; 2 = Several times per week; 3 = Several times per month; 4 = Once a month or less; 5 = Never)
[e]Includes full-time and part-time students

foods (bread, rice, potatoes, lettuce, nectarine, apple, nuts & dried fruit, milk, cheese, cake and chocolate) were both over- and underestimated depending on the aid used. Relative errors were compared between the four experimental conditions for each food (Table 2). For four foods there was no significance between conditions (bread, rice, mixed nuts & dried fruit and grated cheese), with a median error across all four conditions ranging from −7.9% (grated cheese) to +17.6% (rice). The estimation errors for the remaining 13 foods differed significantly between the study groups. Post hoc comparisons revealed that estimation errors for the IFU™ and the measuring cup significantly differed for all 13 foods. Compared to the measuring cup, twelve foods were estimated more accurately using the IFU™, with only one food assessed less accurately (apple). The modelling clay performed better than the IFU™ for the nectarine and milk. The group with no PSEA accurately estimated the apple, pasta and grated cheese and poorly estimated mixed vegetables, lettuce, chicken and French fries. Individual estimation errors varied greatly for all estimation aids and foods.

Estimates made with the IFU™ generally had lower variation compared to the other three study groups, with solid and liquid foods (Fig. 2a) being more accurately estimated than amorphous foods (Fig. 2b). Lettuce was poorly estimated in all four experimental conditions, with large overestimation for the measuring cup, the IFU™ as well as the modelling clay (median estimation error of 294.7%, 168.8% and 168.8% respectively) and considerable underestimation for the group with no PSEA (−55.6%). When estimates for lettuce are excluded, median estimation errors for the group using the IFU™ ranged from −37.1% (apple) to +61.0% (French fries). In contrast, errors for the measuring cup ranged from +11.5% (mixed nuts & dried fruit) to +132.3% (pasta), for the modelling clay from −26.3% (grated cheese) to +106.7% (pasta) and for the group with no estimation aid from −28.8% (nectarine) to +107.5% (chicken).

Estimation accuracy was also assessed by classifying the absolute errors into estimates within 25% and 75% of the objective food amount. The proportion of total estimations within this range was greatest for the group using the IFU™ (38.8%; 81.1%) in comparison to groups using the modelling clay (31.6%; 70.5%), the measuring cup (19.6%; 51.1%) and no PSEA (24.3%; 65.5%).

Comparison of errors for different portion sizes

The influence of portion size on estimation accuracy was investigated for rice, chicken and French fries

Table 2 Relative estimation error by food (N = 17) and experimental condition

Food (portion size)	Total (N = 128)		Measuring cup (N = 36)		IFU™ (N = 31)		Modelling clay (N = 31)		No aid (N = 30)		F-Test
	Mdn	*IQR*	*Mdn*	*IQR*	*Mdn*	*IQR*	*Mdn*	*IQR*	*Mdn*	*IQR*	*H(3)*
Bread	−2.6	71.8	12.2	92.1	−17.8	61.6	−1.4	41.1	−24.9	87.1	3.25
Pasta	80.4	142.9	132.3[a]	101.0	55.0[b,c]	103.4	106.7[a,b]	118.9	4.9[c]	100.1	33.22**
Rice (medium)	17.6	81.9	38.4	57.7	−11.5	59.0	6.3	73.8	25.5	120.8	11.47
Mixed vegetables	74.2	93.6	119.3[a]	109.6	49.8[b]	74.9	68.5[b]	112.3	72.9[b]	152.3	24.01**
Potatoes	32.9	88.1	81.3[a]	93.3	32.5[b,c]	66.3	45.8[a,b]	66.3	−11.1[c]	67.8	32.30**
Lettuce	152.5	297.4	294.7[a]	302.6	168.8[b]	201.6	168.8[b]	201.6	−55.6[c]	44.4	68.96**
Strawberry	39.9	104.9	95.9[a]	135.1	32.9[b,c]	87.4	74.8[a,b]	69.9	27.3[c]	97.7	16.82*
Nectarine	−10.7	58.7	38.1[a]	52.9	−29.3[b]	21.2	−5.7[c]	47.1	−28.8[b,c]	57.4	34.84**
Apple	−12.5	48.6	11.6[a]	33.5	−37.1[b]	28.6	−24.0[b,c]	35.7	2.0[a,c]	71.4	33.39**
Steak	53.5	90.3	113.2[a]	146.6	25.6[b]	54.6	50.2[a,b]	65.5	23.4[b]	84.7	17.09*
Chicken (medium)	73.3	122.9	116.6[a]	86.7	33.2[b]	72.1	33.2[b]	44.4	107.5[a]	176.6	29.43**
Nuts & dried fruit	4.9	69.8	11.5	74.3	−4.7	71.5	−4.7	42.9	50.0	103.8	8.85
Milk	5.5	32.2	17.2[a]	23.4	−9.9[b]	18.8	2.1[a]	36.0	13.8[a]	45.5	24.50**
Grated cheese	−7.9	58.8	20.2	31.3	−26.3	46.1	−26.3	43.0	0.7	73.8	10.75
Cake	29.8	69.7	35.1[a]	42.2	−13.5[b]	47.6	29.8[a]	62.7	21.2[a,b]	148.5	21.56**
Chocolate	33.8	108.7	101.3[a]	129.9	3.7[b,c]	66.9	67.2[a,b]	133.8	−8.5[c]	76.2	22.17**
French fries (medium)	79.9	109.1	129.3[a]	89.9	61.0[b]	92.0	84.0[a,b]	115.0	48.8[b]	120.0	20.08**
All foods	44.1	69.7	87.7[a]	56.1	18.9[b]	50.2	44.8[b]	41.9	23.5[b]	79.8	28.48**

Note: Differences between study groups were investigated using the Kruskal-Wallis test with the Bonferroni correction for 17 comparisons (* P < .05, ** P < .01). Post hoc comparisons were performed using the Mann-Whitney test with the Bonferroni correction for six comparisons. Different superscript letters indicate significant differences between groups

(Fig. 2c and Table 3). For each of these foods, participants estimated three different portion sizes (small, medium, large). The estimation errors tended to increase with increasing portion size. However, significant differences between portion sizes were only observed for chicken and French fries in the group using the measuring cup (P < .05). The large portion of chicken had a significantly larger estimation error compared to the small portion (T = 128, P < .01). The medium and large portions of French fries had significantly larger estimation errors than the small portion of French fries (T = 158, < .05; T = 137, P < .01).

Usability of estimation aids

Participants evaluated helpfulness and ease-of-use for the three estimation aids (Additional file 1: Table S3). The reported helpfulness of the PSEAs was comparable ($H(2)$ = 5.25, P > .05) between groups. Significant differences were found for ease-of-use. The modelling clay was reported to be significantly easier to use compared to the IFU™ (U = 214.00, P < .01) and the measuring cup (U = 202.00, P < .01). In the questionnaire, participants could also comment on usability of the aid in an open-ended question. In general, participants found it difficult to estimate foods of shapes and sizes, which differed from the provided aid, for example non-cube shaped foods using the IFU™. They also had difficulties estimating the volume of irregular shaped foods such as French fries or mixed vegetables. Measuring cups were considered to be useful for liquids such as milk and compact foods such as rice. Participants using the IFU™ appreciated that the cube could be subdivided into smaller units. However, some people stated that they would need training to become more familiar with using it. The modelling clay was seen as helpful and easy because it could be manipulated to replicate food shape and size.

Additional file 1: Table S4 summarizes the foods, which participants considered the easiest to estimate. Foods they found difficult to estimate were similar across the four study groups. They were mostly amorphous, for example French fries, mixed vegetables and rice. The strawberry was perceived to be difficult to estimate using the measuring cup. Foods perceived the easiest to estimate differed between the four experimental conditions. Participants found rice and milk the easiest to estimate using a measuring cup; chocolate using the IFU™ or the modelling clay; and steak, milk and chicken breast by estimating the weight with no PSEA.

Discussion

The IFU™ had the lowest mean estimation error and error variation compared to the measuring cup, the modelling

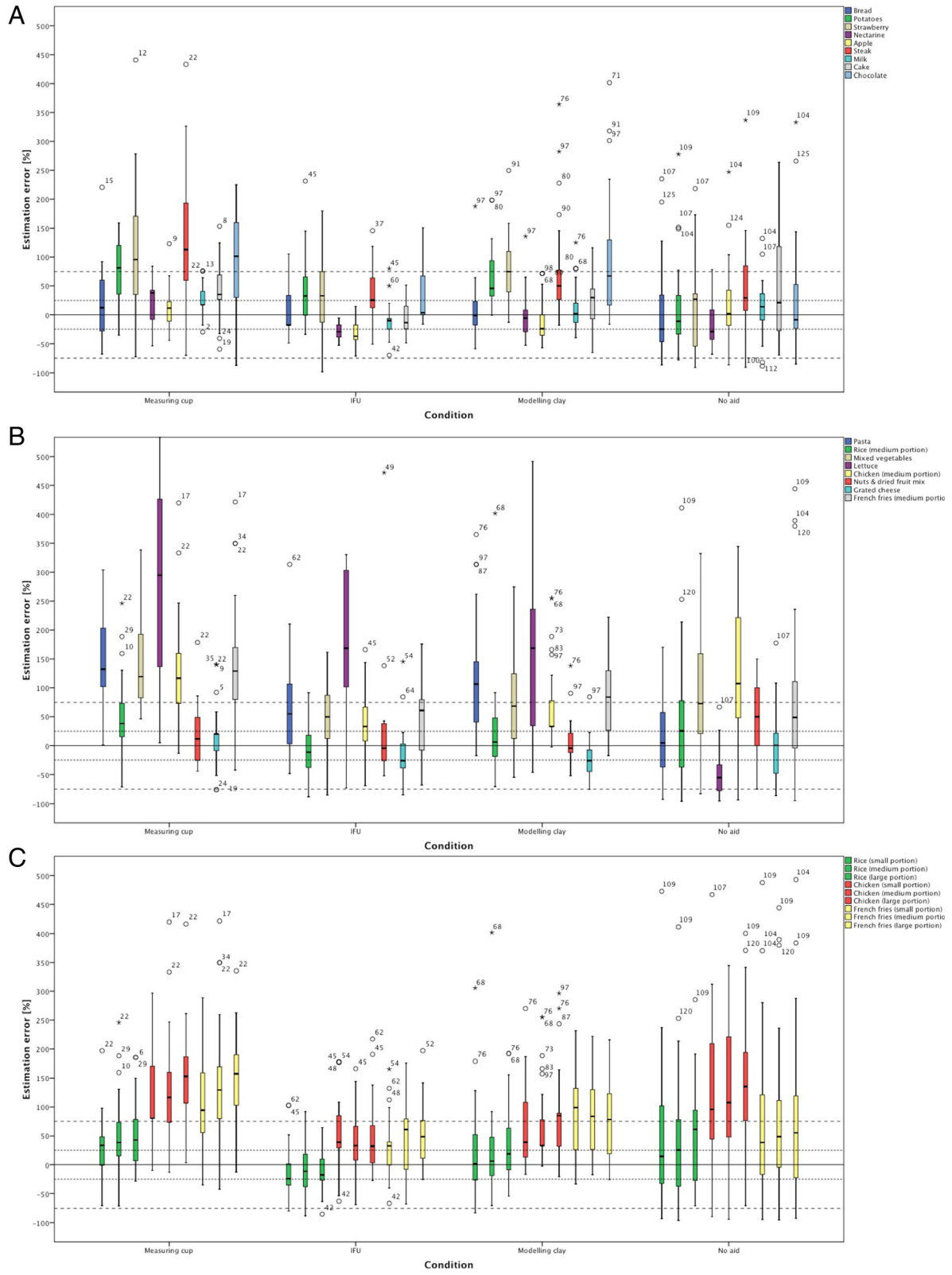

Fig. 2 Variation of the relative estimation error by experimental condition **a**) for solid and liquid foods, **b**) for amorphous foods and **c**) for different portion sizes

Table 3 Relative estimation error by experimental condition, food (*N* = 3) and portion size (small, medium, large)

Condition	Food	Small portion		Medium portion		Large portion		F-test
		Mdn	*IQR*	*Mdn*	*IQR*	*Mdn*	*IQR*	χ2 (2)
Measuring cup (*N* = 36)	Rice	33.7	49.5	38.4	57.7	42.8	71.4	3.72
	Chicken	80.5[a]	90.3	116.6[a,b]	86.7	153.1[b]	81.4	14.39*
	French fries	94.3[a]	103.6	129.3[b]	89.9	157.6[b]	87.1	11.17*
IFU™ (*N* = 31)	Rice	−23.9	38.0	−11.5	59.0	−17.8	36.5	0.84
	Chicken	38.8	55.5	33.2	72.1	32.2	76.7	3.94
	French fries	32.7	46.4	61.0	92.0	48.6	74.3	3.94
Modelling clay (*N* = 31)	Rice	1.4	81.1	6.3	73.8	18.7	80.4	5.10
	Chicken	38.8	120.3	33.2	44.4	85.1	60.8	3.68
	French fries	99.1	112.8	84.0	115.0	78.3	104.0	3.16
No aid (*N* = 30)	Rice	14.6	138.1	25.5	120.8	61.4	121.4	0.47
	Chicken	95.9	170.1	107.5	176.6	135.4	117.7	0.47
	French fries	38.3	145.2	48.8	120.0	55.0	145.2	1.67

Note: Differences between several related groups were investigated using Friedman's ANOVA with the Bonferroni correction for 12 comparisons (* $P < .05$). Post hoc comparisons were performed using the Wilcoxon signed-rank test with the Bonferroni correction for three comparisons. Different superscript letters indicate significant differences between groups

clay and the group that estimated weight with no PSEA. However, none of the study subjects actual disassembled the IFU cube. Future studies should investigate whether training with the IFU could further enhance estimation accuracy. In the future, a standardised food volume unit such as the IFU™ may serve as a 3D reference object on food photographs or potentially within smartphone applications.

Modelling clay has been previously used for portion size estimation [27]. It provided the most accurate estimates in two studies included in that paper (absolute error of 33.2% and 40.6%) compared to measuring cups and spoons, as well as household objects such as tennis balls or decks of cards. The absolute error for modelling clay in the present study was slightly higher (*Mdn* absolute error 54%). The measuring cup performed worst in the current study. All foods were on average overestimated using the measuring cup, with the median relative error ranging from 11.5% (mixed nuts & dried fruit) to 274.7% (lettuce). This is in agreement with other studies that had concluded that measuring cups performed worst compared to several other PSEAs tested [27, 28]. Bernal-Orozco et al. also found an overestimation of portion size using measuring cups [28]. In their study, all food groups were on average overestimated, with errors also being lowest for nuts/oilseeds and highest for meats. This indicates that measuring cups are a useful tool to estimate nut portion size. Meat products might be poorly estimated with cups due to their irregular shape [29]. Lettuce might be difficult to estimate, as the volume of salad leaves is very small. Foods with small volumes, such as spreads were found to be overestimated in other studies as well [22, 30–32].

A source of estimation errors in the measuring cup condition could be subjects' estimation strategy. Some of them reported imagining how much food they could fill in the cup with estimates including air or space in foods that cannot be compressed easily, unless mashed or chopped up (e.g. mixed vegetables or chicken). In contrast, subjects using the IFU™ or the modelling clay predominantly reported accounting for air in between single food items and only compared the actual food volume with the volume of the estimation aid. This might explain the overestimation with measuring cups, indicating that people need specific instructions on how to estimate food portion sizes (i.e. loose vs. compressed/without air). Furthermore, we provided only one measuring cup, rather than a set of measuring cups, which may have been helpful in estimating different volumes. However, the cup provided had measurement increments on it and the IFU cube had visible subunits. Also, we note that none of the participants disassembled the cube in the current study. Future studies need to test, whether training participants on how to use the cube for measuring and estimating volume can further enhance volume estimation accuracy.

Food weight estimation (no aid)

The group without an estimation aid had comparable estimation errors to people using the IFU™. The small estimation error might be due to the fact that participants did not estimate food volume, but weight. Weight estimation might be easier for consumers as most products in supermarkets contain food labels with information on product weight, whereas volume information is usually restricted to liquids. In line with this, subjects

mentioned that their experience in cooking or grocery shopping helped them estimate food weight.

Portion size and food characteristics

In the present study estimation errors tended to increase with increasing portion size. However, significant differences of errors between portion sizes were only found for chicken and French fries, in the group using the measuring cup. Previous studies have reported an influence of portion size on estimation accuracy. Small portions tended to be overestimated and large portions underestimated, a phenomenon called 'flat-slope', or the tendency to avoid extreme response categories [20–22, 33]. Another common finding is that large portions are less accurately estimated than small portions [34, 35], potentially because it is easier to estimate food portions similar in size to the PSEA. However, the two studies that identified this effect were conducted using food photographs [34, 35]. Photographs usually depict a whole range of portion sizes consumed so potentially there may not have been a large deviation from the actual food portion to assess. Further, amorphous foods were reported to be associated with higher estimation errors compared with solid and liquid foods [22, 36]. This is in agreement with the findings of the present study.

Usability of estimation aids

The foods participants perceived the easiest and most difficult to estimate were those foods with the lowest and highest estimation errors respectively. This indicates that people's perception generally corresponds to actual estimation errors. Participants mentioned that they found measuring cups the most useful for compact foods and liquids, while those in the IFU™ and modelling clay conditions reported that chocolate was the easiest to estimate, indicating that cubic or rectangular-shaped objects were easier to estimate with cubic PSEAs than other forms. People estimating food weight (the condition with no PSEA) found steak, milk and chicken breast the easiest to assess. Those foods are usually bought by weight (e.g. meat) or in defined amounts (e.g. 1 L of milk), which probably enhances weight estimation. Amorphous foods such as French fries or mixed vegetables were considered the most difficult to estimate across all four experimental conditions. This is in agreement with previous studies reporting that amorphous foods often have higher estimation errors compared to solid and liquid foods [22, 36].

The use of internationally standardised measurement units, consistent dietary recommendations and unambiguous terminologies could help to avoid consumer confusion, enhance people's ability to accurately estimate portion sizes and improve dietary intakes [11]. Practical tools, clear indications about the aim of PSEAs (optimising health vs. aiding weight loss) as well as detailed instructions on how to use them are recommended [37]. Despite the use of PSEAs, estimation errors with the IFU were still large for some foods. Participants in the current study received minimal instructions only on how to use the aids, with no specific training. Previous research indicates that portion size education/training using PSEAs [36] improves estimation accuracy.

Study limitations

The current study has several limitations. Firstly, only single foods were included, except for the mixed vegetables consisting of broccoli, cauliflower, carrots and beans. However, most dishes such as curries or stir-fries have various components. Estimation errors are expected to be higher for composite dishes than single foods. So far, there are no validated alternative PSEAs for mixed dishes [37]. Further, future studies should also include foods served in bowls such as porridge or soup. Secondly, the sample was relatively young (mean age of 29.2 ± 9.3 years), well educated (71.1% university students) and from one geographical location (Newcastle, Australia). The influence of age and education level has been assessed in several studies with most concluding that there is no effect of age [20, 22, 25, 32, 34, 38] or education level [20, 22, 34]. The influence of ethnicity on estimation accuracy has only been evaluated in one study in children [25] with no significant effect found. Thirdly, there was no group who estimated volume without the use of a PSEA in the current study, as food weight was estimated. However, previous research indicates that people's ability to estimate volume without a reference object is limited and visual tools generally enhance accuracy in estimating food portion sizes [5].

Conclusion

The current study provides evidence that the IFU™, a new measurement cube with standardised dimensions of 64 cm^3, can be a useful tool for food volume estimation. The IFU™ performed best of the PSEAs tested, with the lowest variation in estimation errors. However, consumers may require instructions and/or training to become familiar with the IFU™. Overall, the IFU™ was perceived as a helpful tool to estimate food volumes. Further studies should investigate whether training including the IFU™ enhances estimation accuracy and can assist with food volume estimation in everyday situations. It would also be relevant to investigate the performance of the IFU™ with composite dishes, including curries or stir-fries and with people from other cultural backgrounds and differing eating habits.

Additional file

Additional file 1: Figure S1. Food portions (s; solid, a; amorphous; l; liquid). **Table S1.** Details of food portions. **Table S2.** Portion size estimation aids used in the experiment. **Table S3.** Helpfulness and ease of use of the three PSEAs used in this study**. Table S4.** Foods subjects found the easiest/most difficult to estimate by experimental condition.

Acknowledgments
We thank Ms. Nienke de Vlieger for assistance with data collection.

Funding
TB received a fellowship from the Swiss National Science Foundation (P2EZP1_159086). The contribution of MS was supported in part by the United States National Institutes of Health (Grant No. R01CA165255). The funding bodies had no role in the design of the study, collection, analysis, and interpretation of data or in writing the manuscript.

Authors' contributions
TB, MR, SS, CC, WJ and MS developed the concept of the IFU™ and designed the study. TB and MR led the study and MW collected the data and analysed the data under supervision of TB, MR and MS. TB and MW prepared a draft for the paper and all authors provided feedback and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Department of Health Sciences and Technology, ETH Zurich, Universitätsrasse 16, 8092 Zurich, Switzerland. [2]Priority Research Centre for Physical Activity and Nutrition, Faculty of Health and medicine, The University of Newcastle, Newcastle, Australia. [3]School of Electrical Engineering and Computing, The University of Newcastle, Newcastle, Australia. [4]Departments of Neurosurgery, University of Pittsburgh, Pittsburgh, USA.

References

1. Kelly MT, Wallace JMW, Robson PJ, Rennie KL, Welch RW, Hannon-Fletcher MP, Brennan S, Fletcher A, Livingstone MBE. Increased portion size leads to a sustained increase in energy intake over 4 d in normal-weight and overweight men and women. Br J Nutr. 2009;102:470–7.
2. McConahy KL, Smiciklas-Wright H, Birch LL, Mitchell DC, Picciano MF. Food portions are positively related to energy intake and body weight in early childhood. J Pediatr. 2002;140:340–7.
3. Rolls BJ, Morris EL, Roe LS. Portion size of food affects energy intake in normal-weight and overweight men and women. Am J Clin Nutr. 2002; 76:1207–13.
4. English L, Lasschuijt M, Keller KL. Mechanisms of the portion size effect. What is known and where do we go from here? Appetite. 2015;88:39–49.
5. Byrd-Bredbenner C, Schwartz J. The effect of practical portion size measurement aids on the accuracy of portion size estimates made by young adults. J Hum Nutr Diet. 2004;17:351–7.
6. Almiron-Roig E, Solis-Trapala I, Dodd J, Jebb SA. Estimating food portions. Influence of unit number, meal type and energy density. Appetite. 2013;71:95–103.
7. Rapp SR, Dubbert PM, Buttross Y, Burkett PA. Reducing diabetics' food portion size errors by using feedback training. J Compliance Health Care. 1988;3:115–24.
8. Slawson DL, Eck LH. Intense practice enhances accuracy of portion size estimation of amorphous foods. J Am Diet Assoc. 1997;97:295–7.
9. Spence M, Livingstone MB, Hollywood LE, Gibney ER, O'Brien SA, Pourshahidi LK, Dean M. A qualitative study of psychological, social and behavioral barriers to appropriate food portion size control. Int J Behav Nutr Phys Act. 2013;10:92.
10. Australian Guide to Healthy Eating (AGHE) Accessed: 12 December 2016. https://www.eatforhealth.gov.au/guidelines/australian-guide-healthy-eating.
11. Bucher T, Rollo ME, Smith SP, Dean M, Brown H, Sun M, Collins C. Position paper on the need for portion-size education and a standardised unit of measurement. Health Promot J Austr. 2016 doi: 10.1071/HE15137(Epub ahead of print).
12. Steenhuis IHM, Vermeer WM. Portion size: review and framework for interventions. Int J Behav Nutr Phy. 2009;6. https://ijbnpa.biomedcentral.com/articles/10.1186/1479-5868-6-58.
13. Small L, Lane H, Vaughan L, Melnyk B, McBurnett D. A systematic review of the evidence: the effects of portion size manipulation with children and portion education/training interventions on dietary intake with adults. Worldv Evid-Based Nu. 2013;10:69–81.
14. Ball GD, Friedman A. Dice, golf balls, and CDs: assumptions about portion size measurement aids. Can J Diet Pract Res. 2010;71:146–9.
15. Bucher T, van der Horst K, Siegrist M. The fake food buffet - a new method in nutrition behaviour research. Br J Nutr. 2012;107:1553–60.
16. Bucher T, Siegrist M, Van Der Horst K. Vegetable variety: an effective strategy to increase vegetable choice in children. Public Health Nutr. 2014;17:1232–6.
17. Bucher T, van der Horst K, Siegrist M. Fruit for dessert. How people compose healthier meals. Appetite. 2013;60:74–80.
18. Libotte E, Siegrist M, Bucher T. The influence of plate size on meal composition. Literature review and experiment. Appetite. 2014;82:91–6.
19. Mötteli S, Keller C, Siegrist M, Barbey J, Bucher T. Consumers' practical understanding of healthy food choices: a fake food experiment. Br J Nutr. 2016;116:559–66.
20. Naska A, Valanou E, Peppa E, Katsoulis M, Barbouni A, Trichopoulou A. Evaluation of a digital food photography atlas used as portion size measurement aid in dietary surveys in Greece. Public Health Nutr. 2016;19:2369–76.
21. Nelson M, Atkinson M, Darbyshire S. Food photography. I: the perception of food portion size from photographs. Br J Nutr. 1994;72:649–63.
22. Venter CS, MacIntyre UE, Vorster HH. The development and testing of a food portion photograph book for use in an African population. J Hum Nutr Diet. 2000;13:205–18.
23. Collins C, Bucher T, Taylor A, Pezdirc K, Lucas H, Watson J, Rollo M, Duncanson K, Hutchesson MJ, Burrows T. How big is a food portion? A pilot study in Australian families. Health Promot J Austr. 2015;26:83–8.
24. McDonald's Fries Nutrition Information Accessed: 12 December 2016 [https://mcdonalds.com.au/menu/fries].
25. Baranowski T, Baranowski JC, Watson KB, Martin S, Beltran A, Islam N, Dadabhoy H, Adame S-H, Cullen K, Thompson D, et al. Children's Accuracy of portion size estimation using digital food images: effects of interface design and size of image on computer screen. Public Health Nutr. 2011;14:418–25.
26. Fagerlin A, Zikmund-Fisher BJ, Ubel PA, Jankovic A, Derry HA, Smith DM. Measuring numeracy without a math test: development of the subjective numeracy scale. Med Decis Mak. 2007;27:672–80.
27. Friedman A, Bennett TG, Barbarich BN, Keaschuk RA, Ball GDC. Food portion estimation by children with obesity: the effects of estimation method and food type. J Acad Nutr Diet. 2012;112:302–7.
28. Bernal-Orozco MF, Vizmanos-Lamotte B, Rodríguez-Rocha NP, Macedo-Ojeda G, Orozco-Valerio M, Rovillé-Sausse F, León-Estrada S, Márquez-Sandoval F, Fernández-Ballart JD. Validation of a Mexican food photograph album as a tool to visually estimate food amounts in adolescents. Br J Nutr. 2013;109:944–52.
29. Godwin S, McGuire B, Chambers Iv E, McDowell M, Cleveland L, Edwards-Perry E, Ingwersen L. Evaluation of portion size estimation aids used for meat in dietary surveys. Nutr Res. 2001;21:1217–33.
30. De Keyzer W, Huybrechts I, De Maeyer M, Ocké M, Slimani N, Van't Veer P, De Henauw S. Food photographs in nutritional surveillance: errors in portion size estimation using drawings of bread and photographs of margarine and beverages consumption. Br J Nutr. 2011;105:1073–83.
31. Foster E, Matthews JNS, Lloyd J, Marshall L, Mathers JC, Nelson M, Barton KL, Wrieden WL, Cornelissen P, Harris J, Adamson AJ. Children's Estimates of food portion size: the development and evaluation of three portion size assessment tools for use with children. Br J Nutr. 2008;99:175–84.

32. Lillegaard ITL, Overby NC, Andersen LF. Can children and adolescents use photographs of food to estimate portion sizes. Eur J Clin Nutr. 2005;59:611–17.
33. Lucas F, Niravong M, Villeminot S, Kaaks R, Clavel-Chapelon F. Estimation of food portion size using photographs: validity, strengths, weaknesses and recommendations. J Hum Nutr Diet. 1995;8:65–74.
34. Ovaskainen ML, Paturi M, Reinivuo H, Hannila ML, Sinkko H, Lehtisalo J, Pynnönen-Polari O, Männistö S. Accuracy in the estimation of food servings against the portions in food photographs. Eur J Clin Nutr. 2008;62:674–81.
35. Vereecken C, Dohogne S, Covents M, Maes L. How accurate are adolescents in portion-size estimation using the computer tool young Adolescents' nutrition assessment on computer (YANA-C)? Br J Nutr. 2010;103:1844–50.
36. Weber JL, Cunningham-Sabo L, Skipper B, Lytle L, Stevens J, Gittelsohn J, Anliker J, Heller K, Pablo JL. Portion-size estimation training in second- and third-grade American Indian children. Am J Clin Nutr. 1999;69:782S–7S.
37. Faulkner GP, Livingstone MBE, Pourshahidi LK, Spence M, Dean M, O'Brien S, Gibney ER, Wallace JM, TA MC, Kerr MA. An evaluation of portion size estimation aids: precision, ease of use and likelihood of future use. Public Health Nutr. 2016;19:2377–87.
38. Thoradeniya T, de Silva A, Arambepola C, Atukorala S, Lanerolle P. Portion size estimation aids for Asian foods. J Hum Nutr Diet. 2012;25:497–504.

Item response modeling: a psychometric assessment of the children's fruit, vegetable, water, and physical activity self-efficacy scales among Chinese children

Jing-Jing Wang[1†], Tzu-An Chen[2†], Tom Baranowski[3] and Patrick W.C. Lau[4*]

Abstract

Background: This study aimed to evaluate the psychometric properties of four self-efficacy scales (i.e., self-efficacy for fruit (FSE), vegetable (VSE), and water (WSE) intakes, and physical activity (PASE)) and to investigate their differences in item functioning across sex, age, and body weight status groups using item response modeling (IRM) and differential item functioning (DIF).

Methods: Four self-efficacy scales were administrated to 763 Hong Kong Chinese children (55.2% boys) aged 8-13 years. Classical test theory (CTT) was used to examine the reliability and factorial validity of scales. IRM was conducted and DIF analyses were performed to assess the characteristics of item parameter estimates on the basis of children's sex, age and body weight status.

Results: All self-efficacy scales demonstrated adequate to excellent internal consistency reliability (Cronbach's α: 0.79-0.91). One FSE misfit item and one PASE misfit item were detected. Small DIF were found for all the scale items across children's age groups. Items with medium to large DIF were detected in different sex and body weight status groups, which will require modification. A Wright map revealed that items covered the range of the distribution of participants' self-efficacy for each scale except VSE.

Conclusions: Several self-efficacy scales' items functioned differently by children's sex and body weight status. Additional research is required to modify the four self-efficacy scales to minimize these moderating influences for application.

Keywords: Self-efficacy, Eating behaviors, Physical activity, Item response modeling, Differential item functioning

Background

The alarming rates of chronic diseases have been attributed to dietary habits and physical activity (PA) patterns [1, 2]. Increasing fruit and vegetable consumption, replacing sweetened beverages with water, and engaging in sufficient PA facilitate chronic disease prevention [3]. Furthermore, the dietary and PA practices tend to initiate and develop during childhood at which time it is desired to foster healthier habits [4].

Self-efficacy, a central component of Bandura's social cognitive theory, is concerned with people's beliefs and capabilities to perform or maintain actions at designated levels and has been advanced as an important individual determinant of human behavior [5]. Perceived self-efficacy for fruit, vegetable, and water intakes and PA were strong predictors of corresponding behaviors [6, 7] and key variables mediating change from interventions [8, 9]. Increasing self-efficacy has been adopted as an effective intervention

* Correspondence: wclau@hkbu.edu.hk
†Equal contributors
[4]Department of Physical Education, Faculty of Social Sciences, Hong Kong Baptist University, Academic and Administration Building, 15, Road, Kowloon Tong, Hong Kong, China
Full list of author information is available at the end of the article

strategy [10–12]. Questionnaires on self-efficacy for fruit (FSE), vegetable (VSE), and water intakes (WSE), and PA (PASE) in existing studies have varied in numbers and types of items, subscales and psychometric characteristics. For example, PASE was measured by a 8-item PASE [13–15] developed by Motl and colleagues [16] or a modified version [17], while other studies [18, 19] used the scale developed by Saunders et al. [20], or self-constructed questionnaires [12, 21]. While, some of these self-efficacy scales showed acceptable/adequate internal consistency (Cronbach's alpha coefficient (α) higher than 0.70) and test-retest reliability (TRT larger than 0.60) [13–20], others did not [22].

Valid and reliable measures are needed to test the associations between self-efficacy and behavior and to examine the possible mediating effect of self-efficacy in behavior change programs. Levels of self-efficacy have been reported to be significantly different by children's sex, age, and body weight status [23–25]. True differences in the validity of the measurement scale may make it difficult to compare parameter estimates across these different groups when comparing the results across studies. Furthermore, understanding the group-related differences in item validity across demographic or body weight status groups could help design interventions tailored to specific items in different groups and thereby enhance program effectiveness.

Classical test theory (CTT), the traditional method for evaluating scales, is sample-dependent, and thereby cannot assess the functioning of item responses across different groups. Item response modeling (IRM) is a psychometric analysis method that provides model-based measurements. IRM links the individuals' difficulty of response to each item, provides the distribution of respondents across the scale, and enables differential item functioning (DIF) analysis [26]. While, item functioning of children's FSE and VSE has been evaluated by sex and ethnic groups in American children [27], no one has analyzed item functioning across age and body weight status groups for FSE and VSE, nor conducted this kind of analysis for WSE and PASE, nor among Chinese children.

This study evaluated the psychometric properties of FSE, VSE, WSE, and PASE and investigated item differences in their psychometric properties across sex, age, and body weight status groups using IRM and DIF.

Methods

Participants

The sample was from the validation study of the Physical Activity Questionnaire for Older Children among Chinese children [28]. Children (n = 798, 55.8% males) aged 8-13 years old were recruited from six Hong Kong primary schools that agreed to participate in the study. The schools were located in different administrative districts with varied socio-economic status (SES) (two from high SES, one from medium SES, and three from low SES districts) according to local statistics [29]. Students were excluded if they had any contraindication to participating in PA or eating a normal diet. A subsample of 94 children (54.3% males) was randomly selected to complete the questionnaires twice within 7-10 days to assess the scale test-retest reliability. The ethic committee of Hong Kong Baptist University approved this study.

Measures

A standard translation and back translation procedure was used with three bilingual language speakers (i.e., English and Cantonese). Minor wording revisions were made according to cognitive interviewing feedback from five primary students to ensure that target children could understand the instructions and items. All participants completed the questionnaire set in schools under the administration of research assistants.

Body weight status

Children's height and weight, measured by physical education teachers, were retrieved from the latest school records. Height was measured to the nearest 0.1 cm and weight was measured to the nearest 0.1 kg. Body mass index (BMI, kg/m^2) was calculated as weight in kilograms divided by height in meters squared. According to international age- and sex- specific cutoff points, body weight status of participating children were classified into underweight [30], healthy, overweight and obese [31] groups based on their BMI values.

Self-efficacy for fruit (FSE), vegetable (VSE) and water (WSE)

Validated self-efficacy scales for fruit, vegetable and water intakes were used to assess children's FSE, VSE and WSE [32]. The scales consisted of 12, 8, and 5 items with dichotomous "sure" and "not sure" response categories and demonstrated acceptable internal consistency for FSE (α = 0.75) and VSE (α = 0.70) and marginal level of internal consistency for WSE (α = 0.55) in an American sample [32]. Construct validity was assessed through correlation among the self-efficacy scores and fruit and vegetable consumption, preferences and outcome expectancies (r = 0.10-0.21) [32]. Each item of the self-efficacy scales asked about the participant's confidence in consuming fruit, vegetables or water under diverse circumstances. A FSE sample item included "How sure are you that you can eat 1 portion of fruit for a snack at home at least four days a week?" A VSE sample item included: "How sure are you that you can eat 3 portions of vegetables at least 4 days a week?" A WSE sample item included "How sure

are you that you can drink 4 glasses or bottles of water for at least one day?" Considering item response difficulty, all items featured three response options in this study (1 = I am not sure; 2 = I am a little bit sure; 3 = I am very sure). The internal consistency in this sample was 0.86, 0.85, 0.79 for FSE, VSE, and WSE, respectively.

Self-efficacy for physical activity (PASE)

Children's PASE was assessed by a validated Physical Activity Self-efficacy scale [33]. The scale had 12 items and demonstrated adequate internal consistency (α = 0.81) in the original validation study [33]. Weak but comparable correlations (r = 0.09-0.11) were found between PASE and minutes of moderate- to vigorous- activity. Similar to the FSE, VSE and WSE, children responded how sure they were that they could engage in PA in various conditions with a 3-response category (1 = I am not sure; 2 = I am sure a little; 3 = I am sure a lot). Sample items included "How sure are you that you can be physically active more than 30 minutes for at least 4 days a week, even when the weather outside is bad?" "How sure are you that you can ask your friends to be physically active with you more than 30 minutes for at least 4 days a week?" The scale in this sample presented excellent internal consistency (α = 0.91).

Statistical analyses

Classical test theory (CTT)

First, CTT was used to evaluate the scales and item characteristics using SPSS 20.0 (IBM, Chicago, IL, USA). Item means were calculated to assess item difficulty. Cronbach's alpha coefficient (α) was computed to assess scale internal consistency; values greater than 0.70 are deemed acceptable for general research purposes [34]. Item discrimination was evaluated using corrected item total correlations (CITC) that were calculated by the correlation coefficients between the scores on the item and the sum of scores of all the other items in a scale. Poorly discriminating items were identified with CITC lower than 0.30 [35]. The intraclass correlation coefficient with a two-way random model was computed to determine test-retest reliability; a minimum threshold of 0.70 was considered adequate [36].

Item response modeling (IRM)

Exploratory factor analysis was used to examine the primary assumption of IRM, unidimensionaltiy, for each subscale. The assumption of unidimensionalty was met if the scree plots showed one dominant factor, the first factor explained at least 20% of scale variance, and the factor loadings were >0.30 [37].

IRM models illustrate respondents' latent trait based on their patterns of item responses. Both respondents' trait levels and items' psychometric properties are specified in IRM models. The degree of difficulty in agreeing with an item or endorsing a category is modeled as a function of person trait and item parameters. There are different mathematical forms of item characteristic functions and the number of parameters estimated for IRM models, but all IRM models include one or more item parameters to describe the probability of a certain score on an item, given a person's latent traits [38, 39].

Polytomous IRM models, are used when items present multiple response choices, such as in attitude surveys and personality assessment tests [40, 41]. Only polytomous models are discussed here because the self-efficacy scale items present three response categories. Polytomous models model the probability for any item of endorsing one response category over another. Polytomous models include additional parameters, referred to as *category boundary*, *threshold parameter* or *step difficulty* which indicate the probabilities of responding at or above a given category. For an item with k response options, there are k–1 thresholds between the response options. For example, an item with three response options (*I am not sure*, *I am a little bit sure*, and *I am very sure*) will require two threshold estimates: (1) the step from "*I am not sure*" to "*I am a little bit sure*", and (2) from "*I am a little bit sure*" to "*I am very sure*", One goal of fitting a polytomous model is to determine the location of such thresholds along the latent trait continuum.

Due to the number of the subscales and responses, multidimensional polytomous models, was selected to assess respondents' latent traits. Two polytomous models were considered: the partial credit (PCM) [42] and the rating scale models (RSM) [43, 44]. RSM is a special case of the PCM where the response scale is fixed for all items. That is, the response threshold parameters are assumed to be identical across items. For the present study, the final choice of a model was determined by comparing the deviance of the two competing multidimensional polytomous models using a Chi-square test.

Item fit was evaluated using infit and outfit mean square item fit indices (MNSQ) which have non-negative values. Infit is an information-weighted form of outfit. Infit MNSQ (information-weighted fit statistic) and outfit MNSQ (outlier-sensitive fit statistic) are based on information-weighted sum of squared standardized residuals and non-weighted sum of squared standardized residuals, respectively [45]. An infit or outfit MNSQ value of around one suggests the observed variance is similar to the expected variance. Mean square values greater than one or smaller than one indicate the observed variance is greater or smaller than expected, respectively. Infit or outfit MNSQ values greater than

1.3 indicate poor item fit when sample size is smaller than 500 [46]. With respect to thresholds, outfit MNSQ values greater than 2.0 indicate misfits, identifying candidates for collapsing with a neighboring category [45, 47].

Item-person maps, often called Wright maps (with units referred to as *log odds*), present both the distributions of scale items with that of the respondents on the same scale. Person, item and threshold estimates were placed in the same map where "*x*" on the left side represented the distribution of person trait estimates along the self-efficacy continuum with the student scoring the highest self-efficacy placed at the top of the figure. Item and threshold difficulties were presented on the right side, with the more difficult response items and categories placed at the top. I_k denotes threshold *k* for item I.

Differential item functioning (DIF)

Participants with the same underlying trait level may have different probabilities of endorsing an item. DIF is an indicator when an item performed differently between groups of individuals. For example, a finding of DIF by sex means that a male and a female with the same latent trait level responded differently to an item, indicating that the respondents' interpretation of the item differed for men and women.

DIF was assessed by adding a group main effect and an item-by-group interaction term to the model [27, 48–50]. Whether an overall scale demonstrated DIF was indicated by a significant chi-square for the item-by-group interaction term. The ratio of the item-by-group parameter estimates to the corresponding standard error identified which items displayed DIF. DIF was indicated when the estimate to standard error ratio exceeded 1.96. The magnitude of DIF was determined by examining the differences of the item-by-group interaction parameter estimates. Because the sum of the parameters was constrained to be zero, if only two groups were considered, the magnitude of DIF difference was twice the estimates of the first reference group. For example, the estimate of the sex by item effect for Item 1 for males was −0.2, and then the estimate of the group by item effect for Item 1 for females was 0.2. The difference in item difficulty between older and younger children was −0.4. If comparison was made among three or more groups, the magnitude of DIF was the differences in estimates of the corresponding groups. Items that displayed statistically significant DIF were placed into one of three categories depending on the effect size: small DIF (difference < 0.426), intermediate DIF (0.426 < difference < 0.638), and large DIF (difference > 0.638) [51, 52]. ACER ConQuest [53] was used for all IRM analyses.

Results

Descriptive statistics

Participants' characteristics are shown in Table 1. Thirty-five children (4.4%) did not complete any of the items and were excluded from analyses, resulting in a sample of 763 children with 55.2% boys. Participants were classified into younger children aged 8-10 years (43.5%) and older children aged 11-13 years (56.5%). Body weight status was categorized into three groups with 96 (13.1%) underweight children, 417 (56.8%) children with healthy weight, and 221 (30.1%) overweight/obese children.

Classical test theory (CTT)

The percentages of variance explained by the one-factor solution were 39.7%, 49.0%, 54.5% and 49.7% for FSE, VSE, WSE and PASE, respectively. Each scree plot revealed one dominant factor and factor loadings were higher than 0.30 for all the scales.

As presented in Table 2, CTT revealed that item difficulty (item means) ranged from 1.51 (0.76) to 2.59 (0.65) based on the scale ranging from 1 to 3, indicating that on average the responses were moderately difficult to agree with. Internal consistencies were excellent for PASE (α = 0.91), good for FSE (α = 0.86) and VSE (α = 0.85), and adequate for WSE (α = 0.79). CITCs were acceptable to high (0.40 to 0.74). The test-retest reliabilities were acceptable: 0.80 for FSE, 0.78 for VSE, 0.71 for WSE, and 0.79 for PASE.

IRM model fit

The relative fit of multidimensional RSM and multidimensional PCM was evaluated by considering the deviance difference, where *df* was equal to the difference in the number of estimated parameters between the two models. The chi-square (χ^2) deviance statistic was calculated by considering differences in model deviances (RSM: 46,107.92; PCM: 45,903.92) and differences in numbers of parameters (RSM: 48; PCM: 84) for the nested models. The chi-square test of the

Table 1 Participants' characteristics (*N* = 763)

Demographic characteristics	n	%
Sex		
Boys	421	55.2
Girls	342	44.8
Age (yrs)		
8-10	332	43.5
11-13	431	56.5
Body status		
Underweight	96	13.1
Healthy weight	417	56.8
Overweigh/obesity	221	30.1

Table 2 Item description, and estimated of differential item functioning where significant

Item	Item Question	CTT		IRM				
		Mean (SD)	CITC	Difficulty differences				
				Boy - Girl[a]	8-10 yo – 11-13 yo[b]	UW - HW[c]	UW - OW/OB[d]	HW - OW/OB[e]
Fruits self-efficacy (Cronbach's alpha = 0.86)								
12	… eat 1 portion of fruit most times when you eat at a fast food place.	1.51 (0.76)	0.49					
11	… eat 1 portion of fruit at a fast food place at least one time.	1.55 (0.78)	0.49	−0.47**	−0.30*		0.20*	0.21*
10	… eat 1 portion of fruit for dinner at home at least one time.	1.84 (0.89)	0.48	−0.17*				0.27*
3	…ask someone in your family to buy 3 fruit at least every week.	2.02 (0.85)	0.64					
4	… eat 1 portion of fruit at lunch at least one time on a school day.	2.06 (0.87)	0.43					
6	… eat 1 portion of fruit for lunch most non-school days, including weekends.	2.09 (0.85)	0.59					
2	…ask someone in your family to buy 3 fruit at least one time.	2.13 (0.83)	0.59			0.18*		−0.19*
1	…ask someone in your family to buy your favorite fruit every week.	2.14 (0.78)	0.54	0.19*				
5	… eat 1 portion of fruit for lunch at least one time on a non-school day, including weekends.	2.23 (0.84)	0.59	0.19*	0.18*			
8	…eat 1 portion of fruit for a snack at home at least 4 days a week.	2.24 (0.83)	0.55	0.23*				
9	…ask someone in your family to serve 1 fruit instead of your usual dessert for dinner most nights.	2.26 (0.83)	0.52			−0.16*		
7	… eat 1 portion of fruit for a snack at home at least one time.	2.35 (0.79)	0.55	0.36*	0.25*		−0.32*	−0.25*
Vegetables self-efficacy (Cronbach's alpha = 0.85)								
6	… eat 3 portions of vegetables at least 4 days a week, even when you are stressed.	1.80 (0.83)	0.61	−0.20*	−0.20*	0.48**	0.45**	
7	… eat 1 portion of a vegetable most times when you eat at a fast food place.	1.91 (0.84)	0.56					
2	…cut up 1 portion of a vegetable and eat it with a dip for a snack at least one time.	1.91 (0.85)	0.59			0.20*	0.21*	
4	… ask someone in your family to serve 2 vegetables for dinner most nights.	1.94 (0.84)	0.67			−0.17*	−0.28*	
3	… ask someone in your family to serve 2 vegetables for dinner at least one time.	2.03 (0.85)	0.68					
8	… eat 1 portion of a vegetable most times when you eat at a cafeteria type restaurant.	2.07 (0.85)	0.55					
5	…eat 3 portions of vegetables at least 4 days a week.	2.18 (0.84)	0.59		0.19*		0.27*	0.21*
1	…eat 1 portion of a vegetable at lunch at least one time on a school day.	2.37 (0.80)	0.45			−0.46**	−0.44**	
Water self-efficacy (Cronbach's alpha = 0. 79)								
5	… drink 6 glasses or bottles of water for at least one day.	2.21 (0.85)	0.55			0.47**	0.44**	
4	…drink 6 glasses or bottles of water for at least 4 days a week.	2.26 (0.80)	0.65			0.19*		
3	… drink only water whenever you are thirsty for at least 4 days a week.	2.26 (0.82)	0.55		−0.29*			
1	…drink only water whenever you are thirsty for at least one day.	2.42 (0.77)	0.43	0.25*		−0.39*	−0.38*	
2	… drink 4 glasses or bottles of water for at least one day.	2.48 (0.75)	0.65		0.32*			
Physical Activity self-efficacy (Cronbach's alpha = 0.91)								
11	… be physically active more than 30 min for at least 4 days a week, even when the weather outside is bad.	1.83 (0.82)	0.70					

Table 2 Item description, and estimated of differential item functioning where significant *(Continued)*

6	… ask your friends to be physically active with you more than 30 min for at least 4 days a week.	1.87 (0.85)	0.69			−0.21*		
10	… be physically active more than 30 min for at least 4 days a week when your friends want to do something else.	1.90 (0.84)	0.73	−0.22*	−0.25*			
8	… be physically active more than 30 min for one day, even when you have lots of other things to do.	1.93 (0.84)	0.74				−0.26*	
7	… be physically active more than 30 min for one day, even when you have homework.	1.94 (0.85)	0.71					
9	… be physically active more than 30 min for at least 4 days a week, even when you have lots of other things to do.	1.98 (0.85)	0.74		−0.25*			
4	… the ability to play team sports like basketball, soccer or softball really well.	2.05 (0.84)	0.60	−0.71***			0.28*	0.38*
5	… ask your friends to be physically active with you more than 30 min for at least one day.	2.20 (0.83)	0.56		0.19*		0.26*	0.21*
12	… be physically active more than 30 min for most nonschool days, including weekends.	2.26 (0.80)	0.58					
2	… the ability to do physical activities like running, dancing, bicycling, or jumping rope really well.	2.24 (0.75)	0.58	0.44**	−0.22*		−0.42*	−0.50**
3	… the ability to play team sports like basketball, soccer or softball.	2.29 (0.81)	0.54	−0.79***	0.27*	0.31*	0.54**	0.23*
1	… the ability to do physical activities like running, dancing, bicycling, or jumping rope	2.59 (0.65)	0.40	0.79***	0.23*		−0.43*	−0.46**

Note: *CTT* classical test theory, *IRM* item response model, *CITT* corrected item total correlations, *SD* standard deviation, *UW* underweight, *HW* healthy weight, *OW* overweight, *OB* obesity
IRM difficulty difference was assessed to indicate whether an item performed differently between groups of individuals, including sex, age, and body weight status groups. Specifically
[a] Positive numbers, easier for girls; Negative numbers, easier for boys
[b] Positive numbers, easier for 11-13-year-old children; Negative numbers, easier for 8-10-year-old children
[c] Positive numbers, easier for children with healthy weight; Negative numbers, easier for underweight children
[d] Positive numbers, easier for overweight/obese children; Negative numbers, easier for underweight children
[e] Positive numbers, easier for overweight/obese children; Negative numbers, easier for children with Healthy weight
*small effect (difference < 0.426)
**moderate effect (0.426 < difference < 0.638)
***large effect (difference > 0.638)

deviance differences showed that RSM significantly reduced model fit (Δ deviance = 204.01, df = 36, $p < 0.0001$). Thus, the analyses indicated that the multidimensional RSM did not perform as well as the multidimensional PCM. As a result, further analyses reflect those from PCM.

Item fit

A summary of misfit indicators (MNSQ) and item difficulties are shown in Table 3. The MNSQ values greater than 1.3 indicate poor item fit. One VSE item (item 1, infit mean square = 1.60) and one PASE item (infit mean square for item 1 = 1.33) did not meet the recommended criterion value of 1.3. Both items were also misfits in the differential item functioning analyses when the subgroups were students' sex (VSE Item 1 infit mean square = 1.35; PASE Item 1 infit mean square = 1.32), age (VSE Item 1 infit mean square = 1.63; PASE Item 1 infit mean square = 1.68), and weight status (VSE Item 1 infit mean square = 1.39; PASE Item 1 infit mean square = 1.46).

Item-person fit Wright map

Table 4 presents the PCM item-person maps. The participants' self-efficacy estimates (confidence for fruit, vegetable, water intakes, and PA engagement), and the item and item threshold difficulty distributions are on the same logit scale. The difficulty distribution is ideally presented with a normal distribution from −3.0 to +3.0. As shown in the figure, FSE and VSE approached a normal distribution. There were small portions of participants with higher and lower levels of WSE and PASE (logits >3.0/ < −3.0).

The items were distributed in the centre of the Wright diagram. Item difficulties showed that the logits ranged from − 0.719 to 1.171 for FSE, from −0.841 to 0.556 for VSE, from −0.413 to 0.345 for WSE, and from −1.515 to 0.748 for PASE, respectively. The distributions nearly overlapped between item threshold and person measures (indicating the full distribution of individuals was measured by items across the whole distribution, as desired) for three of the self-efficacy scales, except VSE. Participants at the lower and higher ends of VSE did not coincide with the item's first and second threshold.

Differential item functioning (DIF)

Children's sex groups

Item difficulty differences across sex, age, and body weight status groups are presented in Table 2. Small DIF was detected for items 1, 5, 7, 8, 10 as well as moderate DIF for item11 in FSE across sex groups. Among these items, boys found it easier to endorse items 10 and 11, but more difficult to endorse the others. Only item 6 in VSE had significant DIF by sex at −0.20, a small DIF effect: it was easier for boys to endorse item 6. Item 1 of WSE was detected with a small DIF effect, easier for girls. Five items had significant DIF (small: item 10; moderate: item 2; large: items 1, 3, and 4) in PASE. It was easier for boys to endorse items 3, 4, and 10.

Children's age groups

Older children aged 11-13 years were more likely to endorse item 5 (small DIF at 0.18) and item 7 in FSE (small DIF at 0.25), but less likely to endorse item 11 with small DIF at −0.30. Two items had small DIF in VSE (items 5 and 6) and WSE (items 2 and 3) among different age groups, respectively. Older children found that somewhat easier to endorse item 5 of VSE and item 2 of WSE. Small DIF was indicated for six items (items 1, 2, 3, 5, 9, 10) of PASE between younger and older children. It was easier for older children to endorse items 1, 3, and 5.

Children's body weight status

Between underweight and healthy weight children, small DIF was detected for items 2 (easier for healthy weight children) and 9 of FSE, item 2 (easier for healthy weight children) and 4 of VSE, items 1 and 4 (easier for healthy weight children) of WSE, and items 3 (easier for healthy weight children) and 6 of PASE as well as medium DIF detected for items 1 and 6 (easier for healthy weight children) of VSE, item 5 (easier for healthy weight children) of WSE. In comparison of underweight and overweight/obese children, items 7 (easier for underweight children) and 11 of FSE, items 2, 4 (easier for underweight children) and 5 of VSE, item 1 (easier for underweight children) of WSE, and items1, 2, 4, 5 and 8 of PASE (easier for underweight children for item 1, 2, and 8) were examined with small DIF; items 1 (easier for underweight children) and 6 of VSE, item 5 of WSE, and item 3 of PASE showed medium DIF. Between healthy and overweight and obese children, small DIF was indicated for items 2, 7, 10, and 11 of FSE (easier for healthy children for item 2 and 7), items 5 of VSE, and items 3, 4, 5 of PASE; and medium DIF were indicated for items 1 and 2 (both easier for healthy children) of PASE. No large DIF was found across different body weight status groups.

Discussion

The present study investigated the psychometric properties of FSE, VSE, WSE and PASE scales using CTT and IRM, and their stability across sex, age and body weight status groups based on IRM using the partial credit model. CTT results showed that the examined scales had adequate to excellent internal consistency and adequate test-retest reliability. The item difficulties were

Table 3 Item description, item difficulty, and misfit item(s)

Item	Item questions	All	Boys	8-10 yrs	Underweight	Healthy Weight	Overweight /Obesity
Fruits self-efficacy (Cronbach's alpha = 0.86)							
12	…eat 1 portion of fruit most times when you eat at a fast food place.	1.171	−0.197	−0.159	0.031	0.076	−0.107
11	…eat 1 portion of fruit at a fast food place at least one time.	1.052	−0.233	−0.149	0.063	0.073	−0.136
10	…eat 1 portion of fruit for dinner at home at least one time.	0.402	−0.085	0.075	−0.005	0.138	−0.133
3	…ask someone in your family to buy 3 fruit at least every week.	0.011	−0.001	−0.030	0.065	−0.061	−0.004
4	…eat 1 portion of fruit at lunch at least one time on a school day.	−0.049	−0.019	−0.075	0.085	−0.042	−0.043
6	…eat 1 portion of fruit for lunch most non-school days, including weekends.	−0.100	0.061	−0.018	0.009	0.003	−0.011
2	…ask someone in your family to buy 3 fruit at least one time.	−0.189	−0.051	0.029	0.053	−0.123	0.070
1	…ask someone in your family to buy your favorite fruit every week.	−0.256	0.096	0.078	−0.018	0.042	−0.023
5	…eat 1 portion of fruit for lunch at least one time on a non-school day, including weekends.	−0.400	0.096	0.090	−0.017	−0.057	0.074
8	…eat 1 portion of fruit for a snack at home at least 4 days a week.	−0.436	0.115	0.061	−0.017	−0.032	0.050
9	…ask someone in your family to serve 1 fruit instead of your usual dessert for dinner most nights.	−0.487	0.039	−0.025	−0.115	0.041	0.074
7	…eat 1 portion of fruit for a snack at home at least one time.	−0.719	0.179	0.123	−0.133	−0.057	0.190
Vegetables self-efficacy (Cronbach's alpha = 0.85)							
6	…eat 3 portions of vegetables at least 4 days a week, even when you are stressed.	0.556	−0.098	−0.102	0.308	−0.171	−0.137
7	…eat 1 portion of a vegetable most times when you eat at a fast food place.	0.267	0.017	0.012	−0.049	−0.044	0.092
2	…cut up 1 portion of a vegetable and eat it with a dip for a snack at least one time.	0.250	−0.074	−0.029	0.136	−0.062	−0.074
4	…ask someone in your family to serve 2 vegetables for dinner most nights.	0.214	0.016	0.027	−0.151	0.021	0.130
3	…ask someone in your family to serve 2 vegetables for dinner at least one time.	0.028	0.000	0.020	−0.030	0.041	−0.011
8	…eat 1 portion of a vegetable most times when you eat at a cafeteria type restaurant.	−0.110	0.095	−0.016	−0.022	0.007	0.015
5	…eat 3 portions of vegetables at least 4 days a week.	−0.363	−0.014	0.095	0.108	0.050	−0.158
1	…eat 1 portion of a vegetable at lunch at least one time on a school day.	−0.841[a]	0.057[c]	−0.007[e]	−0.300[g]	0.157[g]	0.143[g]
Water self-efficacy (Cronbach's alpha = 0. 79)							
5	..drink 6 glasses or bottles of water for at least one day.	0.345	−0.042	−0.049	0.303	−0.164	−0.139
4	…drink 6 glasses or bottles of water for at least 4 days a week.	0.168	−0.068	0.032	0.103	−0.087	−0.016
3	…drink only water whenever you are thirsty for at least 4 days a week.	0.167	−0.032	−0.145	−0.082	0.045	0.036
1	…drink only water whenever you are thirsty for at least one day.	−0.268	0.123	0.001	−0.258	0.135	0.124
2	…drink 4 glasses or bottles of water for at least one day.	−0.413	0.019	0.162	−0.066	0.071	−0.005

Table 3 Item description, item difficulty, and misfit item(s) *(Continued)*

Physical Activity self-efficacy (Cronbach's alpha = 0.91)							
11	…be physically active more than 30 min for at least 4 days a week, even when the weather outside is bad.	0.748	0.035	−0.077	0.097	−0.052	−0.044
6	…ask your friends to be physically active with you more than 30 min for at least 4 days a week.	0.623	−0.067	0.058	−0.106	0.106	0.001
10	…be physically active more than 30 min for at least 4 days a week when your friends want to do something else.	0.547	−0.109	−0.124	0.028	0.009	−0.038
8	…be physically active more than 30 min for one day, even when you have lots of other things to do.	0.462	−0.006	−0.075	−0.135	0.012	0.122
7	…be physically active more than 30 min for one day, even when you have homework.	0.397	−0.019	−0.058	−0.068	0.011	0.058
9	…be physically active more than 30 min for at least 4 days a week, even when you have lots of other things to do.	0.331	0.055	−0.125	−0.024	0.052	−0.027
4	…the ability to play team sports like basketball, soccer or softball really well.	0.104	−0.357	0.014	0.057	0.163	−0.220
5	…ask your friends to be physically active with you more than 30 min for at least one day.	−0.277	0.068	0.094	0.107	0.050	−0.157
12	…be physically active more than 30 min for most nonschool days, including weekends.	−0.450	0.180	0.152	0.001	0.036	−0.038
2	…the ability to do physical activities like running, dancing, bicycling, or jumping rope really well.	−0.453	0.219	−0.108	−0.114	−0.191	0.304
3	…the ability to play team sports like basketball, soccer or softball.	−0.516	−0.395	0.133	0.286	−0.028	−0.258
1	…the ability to do physical activities like running, dancing, bicycling, or jumping rope	−1.515[b]	0.396[d]	0.117[f]	−0.129[h]	−0.167[h]	0.296[h]

Item fit was evaluated using infit and outfit mean square item fit indices (MNSQ), which are based on information-weighted sum of squared standardized residuals and non-weighted sum of squared standardized residuals, respectively. Infit or outfit MNSQ values greater than 1.3 indicate poor item fit

[a] Misfit item (item 1) outfit mean square = 1.60
[b] Misfit item (item 1) outfit mean square = 1.33
[c] Misfit item (item 1) outfit mean square = 1.35
[d] Misfit item (item 1) outfit mean square = 1.32
[e] Misfit item (item 1) outfit mean square = 1.63
[f] Misfit item (item 1) outfit mean square = 1.68
[g] Misfit item (item 1) outfit mean square = 1.39
[h] Misfit item (item 1) outfit mean square = 1.46

Table 4 Wright map of item thresholds for FSE, VSE, WSE, and PASE

Logit	Latent Ability Distribution				Item Distribution				Item Threshold Distribution			
	Fruit	Vegetable	Water	Physical activity	Fruit	Vegetable	Water	Physical activity	Fruit	Vegetable	Water	Physical activity
	Extremely high self-efficacy								Extremely difficult to endorse response			
5												
4				X								
			X	X								
			X	X								
			X	XX								
			XX	X								2.2
3		X	XX	X								
		X	XX	X								
	X	XX	XXXX	X					1.2			1.2 12.2
	XX	X	XXX	XX							4.2	4.2 11.2
2	X	XX	XXXX	XX								10.2
	XX	XXX	XXXX	XX					10.1			5.2 7.2 8.2
	XXX	XXX	XXXX	XXX						4.2	3.2	3.2 6.2 9.2
	XXX	XX	XXXX	XXX						6.2		
	XXXX	XXXX	XXXX	XXX	11 12				11.1 12.1	3.2 5.2		
1	XXXXX	XXXXX	XXXXX	XXXX					2.2	2.2 7.2 8.2	1.2	
	XXXXXX	XXXXX	XXXXXX	XXXXX				6 11	3.2 4.1	1.2	2.2 5.2	
	XXXXXXX	XXXXX	XXXXXX	XXXX	10	6		7 8 10	7.2			
	XXXXXXX	XXXXXX	XXXXXX	XXXXXX		2 4 7	3 4 5	9	5.1 6.2 8.2 9.2			
0	XXXXXXXXXX	XXXXXXXX	XXXXX	XXXXXX	3 4	3		4				
	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXX	1 2 6	8	1	5	5.2 6.1 8.1 9.1			
	XXXXXX	XXXXX	XXXX	XXXX	5 8 9	5	2	2 3 12	7.1			
	XXXXXX	XXXXX	XXX	XXXXX	7				3.1 4.2	1.1	2.1 5.1	
	XXXXX	XXXXX	XXX	XXXX		1			2.1	2.1 7.1 8.1	1.1	
-1	XXX	XXXX	XX	XXXX					11.2 12.2	3.1 5.1		
	XXX	XXX	X	XXX						6.1		
	XX	XX	X	XX				1		4.1	3.1	3.1 6.1 9.1
	XX	XX	X	X					10.2			5.1 7.1 8.1

Table 4 Wright map of item thresholds for FSE, VSE, WSE, and PASE *(Continued)*

-2	X	X		X			10.1
	X	X	X	X		4.1	4.1 11.1
		X			1.1		1.1 12.1
		X		X			
-3		X		X			
							2.1
				X			
-4							
		Extremely low self-efficacy				Extremely easy to endorse response	

On the left side of figure, the participants' self-efficacy estimates were placed on the map with "X" following the outermost left column of logit scale.
"X" indicated the trait estimates of persons. Each 'X' represents 8.1 cases. Higher self-efficacies were placed at the top of the column, while, the lower self-efficacies were located at the bottom of the column
Item and threshold difficulties were presented on the right side of figure, with the top locations indicating the more difficult to endorse responses

moderately easy to difficult. Items in the scales were considered discriminating. The symmetric distribution of items and item thresholds for individuals from the Wright map indicated the utilization of three-point responses nearly covered the participants from low to high levels of each self-efficacy scale except VSE, suggesting the items in VSE should be revised or new ones developed to cover the more difficult and easy levels.

One item (item1) in VSE and one items (item1) in PASE were identified as misfit items. These items also exhibited DIF across different groups. Item 1 of VSE (i.e., "How sure are you that you can eat 1 portion of a vegetable at lunch at least one time on a school day?") and item 1 of PASE (i.e., "How sure are you that you have the ability to do physical activities like running, dancing, bicycling, or jumping rope?") showed moderate DIF on the basis of children's body weight status. Compared with overweight/obese children, underweight children tended to have 1 portion of a vegetable at least once on a school day. Children with healthy weight were more likely to engage in various kinds of PA than overweight and obese children. These findings suggest children's perceived confidence to comply with the healthy lifestyle differed across different body weight status, consistent with the previous studies [25, 54, 55]. Since these two items did not behave the same way across these groups, they should be substantially revised or deleted from the scales.

DIF presented distinct difficulties by children's sex groups. Given items with small DIF are generally not of major concern [56], we only discuss items with medium/large DIF because they require more attention in the future studies. Ignoring small DIF effects, there was moderate DIF for item 11 of FSE, and item 2 of PASE, and large DIF for items 3 and 5 of PASE. Boys showed higher confidence that they could participate in team sports (e.g., basketball, softball) than girls, but not in flexibility/rhythm-related activities (e.g., dancing, jumping rope). These DIF suggest sex-specific tailoring of an intervention to boys and girls based on their differences of food and activity preferences, as suggested by existing research [57, 58].

DIF across demographic variables could be due to differences in ability to comprehend the meaning of the specific items or actual differences in the efficacy level to adopt healthy eating behaviors or engage in PA. Moderate DIF across body weight status groups and moderate to large DIF across sex groups indicate the need to re-check and revise items to produce non-significant DIF or reduce DIF to a considerably lower level [59]. Developing the sex and body weight status specific self-efficacy scales should be considered.

VSE items and thresholds did not cover the higher and lower difficult to endorse ends of confidence. This may require rewriting existing items or adding new items to extend the end of the distribution of items and thresholds. For example, a VSE item at average difficulty, "I can eat 1 portion of a vegetable at lunch at least one time on a school day", might be revised into "I can eat 1 portion of a vegetable at lunch at least three times on school days" , which would appear to have greater difficulty. An item with large difficulty, e.g., "I can eat 3 portions of vegetables at least 4 days a week", could be transformed to possibly low difficulty, e.g., "I can eat 3 portions of vegetables at least one day a week".

In the study, WSE contained 5 items and the logits of item difficulties ranged from −0.413 to 0.345. WSE showed narrower item distribution compared with the other three ones. To cover a wider range of latent trait, more diverse WSE items should be developed in future studies. For example, items addressing confidence in overcoming different types of barriers to have more water [32] (e.g., social impediments [60] referred to as coping SE [61], or emotional state). Additionally, types of item which could enhance the distributional properties could also be examined in the future.

Several limitations of the study should be mentioned. Even though existing and previously validated instruments were used and demonstrated good internal consistency in this study, validity of the scales are not available among the target children. Further validation studies should be implemented to evaluate the application of scales in different cultural settings among Chinse children (e.g., children from urban and rural areas in mainland China). Furthermore, IRM's complexity requires a large sample size. Recommendations have been ranged from 200 per group [62] to 500 per group [63]. Possible limitations of small sample size should be acknowledged in the current study. Further investigation should retest the findings by recruiting more participants. Moreover, further investigation could be undertaken with other DIF-detection procedures (e.g., non-uniform differential item functioning).

Conclusion

FSE, VSE, WSE and PASE demonstrated acceptable factorial validity, test-retest reliability, and adequate to excellent internal consistency by CTT. IRM provides useful insights on item difficulty estimates that were not dependent on the sample. The latent variables indicated adequate fit to the data, however, the items and thresholds did not adequately cover the easier and more difficult to endorse ends of VSE. A revised VSE questionnaire is needed to provide full range of self-efficacy difficulty estimates. Several items of the four examined self-efficacy scales exhibited moderate or large differential item functioning on the basis of children's sex and body weight status. Additional psychometric work remains to be done while scales can be used in diverse

groups with due caution. Further formative work for questionnaire is necessary.

Abbreviations

BMI: Body mass index; CITC: Corrected item total correlations; CTT: Classical test theory; DIF: Differential item functioning; FSE: Self-efficacy for fruit; IRM: Item response modeling; MNSQ: Mean square item fit indices; PA: Physical activity; PASE: Self-efficacy for physical activity; PCM: Partial credit model; RSM: Rating scale model; SES: Socio-economic status; TRT: Test-retest reliability; VSE: Self-efficacy for vegetable; WSE: Self-efficacy for water

Acknowledgments

The authors want to thank Amanda Pitkethly, and Shuge Zhang for their assistance in data collection.

Funding

This research was supported by the General Research Fund (GRF) from Research Grants Council of Hong Kong (grant no. 244913).

Authors' contributions

JJW and PWL conceived the study. JJW conducted data collection. JJW and TAC analysed and interpreted the data. JJW and TAC wrote the manuscript. TB and PWL edited the manuscript critically. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Mass Sports Research Center, China Institute of Sport Science, Beijing, China. [2]HEALTH Research Institute, University of Houston, Houston, TX 77204, USA. [3]Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, TX 77030, USA. [4]Department of Physical Education, Faculty of Social Sciences, Hong Kong Baptist University, Academic and Administration Building, 15, Road, Kowloon Tong, Hong Kong, China.

References

1. Boeing H, Bechthold A, Bub A, Ellinger S, Haller D, Kroke A, et al. Critical review: vegetables and fruit in the prevention of chronic diseases. Eur J Nutr. 2012;51:637–63.
2. Sothern M, Loftin M, Suskind R, Udall J, Blecker U. The health benefits of physical activity in children and adolescents: implications for chronic disease prevention. Eur J Pediatr. 1999;158:271–4.
3. Ford ES, Bergmann MM, Kroger J, Schienkiewitz A, Weikert C, Boeing H. Healthy living is the best revenge findings from the European prospective investigation into cancer and nutrition-Potsdam study. Arch Intern Med. 2009;169:1355–62.
4. Kelder SH, Perry CL, Klepp K-I, Lytle LL. Longitudinal tracking of adolescent smoking, physical activity, and food choice behaviors. Am J Public Health. 1994;84:1121–6.
5. Bandura A. Self-efficacy. In: Ramachaudran VS, editor. Encyclopedia of human behavior. New York: Academic Press; 1994. p. 71-81.
6. De Bourdeaudhuij I, Velde ST, Brug J, Due P, Wind M, Sandvik C, et al. Personal, social and environmental predictors of daily fruit and vegetable intake in 11-year-old children in nine European countries. Eur J Clin Nutr. 2008;62:834–41.
7. McAuley E, Blissmer B. Self-efficacy determinants and consequences of physical activity. Exerc Sport Sci Rev. 2000;28:85–8.
8. Anderson ES, Winett RA, Wojcik JR, Williams DM. Social cognitive mediators of change in a group randomized nutrition and physical activity intervention social support, self-efficacy, outcome expectations and self-regulation in the guide-to-health trial. J Health Psychol. 2010;15:21–32.
9. Calfas KJ, Sallis JF, Oldenburg B, Ffrench M. Mediators of change in physical activity following an intervention in primary care: PACE. Prev Med. 1997;26:297–304.
10. Luszczynska A, Tryburcy M, Schwarzer R. Improving fruit and vegetable consumption: a self-efficacy intervention compared with a combined self-efficacy and planning intervention. Health Educ Res. 2007;22:630–8.
11. Haerens L, Deforche B, Maes L, Cardon G, Stevens V, De Bourdeaudhuij I. Evaluation of a 2-year physical activity and healthy eating intervention in middle school children. Health Educ Res. 2006;21:911–21.
12. Story M, Sherwood NE, Himes JH, Davis M, Jacobs DR, Cartwright Y, et al. An after-school obesity prevention program for African-American girls: the Minnesota GEMS pilot study. Ethn Dis. 2003;13:S1–54.
13. Dishman RK, Motl RW, Sallis JF, Dunn AL, Birnbaum AS, Welk GJ, et al. Self-management strategies mediate self-efficacy and physical activity. Am J Prev Med. 2005;29:10–8.
14. Saunders RP, Motl RW, Dowda M, Dishman RK, Pate RR. Comparison of social variables for understanding physical activity in adolescent girls. Am J Health Behav. 2004;28:426–36.
15. Barr-Anderson DJ, Young DR, Sallis JF, Neumark-Sztainer DR, Gittelsohn J, Webber L, et al. Structured physical activity and psychosocial correlates in middle-school girls. Prev Med. 2007;44:404–9.
16. Motl RW, Dishman RK, Trost SG, Saunders RP, Dowda M, Felton G, et al. Factorial validity and invariance of questionnaires measuring social-cognitive determinants of physical activity among adolescent girls. Prev Med. 2000;31:584–94.
17. Liang Y, Lau PW, Huang WY, Maddison R, Baranowski T. Validity and reliability of questionnaires measuring physical activity self-efficacy, enjoyment, social support among Hong Kong Chinese children. Prev Med Rep. 2014;1:48–52.
18. Ryan GJ, Dzewaltowski DA. Comparing the relationships between different types of self-efficacy and physical activity in youth. Health Educ Behav. 2002;29:491–504.
19. Winters ER, Petosa RL, Charlton TE. Using social cognitive theory to explain discretionary,"leisure-time" physical exercise among high school students. J Adolesc Health. 2003;32:436–42.
20. Saunders RP, Pate RR, Felton G, Dowda M, Weinrich MC, Ward DS, et al. Development of questionnaires to measure psychosocial influences on children's physical activity. Prev Med. 1997;26:241–7.
21. Wu TY, Pender N. Determinants of physical activity among Taiwanese adolescents: an application of the health promotion model. Res Health Nursing. 2002;25:25–36.
22. Sallis JF, Pinski RB, Grossman RM, Patterson TL, Nader PR. The development of self-efficacy scales for healthrelated diet and exercise behaviors. Health Educ Res. 1988;3:283–92.
23. Bere E, Brug J, Klepp K-I. Why do boys eat less fruit and vegetables than girls? Public Health Nutr. 2008;11:321–5.
24. Granner ML, Sargent RG, Calderon KS, Hussey JR, Evans AE, Watkins KW. Factors of fruit and vegetable intake by race, gender, and age among young adolescents. J Nutr Educ Behav. 2004;36:173–80.
25. Rosenkoetter E, Loman DG. Self-efficacy and self-reported dietary behaviors in adolescents at an Urban School with no competitive foods. J Sch Nurs. 2015;31:345–52.
26. Bolt D, Stout W. Differential item functioning: its multidimensional model and resulting SIBTEST detection procedure. Behaviormetrika. 1996;23:67–95.
27. Watson K, Baranowski T, Thompson D. Item response modeling: an evaluation of the children's fruit and vegetable self-efficacy questionnaire. Health Educ Res. 2006;21:i47–57.
28. Wang JJ, Baranowski T, Lau WP, Chen TA, Pitkethly AJ. Validation of the physical activity questionnaire for older children (PAQ-C) among Chinese children. Biomed Environ Sci. 2016;29:177–86.
29. Census and Statistics Department. Hong kong 2011 population census - summary results. 2011. Retrived from: http://www.censtatd.gov.hk/hkstat/sub/sp170.jsp?productCode=B1120055. Accessed 25 May 2016.
30. Cole TJ, Flegal KM, Nicholls D, Jackson AA. Body mass index cut offs to define thinness in children and adolescents: international survey. BMJ. 2007;335:194.
31. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ. 2000;320:1240.

32. Baranowski T, Watson KB, Bachman C, Baranowski JC, Cullen KW, Thompson D, et al. Self efficacy for fruit, vegetable and water intakes: expanded and abbreviated scales from item response modeling analyses. Int J Behav Nutr Phys Act. 2010;7:1.
33. Jago R, Baranowski T, Watson K, Bachman C, Baranowski JC, Thompson D, et al. Development of new physical activity and sedentary behavior change self-efficacy questionnaires using item response modeling. Int J Behav Nutr Phys Act. 2009;6:1.
34. Cronbach LJ. Coefficient alpha and the internal structure of tests. Psychometrika. 1951;16:297–334.
35. Nunnally JC. Bernstein, IH. Psychometric theory. New York: McGraw-Hill; 1994.
36. McGraw KO, Wong SP. Forming inferences about some intraclass correlation coefficients. Psychol Methods. 1996;1:30–46.
37. Reeve BB, Mâsse LC. Item response theory modeling for questionnaire evaluation. In *Methods for testing and evaluating survey questionnaires.* Edited by Presser S, Rothgeb JM, Couper MP, Lessler JT, Martin E, Martin J, Singer E. Hoboken: John Wiley & Sons; 2004. p. 247-273.
38. Hambleton RK, Swaminathan H, Rogers HJ. Fundamentals of item response theory. Newbury Park: Sage Publications, Inc.; 1991.
39. Embretson S, Reise S. Item response theory for psychologists. Mahwah: Lawrence Erlbaum Associates, Inc.; 2000.
40. Costa PT, McCrae RR. The revised NEO personality inventory (NEO PI R) and NEO five factor inventor (NEO FFI). Odessa: Psychological Assessment Resources; 1992.
41. Chernyshenko OS, Stark S, Chan K-Y, Drasgow F, Williams B. Fitting item response theory models to two personality inventories: issues and insights. Multivariate Behav Res. 2001;36:523–62.
42. Wright BD, Masters GN. Rating scale analysis. Chicago: MESA Press; 1982.
43. Andrich D. Application of a psychometric rating model to ordered categories which are scored with successive integers. Appl Psychol Meas. 1978;2:581–94.
44. Andrich D. A rating formulation for ordered response categories. Psychometrika. 1978;43:561–73.
45. Bond T, Fox CM. Applying the Rasch model. 2nd ed. Mahwah: Lawrence Erlbaum Associates; 2001.
46. Smith R, Schumacker R, Bush M. Using item mean squares to evaluate fit to the Rasch model. J Outcome Meas. 1998;2:66–78.
47. Linacre JM. Investigating rating scale category utility. J Outcome Meas. 1999;3:103–22.
48. Baranowski T, Missaghian M, Broadfoot A, Watson K, Cullen K, Nicklas T, et al. Fruit and vegetable shopping practices and social support scales: a validation. J Nutr Educ Behav. 2006;38:340–51.
49. Chen T-A, O'Connor TM, Hughes SO, Frankel L, Baranowski J, Mendoza JA, et al. TV parenting practices: is the same scale appropriate for parents of children of different ages? Int J Behav Nutr Phys Act. 2013;10:1.
50. Chen T-A, O'Connor TM, Hughes SO, Beltran A, Baranowski J, Diep C, et al. Vegetable parenting practices scale. Item response modeling analyses. Appetite. 2015;91:190–9.
51. Wilson M. Constructing measures: an item response modeling approach. Mahwah: Lawrence Erlbaum Associates; 2005.
52. Paek I. Investigations of differential item functioning: comparisons among approaches, and extension to a multidimensional context [doctoral dissertation]. Berkeley: University of California, Berkeley; 2002.
53. Wu ML, Adams R, Wilson M, Haldane S. ConQuest [computer software]. Berkeley: ACER; 2003.
54. Trost SG, Kerr L, Ward DS, Pate RR. Physical activity and determinants of physical activity in obese and non-obese children. Int J Obes Relat Metab Disord. 2001;25:822–9.
55. Kitzman-Ulrich H, Wilson DK, Van Horn ML, Lawman HG. Relationship of body mass index and psychosocial factors on physical activity in underserved adolescent boys and girls. Health Psychol. 2010;29:506–13.
56. Angoff WH. Perspectives on differential item functioning methodology. In: Holland PW, Wainer H, editors. Differential item functioning. Hillsdale: Lawrence Erlbaum and Associates; 1993. p. 3–24.
57. Wilson DK, Williams J, Evans A, Mixon G, Rheaume C. Brief report: a qualitative study of gender preferences and motivational factors for physical activity in underserved adolescents. J Pediatr Psychol. 2005;30:293–7.
58. Pérez-Rodrigo C, Ribas L, Serra-Majem L, Aranceta J. Food preferences of Spanish children and young people: the enKid study. Eur J Clin Nutr. 2003;57:S45–S8.
59. Allalouf A. Revising translated differential item functioning items as a tool for improving cross-lingual assessment. Appl Meas Educ. 2003;16:55–73.
60. Maibach E, Murphy DA. Self-efficacy in health promotion research and practice: conceptualization and measurement. Health Educ Res. 1995;10:37–50.
61. Brug J, de Vet E, de Nooijer J, Verplanken B. Predicting fruit consumption: cognitions, intention, and habits. J Nutr Educ Behav. 2006;38(2):73–81.
62. Scott NW, Fayers PM, Aaronson NK, Bottomley A, de Graeff A, Groenvold M, et al. A simulation study provided sample size guidance for differential item functioning (DIF) studies using short scales. J Clin Epidemiol. 2009;62:288–95.
63. Embretson SE, Reise SP. Item response theory. Mahwah: Lawrence Erlbaum Associates, Inc.; 2000.

Appetitive traits associated with higher and lower body mass index: evaluating the validity of the adult eating behaviour questionnaire in an Australian sample

Kimberley M. Mallan[1,2*], Alison Fildes[3,4], Xochitl de la Piedad Garcia[1], Jayne Drzezdzon[1], Matthew Sampson[1] and Clare Llewellyn[4]

Abstract

Background: The aims of this study were to evaluate the factor structure of the newly developed Adult Eating Behaviour Questionnaire (AEBQ) (Hunot et al., Appetite 105:356-63, 2016) in an Australian sample, and examine associations between the four food approach and four food avoidance appetitive traits with body mass index (BMI).

Methods: Participants (N = 998) recruited between May and October 2016 via a university research participation scheme and online social network sites completed an online version of the AEBQ and self-reported demographic and anthropometric data. Of the sample, 84.8% were females, 29.6% had completed a university degree and the overall mean age was 24.32 years (SD = 8.32). Confirmatory factor analysis (CFA) was used to test three alternative factor structures (derived from issues raised in the original development study): the original 8 factor model, a 7 factor model with Food Responsiveness and Hunger scales combined, and a 7 factor model with the Hunger scale removed.

Results: The CFA revealed that the original 8 factor model was a better fit to the data than the 7 factor model in which Food Responsiveness and Hunger scales were combined. However, while reliability estimates for 7 of the 8 scales were good (Cronbach's α between 0.70-0.86), the reliability of the Hunger scale was modest (0.67) and dropping this factor resulted in a good fitting model. All food avoidance scales (except Food Fussiness) were negatively associated with body mass index (BMI) whereas Emotional Overeating was the only food approach scale positively associated with BMI.

Conclusions: The study supports the use of the AEBQ as a reliable and valid measure of food approach and avoidance appetitive traits in adults. Longitudinal studies that examine continuity and stability of appetitive traits across the lifespan will be facilitated by the addition of this measurement tool to the literature.

Keywords: Appetitive traits, Eating behaviour, Appetite, Obesity, Adults, Confirmatory factor analysis

Background

At a time when obesity has become a public health crisis affecting children and adults across the globe, there has never been more focus on our eating habits. The current food environment and sedentary lifestyles, dubbed 'obesogenic', may to some extent explain the global rise in the prevalence of obesity [1]. However a potential explanation as to why some individuals maintain a healthy weight whilst others become obese has been provided by the behavioural susceptibility model in which inherited traits may interact with these environmental factors to increase or attenuate obesity risk [2]. In particular, inherited differences in eating behaviours – or 'appetitive traits' – that make some individuals more susceptible to *overeating*, may account for differences in energy intake and ultimately weight status from early in life [3–5].

Individual differences in appetitive traits such as heightened responsiveness to food cues (e.g., eating in

* Correspondence: Kimberley.Mallan@acu.edu.au
[1]School of Psychology, Australian Catholic University, 1100 Nudgee Road, Banyo, QLD 4014, Australia
[2]School of Exercise and Nutrition Sciences, Queensland University of Technology, 60 Musk Avenue, Kelvin Grove, QLD 4059, Australia
Full list of author information is available at the end of the article

response to the sight, smell, or taste of palatable foods) and emotional overeating (e.g., eating more in response to negative emotions) have consistently been associated with excess energy intake and higher weight [4, 6]. From birth, differences in 'appetite' have been prospectively associated with rate of weight gain [7–9]. In children, the study of the relationship between both 'food approach' (e.g., Food Responsiveness, Enjoyment of Food) and 'food avoidance' (e.g., Satiety Responsiveness, Food Fussiness) appetitive traits and body mass index (BMI) [10–13], observed eating behaviour/intake [5, 14], food preferences [15], and parental feeding practices [16–19] has been facilitated by the widely used Children's Eating Behaviour Questionnaire (CEBQ) [20].

The CEBQ is a parent-report instrument that measures 8 appetitive traits. In multiple samples across the world the CEBQ has shown good reliability and a robust factor structure [11, 20–22]. In 2011 an infant version of the CEBQ – the Baby Eating Behaviour Questionnaire (BEBQ) [23] was developed to assess equivalent food approach and food avoidance appetitive traits during the period of exclusive milk feeding. The BEBQ has shown good reliability, robust factor structure and associations with weight status in multiple samples [23, 24].

To date the measurement of eating behaviours in adults has tended to focus heavily on eating behaviours specifically related to disordered eating and/or obesity risk. The two most prominent and extensively validated questionnaires in the field are the Three-factor Eating Questionnaire [25] which measures constructs of dietary restraint, disinhibition and hunger, and the Dutch Eating Behaviour Questionnaire [6, 26] which also measures three constructs: restraint, emotional eating and external eating. However, these measurement tools for use in adult samples have not included items that reflect appetitive traits such as satiety responsiveness and slowness in eating which may protect against excess energy intake and overweight. Similarly, there has been little research in adults on picky or fussy eating, and when fussy eating has been assessed it tends to have been treated as a categorical variable (i.e., picky vs not picky) [27]. The recently developed Adult Eating Behaviour Questionnaire (AEBQ) [28] was specifically designed to address these gaps in the literature. The AEBQ includes 8 scales encompassing both food approach (Hunger, Food Responsiveness, Emotional Overeating and Enjoyment of Food) and avoidance appetitive traits (Satiety Responsiveness, Food Fussiness, Emotional Under-eating and Slowness in Eating).

The AEBQ was developed based on the CEBQ/BEBQ with the intention that it would allow for future studies to examine the continuity and stability of appetitive traits from infancy into adulthood using similar measurement tools. In a community sample of 954 UK adults the factor structure of the AEBQ was evaluated using confirmatory factor analysis and the mean scale scores were correlated with self-reported BMI. An 8 factor model showed a good fit to the data and, as expected, the food approach scales (except Hunger) and the food avoidance scales (except Food Fussiness) were significantly associated with lower and higher BMI respectively [28].

To our knowledge the factor structure of the AEBQ has not yet been replicated and has not been validated in a sample outside the UK. As with all new measurement tools it is important to replicate the factor structure in a new sample and to examine aspects of validity, such as associations between subscales and BMI. Furthermore, the authors of the AEBQ indicated some reservation over the novel 'Hunger' scale (unlike the other scales, this was an entirely novel scale and is not included in the CEBQ); specifically whether the items on this scale should be combined with or remain separate from the Food Responsiveness items, or whether the scale should be retained at all [28]. The present study aimed to examine the reliability and validity of the AEBQ in an Australian sample by evaluating: 1) the psychometric properties of the scales and the overall factor structure using the gold-standard method of confirmatory factor analysis; and 2) associations between the scales and BMI to establish construct validity. It was hypothesised that the food approach scales would be associated with higher BMI whereas the food avoidance scales would be associated with lower BMI.

Method

Study design and participants

In this cross-sectional study participants were invited to complete an anonymous online survey via an online research participation site whereby students studying psychology at Australian Catholic University could voluntarily participate in research studies and through a social networking site (i.e., Facebook). Of the total sample (N = 998), 313 were recruited via the university psychology research participation site and 590 were recruited via Facebook. Due to the nature of the sampling approach used a response rate could not be estimated. Eligibility criteria for participation were: English speaking, no current diagnosed psychological disorder and no current or history of diagnosed eating disorder(s). Participants recruited through the university research site gained credit towards a psychology unit. All other participants were eligible to enter a draw to win a set of headphones (valued at approximately AUD250) or one of 10 shopping vouchers (valued at AUD20 each).

Measures

Demographics

Participants self-reported age, gender, highest level of education completed (primary, secondary, post-secondary school

certificate/diploma, undergraduate university degree, postgraduate university degree), and ethnic background.

Appetitive traits

Appetitive traits were assessed via the AEBQ [28]. The 35 item questionnaire comprises 4 'food approach' subscales: Hunger (5 items; e.g. *I often feel hungry*); Food Responsiveness (4 items; e.g. *I am always thinking about food*); Emotional Over-eating (5 items; e.g. *I eat more when I'm upset*); Enjoyment of Food (3 items; e.g. *I enjoy eating*), and four 'food avoidance' subscales: Satiety Responsiveness (3 items; e.g. *I get full up easily*); Emotional Under-eating (5 items; e.g. *I eat less when I'm worried*); Food Fussiness (5 items including 3 reverse coded items; e.g. *I refuse new foods at first*), and Slowness in Eating (4 items including 1 reference coded items; e.g. *I eat slowly*). Item responses were recorded on a 5-point Likert scale ranging from 'Strongly Disagree' to 'Strongly Agree'. Mean scores were calculated for each subscale.

Anthropometrics

Body mass index (kg/m^2) was calculated based on self-reported height and weight data.

Statistical analysis

Descriptive statistics and reliability estimates for the AEBQ scales were conducted in IBM SPSS Version 22. Similarly, relationships between AEBQ scales (unweighted means) and BMI were examined via Pearson's correlations and multivariable linear regression analyses were used to control for gender, age and sample (university vs online).

The sample had 0.33% missing data on the AEBQ items overall and ≤1.00% missing data on each of the 35 items. Thus, in order to avoid deletion of cases, missing data were imputed using Expectation Maximisation (EM) imputation in SPSS Version 22 prior to further analysis. Confirmatory factor analysis using structural equation modelling (IBM AMOS V.22) tested the fit to the data of three alternate models based on the findings of Hunot et al. [28]. Model 1 included all 35 items loading onto the 8 original factors of the AEBQ. Model 2 included all 35 items loading onto 7 factors, with the Hunger and Food Responsiveness items loading onto a single factor. Finally, Model 3 excluded the Hunger factor (i.e. only 30 items loading onto 7 factors were included). In all cases specifications for the models included: correlated factors, uncorrelated error variances and fixing the variance of the first item on each factor to 1. The hypothesised models were un-identified. Based on recommendations [29, 30], the acceptability of model fit was evaluated against achievement of the following criteria: Tucker Lewis Index (TLI) approaching 0.90; Comparative Fit Index (CFI) ideally >0.90, and Root Mean Square Error of Approximation (RMSEA) ideally ≤0.06. Item-factor loadings, factor variance and item variance were also considered when evaluating model fit. Parsimony of alternate models (1 and 2 only) was assessed using Akaike's Information Criteria (AIC) whereby small values indicated a more parsimonious model. Given that the primary aim of the study was to compare these three alternate factor structures of the AEBQ, modifications (e.g. adding error covariances) to improve model fit were not considered.

Results

The characteristics of the sample are presented in Table 1. The sample was over-represented by young, Caucasian females.

Reliability estimates and mean scale scores for the AEBQ are presented in Table 2 alongside the corresponding values from the Hunot et al. study [28] (includes unpublished data obtained directly from the author). In the present sample Cronbach's alpha values for all scales except for Hunger were ≥.70, and were generally comparable to those values from the original UK sample. Examination of mean scale scores indicated relatively higher means for food approach scales compared to food avoidance scales (Table 2) within the present sample. Numerically higher mean scores were observed for the food approach scales in the present sample compared to the original UK sample (Food Responsiveness +.51, Enjoyment of Food + .37 and

Table 1 Characteristics of $N = 998$ participants recruited via a university research scheme ($n = 408$) and via social media ($n = 590$)

Characteristics	Mean ± standard deviation or % (n)
Age (years) ($n = 893$)	24.32 ± 8.32
Gender (female) ($n = 996$)	84.8% (845)
BMI (kg/m^2)[a] ($n = 983$)	24.90 ± 5.60
Highest level of education ($n = 995$)	
Primary school	1.2 (12)
Secondary school	44.0 (438)
Certificate/diploma	25.1 (250)
Undergraduate university degree	24.2 (241)
Postgraduate university degree	5.4 (54)
Ethnicity (n = 996)	
Caucasian	80.9 (806)
Asian	6.3 (63)
Hispanic	1.6 (16)
African	1.1 (11)
Aboriginal or Torres Strait Islander	1.6 (16)
Pacific Islander	1.8 (18)
Other	6.6 (66)

[a]based on self-reported height and weight data

Table 2 Descriptive statistics (mean ± standard deviation) and internal consistency estimates (Cronbach's α) for the 8 factor Adult Eating Behaviour Questionnaire (AEBQ) in the present Australian sample (N = 998; mean age = 24 ± 8; 84.8% female) and in the original validation sample of British adults (*N* = 954; mean age = 44 ± 13; 57.3% female)

	Australian sample (present study)		UK sample (Hunot et al. study [28][a])	
AEBQ subscale	Cronbach's α	Mean ± SD	Cronbach's α	Mean ± SD
Food approach subscales				
Hunger	.67	3.22 ± 0.74	0.75	2.92 ± 0.78
Food responsiveness	.70	3.49 ± 0.74	0.75	2.98 ± 0.78
Emotional over-eating	.85	2.96 ± 0.91	0.90	2.74 ± 0.98
Enjoyment of food	.85	4.37 ± 0.69	0.86	4.00 ± 0.74
Food avoidance subscales				
Satiety responsiveness	.75	2.76 ± 0.83	0.75	2.61 ± 0.81
Emotional under-eating	.87	2.96 ± 0.89	0.90	2.83 ± 0.92
Food fussiness	.87	2.26 ± 0.83	0.88	2.29 ± 0.84
Slowness in eating	.86	2.74 ± 1.00	0.88	2.62 ± 0.97

[a]includes unpublished data

Hunger + .30, Emotional overeating +.22). Differences in mean scores were negligible between the samples for the food avoidance scales.

Fit indices for the three alternate models of the AEBQ are presented in Table 3. For all models all factor variances were significant ($p < .001$), all factor-item loadings were above .300 and significant ($p < .001$), and all item squared multiple correlations were above .1. The original 35-item, 8 factor model Model 1) showed good fit to the data and was clearly superior to the 35-item, 7 factor model (Model 2) according to all fit indices considered and was a more parsimonious model according to the AIC values (Table 3). The 30 item, 7 factor Model (Model 3), although not directly comparable to Models 1 and 2 due to a different number of items, also showed good fit overall (see Table 3). These results provide support for the original 8 factor model (Model 1) or a 7 factor model that excludes the Hunger factor/items entirely (Model 3).

As expected the food approach scales were positively inter-correlated and were generally negatively correlated with the food avoidance scales (Table 4). Unexpectedly there was a positive correlation between Hunger and Emotional Under-eating. The food avoidance scales were also positively inter-correlated however Food Fussiness was not significantly related to Emotional Undereating (Table 4). Associations with self-reported BMI are also presented in Table 4 (unadjusted and adjusted for age, gender and sample). As expected Emotional Over-eating was associated with a higher BMI but contrary to predictions the other food approach scales were not: Food Responsiveness and Enjoyment of Food were not associated with BMI and Hunger was significantly associated with a lower BMI. In line with expectations, all food avoidance scales, except for Food Fussiness, were associated with a lower BMI.

Discussion

The purpose of this study was to evaluate the reliability and validity of the AEBQ using CFA, and examine associations with BMI in an Australian sample. The AEBQ was designed to measure 4 food approach and 4 food avoidance appetitive traits in human adults. The results of the CFA provided support for the 8 factor structure of the AEBQ proposed by Hunot et al. [28] over a 7 factor version in which the Hunger and Food Responsiveness items were combined. Correlations between subscales and internal reliability estimates added further support to the utility of the questionnaire. Consistent with the hypothesised pattern of associations and the findings of Hunot et al. [28], all food avoidance scales, except for Food Fussiness, were associated with a lower BMI and Emotional Over-eating was associated with

Table 3 Fit indices of three models of the Adult Eating Behaviour Questionnaire evaluated via confirmatory factor analysis in a sample of 998 Australian adults

Model	Items	Factors	χ^2(df)	χ^2/df	TLI	CFI	RMSEA	AIC
Model 1	35	8 (H and FR items load on separate factors)	2059.853 (532)	3.872	.894	.905	.057	2325.853
Model 2	35	7 (H and FR items load on combined factor)	2232.461 (539)	4.142	.884	.895	.056	2484.461
Model 3	30	7 (H items/factor deleted)	1652.769 (384)	4.304	.914	.914	.058	n/a

H Hunger scale, *FR* Food Responsiveness scale, χ^2/df normed chi-square, *TLI* Tucker Lewis Index, *CFI* Comparative Fit Index, *RMSEA* Root Mean Square Error of Approximation, *AIC* Akaike's Information Criteria

Table 4 Pearson's correlations between the 8 Adult Eating Behaviour Questionnaire subscales (N = 998) and with self-reported BMI (n = 983) in an Australian sample

	Correlations									
	H	FR	EOE	EF	SR	EUE	FF	SE	BMI	
									Unadjusted (r)	Adjusted [a] (β)
Food approach subscales										
Hunger	1	.52**	.27**	.33**	−.093**	.099*	>.001	−.023	−.16**	−.13**
Food responsiveness		1	.38**	.51**	−.26**	−.075*	−.054	−.17**	−.081*	−.024
Emotional over-eating			1	.18**	−.091*	−.52**	.069*	−.13**	.14**	.15**
Enjoyment of food				1	−.25**	−.056	−.21**	−.42**	−.022	.011
Food avoidance subscales										
Satiety responsiveness					1	.25**	.27**	.48**	−.17**	−.15**
Emotional under-eating						1	−.026	.19**	.007	.030
Food fussiness							1	.087*	−.15**	−.11**
Slowness in eating								1	−.16**	−.13**

[a]Analyses adjusted for gender, age and sample (university or online); n = 883 due to missing data; *p < .05, **p < .001

higher BMI. However, inconsistent with predictions, the Hunger scale was negatively associated with BMI and the Food Responsiveness and Enjoyment of Food scales showed no association with BMI in this sample.

Three alternative factor structures of the AEBQ were evaluated in this study and the results favoured the original 8 factor model over a 7 factor model combining Hunger and Food Responsiveness. However, it was suggested by Hunot et al. [28] that the Hunger scale may be removed altogether in future iterations of the questionnaire as it failed to show the expected positive association with BMI in the original study. The utility of the scale was also questioned by the authors because individuals differ in how they perceive and interpret physical hunger [6] and because it may be affected by other aspects of eating regulation such as dietary restraint [31]. The present results provide some support for the suggestion that the Hunger scale may require further investigation to determine its value to the AEBQ. Firstly, the reliability of the Hunger scale fell below .70, substantially lower than in the original sample (0.67 vs 0.75) [28] and deletion of items (with the lowest loading in the CFA) did not improve reliability. Secondly, combining the Hunger and Food Responsiveness items did not improve the structure of the AEBQ and resulted in a less parsimonious and worse-fitting model. Thirdly, removal of the Hunger scale entirely resulted in a model that showed a good fit to the data. Finally, as will be discussed further below, the Hunger scale showed a number of unexpected correlations with another scale of the AEBQ and with BMI.

Generally, the patterns of associations between the scales of the AEBQ were similar to those reported in the original validation paper [28]. The food approach scales were positively related to one another and tended to be negatively correlated with the food avoidance scales. Of note, however, was the positive association between Hunger and the food avoidance trait Emotional Under-eating, a finding which was also observed in the original study [28] and further clouds the interpretation of the Hunger scale. As expected the food avoidance scales were positively related to one another; although Food Fussiness was not significantly related to Emotional Under-eating and was only weakly associated with Slowness in Eating. These patterns of association seem to indicate that Food Fussiness is qualitatively distinct from the other food avoidance traits. At face value, it seems logical that Food Fussiness reflects selectivity in food choice whereas the other food avoidance scales reflect smaller appetite and heightened sensitivity to satiety cues. Nevertheless, longitudinal studies of the relationship between all of the appetitive traits and BMI are needed to assess direction of effects. While Food Fussiness was not associated with BMI in this sample, it may be maladaptive in terms of achieving adequate dietary variety and diversity [32]. Examining associations between the AEBQ scales and measures of food preferences, intake or diet quality will help to test these predictions.

As hypothesised, the food avoidance traits Satiety Responsiveness, Emotional Under-eating and Slowness in Eating, were all associated with lower BMI; indicating that these scales capture dimensions of appetite. Food Fussiness was unrelated to BMI further supporting the suggestion that this scale reflects a qualitatively different food avoidance trait and is not protective against excess weight gain in an obesogenic environment. Whilst there is some evidence that Food Fussiness may be negatively associated with BMI in children [21, 33, 34], fussiness in children has been associated with higher intake of

sweetened foods [35] and has been suggested as a risk factor for excessive weight gain in the longer term if intake of foods such as fruits and vegetables are replaced with intake of energy-dense, highly palatable foods (high in sugar, fat and/or salt) [36]. In adults, the relationship between fussy eating and BMI is also unclear. In a study of young adults no differences in BMI between 'selective eaters' and 'non-selective eaters' was found [37]. In contrast, findings from both human and animal studies of obesity have suggested that fussiness may be higher in obese individuals and be associated with excess energy intake depending on the availability of highly palatable foods [38, 39].

The relationships between the food approach traits and BMI were less straightforward. While Emotional Over-eating was associated with significantly higher BMI in this sample, the other food approach scales were not significantly associated with BMI. In fact, both Hunger and Food Responsiveness showed small but significant correlations with lower BMI in the unadjusted analyses. After adjusting for gender, age and sample the association between BMI and Food Responsiveness became non-significant whereas the association with Hunger remained. These results are not consistent with those of Hunot et al. [28]. However, it is worth considering that the positive and significant ($p < .05$) correlations between self-reported BMI and Food Responsiveness and Enjoyment of Food scales in their study were very small ($r = 0.071$ and 0.067, respectively) and there was actually a very small and nonsignificant negative correlation between BMI and the Hunger scale ($r = -.028$, $p > .05$). Interpretation of these somewhat discrepant findings is complicated by the fact that BMI was self-reported in both the present and earlier study, and therefore less reliable than researcher-measured anthropometrics.

Higher scores on the Hunger items (meant to measure physical hunger [28]) and/or Food Responsiveness items of the AEBQ may reflect restrained eating or dieting behaviour in some individuals. This could be particularly relevant for this predominantly young Caucasian female sample. It seems plausible that actively restricting food intake may result in more frequent feelings of hunger and greater responsiveness to the sight and smell of palatable foods. Thus, the Hunger scale in particular may capture the *state* of physical hunger rather than an established appetitive *trait.* There is no Hunger scale included in the CEBQ [20] which means it is not possible to make comparisons with child samples, but the CEBQ Food Responsiveness scale has consistently been associated with both higher weight [20] and increased energy intake measured objectively [14] in children. Thus the absence of a positive association with BMI in the present study is surprising. However, children are unlikely to actively restrict their energy intake, whereas conscious attempts at controlling food intake in order to regulate weight might be responsible for supressing the expected relationship between Food Responsiveness and BMI in the present sample. Interestingly, mean scores on the Hunger and Food Responsiveness scales appeared to be higher in the present sample compared to the older UK sample [28] (mean age = 44, SD = 13) which consisted of a more balanced number of males and females (42.7% male). Basic demographic differences could be responsible for the different findings across the two studies. In our young female sample, many of whom were university students, newly-obtained independence from the family home setting, and associated changes in eating patterns and alcohol consumption, along with peer influences, may impact on appetitive traits – or the perception of one's own appetitive traits. Further testing of these hypotheses by investigating associations between Hunger and Food Responsiveness and measures of dietary restraint is needed to better understand how these scales should be interpreted.

Despite the novelty of the data presented here and the large sample size there are a number of limitations to consider. The most salient being the over-representation of young Caucasian women in the sample. Whilst gender was adjusted for in the analyses, due to the relatively small number of men, gender differences on scale scores nor potential moderation effects of gender with association between eating behaviours and BMI could not be confidently explored. Future validation of the AEBQ in diverse populations will allow for the broader use of the tool. As indicated, measures of restrained eating [25] or dieting behaviour would be useful to include in future studies to understand better the interaction between the appetitive traits assessed via the AEBQ and other dietary control behaviours that may contribute to energy intake and BMI in adults. Finally, the use of self-reported height and weight to calculate BMI is a limitation and reporting of these anthropometrics may be subject to bias.

Conclusions

In sum, the current study supports the reliability of the AEBQ as a measure of appetitive traits in adults. The robust factor structure and pattern of associations between the AEBQ scales and BMI lend support to the construct validity of the tool. Future investigation of systematic variation in appetitive traits by factors such as gender and age may give insight into the specific eating behaviours that may make individuals more or less susceptible to excess weight gain throughout adulthood. Furthermore, investigation of the relationship between food approach scales and dieting or restrained eating as well as between Food Fussiness and measures of poor dietary variety is warranted. It is anticipated that the present findings will encourage use of the AEBQ as a convenient

and cost-effective self-report tool that will be useful in characterising obesity risk behaviours in adults and will allow researchers to track the development of appetitive traits throughout infancy, childhood and across adulthood by using the BEBQ [23], CEBQ [20] and AEBQ [28], respectively.

Abbreviations

AEBQ: Adult Eating Behaviour Questionnaire; AIC: Akaike's Information Criterion; BEBQ: Baby Eating Behaviour Questionnaire; BMI: Body mass index; CEBQ: Children's Eating Behaviour Questionnaire; CFA: Confirmatory factor analysis; CFI: Comparative fit index; RMSEA: Root Mean Square Error of Approximation; TLI: Tucker Lewis Index

Acknowledgments

We would also like to acknowledge the valuable contributions of Dr. Rebecca Beeken (University College London) and Dr. Claudia Hunot (Universidad de Guadalajara, México) to this manuscript.

Funding

This study was supported by a grant awarded to KM, JD and MS by the School of Psychology, Australian Catholic University, funding scheme for Honours student research projects.

Authors' contributions

KM, JD and MS designed and implemented the study. KM analysed the data. All authors contributed to interpretation of the data and writing of the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]School of Psychology, Australian Catholic University, 1100 Nudgee Road, Banyo, QLD 4014, Australia. [2]School of Exercise and Nutrition Sciences, Queensland University of Technology, 60 Musk Avenue, Kelvin Grove, QLD 4059, Australia. [3]School of Psychology, University of Leeds, Woodhouse Lane, Leeds LS2 9JT, UK. [4]Department of Behavioural Science and Health, University College London, Gower St, London WC1E 6BT, UK.

References

1. French SA, Story M, Jeffery RW. Environmental influences on eating and physical activity. Annu Rev Public Health. 2001;22:309–35.
2. Llewellyn C, Fildes A. Behavioural susceptibility theory: professor Jane Wardle and the role of appetite in genetic risk of obesity. Curr Obes Rep. 2017;6(1):38–45.
3. Llewellyn CH, et al. Inherited behavioral susceptibility to adiposity in infancy: a multivariate genetic analysis of appetite and weight in the Gemini birth cohort. Am J Clin Nutr. 2012;95(3):633–9.
4. French SA, et al. Eating behavior dimensions. Associations with energy intake and body weight. A review. Appetite. 2012;59(2):541–9.
5. Syrad H, et al. Appetitive traits and food intake patterns in early life. Am J Clin Nutr. 2016;103(1):231–5.
6. Wardle J. Eating style: a validation study of the Dutch eating behaviour questionnaire in normal subjects and women with eating disorders. J Psychosom Res. 1987;31(2):161–9.
7. Parkinson KN, et al. Do maternal ratings of appetite in infants predict later child eating behaviour questionnaire scores and body mass index? Appetite. 2010;54(1):186–90.
8. van Jaarsveld C, et al. Prospective associations between appetitive traits and weight gain in infancy. Am J Clin Nutr. 2011;94(6):1562–7.
9. van Jaarsveld CH, et al. Appetite and growth: a longitudinal sibling analysis. JAMA Pediatr. 2014;168(4):345–50.
10. Birch LL, Fisher JO. Development of eating behaviors among children and adolescents. Pediatrics. 1998;101(Supplement 2):539–49.
11. Sleddens E, Kremers S, Thijs C. The Children's eating behaviour questionnaire: factorial validity and association with body mass index in Dutch children aged 6-7. Int J Behav Nutr Phys Act. 2008;5(1):49.
12. Webber L, et al. Eating behaviour and weight in children. Int J Obes (Lond). 2008;33(1):21–8.
13. Carnell S, Wardle J. Appetite and adiposity in children: evidence for a behavioral susceptibility theory of obesity. Am J Clin Nutr. 2008;88(1):22–9.
14. Carnell S, Wardle J. Measuring behavioural susceptibility to obesity: validation of the child eating behaviour questionnaire. Appetite. 2007;48(1):104–13.
15. Fildes A, et al. The relationship between appetite and food preferences in British and Australian children. Int J Behav Nutr Phys Act. 2015;12(1):1.
16. Farrow C, Galloway A, Fraser K. Sibling eating behaviours and differential child feeding practices reported by parents. Appetite. 2009;52(2):307–12.
17. Gregory JE, Paxton SJ, Brozovic AM. Pressure to eat and restriction are associated with child eating behaviours and maternal concern about child weight, but not child body mass index, in 2-to 4-year-old children. Appetite. 2010;54(3):550–6.
18. Webber L, et al. Associations between children's appetitive traits and maternal feeding practices. J Am Diet Assoc. 2010;110(11):1718–22.
19. Harris HA, et al. Maternal feeding practices and fussy eating in toddlerhood: a discordant twin analysis. Int J Behav Nutr Phys Act. 2016;13(1):81.
20. Wardle J, et al. Development of the Children's eating behaviour questionnaire. J Child Psychol Psychiatry. 2001;42(7):963–70.
21. Viana V, Sinde S, Saxton J. Children's eating behaviour questionnaire: associations with BMI in Portuguese children. Br J Nutr. 2008;100(02):445–50.
22. Mallan KM, et al. Maternal report of young children's eating styles. Validation of the Children's eating behaviour questionnaire in three ethnically diverse Australian samples. Appetite. 2013;64(0):48–55.
23. Llewellyn CH, et al. Development and factor structure of the baby eating behaviour questionnaire in the Gemini birth cohort. Appetite. 2011;57(2):388–96.
24. Mallan KM, Daniels LA, De Jersey S. Confirmatory factor analysis of the baby eating behaviour questionnaire and associations with infant weight, gender and feeding mode in an Australian sample. Appetite. 2014;82:43–9.
25. Stunkard AJ, Messick S. The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. J Psychosom Res. 1985;29(1):71–83.
26. Van Strien T, et al. The Dutch eating behavior questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. Int J Eat Disord. 1986;5(2):295–315.
27. Wildes JE, Zucker NL, Marcus MD. Picky eating in adults: results of a web-based survey. Int J Eat Disord. 2012;45(4):575–82.
28. Hunot C, et al. Appetitive traits and relationships with BMI in adults: development of the adult eating behaviour questionnaire. Appetite. 2016;105:356–63.
29. Byrne BM. Structural equation modeling with AMOS: basic concepts, applications and programming. Mahwah: Lawrence Erlbaum Associates Publishers; 2001.
30. Hu Lt, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct Equ Model Multidiscip J. 1999;6(1):1–55.
31. Karlsson J, et al. Psychometric properties and factor structure of the three-factor eating questionnaire (TFEQ) in obese men and women. Results from the Swedish obese subjects (SOS) study. Int J Obes Relat Metab Disord. 2000;24(12):1715–25.
32. Maitre I, et al. Food pickiness in the elderly: relationship with dependency and malnutrition. Food Qual Prefer. 2014;32:145–51.
33. Spence JC, et al. Examining behavioural susceptibility to obesity among Canadian pre-school children: the role of eating behaviours. Int J Pediatr Obes. 2011;6(2Part2):e501–7.
34. Webber L, et al. Eating behaviour and weight in children. Int J Obes (Lond). 2009;33(1):21–8.
35. Carruth BR, et al. Prevalence of picky eaters among infants and toddlers and their caregivers' decisions about offering a new food. J Am Diet Assoc. 2004;104:57–64.
36. Dovey TM, et al. Food neophobia and 'picky/fussy' eating in children: a review. Appetite. 2008;50(2–3):181–93.

Relationship between mean daily energy intake and frequency of consumption of out-of-home meals in the UK National Diet and Nutrition Survey

Louis Goffe[1,2,3*], Stephen Rushton[4], Martin White[1,5], Ashley Adamson[1,2,3] and Jean Adams[5]

Abstract

Background: Out-of-home meals have been characterised as delivering excessively large portions that can lead to high energy intake. Regular consumption is linked to weight gain and diet related diseases. Consumption of out-of-home meals is associated with socio-demographic and anthropometric factors, but the relationship between habitual consumption of such meals and mean daily energy intake has not been studied in both adults and children in the UK.

Methods: We analysed adult and child data from waves 1–4 of the UK National Diet and Nutrition Survey using generalized linear modelling. We investigated whether individuals who report a higher habitual consumption of meals out in a restaurant or café, or takeaway meals at home had a higher mean daily energy intake, as estimated by a four-day food diary, whilst adjusting for key socio-demographic and anthropometric variables.

Results: Adults who ate meals out at least weekly had a higher mean daily energy intake consuming 75–104 kcal more per day than those who ate these meals rarely. The equivalent figures for takeaway meals at home were 63–87 kcal. There was no association between energy intake and frequency of consumption of meals out in children. Children who ate takeaway meals at home at least weekly consumed 55–168 kcal more per day than those who ate these meals rarely. Additionally, in children, there was an interaction with socio-economic position, where greater frequency of consumption of takeaway meals was associated with higher mean daily energy intake in those from less affluent households than those from more affluent households.

Conclusions: Higher habitual consumption of out-of-home meals is associated with greater mean daily energy intake in the UK. More frequent takeaway meal consumption in adults and children is associated with greater daily energy intake and this effect is greater in children from less affluent households. Interventions seeking to reduce energy content through reformulation or reduction of portion sizes in restaurants, cafés and takeaways could potentially lead to reductions in mean daily energy intake, and may reduce inequalities in health in children.

Keywords: Food intake, Eating out, Out-of-home meals, Energy intake, Restaurant, Takeaway, NDNS, Food environment

* Correspondence: louis.goffe@newcastle.ac.uk
[1]Institute of Health & Society, Newcastle University, Newcastle, UK
[2]Human Nutrition Research Centre, Newcastle University, Newcastle, UK
Full list of author information is available at the end of the article

Background

Meals purchased out-of-home are considered to be less healthy than homemade meals [1]. Out-of-home fast-food meals tend to be higher in energy, fat, salt and sugar and lower in vitamins and minerals than meals prepared at home [2–9]. In particular, meals from independent takeaway outlets are inconsistent with dietary recommendations, delivering portions that are high in energy, all macronutrients and salt [5, 8]. Whilst the mechanisms that lead to overconsumption are not fully understood [10], experiments in both laboratory and natural settings have shown that large portion sizes, particularly of energy-dense foods, contribute to the overconsumption of energy [11]. Furthermore, consumption of meals from out-of-home sources has been linked to weight gain [12, 13] and an increased risk of insulin resistance [14] and type 2 diabetes [15].

Consumption of ready-to-eat food from out-of-home outlets such as cafés, takeaways, restaurants, and convenience stores is common [16, 17]. Our previous work identified that during 2008 to 2012 in the UK almost one-quarter of adults and one-fifth of children ate a meal out weekly and one-fifth of both adults and children ate a takeaway meal at home at least weekly [18]. A comparable study in the United States, during 2007 to 2010, found that adults consumed on average 11.3% of their energy intake from fast-food [19]. The proportion of household budgets spent on out-of-home meals has increased. In the United States in the 1970s approximately 20% of food expenditure was spent on out-of-home food, [20] rising to 38% by 1992 [17] and 50.1% in 2014 [21]. In the UK, excluding alcohol, the proportion of household food and drink budgets spent out-of-home has risen from 21% in 1995 to 26% in 2014 [22]. This increase in expenditure corresponds to an increase in availability [23], particularly with regards to multinational chain restaurants, which have pursued rapid global expansion since the 1980s [24].

Increased intake of takeaway food is associated with increased exposure to takeaway outlets [25]. A number of epidemiological studies have detailed the association between increased exposure and weight gain, obesity, insulin resistance and type 2 diabetes [12, 14, 15]. The consumption of out-of-home meals is socio-demographically patterned; our analysis of UK data found that boys eat takeaway meals more frequently than girls and peak consumption is found in young adults between the ages of 19 to 29 [18]. We also found that more affluent adults were more likely to eat meals out at least once per week, but children from less affluent households were more likely to eat takeaway meals at least weekly [18]. Additionally, exposure to out-of-home food outlets is strongly socio-demographically patterned, since there is greater takeaway outlet density in more deprived communities [23, 26–28].

As a result of these emerging associations, there have been a number of studies in the US that have attempted to quantify the effect of food from fast-food and full-service restaurants on dietary intake whilst adjusting for socio-demographic variables [29–32]. In adults, consumption of any food from a fast-food outlets or full-service restaurants was respectively associated with a 190 and 187 kcal greater daily energy intake [30]. The equivalent figures for children (aged 2 to 11 years) were an additional 126 and 160 daily kilocalories [29] and adolescents (aged 12 to 19 years) were 310 and 267 kcal [29]. However, to our knowledge, no work has been carried out on UK populations exploring how habitual patterns of out-of-home meal consumption impact on mean daily energy intake across all ages.

We hypothesised that mean daily energy intake is dependent on frequency of consumption of out-of-home meals in both adults and children (hypothesis 1). We also hypothesised that this relationship is dependent on age, gender, socio-economic position and body size (hypothesis 2).

Methods

We undertook secondary analysis of individual-level data from a large, annual UK cross-sectional survey of adults and children to estimate the impact on mean daily energy intake of frequency out-of-home meal consumption, including both meals eaten out and takeaway meals eaten at home, whilst adjusting for a range of socio-demographic and anthropometric factors.

Data source

We combined data from the first four annual waves of the UK National Diet and Nutrition Survey (NDNS) from 2008 to 9 to 2012–13. The NDNS is a rolling programme of cross-sectional surveys carried out across the United Kingdom. NDNS aims to recruit 1000 individuals per year, 500 adults aged 19 years and over, and 500 children aged 1.5 to 18 years, broadly representing the UK population, and collects data on food consumption, nutrient intake and nutritional status of people living in private households. As far as possible sampling, recruitment and data collection methods are constant across years to enable data to be combined across survey years [33]. Individuals in the study completed an estimated four-day food diary and participated in an interview to collect background data that included data on dietary habits, socio-demographic status and lifestyle [33]. Overall, 91% of households eligible for inclusion agreed to take part in the first four waves of NDNS. Usable food diaries (three or four completed days) were collected from at least one household member in 58% of eligible households. At an individual level, 56% of those selected to take part completed usable food diaries: 2083 adults and 2073 children [33].

Variables

Mean daily energy intake

For each individual, mean daily energy intake (kilocalories) was derived from food diary data. The NDNS does not collect data on the source of the food consumed.

Socio-demographic variables

We included three socio-demographic variables to test the second hypothesis: age (years), gender (male/female) and socio-economic position (SEP). SEP was measured using the National Statistics Socio-economic Classification (NS-SeC) [34], where individuals are assigned a class based on the employment of the person in their household with the highest income. Data were collapsed into two levels for analysis – Class 1 (managerial, professional and intermediate occupations) and Class 2 (routine and manual occupations) – as this maximised model fit, as measured by Akaike Information Criterion (AIC). Individuals were excluded where either a response was not provided or the householder had never worked. We anticipated that SEP will impact on behaviour but not necessarily in a monotonic way (e.g. increasing or decreasing with SEP). Therefore, we used SEP as a grouping variable to analyse the differences between classes.

Anthropometric variables

There are many ways of quantifying body size. We considered both body mass index (BMI) and the cubic transformation of height. The cubic transformation of height provides a body mass measure that does not include an estimate of specific tissue mass (e.g. muscle, fat or bone). In full model analysis the cubic transformation of height variable resulted in better model fit than BMI, as measured by AIC.

Frequency of eating meals out and takeaway meals at home

The NDNS does not contain details about where food reported in food diaries was obtained but the interview contained two questions to estimate habitual out-of-home food consumption. These were: "On average, how often do you/does [child's name] eat meals out in a restaurant or café?"; and "On average, how often do you/does [child's name] eat takeaway meals at home?". Individuals were informed by the researcher leading the interview that "'meals means more than a beverage or bag of chips". The responses available to individuals fell on a five point ordinal scale: "Rarely or never?"; "1–2 times per month"; "1–2 times per week"; "3–4 times per week"; or "5 or more times per week". Due to the low number of individuals reporting frequency of consumption in the highest three categories, these were merged to form one category "1 or more times per week".

Data analysis

We used generalized linear modelling (GLM) to investigate the relationships between frequency of consumption of out-of-home meals and individual's mean daily energy intake, with separate models for adults (aged 19 years and over), and children (aged 1.5 to 18 years) (Hypothesis 1). To explore the influence of socio-demographic variables, we included gender, age, height cubed, NS-SeC, frequency of meals out and frequency of takeaway meals as independent predictors (Hypothesis 2). In the adult model, we included potential interactions between: age and both frequency of meals out and takeaways (as consumption peaks in young adults [18]); and NS-SeC and meals out (as adults living in more affluent household are more likely to eat meals out at least once per week [18]). In the child model we included potential interactions between: gender and takeaway meal consumption (as more boys than girls eat takeaway meals [18]); age and both frequency of meals out and takeaways (as consumption peaks in young adults [18]); and NS-SeC and takeaway meal consumption (as children living in less affluent households are more likely to eat takeaways [18]). We used stepwise deletion to identify the significant independent variables ($P < 0.05$). Using the derived regression equations from the GLMs we were able to estimate mean daily energy intake for both adults and children, adjusted for key socio-demographic and anthropometric variables to illustrate the relationship with habitual consumption of out-of-home meals.

In order to illustrate the relationship between mean daily energy intake and the frequency of consumption variables in both adults and children, the derived regression equations from the GLMs were used to generate estimates, which were transformed into kilocalories and plotted with errors bars representing 95% confidence intervals. To calculate the estimates for adults we used the mean height for both females and males in the modelled dataset, 161 cm and 175 cm respectively. To calculate the estimates for the children we used the mean height for both females and males in the modelled dataset, 138 cm and 139 cm respectively.

We carried out data analyses in R [35].

Results

We only included individuals in the analysis where there was a complete set of records for the variables of interest. This resulted in 1889 (90.7%) adults and 1797 (86.7%) children from the first four annual waves of the NDNS (2008–9 to 2012–13). A summary of variables of interest for adults is shown in Table 1 and for children in Table 2. Since the data were not complete for all individuals, some individuals were omitted from the analyses. We assessed the extent to which excluded and included cases differed in their mean daily energy intake,

Table 1 Summary of adult model variables

Variable	Level	N (%)	Mean (SD)
Categorical variables			
All adults		1889	
Gender	Male	829 (43.9)	
	Female	1060 (56.1)	
NS-SeC	Class 1: Higher managerial, administrative, professional and intermediate occupations	1217 (64.4)	
	Class 2: Routine and manual occupations	672 (35.6)	
Frequency of eating meals out	Rarely or never	537 (28.4)	
	1–2 times per month	851 (45.1)	
	1 or more times per week	501 (26.5)	
Frequency of eating takeaway meals at home	Rarely or never	848 (44.9)	
	1–2 times per month	667 (35.3)	
	1 or more times per week	374 (19.8)	
Continuous variables			
Age	Years		49.2 (16.9)
Height	Centimetres		167.5 (9.5)
Mean daily energy intake	Kilocalories		1811.2 (573.1)

socio-demographic, anthropometric characteristics and frequency of consumption of out-of-home meals variables using chi-squared tests and GLMs, as appropriate. Significant differences in the adult model included: mean daily energy intake, where included cases were more likely to have a higher mean daily energy intake; NS-SeC, where included cases were more likely to be in a higher social group; and frequency of meals out consumed, where included cases were more likely to eat meals out more frequently. Significant differences in the child model included: mean daily energy intake, where included cases were more likely to have a higher mean

Table 2 Summary of child model variables

Variable	Level	N (%)	Mean (SD)
Categorical variables			
All children		1797	
Gender	Male	934 (52.0)	
	Female	863 (48.0)	
NS-SeC	Class 1: Higher managerial, administrative, professional and intermediate occupations	1158 (64.4)	
	Class 2: Routine and manual occupations	639 (35.6)	
Frequency of eating meals out	Rarely or never	497 (27.7)	
	1–2 times per month	923 (51.4)	
	1 or more times per week	377 (21.0)	
Frequency of eating takeaway meals at home	Rarely or never	682 (38.0)	
	1–2 times per month	733 (40.8)	
	1 or more times per week	382 (21.3)	
Continuous variables			
Age	Years		9.8 (5.0)
Height	Centimetres		138.4 (27.8)
Mean daily energy intake	Kilocalories		1595.3 (462.1)

daily energy intake; age, where included cases were more likely to be older; frequency of meals out consumed, where included cases were more likely to eat meals out more frequently; and frequency of takeaway meals consumed, where included cases were more likely to eat takeaway meals more frequently.

Adults

Adult mean daily energy intake was dependent on gender, body size, NS-SeC, frequency of eating meals out, and in the highest consumers of takeaway meals (Table 3).

Men consumed more energy per day ($t = 9.20$, $P < 0.01$), as did larger adults ($t = 7.69$, $P < 0.01$) and those living in routine and manual households consumed less ($t = -3.30$, $P < 0.01$). Adults who ate out more frequently consumed more energy, 1–2 times per month ($t = 3.26$, $P < 0.01$), 1 or more times per week ($t = 2.91$, $P < 0.01$). Only adults who ate takeaway meals most frequently (1 or more times per week ($t = 2.48$, $P = 0.01$)), consumed significantly more energy. There was a suggestion of a positive effect of eating takeaway meals at home 1–2 times per month, but this was not significant ($t = 1.72$, $P = 0.08$). There were no significant interaction terms in the adult GLM relating to mean daily energy intake.

Children

Child mean daily energy intake was dependent on gender, body size and NS-SeC (Table 4).

Boys consumed more ($t = 9.56$, $P < 0.01$) as did larger children ($t = 21.33$, $P < 0.01$) and those living in routine and manual households consumed less ($t = -2.21$, $P = 0.03$). There was a suggestion that children who ate takeaway meals more frequently consumed more: 1–2 times per month ($t = 1.65$, $P < 0.10$), 1 or more times per week ($t = 1.91$, $P = 0.06$). Despite this non-significance, the frequency of consumption of takeaway meals at home variables were retained due to a significant interaction between NS-SeC and frequency of eating takeaway meals at home, where the model estimate increased as frequency of consumption increased, 1–2 times per month ($t = 2.01$, $P = 0.04$), 1 or more times per week ($t = 2.10$, $P = 0.04$). This interaction represents a synergistic effect of the two single dependent variables alone. The mean daily energy intake of children living in routine or manual households was more positively related to a greater frequency of consumption of takeaway meals at home than in children living in higher managerial, administrative, professional and intermediate households.

Model residuals

For a GLM with a Gaussian error structure to be an adequate model for the data, the residuals (error) should be normally distributed with zero mean. The distribution of residuals from the adult and child models were normal but there were outliers at the lower end of the body size (height cubed) range where the model appeared to overestimate. Consideration of the records for the individuals concerned showed a level of recorded mean daily energy intake that was lower than the intake required to maintain an estimated basal metabolic rate, indicating poor or inadequate recording.

The estimated mean daily energy intake in adults from the GLMs in relation to the frequency of meals out consumed are shown in Fig. 1. This suggests there is an upward trend between a greater consumption of meals out and mean daily energy intake, which levels off at a consumption of 1–2 meals out per month in all groups modelled. The estimated mean daily energy intake in adults from the GLMs in relation to the frequency of takeaway meals consumed is shown in Fig. 2, which suggests greater consumption of takeaway meals is associated with greater mean daily energy intake in all groups modelled. The estimated mean daily energy intake in children from the GLMs in relation to the frequency of takeaway meals consumed are shown in Fig. 3. Here

Table 3 Significant coefficients from adult GLM

Coefficients	Estimate (Std. Error)	t value	Pr(>|t|)
Intercept	6.9156 (0.0507)	136.4009	< 0.001
Gender: Male	0.1733 (0.0188)	9.2008	< 0.001
Body size	< 0.001 (< 0.001)	7.6875	< 0.001
NS-SeC: Class 2	−0.0457 (0.0139)	−3.2976	< 0.001
Frequency of eating meals out: 1–2 times per month	0.0518 (0.0159)	3.2622	0.0011
Frequency of eating meals out: 1 or more times per week	0.0526 (0.0180)	2.9124	0.0036
Frequency of eating takeaway meals at home: 1–2 times per month	0.0256 (0.0149)	1.7243	0.0848
Frequency of eating takeaway meals at home: 1 or more times per week	0.0442 (0.0179)	2.4754	0.0134

AIC: 586.61
Null deviance: 194.80 on 1888 degrees of freedom
Residual deviance: 149.45 on 1881 degrees of freedom
D-squared: 0.23

Table 4 Significant coefficients from child GLM

Coefficients	Estimate (Std. Error)	t value	Pr(>|t|)
Intercept	7.0228 (0.0156)	449.9743	< 0.001
Male	0.1114 (0.0116)	9.5896	< 0.001
Body size	< 0.001 (< 0.001)	21.3252	< 0.001
NS-SeC Class 2	−0.0449 (0.0203)	−2.2084	0.0273
Eating takeaway meals 1–2 times per month	0.0267 (0.0162)	1.6471	0.0997
Eating takeaway meals 1 or more times per week	0.0392 (0.0205)	1.9083	0.0565
Interaction: NS-SeC Class 2: Eating takeaway meals 1–2 times per month	0.0558 (0.0278)	2.0076	0.0448
Interaction: NS-SeC Class 2: Eating takeaway meals 1 or more times per week	0.0682 (0.0325)	2.1020	0.0357

AIC: 60.33
Null deviance: 148.00 on 1796 degrees of freedom
Residual deviance: 107.72 on 1789 degrees of freedom
D-squared: 0.27

there is also a trend suggesting greater consumption of takeaway meals is associated with greater mean daily energy intake. However, this association is more marked in those individuals from NS-SeC Class 2. There is no figure illustrating the impact of frequency of meals out on mean daily energy intake in children as this variable was non-significant in the child GLM. The estimated difference in mean daily energy intake between the highest and lowest consumers of both meals out and takeaway meals are shown in Table 5.

Discussion

Summary of principal findings

We found a positive relationship between habitual consumption of out-of-home meals and mean daily energy intake. In adults, after adjusting for key socio-

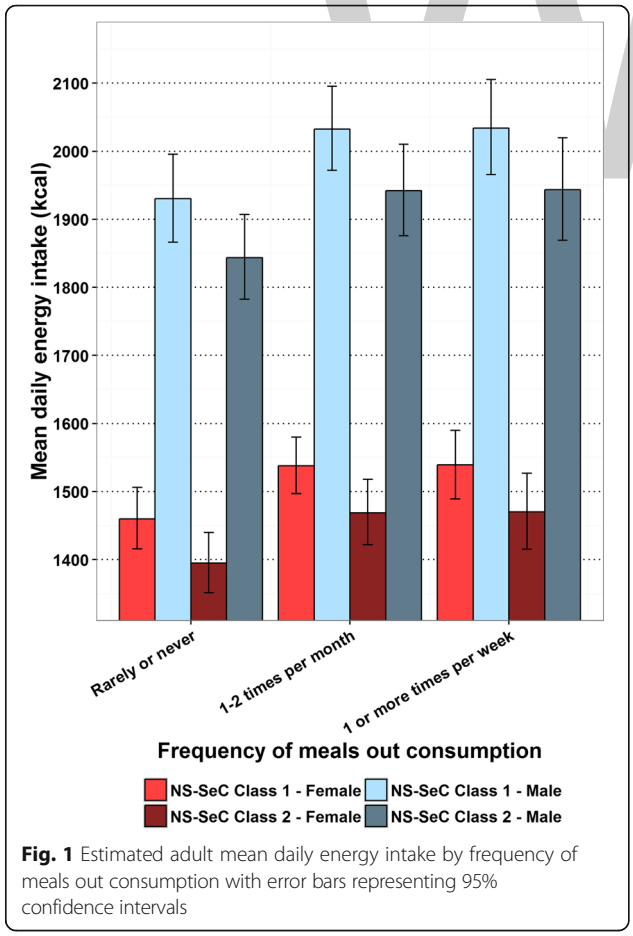

Fig. 1 Estimated adult mean daily energy intake by frequency of meals out consumption with error bars representing 95% confidence intervals

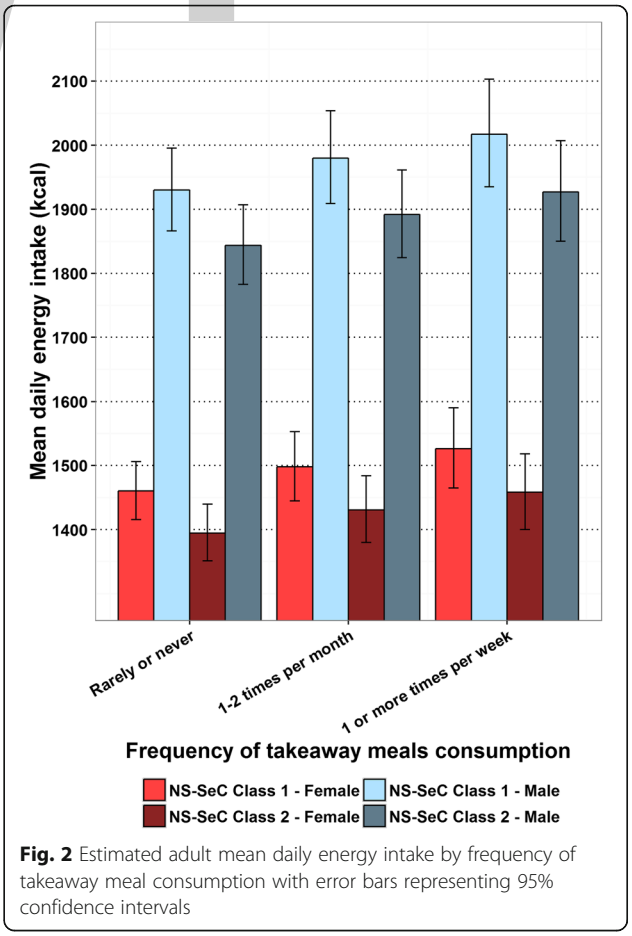

Fig. 2 Estimated adult mean daily energy intake by frequency of takeaway meal consumption with error bars representing 95% confidence intervals

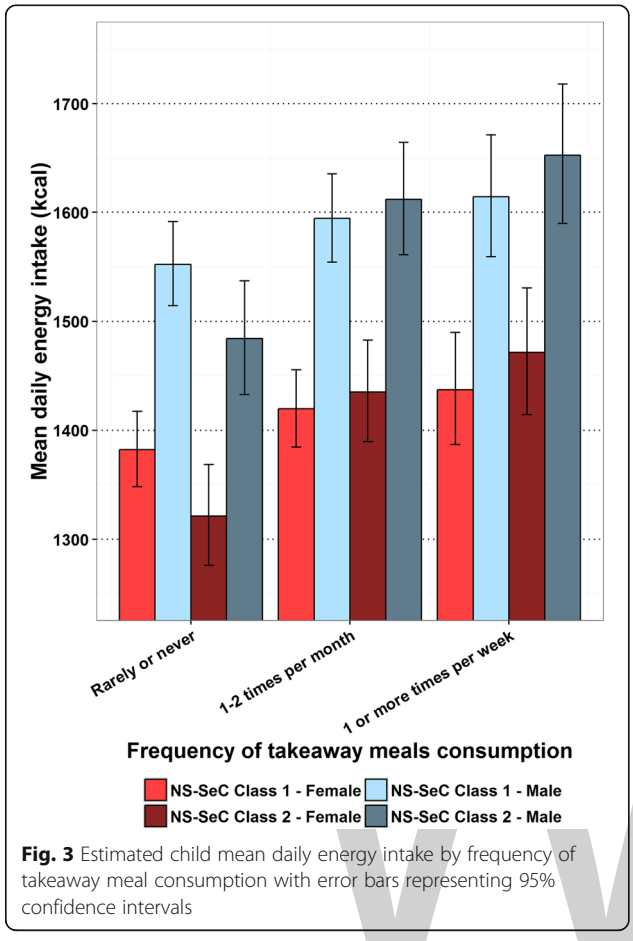

Fig. 3 Estimated child mean daily energy intake by frequency of takeaway meal consumption with error bars representing 95% confidence intervals

demographic and body size variables, we found that greater habitual frequency of consumption of both meals out in a restaurant or café, and takeaway meals was associated with greater mean daily energy intake. Adults who ate meals out at least weekly consumed on average 75–104 kcal more per day than those who ate these meals rarely. Comparable figures for eating takeaway meals at home at least weekly were 63–87 kcal. In children, only habitual consumption of takeaway meals at home had a suggested positive relationship with mean daily energy intake. Children who ate takeaway meals at home at least weekly consumed 55–168 kcal more than those eating these meals rarely. In addition, we found that the impact was amplified by SEP in children, where the larger mean daily energy intake associated with habitual consumption of takeaway meals at home was greater in children from less versus more affluent households.

Table 5 Estimated difference in mean daily energy intake between the highest and lowest consumers

		Difference in consumption between 'Rarely or never' and '1 or more times per week'	
		Meals out (kcal)	Takeaways (kcal)
Adult	NS-SeC Class 1 - Male	104	87
	NS-SeC Class 2 - Male	100	83
	NS-SeC Class 1 - Female	79	66
	NS-SeC Class 2 - Female	75	63
Child	NS-SeC Class 1 - Male		62
	NS-SeC Class 2 - Male		168
	NS-SeC Class 1 - Female		55
	NS-SeC Class 2 - Female		150

Strengths and limitations of study

The modelling method that we applied allowed us to investigate a range of explanatory variables. The range of significant relationships we found indicates that our analyses are unlikely to be underpowered. Although the NDNS attempts to attain a nationally representative sample, because some records were excluded from our analyses due to incomplete data, our results may not be generalisable across the UK. However, it is unclear why the relationships we have identified might vary in other UK groups. As the UK out-of-home food environment is unique [36, 37], our findings may not apply to settings outside the UK. The NDNS does not publish data on participants who did not complete a food diary. Therefore, there is no straightforward method to compare characteristics between those who completed a food diary and those who did not. The NDNS acknowledges that non-response bias exists in their sample and provide survey weights. While there are advantages of using weights for simple population averages, it is not clear how such weights are applied to more complex methods (e.g. regression coefficients). Creating weights requires arbitrary choices regarding inclusion of weighting factors and interactions. We chose not to use these weights in our analysis. However, each of our models were appropriately adjusted for by model covariates in order to take account of potential confounding by socio-demographic variables. While there were some individuals that had recorded mean daily energy intake that was lower than the intake required to maintain an estimated basal metabolic rate, indicating potentially aberrant data, we cannot state conclusively if they were erroneous records. Therefore, no data was excluded from our analysis.

A limitation of the data is that the two self-reported out-of-home consumption variables have not been validated and do not detail what out-of-home food was purchased. If systematic variation exists between what different socio-demographic groups purchase in terms of out-of-home meals and what types of outlets they frequent, this could have led to bias. A related study in Irish children cautioned that assessment of out-of-home food intake using questionnaire data might lead to underreporting, specifically when compared to food diary data [38]. Therefore, the two out-of-home

consumption variables that we used may underestimate actual consumption. Daily energy intake data based on food diary data is also prone to misreporting, particularly underreporting, and there is some evidence this varies by age [39] and BMI [40].

We used a binary variable measure of SEP based on NS-SeC, which produced a better fitting GLM than the original eight class equivalent, as measured by AIC. Other SEP measures are available in NDNS including markers of education and income. We did not use these as the majority of child participants were still in full time education and a large proportion of participants refused to give details regarding their income.

Our data were cross-sectional and as such we cannot conclude that there is a definitive causal relationship between habitual consumption of meals out or takeaway meals at home and mean daily energy intake, nor the direction of causation between these variables.

Comparison with other studies and interpretation of findings

Burgoine et al. (2014) showed that exposure to takeaway food outlets was positively associated with both increased consumption of out-of-home foods and with a higher BMI and obesity in UK adults [25]. Our work provides a potential explanation as to why the increased consumption may lead to an increased BMI and obesity through individuals increasing their overall mean daily energy intake as a result of increased habitual consumption of out-of-home food.

Our results reflect a previous systematic review which found that eating out-of-home was associated with a higher daily energy intake [1]. Six of the ten studies included in this systematic review used data that was both from a Western country and that was either nationally representative or from a large cohort. Of these comparable studies only one found no significant influence of food consumed out-of-home on daily energy intake - in Irish children aged 5–12 [38]. The difference between studies could potentially be explained by contextual differences in out-of-home environments, differences in populations studied (we included participants aged 1.5 years and older, rather than just 5–12 years) or details of data used. Whilst the Irish study used data on where all food eaten over a short period was prepared or obtained, we measured habitual consumption of out-of-home food over the longer term.

Comparable modelling studies that explored the association between fast-food consumption and diet quality in the US [29, 30, 32] also found significant positive associations between frequency of fast-food consumption and energy intake. In US adults, consumption of any fast-food or full-service restaurant meals on a given day was associated with a daily energy intake increase of 190 and 187 kcal respectively [30], in children (aged 2 to 11) an increase of 126 and 160 kcal [29] and adolescents (aged 12 to 19) an increase of 310 and 267 kcal [29]. Our models estimated a mean daily difference of 63–87 kcal in adults and 55–168 kcal in children eating takeaway meals at least weekly compared to rarely, and 75–104 kcal per day in adults eating meals out at least weekly compared to rarely. Although our findings are not directly comparable, both studies found a positive association between greater out-of-home meal consumption and daily energy intake. Our estimates represent a sizeable difference in mean daily energy intake in comparison to government dietary recommendations. The UK government recommends that both adult and 15 to 18 year old females should consume 2000 kcal per day [41]. Therefore, adults and children in our study who ate takeaway meals at least weekly are respectively expected to consume 3.2%–4.4% and 2.8%–8.4% more energy per day than those that consume takeaway meals rarely. Comparable figures for eating meals out at least weekly in adults are 3.8%–5.2%. In adults, the mean daily energy intake estimate for eating meals out was greater than for takeaways. This may be due to cultural practices, such as when eating out is linked to celebrating specific events leading to a combination of consumption of multiple courses and beverages.

Of particular interest in our study is the relationship between takeaway meal consumption and SEP in children, suggesting an amplified impact of takeaway consumption on mean daily energy intake in children from a lower SEP. This combined with the established relationship between deprivation and the density of takeaway outlets [23, 26–28], means that children living in less affluent areas may be both more exposed to and more susceptible to the effects of eating takeaway meals. An also reported that daily energy intake appeared larger among individuals from lower SEP [30], and a UK study that found that greater fast-food consumption, BMI, and odds of obesity were associated with greater fast-food outlet exposure and lower SEP [42], also suggesting amplification of a neighbourhood effect on inequalities in diet and obesity.

Implications for policy and practice

Our results suggest that increased frequency of consumption of meals out in a restaurant or café by adults, and takeaway meals at home by both adults and children is likely to be associated with an increase in mean daily energy intake. With a secular trend towards increasing exposure and ease of access to out-of-home food outlets through online portals [43], and increased expenditure [21, 22], this has potential to have an adverse impact on overall diet quality. Policy makers, local government and caterers should therefore consider options that aim to

limit consumption of such meals, or seek to improve the nutritional quality of out-of-home food, primarily by reformulating, reducing portion size and by providing customers with suitable information to enable them to make informed choices [44]. However, to date there is limited evidence regarding the effectiveness of such interventions [45, 46].

We found the association between habitual consumption of takeaway food and mean daily energy intake to be greater in children from less versus more affluent households. Addressing known socio-economic differences in neighbourhood exposure to takeaway outlets, and possible socio-economic differences in nutritional composition of food chosen, may help reduce known socio-economic differences in diet and obesity in children.

Unanswered questions and future research

The nutritional profile of out-of-home food meals varies greatly [5] and consumption varies by socio-demographic group [18]. But we do not know if there is any socio-demographic patterning in the type of out-of-home food consumed – and this may explain the interaction between SEP and takeaway consumption on mean daily energy intake we found in children. Furthermore, it is not clear if out-of-home food is consumed in total by the purchaser, shared with others, or wasted – or any determinants of this. Future work could explore these points further in order to help tailor and target different interventions to different outlets and socio-demographic groups [18].

This study adds to the substantial body of evidence that suggests that frequent out-of-home food consumption is not conducive to health [1–6, 8, 14, 15, 19, 25, 30, 32, 36]. There remains limited evidence concerning what interventions might be effective in this area [45, 46] but the needs of all stakeholders, including out-of-home food vendors, [47] need to be taken into account in developing intervention strategies. Future work should focus on interventions that aim to reduce the portion size and energy density of meals in cafés, restaurants and takeaways, but also help customers to make healthier choices and incentivise outlet vendors to provide an increased range of healthy options.

Conclusions

Using data from a large UK cross-sectional study we modelled and estimated the impact on mean daily energy intake of habitual consumption of meals eaten out in a restaurant or café and takeaway meals eaten at home in both adults and children, whilst adjusting for socio-demographic and anthropometric measures. In adults, at least weekly consumption of meals out in a restaurant or café was associated with consuming 75–104 kcal more per day compared to rarely eating these meals; and at least weekly consumption of takeaways meals at home was associated with consuming 63–87 kcal more per day. In children, only consumption of takeaway meals at home had a positive association with mean daily energy intake; with at least weekly consumption associated with consuming 55–168 kcal more per day. Additionally, the impact of consumption of takeaway food was amplified in children from less affluent households, suggesting that children of such households are more susceptible to the effects of consumption from takeaway meals than those from more affluent households. Future work should identify interventions that seek to redress the positive association between consumption of out-of-home food and daily energy intake.

Abbreviations

AIC: Akaike information criterion; BMI: Body mass index; GLM: Generalized linear models; kcal: Kilocalories; NS-SeC: National statistics socio-economic classification; SEP: Socio-economic position

Acknowledgements

Not applicable.

Funding

This research was funded by the NIHR School for Public Health Research (SPHR). The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health. The SPHR was not involved in the design of the study, analysis, interpretation of data nor writing the manuscript.

This research was part of the SPHR funded project: Transforming the 'foodscape': development and feasibility testing of interventions to promote healthier takeaway, pub or restaurant food. With additional support from Durham and Newcastle Universities, and the NIHR Collaboration for Leadership in Applied Health Research and Care of the South West Peninsula (PenCLAHRC). SPHR is funded by the National Institute for Health Research (NIHR). SPHR is a partnership between the Universities of Sheffield, Bristol, Cambridge, Exeter, University College London; The London School for Hygiene and Tropical Medicine; the LiLaC collaboration between the Universities of Liverpool and Lancaster; and Fuse, the Centre for Translational Research in Public Health, a collaboration between Newcastle, Durham, Northumbria, Sunderland and Teesside Universities. Authors LG and AA are members of Fuse. Funding for Fuse comes from the British Heart Foundation, Cancer Research UK, Economic and Social Research Council, Medical Research Council, the National Institute for Health Research, under the auspices of the UK Clinical Research Collaboration, and is gratefully acknowledged. AA is funded by the NIHR as a NIHR Research Professor. JA and MW are funded by the Centre for Diet and Activity Research (CEDAR), MRC Epidemiology Unit, University of Cambridge, a UKCRC Public Health Research Centre of Excellence. Funding from the British Heart Foundation, Cancer Research UK, Economic and Social Research Council, Medical Research Council, the National Institute for Health Research, and the Wellcome Trust, under the auspices of the UK Clinical Research Collaboration, is gratefully acknowledged.

Authors' contributions

LG, JA and SR conceived the idea for the analysis. All authors contributed to methods development. LG and SR performed the analysis. All authors contributed to data interpretation. LG drafted the manuscript. All authors provided critical comments on the manuscript. All authors read and approved the final manuscript.

Competing interests
MW is funded by NIHR as Director of its Public Health Research Funding Programme.

Author details
[1]Institute of Health & Society, Newcastle University, Newcastle, UK. [2]Human Nutrition Research Centre, Newcastle University, Newcastle, UK. [3]Fuse – UKCRC Centre for Translational Research in Public Health, Newcastle, UK. [4]School of Natural and Environmental Sciences, Newcastle University, Newcastle, UK. [5]Centre for Diet and Activity Research, (CEDAR), MRC Epidemiology Unit, University of Cambridge, Cambridge, UK.

References

1. Lachat C, Nago E, Verstraeten R, Roberfroid D, Van Camp J, Kolsteren P. Eating out of home and its association with dietary intake: a systematic review of the evidence. Obes Rev. 2012;13:329–46.
2. Dunford E, Webster J, Barzi F, Neal B. Nutrient content of products served by leading Australian fast food chains. Appetite. 2010;55:484–9.
3. Jaworowska A, Blackham T, Davies IG, Stevenson L. Nutritional challenges and health implications of takeaway and fast food. Nutr Rev. 2013;71:310–8.
4. Jaworowska A, Blackham T, Stevenson L, Davies IG. Determination of salt content in hot takeaway meals in the United Kingdom. Appetite. 2012;59:517–22.
5. Jaworowska A, Blackham TM, Long R, Taylor C, Ashton M, Stevenson L, Glynn Davies I. Nutritional composition of takeaway food in the UK. Nutr Food Sci. 2014;44:414–30.
6. Rasmussen LB, Lassen AD, Hansen K, Knuthsen P, Saxholt E, Fagt S. Salt content in canteen and fast food meals in Denmark. Food Nutr Res. 2010; 54. doi:10.3402/fnr.v3454i3400.2100.
7. Tanase CM, Griffin P, Koski KG, Cooper MJ, Cockell KA. Sodium and potassium in composite food samples from the Canadian Total Diet Study. J Food Compos Anal. 2011;24:237–43.
8. Urban LE, Lichtenstein AH, Gary CE, et al. The energy content of restaurant foods without stated calorie information. JAMA Intern Med. 2013;173:1292–9.
9. Wagner K-H, Plasser E, Proell C, Kanzler S. Comprehensive studies on the trans fatty acid content of Austrian foods: Convenience products, fast food and fats. Food Chem. 2008;108:1054–60.
10. Peter Herman C, Polivy J, Pliner P, Vartanian LR. Mechanisms underlying the portion-size effect. Physiol Behav. 2015;144:129–36.
11. Ledikwe JH, Ello-Martin JA, Rolls BJ. Portion Sizes and the Obesity Epidemic. J Nutr. 2005;135:905–9.
12. Summerbell CD, Douthwaite W, Whittaker V, Ells LJ, Hillier F, Smith S, Kelly S, Edmunds LD, Macdonald I. The association between diet and physical activity and subsequent excess weight gain and obesity assessed at 5 years of age or older: a systematic review of the epidemiological evidence. Int J Obes. 2009;33(Suppl 3):S1–92.
13. Bezerra IN, Curioni C, Sichieri R. Association between eating out of home and body weight. Nutr Rev. 2012;70:65–79.
14. Pereira MA, Kartashov AI, Ebbeling CB, Van Horn L, Slattery ML, Jacobs DR Jr, Ludwig DS. Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis. Lancet. 2005;365:36–42.
15. Krishnan S, Coogan PF, Boggs DA, Rosenberg L, Palmer JR. Consumption of restaurant foods and incidence of type 2 diabetes in African American women. Am J Clin Nutr. 2010;91:465–71.
16. Cullen P. Time, Tastes and Technology: The Economic Evolution of Eating out. Br Food J. 1994;96:4–9.
17. Harnack LJ, Jeffery RW, Boutelle KN. Temporal trends in energy intake in the United States: an ecologic perspective. Am J Clin Nutr. 2000;71:1478–84.
18. Adams J, Goffe L, Brown T, Lake A, Summerbell C, White M, Wrieden W, Adamson A. Frequency and socio-demographic correlates of eating meals out and take-away meals at home: cross-sectional analysis of the UK national diet and nutrition survey, waves 1-4 (2008-12). Int J Behav Nutr Phys Act. 2015;12:51.
19. Fryer CD, Ervin RB. Caloric intake from fast food among adults: United States, 2007–2010. NCHS Data Brief 2013:1–8. Data Brief No. 114, February 2013. https://www.cdc.gov/nchs/products/databriefs/db114.htm.
20. Schwenk NE: Trends in food and alcohol consumption away from home. Family economics and nutrition review (USA) 1995.
21. USDA Economic Research Service: U.S. food-away-from-home sales topped food-at-home sales in 2014. 2016.
22. Department for Environment Food and Rural Affairs. Family Food 2014. London: National Statistics; 2015.
23. Maguire ER, Burgoine T, Monsivais P. Area deprivation and the food environment over time: A repeated cross-sectional study on takeaway outlet density and supermarket presence in Norfolk, UK, 1990–2008. Health Place. 2015;33:142–7.
24. Hawkes C. Marketing activities of global soft drink and fast food companies in emerging markets: a review. In: Globalization, diets and noncommunicable diseases. 2002. p. 1–78.
25. Burgoine T, Forouhi NG, Griffin SJ, Wareham NJ, Monsivais P. Associations between exposure to takeaway food outlets, takeaway food consumption, and body weight in Cambridgeshire, UK: population based, cross sectional study. BMJ. 2014;348:g1464. http://www.bmj.com/content/348/bmj.g1464.
26. Fraser LK, Edwards KL, Cade J, Clarke GP. The Geography of Fast Food Outlets: A Review. Int J Environ Res Public Health. 2010;7:2290–308.
27. Macintyre S, McKay L, Cummins S, Burns C. Out-of-home food outlets and area deprivation: case study in Glasgow, UK. Int J Behav Nutr Phys Act. 2005;2:1–7.
28. Powell LM, Chaloupka FJ, Bao Y. The Availability of Fast-Food and Full-Service Restaurants in the United States: Associations with Neighborhood Characteristics. Am J Prev Med. 2007;33:S240–5.
29. Powell LM, Nguyen BT. Fast-food and full-service restaurant consumption among children and adolescents: Effect on energy, beverage, and nutrient intake. JAMA Pediatr. 2013;167:14–20.
30. An R. Fast-food and full-service restaurant consumption and daily energy and nutrient intakes in US adults. Eur J Clin Nutr. 2016;70:97–103.
31. Bowman SA, Gortmaker SL, Ebbeling CB, Pereira MA, Ludwig DS. Effects of Fast-Food Consumption on Energy Intake and Diet Quality Among Children in a National Household Survey. Pediatrics. 2004;113:112–8.
32. Barnes TL, French SA, Mitchell NR, Wolfson J. Fast-food consumption, diet quality and body weight: cross-sectional and prospective associations in a community sample of working adults. Public Health Nutr. 2016;19:885–92.
33. Bates B, Lennox A, Prentice A, Bates C, Page P, Nicholson S. National Diet and Nutrition Survey Results from Years 1, 2, 3 and 4 (combined) of the Rolling Programme (2008/2009–2011/2012). London: Public Health England; 2014.
34. Rose D, Pevalin D, O'Reilly K. The National Statistics Socio-economic Classification: origins, development and use. Hampshire: Palgrave Macmillan; 2005.
35. R Core Team. R: A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing; 2016. https://www.R-project.org/.
36. Orfanos P, Naska A, Trichopoulos D, Slimani N, Ferrari P, van Bakel M, Deharveng G, Overvad K, Tjønneland A, Halkjær J, et al. Eating out of home and its correlates in 10 European countries. The European Prospective Investigation into Cancer and Nutrition (EPIC) study. Public Health Nutr. 2007;10:1515–25.
37. Slimani N, Fahey M, Welch A, Wirfält E, Stripp C, Bergström E, Linseisen J, Schulze MB, Bamia C, Chloptsios Y, et al. Diversity of dietary patterns observed in the European Prospective Investigation into Cancer and Nutrition (EPIC) project. Public Health Nutr. 2002;5:1311–28.
38. Burke SJ, McCarthy SN, O'Neill JL, Hannon EM, Kiely M, Flynn A, Gibney MJ. An examination of the influence of eating location on the diets of Irish children. Public Health Nutr. 2007;10:599–607.
39. Black AE, Prentice AM, Goldberg GR, Jebb SA, Bingham SA, Livingstone MBE, Coward A. Measurements of total energy expenditure provide insights into the validity of dietary measurements of energy intake. J Am Diet Assoc. 1993;93:572–9.
40. Pietilainen KH, Korkeila M, Bogl LH, Westerterp KR, Yki-Jarvinen H, Kaprio J, Rissanen A. Inaccuracies in food and physical activity diaries of obese subjects: complementary evidence from doubly labeled water and co-twin assessments. Int J Obes. 2010;34:437–45.
41. Public Health England. Government Dietary Recommendations: Government recommendations for food energy and nutrients for males and females aged 1–18 years and 19+ years. London; 2016. p. 12.
42. Burgoine T, Forouhi NG, Griffin SJ, Brage S, Wareham NJ, Monsivais P. Does neighborhood fast-food outlet exposure amplify inequalities in diet and obesity? A cross-sectional study. Am J Clin Nutr. 2016;103:1540–7.
43. Goffe L, Obertelli G, Wrieden W. The emerging role of takeaway Online Ordering Platforms: A qualitative study of vendors' and customers' experiences. In: UKCRC Public Health Research Centres of Excellence Conference. Edinburgh; 2015.
44. Marteau TM, Hollands GJ, Shemilt I, Jebb SA. Downsizing: policy options to

reduce portion sizes to help tackle obesity. BMJ. 2015;351:h5863. http://www.bmj.com/content/351/bmj.h5863.long.
45. Hillier-Brown FC, Summerbell CD, Moore HJ, Routen A, Lake AA, Adams J, White M, Araujo-Soares V, Abraham C, Adamson AJ, Brown TJ. The impact of interventions to promote healthier ready-to-eat meals (to eat in, to take away or to be delivered) sold by specific food outlets open to the general public: a systematic review. Obes Rev. 2017;18:227–46.
46. Hillier-Brown FC, Summerbell CD, Moore HJ, Wrieden WL, Adams J, Abraham C, Adamson A, Araújo-Soares V, White M, Lake AA. A description of interventions promoting healthier ready-to-eat meals (to eat in, to take away, or to be delivered) sold by specific food outlets in England: a systematic mapping and evidence synthesis. BMC Public Health. 2017;17:93.
47. Estrade M, Dick S, Crawford F, Jepson R, Ellaway A, McNeill G. A qualitative study of independent fast food vendors near secondary schools in disadvantaged Scottish neighbourhoods. BMC Public Health. 2014;14:793.

Externalizing behavior is prospectively associated with intake of added sugar and sodium among low socioeconomic status preschoolers in a sex-specific manner

Erica C. Jansen[1,8*], Alison L. Miller[2,3], Julie C. Lumeng[2,4], Niko Kaciroti[2], Holly E. Brophy Herb[5], Mildred A. Horodynski[6], Dawn Contreras[5,7] and Karen E. Peterson[1]

Abstract

Background: High intake of added sugar and sodium is a public health concern for preschool-aged children living in the US. Externalizing behavior may predict higher consumption of added sugar and/or sodium; however, previous studies have mostly been cross-sectional. The aim was to evaluate whether externalizing behavior is prospectively related to added sugar and intake in a sex-specific manner among preschoolers.

Methods: This was a secondary analysis of 524 preschool children (48% male) from Michigan who participated in an obesity prevention trial that occurred during one school year from 2011 to 2015. Teacher-assessed externalizing behaviors and three 24-h dietary recalls were completed at baseline and follow-up. We used linear mixed effects regression to evaluate the association between externalizing behavior at baseline and added sugar (% of total Calories) and sodium intake (mg/1000 Calories) at follow-up. In adjusted analysis, we included baseline income-to-needs ratio, child race/ethnicity, and baseline overweight status. All models were adjusted for total energy intake and accounted for clustering by classroom.

Results: Baseline externalizing behavior was positively associated with added sugar intake at follow-up among boys; after adjustment for confounders, every 5 points lower externalizing T-score (corresponding to higher externalizing behavior) was associated with a 0.6 higher percentage of added sugar per total Calories (95% CI 0.2 to 1.1; *P* value = 0.004). In contrast, girls with higher levels of externalizing behavior had lower consumption of added sugars; after confounder adjustment, every 5 points lower externalizing T-score was related to 0.6 lower percentage intake (95% CI -1.0 to −0.1; *P* value = 0.01). Baseline externalizing behavior was inversely associated with sodium intake at follow-up among boys. After potential confounder adjustment, for every 5 points lower externalizing behavior T-score, there was a 22 mg/1000 Cal lower sodium intake (95% CI -45 to 1; *P* value = 0.06). In contrast, after adjustment for confounders, every 5 points lower externalizing T-score among girls was related to 24 mg/1000 Cal higher sodium intake (95% CI 1 to 46; *P* value = 0.04).

Conclusions: Externalizing behavior among preschool-aged children was prospectively related to added sugar and sodium intake in a sex-dependent manner.

Trial registration: NCT01398358 Registered 19 July 2011.

Keywords: Sodium, Added sugar, Externalizing behavior

* Correspondence: janerica@umich.edu
[1]Department of Nutritional Sciences, School of Public Health, Ann Arbor, MI, USA
[8]Department of Nutritional Sciences, University of Michigan School of Public Health, 1415 Washington Heights, Ann Arbor, MI 48109, USA
Full list of author information is available at the end of the article

Background

High intake of added sugar and sodium among US preschool-aged children is a public health concern; recent nationally-representative surveys indicate that US preschool-aged children on average obtain between 13 and 16% of total Calories from added sugar [1] and over 90% of children ages 4–8 years (y) old exceed recommended levels of sodium intake [2] This is concerning because high consumption of sodium as well as added sugar in early childhood has been implicated in the development of cardiometabolic risk factors during childhood and adolescence [3, 4]. In addition, there is evidence that free sugar intake >10% of total Calories is positively associated with dental caries among children [5]. Thus, elucidating the predictors of higher added sugar and sodium intake among young children could provide valuable information for intervention.

One potential predictor of these dietary risk factors is externalizing behavior. Externalizing behavior during early childhood is marked by angry, aggressive, selfish and oppositional conduct; it includes fighting with or bullying other children, physically hitting, and taking things from others [6]. Externalizing behaviors have been linked with higher consumption of salty and/or sugary foods in a few cross-sectional studies [7, 8]. For example, a study of 13,486 Iranian children and adolescents found that those with higher self-reported aggressive behaviors also reported higher consumption of salty snacks [7]. Another study among 1324 adolescents in Australia found that those with more externalizing behaviors had higher intake of fast foods, confectionary items, and red meat [8]. There has also been one longitudinal study examining externalizing behavior and frequency of sugary food consumption, although not sodium. In this study of 6997 Norwegian children, researchers found that children with higher externalizing behavior at age 1.5 y had higher intake of sugary foods at age 3 y and 7 y [9]. A longitudinal study design is important as it separates the exposure from the outcome in time, lending stronger support to the notion that behavior leads to consumption patterns. There are some plausible mechanisms to support this pathway. For example, externalizing behavior during early childhood could be a marker of stress [10], and stress has been linked to higher consumption of snacks and sweet foods in young children [11–13]. Also, children with more externalizing behavior may have greater control over dietary choices because caregivers impose fewer restrictions and/or use food to calm them [14, 15].

The aim of this study was to examine the longitudinal association between externalizing behavior and intake of added sugar (% of Calories) and sodium (mg/1000 Calories) among low socioeconomic status (SES) preschoolers [16]. We hypothesized that children with higher levels of externalizing behavior at baseline would have higher percentage of Calories from added sugar intake and sodium intake (mg/1000 Calories) at follow-up. All analyses were stratified by sex, a potential effect modifier when examining associations between behavior and diet [13].

Methods

Study population

The present study was a secondary data analysis of the Growing Healthy Study, a cluster-randomized community-based obesity intervention trial among 697 preschoolers in Head Start programs in urban and rural Michigan from 2011 to 2015. The study is described in detail elsewhere [16]. Briefly, children in 18 classrooms per year were randomized to one of three study arms. Parents/guardians were invited to participate and received up to $150 for data collection activities. One arm consisted of exposure to the Preschool Obesity Prevention Series (POPS), a Social Cognitive Theory-based approach to obesity prevention. The second arm included POPS exposure in addition to the Incredible Years Series, a program that emphasizes positive behavioral management techniques [17]. The interventions consisted of classroom lessons for children during Head Start as well as separate parent/guardian lessons. The control arm consisted of usual Head Start exposure. Baseline visits occurred during the fall of one school year and follow-up visits occurred during the following spring, with a mean duration of 6 months (standard deviation 1 month). Exclusion criteria included the child having significant developmental disability, the child being in foster care, or the parent/guardian not being fluent in English. Informed consent was obtained, and the study was approved by the Institutional Review Boards of the University of Michigan and Michigan State University.

Data collection

Externalizing behavior

Externalizing behaviors were assessed by Head Start teachers, who completed the Social Competence and Behavior Scale (SCBE) during baseline and follow-up visits [6]. This 60-item instrument has been validated for children aged 2.5 to 6 y and is used to assess child social, emotional and behavioral functioning. Teachers were asked to rate aspects of the child's behavior on a 6-point Likert scale ("never" to "always"). The 15-item Externalizing Problems subscale assessed externalizing behaviors (e.g., "gets angry when interrupted"; "refuses to share toys"; Cronbach's alpha = 0.92). Items are summed and typically scored such that higher scores indicate lower levels of externalizing behavior [6]. T- scores standardized for age and sex were used, which typically have a

mean of 50 and standard deviation of 10. Scores were examined as a continuous variable, and beta estimates were reported per 5-points lower externalizing T-scores (corresponding to higher externalizing behavior).

Diet measures

Multiple 24-h dietary recalls were used to measure usual dietary consumption of the child at follow-up (including supplement intake). Trained dieticians sought to collect three unannounced 24-h dietary recalls via phone from parents/guardians, who were provided handouts showing child-appropriate portion sizes. The United States Department of Agriculture (USDA) 5-step automated multiple-pass method, which has been shown to improve accuracy of diet recall [18] was used. Calls occurred over a 2–3 week period, and parents/guardians were asked to provide 24-h recalls from 2 weekdays and 1 weekend day. Dieticians contacted the same parent/guardian each time and confirmed this parent/guardian had knowledge regarding the child's consumption that day. Because the children consume food at Head Start classrooms during school days, research staff observed and recorded what the child ate during the same weekdays that the parents/guardians provided 24-h recall information. Nutrient and caloric content of each food item was calculated with the aid of the USDA Food Composition Database using the Nutrition Data System for Research program (NDSR, University of Minnesota, Minneapolis, Minnesota). Calories of all foods consumed in the 24-h period were summed to calculate total energy intake. Recalls with implausible energy intakes were removed prior to analysis (n = 20 of 1287 total recalls at follow-up) using established criteria [19]. To reduce within-person random measurement error, summary variables representing nutrient contents per day for each participant were created by averaging all the valid 24-h recalls collected at follow-up. Added sugar was analyzed as average percentage of total Calories and sodium intake was analyzed as average milligrams (mg) per 1000 Calories. Nutrients were also classified into dichotomous variables for descriptive statistics, based on recommended cutoffs of intake in the United States (US) [20]. Higher than recommended intake for added sugar was classified as ≥10% of Calories from added sugar; for sodium, higher than recommended intake for sodium was classified as ≥2300 mg/day.

Other covariates

Trained research assistants measured height (in meters) and weight (in kilograms) of children and parents/guardians during home visits using calibrated equipment (Seca 213/217 portable stadiometer and Detecto Portable Scale Model #DR550C, respectively). BMI-for-age percentiles were calculated with the use of the Center for Disease Control (CDC) reference [21], and overweight/obesity was defined as ≥85th percentile. As a part of the demographic questionnaire administered during the first visit, parents/guardians provided information on the child's race/ethnicity, parent/guardian's education, and household income from all sources. Child race/ethnicity was classified into two categories: non-Hispanic White and Hispanic or not White. Education was categorized into those parent/guardians who did not graduate from high school, those who graduated from high school/obtained a General Educational Development (GED) certification, and those with a post-high school education. Income-to-needs ratio was calculated as the total reported household income divided by the federal poverty line for a family of the same size during the corresponding year, and it was categorized into quartiles. Parents/guardians also answered questions about their child's physical activity (hours per week) and screen time (hours per day) habits. Screen time and physical activity were each categorized into 4 categories, as shown in Table 2. Finally, parents/guardians completed the Center for Epidemiologic Studies Depression (CES-D) scale, a 20-item survey with higher scores indicating more depression symptoms [22]. Depression symptoms were classified as a dichotomous variable, with those reporting a score of ≥16 considered to have clinically significant depressive symptoms [23].

Data analysis

There were 697 children enrolled in the trial. Thirty-seven children did not have teacher-reported SCBE measures at baseline; of these, three children were excluded because none of the collected recalls were deemed valid, and 133 were excluded because no dietary information was provided. Thus, the analytic sample included 524 children. The parents/guardians who took part in the study were mostly biological mothers (90%), some biological fathers (4%) or other relatives (4%), and a few were foster parents (1%), or other (1%). The analytic sample did not differ from the baseline study population according to the sociodemographic characteristics listed in Table 1. All analyses were stratified by sex. This decision was made a priori, and sex differences were confirmed in preliminary interaction models ($P < 0.05$ for sodium intake model and $P < 0.1$ for added sugar models).

First, the mean ± standard deviation (SD) externalizing behavior T-scores at baseline according to baseline child and household covariates were examined. The mean ± SD percentage of Calories from added sugar intake and sodium (mg/1000 Calories) at follow-up according to baseline child and household covariates were also examined. The P values of unadjusted associations were obtained using linear mixed effects regression models with the

Table 1 Characteristics of the study population

Baseline child and household correlates	Mean ± SD (unless otherwise specified)
Child's age, months	49.5 ± 6.2
Male sex, %	48
Overweight/obese, %	34
Physical activity, hours/wk[a]	18.5 ± 10.9
Screen time, hours/day[b]	2.6 ± 1.6
Added sugar intake, % of total Calories[c]	12.9 ± 6.1
Sodium intake, mg/1000 Calories[d]	1604 ± 332
Externalizing SCBE T-score[e]	51.9 ± 9.4
Parent/guardian education level, %	
Did not graduate HS	15
HS graduate/GED	33
Post-HS education	52
Household income-to-needs ratio[f]	0.86 ± 0.54
Parent/guardian CES-D score[g]	
≥ 16, depressed, %	30
Child race/ethnicity	
White, non-Hispanic, %	51

[a]There are not consistent physical activity recommendations for children <6 in the US, although Canadian and Australian recommendations are 3 h/day (21 h/week) [40]
[b]Recommendations for children under 5 years are <2 h/day [41]
[c]US dietary recommendations are <10% of total Caloric intake from added sugar per day [20]
[d]US dietary recommendations are <2300 mg per day [20]; depending on Calorie needs which range from 1200 to 2000 Calories in this age group, that equates to >1150 mg/1000 Calories to >1917 mg/1000 Calories
[e]An externalizing SCBE T-score of 70 is considered the cutoff for externalizing behavior [6]
[f]An income-to-needs poverty ratio < 2 is classified as poverty [42, 43]
[g]The CES-D scores range from 0 to 60, with a score of 16 or greater considered at risk of clinical depression [22]

nutrient intake or behavior scores as the outcome and the baseline covariate as the predictor. Clustering by classroom was accounted for in all models by using a random intercept term. To determine the primary food sources of sodium and added sugar intake, the total amount of sodium and added sugar was analyzed at the food group (specified by the NDSR software) level. The sodium and added sugar content from every food item consumed (including all children and both time points) was summed and then the percentage of sodium or added sugar contributed by each food group (specified by NDSR) was calculated. The top 10 food group sources of each nutrient were ranked according to percentage contributed.

To evaluate the crude association between baseline externalizing behavior and continuous percentage of Calories from added sugar or mg of sodium/1000 Calories at follow-up, linear mixed effects regression models were utilized, with the nutrient as the outcome and continuous externalizing behavior T-score as the exposure. A random intercept for classroom was used to account for clustering (since children in the same classroom may be more similar in terms of diet and behavior), and total energy intake at follow-up was accounted for.

In adjusted analyses, models included indicator variables for child race/ethnicity, quartiles of income-to-needs ratio, and a dichotomous variable for overweight/obese status. These covariates were chosen based on prior knowledge. Intervention arm was not treated as a potential confounder because the exposure (baseline externalizing behavior score) was assumed to be equally distributed among intervention arms. We evaluated this assumption in sensitivity analyses where we adjusted for intervention arm. All analyses were performed in Stata 14.0.

Results

The mean age ± SD of the children at baseline was 4.1 ± 0.5 y; 48% were boys (Table 1).

The mean standardized externalizing score ± SD for boys at baseline 51.7 ± 9.4, and for girls it was 52.2 ± 9.5. Girls who were overweight/obese and from households with lower income-to-needs ratio at baseline had higher levels of baseline externalizing behavior (Table 2).

The mean percentage of Calories from added sugar ± SD at follow-up was 12.9 ± 5.9 among boys; it was 12.8 ± 6.3 among girls. The mean sodium intake ± SD (mg/1000 Calories) for boys at follow-up was 1596 ± 333. For girls it was 1610 ± 332 mg/1000 Calories. Sixty-nine percent of boys and 65% of girls consumed higher than recommended intake from added sugar (≥ 10% of total Calories) at follow-up. Fifty-one percent of boys and 47% of girls had higher than recommended average sodium intakes (≥ 3200 mg/day) at follow-up. The highest food source of added sugar in this population was soda, whereas meat, poultry, and fish recipes were the highest source of sodium (Additional file 1: Table S1). In both boys and girls, higher levels of parent/guardian-reported screen time were associated with a higher percentage of Calories from added sugar at follow-up (Table 3). For boys, those whose mothers had a CESD score ≥ 16 had a higher % of Calories from added sugar at follow-up. White, non-Hispanic children had a lower average intake of mg sodium/1000 Calories at follow-up than children of other race/ethnicities (Table 3). Among girls only, being overweight/obese was associated with higher mg sodium/1000 Calories at follow-up than the referent group.

There was a positive association between externalizing behavior at baseline and added sugar intake at follow-up among boys (Table 4). After adjustment for potential confounders, every 5 points lower externalizing T-score (more externalizing behavior) was associated with a 0.6 higher percentage of added sugar per total Calories (95% CI 0.2 to 1.1; P value = 0.008). In contrast, girls with higher levels of externalizing behavior had lower

Table 2 Mean ± SD externalizing SCBE T-scores[a] at baseline, according to baseline correlates

Baseline child and household correlates	Boys		Girls	
	N	Externalizing SCBE T-score, mean ± SD	N	Externalizing SCBE T-score, mean ± SD
Child's age				
3 y	92	51.2 ± 9.2	99	52.1 ± 9.9
4 y or older	156	52.0 ± 9.6	171	52.2 ± 9.2
P value[b]		0.40		0.80
Child's race/ethnicity				
White, non-Hispanic	126	52.3 ± 8.3	139	51.3 ± 8.8
Hispanic or not White	123	51.1 ± 10.4	132	53.2 ± 10.1
P value		0.26		0.16
Overweight/obese status				
Not overweight/obese	150	52.5 ± 9.5	194	53.3 ± 9.2
Overweight/obese	98	50.5 ± 9.2	76	49.4 ± 9.7
P value		0.11		0.002
Physical activity, hours/wk				
< 7	28	52.1 ± 11.1	26	54.4 ± 8.5
7 to <14	54	50.3 ± 8.9	70	51.4 ± 10.2
14 to <24	74	52.6 ± 9.7	79	51.4 ± 8.6
≥ 24	73	52.2 ± 8.9	63	52.3 ± 10.3
P value		0.94		0.84
Screen time, hours/day				
< 1.5	53	51.8 ± 10.1	62	51.2 ± 9.7
1.5 to <2.5	66	52.2 ± 8.7	82	52.0 ± 9.5
2.5 to <3.5	57	51.8 ± 9.8	56	51.1 ± 9.5
≥ 3.5	56	51.4 ± 9.4	47	54.3 ± 9.5
P value		0.66		0.13
Parent/guardian education level				
Did not graduate HS	36	53.8 ± 9.1	42	54.6 ± 9.8
HS graduate/GED	81	51.7 ± 9.4	92	50.2 ± 9.4
Post-HS education	134	51.1 ± 9.5	135	52.8 ± 9.1
P value		0.45		0.50
Household income-to-needs ratio				
Quartile 1, <0.47	46	53.5 ± 10.5	66	49.6 ± 9.0
Quartile 2, ≥0.47 to <0.76	55	51.6 ± 10.3	58	54.3 ± 8.8
Quartile 3, ≥0.76 to <1.12	56	52.2 ± 9.2	55	52.5 ± 10.8
Quartile 4, ≥1.12	52	51.4 ± 8.3	55	53.2 ± 9.4
P value		0.91		0.05
Parent/guardian CES-D score				
< 16, not depressed	168	51.9 ± 9.6	163	52.5 ± 9.5
≥ 16, depressed	65	51.6 ± 9.3	80	51.1 ± 9.8
P value		0.35		0.34

[a]Higher T-scores on the SCBE indicate lower levels of externalizing behavior
[b]From a linear mixed effects model with externalizing SCBE T-score as the outcome and a continuous variable for each ordinal sociodemographic predictor. For nominal categorical variables, a type III F test was used. A random intercept was specified to account for clustering by classroom

Table 3 Mean ± SD added sugar and sodium intake at follow-up according to baseline correlates

		Boys			Girls	
Baseline child and household correlates	N	Added sugar, % of total Calories	Sodium, mg/1000 Calories	N	Added sugar, % of total Calories	Sodium, mg/1000 Calories
Child's age						
3 y	92	12.5 ± 7.3	1586 ± 375	99	12.6 ± 6.5	1601 ± 326
4 y or older	156	13.2 ± 5.0	1599 ± 308	171	13.0 ± 6.1	1614 ± 336
P value[1]		0.39	0.99		0.16	0.55
Child's race/ethnicity						
White, non-Hispanic	126	13.5 ± 6.0	1539 ± 308	139	12.4 ± 6.3	1562 ± 313
Hispanic or not White	123	12.3 ± 5.8	1661 ± 334	132	13.5 ± 6.2	1663 ± 347
P value		0.07	0.003		0.43	0.02
Overweight/obese status						
Not overweight/obese	150	12.7 ± 5.5	1569 ± 345	194	12.8 ± 6.0	1587 ± 314
Overweight/obese	98	13.2 ± 6.5	1632 ± 315	76	13.1 ± 7.0	1666 ± 370
P value		0.66	0.12		0.78	0.03
Physical activity, hours/wk						
< 7	28	12.9 ± 5.5	1598 ± 301	26	13.6 ± 6.4	1609 ± 378
7 to <14	54	12.6 ± 5.5	1601 ± 324	70	13.1 ± 7.0	1625 ± 362
14 to <24	74	13.1 ± 5.8	1617 ± 328	79	12.7 ± 5.6	1651 ± 310
≥ 24	73	13.2 ± 6.6	1588 ± 376	63	12.4 ± 5.9	1598 ± 323
P value		0.56	0.70		0.61	0.67
Screen time, hours/day						
< 1.5	53	12.3 ± 4.3	1548 ± 313	62	11.6 ± 5.3	1576 ± 319
1.5 to <2.5	66	12.2 ± 5.7	1627 ± 308	82	13.1 ± 5.6	1679 ± 363
2.5 to <3.5	57	13.0 ± 5.4	1601 ± 424	56	13.2 ± 6.0	1616 ± 295
≥ 3.5	56	15.0 ± 7.7	1629 ± 284	47	14.1 ± 8.1	1610 ± 324
P value		0.01	0.28		0.01	0.81
Parent/guardian education level						
Did not graduate HS	36	13.2 ± 7.9	1623 ± 333	42	13.2 ± 7.3	1591 ± 355
HS graduate/GED	81	12.4 ± 5.6	1644 ± 318	92	12.5 ± 6.3	1626 ± 356
Post-HS education	134	13.2 ± 5.5	1560 ± 341	135	13.1 ± 6.0	1608 ± 313
P value		0.81	0.11		0.60	0.55
Household income-to-needs ratio						
Quartile 1, <0.47	46	12.0 ± 5.5	1587 ± 318	66	12.3 ± 5.9	1675 ± 311
Quartile 2, ≥0.47 to <0.76	55	13.4 ± 5.0	1606 ± 405	58	14.6 ± 7.6	1629 ± 333
Quartile 3, ≥0.76 to <1.12	56	13.8 ± 7.4	1631 ± 316	55	13.1 ± 6.1	1557 ± 336
Quartile 4, ≥1.12	52	13.8 ± 6.1	1583 ± 305	55	12.1 ± 5.3	1599 ± 333
P value		0.46	0.41		0.94	0.07
Parent/guardian CES-D score						
< 16, not depressed	168	12.5 ± 4.9	1609 ± 344	163	13.0 ± 6.0	1597 ± 305
≥ 16, depressed	65	14.6 ± 7.6	1588 ± 317	80	12.9 ± 6.8	1688 ± 365
P value		<0.0001	0.14		0.47	0.07

[1]Each *P* value is from a separate linear mixed effects models with added sugar (% of Calorie) or sodium (mg/1000 Calories) as the outcome, the continuous variable (for ordinal characteristics) as the exposure, and total energy intake at follow-up. For nominal variables, a type III F test was used. A random intercept was specified to account for clustering by classroom

Table 4 Association between externalizing SCBE T-scores at baseline and added sugar and sodium intake at follow-up

Baseline externalizing SCBE T-scores[a]	Added sugar intake, % of Calories		Sodium intake, mg/1000 Calories	
	Unadjusted beta (95% CI)[b]	Adjusted beta (95% CI)[b,c]	Unadjusted beta (95% CI)[b]	Adjusted beta (95% CI)[b,c]
Boys				
Per 5-points lower T-score (more externalizing behaviors)	0.5 (0.1, 0.9)	0.6 (0.2, 1.1)	−19 (−41, 3)	−22 (−45, 1)
P value	0.008	0.004	0.09	0.06
Girls				
Per 5-point lower T-score (more externalizing behaviors)	−0.5 (−0.9, −0.1)	−0.6 (−1.0, −0.1)	28 (8, 49)	24 (1, 46)
P value	0.03	0.01	0.007	0.04

[a]Higher number of externalizing behaviors is equivalent to a lower T-score
[b]From a linear mixed effects regression model with continuous added sugar (% of Calories) or sodium intake (mg/1000 Calories) as the outcome and continuous externalizing SCBE T-scores as the predictor, expressed per 5 points. The model also accounted for total energy intake at follow-up. A random intercept was specified to account for clustering by classroom
[c]Adjusted for race/ethnicity, quartiles of income-to-needs ratio, and overweight/obese status at baseline as potential confounders

consumption of added sugars; after potential confounder adjustment, every 5 points lower externalizing T-score was related to 0.6 lower percentage intake (95% CI -1.0 to −0.1; *P* value = 0.01).

There was not a statistically significant association between externalizing behavior and mg sodium/1000 Calories among boys (Table 4). However, after adjustment for potential confounding, there was a marginally statistically significant inverse association between externalizing behavior at baseline and sodium intake at follow up. For every 5 points lower externalizing T-score, there was a 22 mg/1000 Calories lower sodium intake at follow-up (95% CI -45 to 1; *P* value = 0.06). In contrast, there was a positive association between externalizing behavior at baseline and sodium intake at follow-up among girls. In adjusted analysis, every 5 points lower externalizing T-score was related to 24 mg/1000 Calories greater sodium intake at follow-up (95% CI 1 to 46; *P* value = 0.04). Further adjustment for intervention arm did not alter the estimates in any of the models.

Discussion

In this group of low-SES Michigan preschoolers, we found that preschool boys with higher levels of externalizing behavior had higher percentage of intake from added sugar but lower mg sodium/1000 Calories (after confounder adjustment). In contrast, girls with higher levels of externalizing behavior in the fall of one school year had higher intake of sodium/1000 Calories but lower intake of added sugar as a percentage of total Calories during the spring of the same school year.

Our study findings are in line with some other studies, although the sex-dependency of the findings is distinct. Our findings among boys are in agreement with those of a longitudinal study among Norwegian preschoolers [9]. This study showed that children with higher externalizing behavior (based on the Child Behavior Checklist) at 1.5 y of age were more likely to consume sweet drinks and sweet foods daily at 7 y of age. However, this study did not report on sodium intake, and it is also unclear whether the association was sex-specific. Other studies that specifically examined externalizing behaviors in relation to diet were cross-sectional. One study among 453 Belgian children between 5 and 12 y of age found a positive association between parent-reported "problem" behaviors (including emotional problems, conduct problems, hyperactivity problems, peer problems, and antisocial behavior) and sweet and fatty food consumption [12]. Another study among Iranian adolescents found that children with higher self-reported violent behaviors also had higher consumption of salty snacks [7]. There was no association between violent behaviors and sweet food consumption, but it could have been masked by not stratifying on sex. Finally, a cross-sectional population-based survey among Nova Scotian 5th graders found that those who had higher levels of self-reported externalizing behaviors had lower diet quality scores [24]. Lower diet quality often is related to high sodium and/or added sugar levels, although the study did not examine particular nutrients.

Our findings are also in agreement with some of the literature on stress and dietary patterns. For example, one study among 4th through 6th graders from rural Texas found that those with higher perceived stress also reported greater frequency of consumption of salty snacks or high sugar foods [25]. An experimental study among 43 US children aged 5–9 y of age found that greater stress-related cortisol was related to greater energy intake in the absence of hunger among the 8–9 year olds, although not in the younger children [26]. Finally, another US study showed that high stress self-efficacy (i.e., ability to handle stress) among fourth-graders was related to higher fruit and vegetable intake [27]. In summation, it is possible that the associations we observed

between externalizing behavior and diet could be related to stress and emotional eating. This is plausible, given that children with externalizing behavior may also have higher levels of stress, anxiety and/or depressive symptoms [28, 29]. However, the lack of specificity of foods in prior studies precludes in-depth comparisons. In several of the studies on stress and eating, "comfort foods" including sugary, salty, and energy-dense foods, were assumed to be eaten together and were not further disentangled into sodium and added sugar intake. Prior assumptions about "comfort foods" are problematic because they may not hold in every population. In addition, it is important to separate added sugar from sodium because high intake of sodium and high intake of added sugar may have different health consequences that should be monitored accordingly (e.g. dental caries for added sugar and high blood pressure for sodium). Finally, one of the limitations in most prior studies was the lack of stratification by sex, so associations in the opposite directions could have been hidden.

There are a few potential mechanisms to explain the findings specifically related to externalizing behavior. One is that children with externalizing behaviors exhibit less effortful control and higher impulsivity [30], and higher impulsivity has been related to eating in the absence of hunger [31]. It could be that girls with externalizing behavior eat foods with higher sodium content in the absence of hunger while boys with externalizing behavior eat foods (or consume drinks) with higher added sugar in the absence of hunger. The notion that boys with externalizing behavior may prefer sweet foods is supported by a few adult studies. For example, in one small laboratory study among adults, men who were put through an acute stressor test reported a higher appetite for sweet foods than the control group, but there was a null association for women [32]. In another US study among young men, after watching a violent video game, there was a tendency towards sweet food consumption, but not salty, savory, or fatty food [33]. One possible physiological explanation for the association between aggression and higher sugar consumption is that glucose is required in order for the brain to control aggressive impulses [34]. In support, an experimental study among US undergraduates showed that those who consumed a glucose beverage immediately before being provoked showed reduced aggression compared to those who consumed a placebo drink, and this was most evident among those who scored higher on a pre-experiment aggressive trait survey. Although the authors did not conduct stratified analysis, males had higher aggressive trait scores than females. In contrast, there may be an explanation for sodium preference among females with externalizing behavior. It has been posited that because the renin-angiotensin-aldosterone system is involved in both sodium regulation and the stress response, sodium intake may help to alleviate the short-term effects of psychosocial stress [35]. Furthermore, this association is thought to be most evident among females because their average absolute salt intake is lower than males'. The main caveat to these potential mechanisms is the fact that the research is mostly from adult population and may not be generalizable to preschool-aged children.

Another possible explanation of the study findings is that parent/guardians of externalizing children may try to pacify them with highly-palatable foods [36], which are likely to contain high amounts of added sodium and/or sugar. One reason for the sex difference is that girls could be fed differently than boys due to societal expectations. For example, parents may feel more pressure to shield their daughters from gaining weight than their sons; thus, they may offer foods high in sodium (although not necessarily snack foods) rather than highly sugary foods to daughters due to the perception that sugar causes weight gain. The finding of lower percentage of added sugar intake among girls with higher externalizing behaviors supports this notion. Furthermore, given that the most common sources of sodium consumption were meat dishes, it is possible that girls with externalizing behavior did not have greater salty snack consumption, but rather ate higher proportions of salty entrees at lunch or dinner. Future studies on behavior and diet should consider sex as a potential effect modifier to evaluate the reproducibility of our findings and to further elucidate the potential mechanisms, especially among young children. Understanding mechanisms involved in these associations could inform interventions designed to reduce added sugar and sodium intake among children with externalizing behavior problems. Although parents/guardians would likely be the target of these interventions, teachers may be able to recognize externalizing behaviors that parents/guardians do not perceive; and thus could play a vital role in educating parents/guardians. Future studies investigating the food consumed at school versus home could further elucidate the role that teachers and the school environment could play in establishing healthy eating habits.

Although there were clear differences in added sugar and sodium intake according to externalizing behavior and sex, only about one-third of the children met added sugar recommendations and one-half met sodium guidelines. This is concerning, because the dietary habits and preferences established early in life tend to track into adulthood [37]. Furthermore, both added sugar and sodium intake during childhood are related to adverse health outcomes, even in early life [3, 4]. Thus, although the children with externalizing behavior problems were more likely to consume either added sugar or sodium, the entire population could benefit from reductions in

sodium and added sugar in the food supply. This could be achieved by programs such as the National Salt Reduction Initiative, a US program which calls for voluntary reductions in sodium content of packaged foods and restaurants [38]. Policy-level recommendations for reducing added sugar content of products should also be considered. At the parent/guardian level, providing more specific information on specific foods to avoid or limit to reduce consumption of added sugar or sodium could prove useful. This is more pertinent for sodium, as many public health campaigns currently focus on sugar consumption.

This study has strengths and limitations. One strength was the repeated measures of both diet and behavior, which allowed us to examine the directions using longitudinal analysis. The prospective design was also important for reducing potential recall bias, because the behavior of the child at baseline most likely did not affect the perception of diet at follow-up and vice versa. Another was the incorporation of classroom as a clustering variable in our models; this ensures our standard errors were valid. Another strength was that diet was reported by evaluators unaware of the externalizing behavior score of the child. The fact that the evaluators of externalizing behavior were teachers may increase the objectivity of these scores. There were also limitations. We had to rely on multiple 24-h recalls for sodium and added sugar measurements rather than biomarkers (e.g., urinary sodium). Diet measurements are always subject to measurement error, and diet among young children can be especially difficult to measure [39]. These study findings may not be generalizable to other US populations, since all of the families were of low SES. We did not have a measure of the child's stress in order to evaluate the correlation between child stress and externalizing behavior. Finally, there could be unmeasured confounding that we were not able to account for.

Conclusions

In summary, we found that young children with teacher-reported externalizing behavioral problems had higher proportions of sodium or added sugar in their diet at follow-up in a sex-specific manner. Girls with higher externalizing behavior had higher sodium intake/1000 Calories at follow-up and lower percentage of Calories from added sugar, whereas boys with higher externalizing behavior at baseline had higher percentage of added sugar and lower sodium intake/1000 Calories at follow-up. Further studies are warranted to examine the mechanisms for these associations and to understand the most effective ways to encourage healthy eating habits in boys versus girls with externalizing behaviors. Dietary-based interventions and recommendations directed towards parents/guardians of preschoolers may need to be tailored based on the behavior and sex of the child.

Abbreviations

CDC: Center for Disease Control; CES-D: Center for Epidemiologic Studies Depression; GED: General Educational Development; NDSR: Nutrition Data System for Research program; POPS: Preschool Obesity Prevention Series; SCBE: Social Competence and Behavior Scale; SD: Standard deviation; SES: Socioeconomic status; US: United States; USDA: United States Department of Agriculture

Acknowledgements

Not applicable.

Funding

This study was funded by the United States Department of Agriculture (USDA)/ National Institute of Food and Agriculture/Agriculture and Food Research Initiative (NIFA/AFRI) Grant # 2011–68,001-30,089, PI J. Lumeng. This work also utilized Core Services supported by grant DK089503 (MNORC) of NIH to the University of Michigan; PI Charles Burant.

Authors' contributions

ECJ, KEP, and AM conceived of the research questions. ECJ carried out analysis and drafted the paper. ALM, JCL, MAH, HBH, KEP, and DC conceived of the initial project, contributed to the development of the study design and obtained funding, and developed and carried out the interventions, and revised the current manuscript. NK provided statistical support and revised the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Department of Nutritional Sciences, School of Public Health, Ann Arbor, MI, USA. [2]Center for Human Growth and Development, University of Michigan, Ann Arbor, MI, USA. [3]Department of Health Behavior and Health Education, School of Public Health, Ann Arbor, MI, USA. [4]Department of Pediatrics, University of Michigan, Ann Arbor, MI, USA. [5]Department of Human Development and Family Studies, Michigan State University, East Lansing, MI, USA. [6]College of Nursing, Michigan State University, East Lansing, MI, USA. [7]Health and Nutrition Institute, Michigan State University Extension, East Lansing, MI, USA. [8]Department of Nutritional Sciences, University of Michigan School of Public Health, 1415 Washington Heights, Ann Arbor, MI 48109, USA.

References

1. Ervin RB, Kit BK, Carroll MD, Ogden CL. Consumption of added sugar among U. S. children and adolescents, 2005-2008. NCHS Data Brief. 2012;87:1–8.
2. Cogswell ME, Yuan K, Gunn JP, Gillespie C, Sliwa S, Galuska DA, Barrett J, Hirschman J, Moshfegh AJ, Rhodes D, et al. Vital signs: sodium intake among U.S. school-aged children - 2009-2010. MMWR Morb Mortal Wkly Rep. 2014;63:789–97.
3. Vos MB, Kaar JL, Welsh JA, Van Horn LV, Feig DI, Anderson CA, Patel MJ, Cruz Munos J, Krebs NF, Xanthakos SA, Johnson RK: Added Sugars and Cardiovascular Disease Risk in Children: A Scientific Statement From the American Heart Association. Circulation. 2017;135(19):e1017-34.
4. Appel LJ, Lichtenstein AH, Callahan EA, Sinaiko A, Van Horn L, Whitsel L. Reducing Sodium Intake in Children: A Public Health Investment. J Clin Hypertens (Greenwich). 2015;17:657–62.
5. Moynihan PJ, Kelly SA. Effect on caries of restricting sugars intake: systematic review to inform WHO guidelines. J Dent Res. 2014;93:8–18.
6. LaFreniere PJ, Dumas JE: Social Competence and Behavior Evaluation, Preschool Edition (SCBE). 1995.
7. Zahedi H, Kelishadi R, Heshmat R, Motlagh ME, Ranjbar SH, Ardalan G, Payab M, Chinian M, Asayesh H, Larijani B, Qorbani M. Association between junk food consumption and mental health in a national sample of Iranian

children and adolescents: the CASPIAN-IV study. Nutrition. 2014;30:1391–7.
8. Oddy WH, Robinson M, Ambrosini GL, O'Sullivan TA, de Klerk NH, Beilin LJ, Silburn SR, Zubrick SR, Stanley FJ. The association between dietary patterns and mental health in early adolescence. Prev Med. 2009;49:39–44.
9. Vollrath ME, Stene-Larsen K, Tonstad S, Rothbart MK, Hampson SE. Associations between temperament at age 1.5 years and obesogenic diet at ages 3 and 7 years. J Dev Behav Pediatr. 2012;33:721–7.
10. Kim KJ, Conger RD, Elder GH Jr, Lorenz FO. Reciprocal influences between stressful life events and adolescent internalizing and externalizing problems. Child Dev. 2003;74:127–43.
11. Lumeng JC, Miller A, Peterson KE, Kaciroti N, Sturza J, Rosenblum K, Vazquez DM. Diurnal cortisol pattern, eating behaviors and overweight in low-income preschool-aged children. Appetite. 2014;73:65–72.
12. Michels N, Sioen I, Braet C, Eiben G, Hebestreit A, Huybrechts I, Vanaelst B, Vyncke K, De Henauw S. Stress, emotional eating behaviour and dietary patterns in children. Appetite. 2012;59:762–9.
13. Michels N, Sioen I, Boone L, Braet C, Vanaelst B, Huybrechts I, De Henauw S. Longitudinal association between child stress and lifestyle. Health Psychol. 2015;34:40–50.
14. Gubbels JS, Kremers SP, Stafleu A, Dagnelie PC, Goldbohm RA, de Vries NK, Thijs C: Diet-related restrictive parenting practices. Impact on dietary intake of 2-year-old children and interactions with child characteristics. Appetite 2009; 52**:**423-429.
15. Dallman MF, Pecoraro N, Akana SF, La Fleur SE, Gomez F, Houshyar H, Bell ME, Bhatnagar S, Laugero KD, Manalo S. Chronic stress and obesity: a new view of "comfort food". Proc Natl Acad Sci U S A. 2003;100:11696–701.
16. Miller AL, Horodynski MA, Herb HE, Peterson KE, Contreras D, Kaciroti N, Staples-Watson J, Lumeng JC. Enhancing self-regulation as a strategy for obesity prevention in Head Start preschoolers: the growing healthy study. BMC Public Health. 2012;12:1040.
17. Webster-Stratton C, Reid MJ. The Incredible Years Parents, Teachers, and Children Training Series: A Multifaceted Treatment Approach for Young Children with Conduct Disorders. In: Weisz J, Kazdin A, editors. Evidence-based psychotherapies for children and adolescents. 2nd ed. New York: Guilford Publications; 2010.
18. Conway JM, Ingwersen LA, Moshfegh AJ. Accuracy of dietary recall using the USDA five-step multiple-pass method in men: an observational validation study. J Am Diet Assoc. 2004;104:595–603.
19. Rosner B: Percentage points for a generalized ESD many-outlier procedure. Technometrics. 1983;25(2):165–72.
20. 2015–2020 Dietary Guidelines for Americans. 8 edition: U.S. Department of Health and Human Services and U.S. Department of Agriculture; 2015.
21. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Guo SS, Wei R, Mei Z, Curtin LR, Roche AF, Johnson CL: CDC growth charts: United States. Adv Data 2000**:**1–27.
22. Radloff LS. The CES-D scale a self-report depression scale for research in the general population. Appl Psychol Meas. 1977;1:385–401.
23. Beeber LS, Meltzer-Brody S, Martinez M, Matsuda Y, Wheeler AC, Mandel M, LaForett D, Waldrop J: Recognizing Maternal Depressive Symptoms: An Opportunity to Improve Outcomes in Early Intervention Programs. Matern Child Health J. 2017;21(4):883–92
24. Wu X, Kirk SF, Ohinmaa A, Veugelers P. Health behaviours, body weight and self-esteem among grade five students in Canada. Spring. 2016;5:1099.
25. Jenkins SK, Rew L, Sternglanz RW. Eating behaviors among school-age children associated with perceptions of stress. Issues Compr Pediatr Nurs. 2005;28:175–91.
26. Francis LA, Granger DA, Susman EJ. Adrenocortical regulation, eating in the absence of hunger and BMI in young children. Appetite. 2013;64:32–8.
27. Tate EB, Spruijt-Metz D, Pickering TA, Pentz MA. Two facets of stress and indirect effects on child diet through emotion-driven eating. Eat Behav. 2015;18:84–90.
28. Koss KJ, Mliner SB, Donzella B, Gunnar MR. Early adversity, hypocortisolism, and behavior problems at school entry: A study of internationally adopted children. Psychoneuroendocrinology. 2016;66:31–8.
29. Blain-Arcaro C, Vaillancourt T: Longitudinal Associations between Depression and Aggression in Children and Adolescents. J Abnorm Child Psychol. 2017; 45(5):959-70.
30. Eisenberg N, Valiente C, Spinrad TL, Liew J, Zhou Q, Losoya SH, Reiser M, Cumberland A. Longitudinal relations of children's effortful control, impulsivity, and negative emotionality to their externalizing, internalizing, and co-occurring behavior problems. Dev Psychol. 2009;45:988–1008.
31. Nederkoorn C, Dassen FC, Franken L, Resch C, Houben K. Impulsivity and overeating in children in the absence and presence of hunger. Appetite. 2015;93:57–61.
32. Oliver G, Wardle J, Gibson EL. Stress and food choice: a laboratory study. Psychosom Med. 2000;62:853–65.
33. Siervo M, Sabatini S, Fewtrell MS, Wells JC. Acute effects of violent video-game playing on blood pressure and appetite perception in normal-weight young men: a randomized controlled trial. Eur J Clin Nutr. 2013;67:1322–4.
34. Denson TF, von Hippel W, Kemp RI, Teo LS. Glucose consumption decreases impulsive aggression in response to provocation in aggressive individuals. J Exp Soc Psychol. 2010;46:1023–8.
35. Goldstein P, Leshem M. Dietary sodium, added salt, and serum sodium associations with growth and depression in the U.S. general population. Appetite. 2014;79:83–90.
36. Stifter CA, Anzman-Frasca S, Birch LL, Voegtline K. Parent use of food to soothe infant/toddler distress and child weight status. An exploratory study. Appetite. 2011;57:693–9.
37. Mikkila V, Rasanen L, Raitakari OT, Pietinen P, Viikari J. Consistent dietary patterns identified from childhood to adulthood: the cardiovascular risk in Young Finns Study. Br J Nutr. 2005;93:923–31.
38. Curtis CJ, Clapp J, Niederman SA, Ng SW, Angell SY. US Food Industry Progress During the National Salt Reduction Initiative: 2009-2014. Am J Public Health. 2016;106:1815–9.
39. Burrows TL, Martin RJ, Collins CE. A systematic review of the validity of dietary assessment methods in children when compared with the method of doubly labeled water. J Am Diet Assoc. 2010;110:1501–10.
40. Colley RC, Garriguet D, Adamo KB, Carson V, Janssen I, Timmons BW, Tremblay MS. Physical activity and sedentary behavior during the early years in Canada: a cross-sectional study. Int J Behav Nutr Phys Act. 2013;10:54.
41. Media and Young Minds. Pediatrics 2016; 138.
42. Citro CF, Michael RT: Measuring Poverty: A New Approach. Washington, D. C.: The National Academies Press; 1995.
43. Lee H, Andrew M, Gebremariam A, Lumeng JC, Lee JM. Longitudinal associations between poverty and obesity from birth through adolescence. Am J Public Health. 2014;104:e70–6.

Food parenting and child snacking

Rachel E. Blaine[1*], Alexandria Kachurak[2], Kirsten K. Davison[3], Rachel Klabunde[4] and Jennifer Orlet Fisher[2]

Abstract

Background: While the role of parenting in children's eating behaviors has been studied extensively, less attention has been given to its potential association with children's snacking habits. To address this gap, we conducted a systematic review to describe associations between food parenting and child snacking, or consuming energy dense foods/foods in between meals.

Methods: Six electronic databases were searched using standardized language to identify quantitative studies describing associations of general and feeding-specific parenting styles as well as food parenting practices with snacking behaviors of children aged 2–18 years. Eligible peer-reviewed journal articles published between 1980 and 2017 were included. Data were extracted using a standard protocol by three coders; all items were double coded to ensure consistency.

Results: Forty-seven studies met inclusion criteria. Few studies focused on general feeding (n = 3) or parenting styles (n = 10). Most studies focused on controlling food parenting practices (n = 39) that were not specific to snacking. Parental restriction of food was positively associated with child snack intake in 13/23 studies, while pressure to eat and monitoring yielded inconsistent results. Home availability of unhealthy foods was positively associated with snack intake in 10/11 studies. Findings related to positive parent behaviors (e.g. role modeling) were limited and yielded mixed results (n = 9). Snacking was often assessed using food frequency items and defined post-hoc based on nutritional characteristics (e.g. energy-dense, sugary foods, unhealthy, etc.). Timing was rarely included in the definition of a snack (i.e. chips eaten between meals vs. with lunch).

Conclusions: Restrictive feeding and home access to unhealthy foods were most consistently associated with snacking among young children. Research is needed to identify positive parenting behaviors around child snacking that may be used as targets for health promotion. Detailed definitions of snacking that address food type, context, and purpose are needed to advance findings within the field. We provide suggested standardized terminology for future research.

Keywords: Snacks, Feeding, Food parenting

Background

Childhood overweight and obesity persist as significant health risks for children globally [1, 2]. Given that excessive energy intake is a primary driver for inappropriate weight gain among children, it is not surprising that child snacking has consistently increased in recent decades [3, 4]. Snacking has been defined interchangeably in the literature as foods consumed between meals and/or consuming "snack foods", typically identified as energy-dense and nutrient-poor (i.e. candy, chips, cookies, sugary drinks). Individual study participants may also self-define snacking occasions. The inconsistency across definitions is problematic and limits the generalizability of findings. Snacking in between meals currently contributes an estimated one third of children's daily energy intakes in the United States [5] and a quarter of daily energy for youth in some European nations [6]. Though data on snacking and obesity in children are limited and equivocal, there is evidence that children who snack frequently consume greater energy, have

* Correspondence: rachel.blaine@csulb.edu
[1]Department of Family and Consumer Sciences, California State University, Long Beach, 1250 Bellflower Blvd, FCS FA-15, Long Beach, CA 90840-0501, USA
Full list of author information is available at the end of the article

poorer quality diets, and exhibit other risk factors for excessive weight gain [7, 8].

Although parental influence on children's overall eating behaviors and weight status has been studied extensively [9, 10], less attention has been given to how food parenting might affect the snacking behaviors of children. Food parenting includes both parent feeding practices, the specific behaviors or strategies that parents use to feed their children (i.e. pressuring a child to eat), and feeding styles, the generalized patterns of these practices. General parenting styles (e.g. uninvolved, authoritarian) approximate how caregivers engage with their children through interaction and disciplinary strategies and may also be informative in the context of child snacking, as different styles have been associated with a variety of childhood dietary and weight-related outcomes [11]. Current literature suggests that in order to promote healthy eating habits, parents must strike a balance between setting reasonable limits, providing healthful foods and structured eating occasions, and supporting children's unique food preferences and regulation of appetite [12, 13].

A recent theoretically guided conceptual model of snack-specific food parenting practices [14] identified four domains specific to snack feeding, which included Coercive Control, Permissiveness, Structure, and Autonomy Support. Coercive Control practices, such as restricting food or rewarding children with food, have been linked with increased energy intake, lower diet quality, and increased weight in children [15, 16]. It is surmised that this domain may be particularly important in the context of snacking, as qualitative work suggests parents of young children, often use snack foods as tools to manage children's behaviors [17, 18]. Permissive practices, such as feeding children to provide comfort, or having few rules or limits on snack intake, have been associated with excessive energy intake and elevated body mass index in children [19]. Given the low cost and portability of many processed snack foods, unrestricted access in the home may be especially problematic [20]. Conversely, it has been proposed that positive food parenting that provides Structure (e.g. routines, making healthy foods available) and Autonomy Support (e.g. role modeling, praise) is more likely to encourage children to establish healthy eating habits [21]. However, there are limited findings that describe such practices, and it is not clear what impact they may have on snacking intake among children [14]. Despite limited data, it is likely that overall parenting practices, whether positive or negative, have a differential impact on the quality of snack foods consumed by children.

To provide an overview of prominent findings in the literature, we conducted a systematic review to describe quantitative studies between 1980 and 2017 that have evaluated associations of parenting styles and food parenting practices with child snacking. Given the inconsistency in definitions, we describe all studies utilizing the word(s) snack/snacking, and provide distinctions between how they are measured and defined. We define snacking as consuming foods or beverages between meals, and snack foods are defined as energy-dense, nutrient poor foods/beverages. Snacking behaviors refer to any behaviors related to snacking/consuming snack foods. To our knowledge, this is the first systematic review that assesses food parenting specifically in the context of child snacking. We are aware of one review that assessed the influence of two specific food parenting practices (e.g. parental pressure to eat and restriction) on children's dietary intake [22], but this review did not include a range of parenting behaviors and did not focus specifically on snacking.

The aims of this review were to: 1) present characteristics of studies on parenting and child snacking, including study design, setting, participant demographics, and measures used to assess food parenting, 2) present the frequency with which food parenting practices were characterized in the literature, 3) summarize associations between food parenting practices and child snack intake, 4) describe characteristics of measures of child snacking, and 5) identify recommendations for future research.

Methods

Search criteria

To ensure consistency in data collection and presentation, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist to conduct our search [23] (Additional file 1) and registered our review with PROSPERO (Registration number: CRD42017062520). To standardize abstract review, we employed a protocol containing inclusion and exclusion criteria, along with an electronic search strategy for the study (Additional file 2).

We searched for English-language articles published in peer-reviewed journals in the following electronic databases: CAB Abstracts, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Embase, PsycINFO, PubMed, and Web of Science. Key search terms were used to search titles, abstracts, and Medical Subject Headings and included text related to parents/caregivers (e.g. mother, father, parent), parenting style (e.g. parenting, parent-child relations, child rearing), food parenting (e.g. child feeding, control, restriction, pressure), and child snacking (e.g. snacks). Abstract files were downloaded, screened, assessed for eligibility, and organized by inclusion or exclusion in EndNote X7 by RB and AK. Full-texts of articles were assessed if they met all inclusion criteria.

Eligibility criteria

We included studies published between January 1980 and January 2017 in order to provide a scope of modern literature over the past four decades that reflects current parenting practices as well as those corresponding to increases in obesity prevalence in children over time [1].

Articles were included if they met the following criteria: 1) Measured snacking or snack-related behaviors of children aged 2 – 18 years and 2) Measured the general parenting, feeding style, and/or food parenting practices of the child's parent or primary caregiver in the context of child snacking. We focused on children aged 2 and older to remove studies of infant breastfeeding and/or complementary feeding. We included studies with samples that included children younger than 2 only if solid food snacks were assessed (e.g. sample of toddlers and preschoolers aged 18 months – 5 years), but excluded studies with samples comprised of only children under 2 years.

Experimental studies that assessed children eating in the absence of hunger (EAH), following meals were included. Their protocols were developed to evaluate dimensions of satiety in children, but we believed the general paradigm was relevant because it focused on eating outside of meals [24]. More specifically, these studies evaluated the extent to which a meal suppressed subsequent intake of snack foods.

We excluded studies that did not directly assess primary caregivers (e.g. child care workers, laboratory feeding studies where parent was not present/assessed). We also excluded studies that did not appreciably measure food parenting, such as those solely assessing frequency of family meals or home availability of food (e.g. pantry audit), as these are often markers of other factors such as socioeconomic status.

We also excluded conference abstracts or dissertations because we sought to describe peer-reviewed journal articles. Qualitative studies and reviews were not included because they are not appropriate for drawing inferences about association. Articles were also excluded if their scope was outside the field of child/family nutrition (e.g. focus on oral health and dental caries) or only studied children with special healthcare needs (e.g. eating disorders, developmental delays) due to lack of applicability to the general population.

Data extraction and analysis

To ensure consistency all full-text articles were extracted and double coded by researchers (AK, RK, RB); 25% were triple coded using the constant comparative method [25] to identify discrepancies in protocol interpretation and to reach a consensus when clarifying questions. Fewer than 5% of data items entered were in disagreement, and thus the protocol and data extraction tool were deemed appropriate for use.

Data extraction of full-texts occurred using a predefined list of items to be coded (Additional file 3) that were collected using Survey Gizmo for ease of data entry and summarization. After data extraction was complete, two researchers (AK and RK) also assessed study quality using existing tools: the National Institutes of Health Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies [26] and the Quality Assessment Tool for Quantitative Studies designed to assess experimental studies [27]; 25% of studies were double coded to ensure study quality tool consistency and no disagreement was found. We used Stata/SE 12.1 (Stata Corporation, College Station, Texas, USA) to obtain frequencies for categorical variables and mean values and standard deviations for continuous variables.

Study characteristics

We documented general study information such as publication date, country, journal name, and study design. To describe study samples, we assessed age of target children, populations recruited (e.g. low-income, minority), and sample sizes of caregivers/children. To describe participant demographics, we examined caregiver race/ethnicity, gender (i.e. mothers vs. fathers), and level of education.

We described the extent to which studies reported on important demographic information associated with child feeding (e.g. parent education, race/ethnicity, inclusion of male caregivers) as well as instrument quality to see how often validated tools were used in their intended way (e.g. all items vs. select subscales vs. individual items), and the level of dietary assessment (e.g. 24-h recall vs. food frequency questionnaire) [9, 28]. Additionally, we described whether or not child snacking outcomes were predefined by the researchers before the outset of data collection, or defined post-hoc during analysis. We also examined the sample sizes and journals of publication to provide a general discussion about the diversity in publication. Finally, we described quality ratings for cohort and cross-sectional studies (Range: Good, Fair, Poor) and experimental studies (Range: Strong, Moderate, Weak) using existing tools [26, 27].

Measures of food parenting

We collected data on whether general parenting style vs. specific practices were assessed and whether measures were snacking-specific. We also identified the type of practices studied using a pre-determined list of specific snack-feeding practices (e.g. role modeling, rewarding behavior) based upon a recently published conceptual model of food parenting practices specific to child snacking [14]. Practices were organized by four higher dimensions from the conceptual model: Coercive Control, Structure, Autonomy Support, and Permissiveness.

Association between food parenting and child snacking

We summarized study results on the association between food parenting and child snacking outcomes. We post-coded these result summaries as positive, negative, null, or

mixed in order to summarize trends in association. Since both the exposure (food parenting) and outcome (child snacking) were measured in myriad ways and not generalizable quantitatively, we opted to conduct a narrative summary of our findings using tables and figures at the level of each individual study.

Measures of child snacking

We examined the types of measures used to assess child snacking, and collected data on the source (i.e. parent vs. child), use of validated tools, how "snack" was defined in both the tools and in the analysis post-hoc, and what types of contextual information was presented about child snacking (e.g. timing, nutrient profile, frequency).

Results

Study characteristics

Our search yielded 2846 articles, of which 84 duplicates were identified and removed (Fig. 1). After reviewing 2762 abstracts based upon inclusion and exclusion criteria (Table 1), 2696 were excluded and 66 were included for full-text assessment. Of full texts reviewed, 47 were included for analysis [13, 18, 29–73]. The primary reason for exclusions was that parenting/feeding practices were not assessed.

We present a brief narrative description of each study, the measures used, and study quality in Table 2 and a summary of overall study characteristics in Table 3. Nearly half of all studies (n = 31) were published within the past 5 years. More than 90% of all studies occurred in four Western nations: the United States (n = 14, 29.8%), the Netherlands (n = 12, 25.5%), Australia (n = 8, 17.0%), and the United Kingdom (n = 8, 17.0%). With the exception of *Appetite*, which published 36% of eligible articles, studies were published in a variety of journals (n = 25), with most journals publishing 1–2 studies each. There was significant diversity in authorship as well, with no author contributing more than 3 studies to the literature.

The majority of studies were cross-sectional (72.3%, n = 34), followed by longitudinal (12.8%, n = 6), and experimental (14.9%, n = 7). A unique grouping of experimental studies focused on EAH (n = 6). Most studies consisted of caregivers only (n = 15, 31.9%) or caregiver-child dyads (n = 21, 44.7%), compared with those recruiting children who self-reported on caregivers' practices (n = 11, 23.4%). The mean sample size of participants or caregiver-child dyads was n = 693 (standard deviation: 789, range: 35–2814, median: 377). Most studies focused on elementary-aged children (n = 30, 63.8%). About 40% of studies (n = 20) reported on race/ethnicity of caregivers. While the majority of samples were predominantly white, a third of studies included samples that were predominantly non-white (n = 6).

Overall, quality was high across cross-sectional and observational articles, with 39/40 receiving a Good quality rating (Range: Good, Fair, Poor) (Table 2). Among experimental studies (n = 6) quality was weaker due to a lack of reporting study participation rates (Range: Strong, Moderate, Weak); most experimental studies scored as moderate (n = 4) compared with weak (n = 1) or strong (n = 1).

Most studies defined the gender of caregivers (n = 29, 55.3%) who were predominantly female. Forty percent of studies exclusively contained mothers/female caregivers (n = 12); when included, males made up 11% of caregiver samples on average. Although these studies distinguished between male and female caregivers, only about one third (n = 10) explicitly mentioned the word "father" or defined the number of fathers in their sample. Most studies reported caregiver level of education (n = 34, 72.3%), with two studies reporting that their samples contained at least 40% of caregivers with a low level of education.

Measures of food parenting

The most commonly used tool adapted to measure food parenting practices was the Child Feeding Questionnaire (n = 16, 34.0%) [74], followed by the Comprehensive Feeding Practices Questionnaire (n = 3) [75]. General feeding styles (n = 3) or parenting styles (n = 10) were examined in fewer studies than specific food parenting practices (n = 42), and often focused their findings on specific practices within styles; few studies evaluated parenting specific to child snacking (n = 10).

Using a theoretically-driven conceptual framework [14], we summarized the frequency with which specific food parenting practices were described across four dimensions of snack feeding in Fig. 2. The practices are presented across the four key dimensions (Coercive Control, Structure, Autonomy Support, and Permissiveness), to indicate how many studies provided data about each practice. Studies appeared to focus on more negative aspects of food parenting, with a strong focus on the dimension of coercive control (n = 39, 90.0%) in the context of child snacking. Within this dimension, specific behaviors related to restriction (n = 32) and pressure to eat (n = 20) were most often described. Within the dimension of structure (n = 32, 68.0%), most studies measured home availability of healthy foods (n = 25) and monitoring of food intake (n = 17), compared with fewer studies examining planning and routines (n = 8) and home availability of healthy foods/snacks (n = 12). Fewer studies described practices within the dimension of autonomy support (n = 20, 42.5%) and permissiveness (n = 15, 31.9%), where home availability of unhealthy food (n = 12) was assessed most frequently.

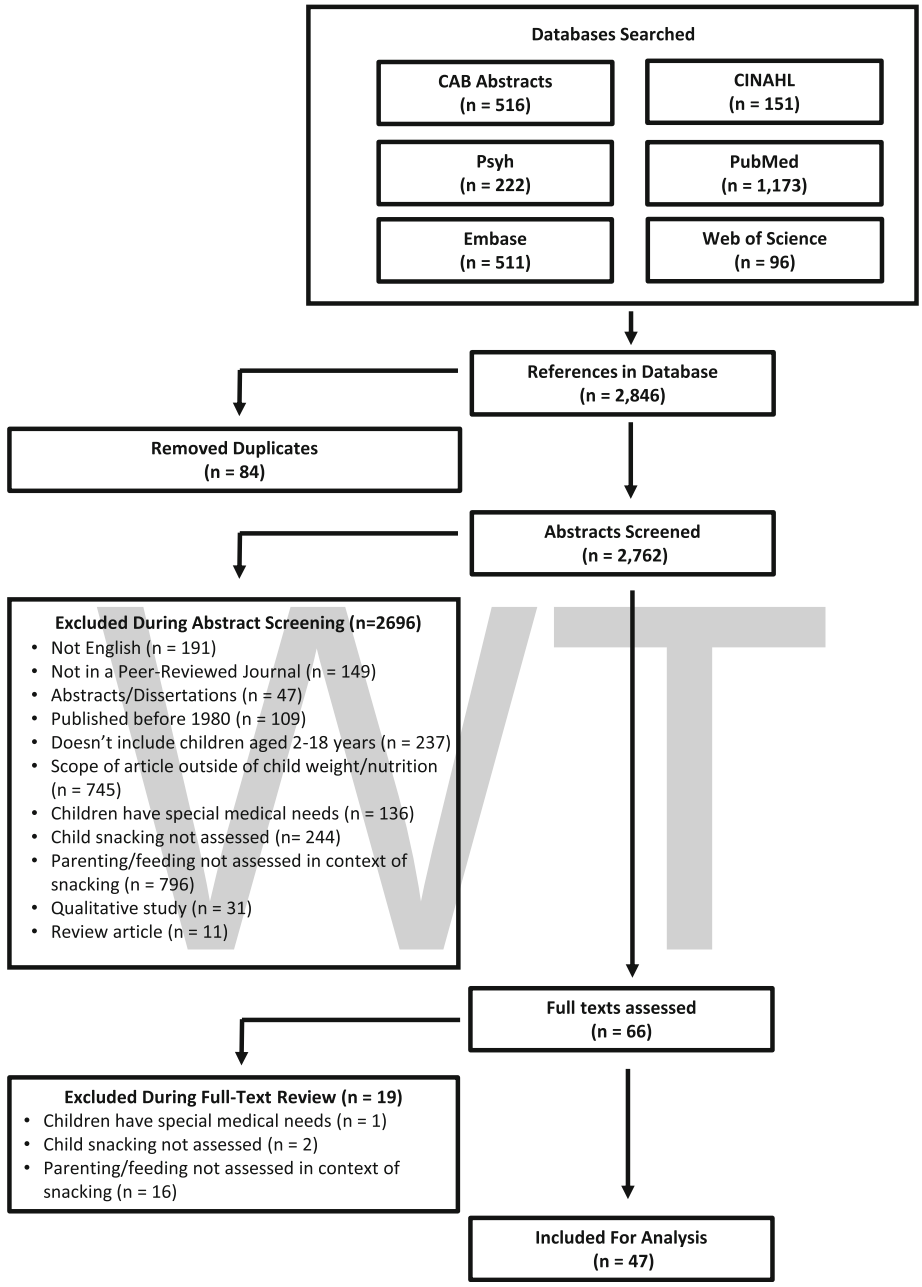

Fig. 1 Flow Diagram Summarizing Search Strategy of Systematic Review of Food Parenting and Child Snacking (1980–2017). Using preferred reporting items for systematic reviews and meta-analyses (PRISMA), diagram illustrates studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage

Association between food parenting on child snacking

We summarize associations of the most commonly studied aspects of parenting with child snacking in Fig. 3. No noticeable differences in trends based on feeding practices versus feeding or parenting styles were observed. Parental restriction of food was positively associated with child snack intake in 13/23 studies (n = 2 experimental, n = 2 longitudinal, *n* = 9 cross-sectional), while pressure to eat and monitoring yielded inconsistent results. Home availability of unhealthy foods was positively associated with snack intake in 10/11 studies (*n* = 8 cross-sectional, 2 = experimental). Instrumental feeding was described in 7 studies and was typically a combination of coercive controlling practices (e.g. restriction and rewarding with food). Findings related to positive parent behaviors (e.g. role modeling, reasonable rules about eating) were limited to less than a fifth of all studies (n = 9). Four of seven studies found parent food rules were negatively associated

Table 1 Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
1. Measured snacking or snack-related behaviors of children aged 2 years to 18 years through either objective (e.g., meal observations) or subjective (i.e., self-report) methods. This could include nutrient intake, snack foods, frequency, quality, or context. 2. Measured the feeding style, feeding practices, and/or parenting style of the child's parent or primary caregiver through self-report of caregiver, child, or direct observation (e.g. observed snack time) in the context of child snacking.	1. Not in English 2. Published prior to 1980 3. Not in a peer-reviewed journal (e.g. TIME magazine) 4. Not a research article (e.g. published in *Pediatrics* but is an interest piece or compilation of abstracts) 5. Scope of article is outside of child/family nutrition or weight status (e.g. focus on oral health, a particular foodstuff, etc.) 6. Population studied was not children ages 2–18. As long as child was under 18 at baseline, we can use the study. 7. Exclude studies of nursing 8. Population focused on children with special healthcare needs (e.g. feeding disorders, diabetes, eating disorders 9. Child snacks or snacking not assessed 10. Parenting/parent feeding and child snacking not examined together[a,b] 11. Review paper 12. Qualitative paper

[a]Did not include family meals or parent diet as a marker of food parenting
[b]Excluded if primary caregivers were not assessed at all (e.g. a study of the feeding patterns of child care workers)

with snack intake. Based on the small sample sizes, it is not possible to identify trends by study design (e.g. experimental vs. cross-sectional).

Measures of child snacking

We summarize characteristics of measures used to assess child snacking in Table 4. A wide variety of measures were used, with little consistency across the literature. The vast majority of studies used self-report to assess child snacking behaviors (n = 39), with caregivers frequently reporting on their child's intake (n = 20). Nearly half the time, a food frequency questionnaire (FFQ) was used to assess snacking (n = 22, 46.8%), with survey tools used less frequently (n = 14). Open-ended tools (e.g. 24-h recalls) were rarely used.

Most studies adapted an existing tool (n = 33, 70.2%); fewer reported the use of a validated tool to assess their particular age group (n = 10, 21.3%). The definition of snacking or snack intake varied greatly across measures. Since FFQs were employed often, it is not surprising that many studies defined individual food items as "snacks." However, snacks were also defined categorically based on healthy or nutritional characteristics (e.g. "junk food", "sweets", "dessert", "unhealthy", "energy dense"), or in other ways (e.g. "excessive snacking: eating between meals and at night" [63]).

Although snacks were typically measured as individual food items, they were often grouped together in a variety of ways post-hoc and then defined as snacks during analysis (n = 26, 55.3%). For example, a FFQ might assess child consumption of cookies, chips, and soda as separate food items, but during subsequent analysis, the author(s) would group them together and label them as "energy-dense snacks." Studies of EAH (n = 6) were often laboratory-based and presented children with a specific set of foods, sometimes described as palatable snack foods, to evaluate children's satiety [40, 43, 48, 52, 57, 62]. Three studies did not provide any definition of snacks and left it to the caregiver or child to determine what this word meant (e.g. "How often do you give your child snacks…").

Timing was not consistently assessed as a factor used to define a snack (i.e. chips eaten between meals vs. with lunch) during measurement or analysis. More than half the time (n = 26, 55.3%) beverages would be included in the definition of snack (e.g. soda and chips combined together as "unhealthy snacks"), but only 2 studies distinguished between beverages consumed during or between meal times. Consequently, a soda consumed with lunch could not be distinguished from a soda consumed with chips during a snack.

Frequency of snacking was the factor most often assessed (n = 38, 80.9%), but some studies also evaluated total energy intake from snacks or child snack preferences. In rare cases, fat intake was estimated. No studies reported on snack context (e.g. where or precisely when snacking occurred) and only one described parent rationale/purpose for providing snacks.

Discussion

The aim of this systematic review was to describe how food parenting behaviors were described in the context of child snacking in quantitative studies published between 1980 and 2017. We also sought to identify how child snacking was operationalized in studies that examined food parenting and describe the demographic characteristics of study participants present in this field of research. Using evidence-based, replicable methods, we found that most studies were of good quality and reported cross-sectional findings utilizing samples that contained mostly white, college educated, female caregivers who self-reported their food parenting behaviors and their children's snack behaviors. Dietary assessment was self-reported in 3 out of 4 studies, typically using abbreviated food frequency questionnaires or brief survey items. No

Table 2 Narrative Summary of Studies Examining Food Parenting Practices and Child Snacking (n = 47)

Author, Year, Citation	Design & Sample Characteristics	Caregiver Behaviors Assessed[a]			Measure(s) Used to Assess Food Parenting	Measure(s) Used to Assess Child Snacking	Study Quality Rating[b]	Relevant Results Summary
		Parenting style	Feeding style	Feeding practices				
Birch's Child Feeding Questionnaire (CFQ)								
Boots, 2015, [31]	Cross-sectional study of n = 611 highly educated mothers of children aged 2–7 years in Australia.	•		•	Restriction subscale of the CFQ. Covert Control Scale developed by Ogden et al. Authoritative Parenting Index (parenting style).	Parent report using 11-item FFQ adapted from existing tool to assess healthy (e.g. fruit, vegetable, cheese) and unhealthy (e.g. chips) snack foods.(Giles & Ireland, 1996)	Good	Higher restriction and lower covert control (e.g. manage the environment rather than the child) was positively associated with unhealthy snack intake. Lower restriction and higher covert control was positively associated with healthy snack intake.
Campbell, 2006, [34]	Cross-sectional study of n = 560 caregivers of children aged 5–6 years among demographically mixed schools in Melbourne, Australia.			•	Specific items taken from the CFQ to examine restriction, monitoring, and pressure to eat.	Parent report using 56-item FFQ developed based on data from national survey.	Good	Parental pressure to eat was positively associated with savory and sweet snack food intake. Restriction and monitoring was not associated with snack intake.
Campbell, 2007, [35]	Cross-sectional study of n = 347 adolescents aged 12–13 years and their parents in Western Sydney, Australia.	•		•	Items adapted from CFQ for adolescents to assess perception of monitoring, rewards, and pressure. Some items developed for the study (e.g. food availability). Parenting style using existing tool from Baumrind et al.	Child report using 56-item FFQ developed based on data from national survey.	Good	Parenting style not associated with child reported snack consumption. Availability of unhealthy food in the home was positively associated with savory snack consumption.
Couch, 2014, [37]	Cross-sectional study of n = 699 parent-child pairs, with children aged 6–11 years from Washington and California.			•	Multiple items/scales adapted from five existing tools (including CFQ) to measure feeding constructs like restriction, pressure to eat, permissiveness, and food availability	Children aged 8 and older self-reported dietary intake using three days of 24-h recalls, averaged to assess food group servings. Children 6–8 had parents help them with self-report. Sweets and savory snacks were identified as all high-energy, low nutrient dense solid foods.	Good	Food parenting practices not associated with child reported intake of sweet and savory snacks. Home availability of healthy foods positively associated with snack intake.
Dickens, 2014, [38]	Longitudinal study of n = 93 parent-child pairs, with children aged 17–18 years from South East England.			•	Pressure to eat assessed using the CFQ. Items taken from Ogden's measure of overt/covert control of food.	Child report using FFQ items adapted from multiple tools to assess unhealthy snacks.	Good	No aspects of parental control (overt, covert, or pressure to eat) were associated with teen's reported intake of unhealthy snacks.
Fisher, 2002, [43]	Longitudinal study of n = 192 non-Hispanic white girls and their parents in Pennsylvania, assessed when			•	Restriction subscale of the CFQ.	Observed snack food EAH; protocol used in a laboratory setting.	Good	Parent report of restrictive feeding practices at age 5 was positively associated with observed child snack EAH at age 7.

Table 2 Narrative Summary of Studies Examining Food Parenting Practices and Child Snacking (n = 47) *(Continued)*

Author, Year, Citation	Design & Sample Characteristics	Caregiver Behaviors Assessed[a]			Measure(s) Used to Assess Food Parenting	Measure(s) Used to Assess Child Snacking	Study Quality Rating[b]	Relevant Results Summary
		Parenting style	Feeding style	Feeding practices				
	the girls were 5 and 7 years of age.							
Harris, 2014, [48]	Experimental study of n = 37 mother-child pairs in Australia, with children aged 3–4 years.			•	Restriction, pressure to eat, and monitoring subscales of CFQ.	Weighed food intake of items consumed in the laboratory were used to assess child snack EAH.	Weak	Parental restriction and monitoring were not associated with snack EAH for boys or girls. For boys only, pressure to eat was positively associated with observed snack EAH.
Jansen, 2007, [50]	Experimental study of n = 74 parent-child pairs among children aged 5–7 years in the Netherlands.			•	Restriction subscale of the CFQ.	Weighed food intake of sweet and salty snacks consumed in the laboratory were used to assess child snack consumption.	Good	Parental feeding restriction at home was positively associated with observed energy intake of snacks.
Liang, 2016, [52]	Cross-sectional study of n = 117 parents and their overweight children aged 7–12 years in Minnesota.	•		•	Restriction, pressure to eat, and monitoring subscales of CFQ. Parenting assessed using three dimensions from the Child's Report of Parental Behavior Inventory: acceptance vs. rejection, psychological control vs. autonomy, and firm vs. lax control.	Weighed food intake of snack items consumed in the laboratory were used to assess child snack EAH.	Good	Parent monitoring of food intake was positively associated with observed sweet snack EAH. Restriction, pressure to eat, and parenting dimensions were not significantly associated with snack intake.
Loth, 2016, [53]	Cross-sectional study of n = 2383 parent-adolescent pairs (children aged 12–16 years) in Minnesota.			•	Selected items from the restriction subscale of the CFQ. Items developed for the study related to parent modeling. Snack availability assessed using measure from Boutelle et al.	Child report using 149-item Youth and Adolescent FFQ, with a focus on low nutrient, energy dense foods defined as snacks.	Good	Parental food restriction was positively associated with child reported snack food intake. Healthy home food availability and parental modeling of healthy eating were negatively associated with snack food intake.
McGowan, 2012, [56]	Cross sectional study of n = 434 primary caregivers of children aged 2–5 years from preschools in London, UK.			•	Parental monitoring using a subscale of the CFQ. Praise/ encouragement of foods assessed using a subscale of the Parental Feeding Style Questionnaire. Home availability of snacks assessed using binary items developed for the study.	Parent report using food frequency items assessed "non-core snack foods", defined as sweet or savoury snacks consumed between meals, and were adapted from existing Australian measures.	Good	Parental monitoring was negatively associated with child snack intake. Home availability was positively associated with snack intake. There was no association between encouragement and snack intake.
Moens, 2007, [57]	Experimental study of n = 52 parents and their children (half overweight/normal weight), aged 7–13 years in Belgium.			•	Restriction, pressure to eat, and monitoring subscales of the CFQ. Parental modeling of dietary behaviors assessed	Observed snack EAH in a home setting assessed using weight in grams and as a binary outcome ("yes"	Moderate	Parent report of restriction, pressure, monitoring and modeling of dietary behaviors had no association with observed child snack EAH.

Table 2 Narrative Summary of Studies Examining Food Parenting Practices and Child Snacking (n = 47) *(Continued)*

Author, Year, Citation	Design & Sample Characteristics	Caregiver Behaviors Assessed[a]			Measure(s) Used to Assess Food Parenting	Measure(s) Used to Assess Child Snacking	Study Quality Rating[b]	Relevant Results Summary
		Parenting style	Feeding style	Feeding practices				
					using the Parental Dietary Modelling Scale.	or "no" for consuming a snack).		
Reina, 2013, [62]	Cross-sectional study of n = 90 adolescents aged 13–17 years in Washington, DC.			•	Adolescent version of the CFQ was used and assessed three parent feeding subscales: restriction, concern, and monitoring.	Weighed food intake of snack items consumed in the laboratory over 2 days was used to assess snack EAH.	Good	Parental restriction and concern about child eating were positively associated with observed adolescent snack EAH. Parental monitoring was not associated with snack intake.
Rhee, 2015, [63]	Cross-sectional data collected during an intervention weight control study of n = 79 parent-child pairs, with normal and overweight children aged 8–12 years in California and Rhode Island.	•		•	Restriction, pressure to eat, and monitoring subscales of CFQ. Child's Report of Parental Behavior Inventory assessed parenting dimensions	Parent report using Family Eating and Activity Habits Questionnaire (Golan, 1998) assessed frequency of "excessive snacking behavior".	Fair	Restrictive feeding was positively associated with excessive snacking behavior among normal weight children. Firm control parenting style was associated with decreased odds of excessive snacking in the overweight group. There was no association between parental monitoring or pressure to eat and snack intake for either group.
Sleddens, 2014, [65]	Longitudinal study of n = 1654 parent-child pairs, with children aged 6 and 8 years in the Netherlands	•	•		Food parenting styles assessed using items adapted from a variety of tools, including the CFQ; 8 total constructs were assessed (e.g. emotional feeding, covert control, pressure to eat). The Comprehensive General Parenting Questionnaire assessed 5 parenting constructs (e.g. nurturance, behavioral control).	Parent report using validated FFQ items for Dutch children assessed sugar-sweetened and energy-dense food products consumed between meals. Multiple measures cited.	Good	Emotional feeding and pressure to eat were positively associated with increased energy-dense snack intake over time. Covert control was negatively associated with snack intake; this relationship was strongest among children reared in a positive parenting context. Monitoring, encouragement, and restriction were not significantly associated.
Van Strien, 2009, [69]	Cross-sectional study of n = 943 children aged 7–12 years in the Netherlands.			•	A children's version of the CFQ, using two subscales: restriction and pressure to eat.	Child report using food frequency items assessed consumption of sweet and/or savory snacks. Source of measure undefined.	Good	Perceived maternal restriction to eat was negatively associated with snack intake; pressure to eat was not associated with child snack intake.
Wijtzes, 2013, [72]	Cross-sectional study of n = 2814 mothers of 4-year-old children in the Netherlands.			•	Restriction, pressure to eat, and monitoring subscales of CFQ.	Parent report using food frequency items assessing child intake of "high calorie snacks". Source of measure undefined.	Good	Restriction and monitoring mediated the relationship between maternal education and child snack intake; restriction was positively

Table 2 Narrative Summary of Studies Examining Food Parenting Practices and Child Snacking (n = 47) *(Continued)*

Author, Year, Citation	Design & Sample Characteristics	Caregiver Behaviors Assessed[a]			Measure(s) Used to Assess Food Parenting	Measure(s) Used to Assess Child Snacking	Study Quality Rating[b]	Relevant Results Summary
		Parenting style	Feeding style	Feeding practices				
								associated with snack intake regardless of maternal level of education.
Comprehensive Feeding Practices Questionnaire (CFPQ)								
Entin, 2014, [39]	Longitudinal study of n = 63 mother-child pairs, with children aged 5–6 years in Southern Israel.			•	CFPQ assessed 12 practices, categorized as healthy (e.g. availability of healthy food, involvement) and unhealthy (e.g. food as reward, restriction to promote health).	Parent report using 110-item FFQ developed for young children; adapted from existing tool used with adults (Shahar, 2003).	Good	Using food as a reward, food restriction to promote health, and home availability of healthy foods were positively associated with child consumption of junk food, sweets, or snacks.
Farrow, 2015, [40]	Experimental study of n = 41 parent-child pairs, with children aged 2–5 years in East Midlands, United Kingdom.			•	CFPQ assessed food as a reward, for emotion regulation, restriction for weight, restriction for health, and pressure to eat.	Observational protocol of child snack food EAH under conditions of negative emotions.	Moderate	Parent use of food as a reward and restriction of food for health reasons when children were 3–5 years old was positively associated with children consuming more snack under conditions of negative emotion at ages 5–7 years.
Kiefner-Burmeister, 2014, [13]	Cross-sectional study of n = 171 mothers of children aged 3–6 years from a nationally representative sample in the United States.			•	CFPQ subscales: feeding for emotion regulation, food as a reward, and allowing child to control food choices/intake; classified as "Negative Feeding Practices".	Parent report using FFQ developed for the study to assess 5 different items: high-energy drinks, candy/sweets, salty snacks, vegetables, and fruit.	Good	The use of Negative Feeding Practices was positively 2associated with mothers' report of children consuming unhealthy drinks and snacks, despite parents' reported healthy feeding goals.
Other Previously Used Measures								
Ayala, 2007, [29]	Cross-sectional study of n = 167 Mexican American children aged 8–18 years and their mothers in San Diego, California.			•	Family support measure developed by Sorensen et al.	Child report using Block fat and fiber screeners (Block, 2000) with items added by authors regarding child snacking.	Good	Greater family support for healthful eating (e.g. praise, available foods) was negatively associated with child daily consumption of unhealthy snacks.
Ball, 2009, [30]	Cross-sectional study of n = 2529 students aged 12–15 years in Victoria, Australia.			•	Home food availability assessed using an existing tool and vegetable intake among adolescents: findings from Project EAT. Items developed for this study included mothers' social support for healthy eating.	Child report using existing FFQ (Marks, 2001) assessed consumption of energy-dense snack foods.	Good	Availability of energy-dense snacks at home was positively associated with energy-dense snack food intake; mothers' social support for healthy eating was negatively associated with snack intake.
Brown, 2008, [32]	Cross-sectional study of n = 518 parents of children	•		•	Individual items selected from a variety of existing measures of	Parent report using FFQ measuring healthy vs.	Good	Lower levels of snack covert control and higher levels of

Table 2 Narrative Summary of Studies Examining Food Parenting Practices and Child Snacking (n = 47) *(Continued)*

Author, Year, Citation	Design & Sample Characteristics	Caregiver Behaviors Assessed[a]			Measure(s) Used to Assess Food Parenting	Measure(s) Used to Assess Child Snacking	Study Quality Rating[b]	Relevant Results Summary
		Parenting style	Feeding style	Feeding practices				
	aged 4–7 years from primary schools in southern England.				parental control practices, overt/covert control, and pressure to eat. Multiple measures cited.	unhealthy snack intake adapted from multiple existing questionnaires and market research data.		pressure to eat were positively associated with unhealthy snack intake.
Corsini, 2010, [36]	Cross-sectional study using two samples from South Australia: n = 175 mothers of toddlers aged 18–24 months and n = 216 mothers of children aged 4–5 years.			•	Toddler Snack Food Feeding Questionnaire (developed for this study) measuring parental feeding practices used to manage toddlers' access to and consumption of snack foods (e.g. Rules, Flexibility, Allow Access, Self-efficacy and Child's Attraction)	Parent report using adapted to be appropriate for toddlers from the Cancer Council Food Frequency Questionnaire Giles & Ireland, 1996).	Good	Among parents of toddlers, parent feeding flexibility, allowing access, and a child's attraction to snacks were all positively associated with increased frequency of child snack food consumption. Rules to manage snacks had a weak negative association with frequency of child snack intake.
Gebremariam, 2016, [44]	Cross-sectional study of n = 742 adolescents (mean age 13.6 years) in Norway.			•	Items adapted from various measures assessing perceived parental rules, accessibility of snacks, and parental role modeling of healthy eating. Multiple measures cited.	Child report of snacks, fatty snacks, and sweets assessed using food frequency items developed for study.	Good	Snack accessibility and parental role modeling were positively associated with intake of snacks (times/week). Perceived parental rules about snacking were negatively associated with snack intake.
Gevers, 2015, [45]	Cross-sectional study of n = 888 parents of children aged 4–12 years in the Netherlands.			•	Comprehensive Snack Parenting Questionnaire (CSPQ), assessing food parenting behavior clusters related to snack intake. Citation for tool was unpublished.	Parent report using FFQs about child intake of energy-dense foods adapted from a validated Dutch food questionnaire (Brants, 2006).	Good	"High involvement and supportive" cluster was found to have lowest energy-dense snack food intake by children. Children of parents from the "low covert control and non-rewarding" and "low involvement and indulgent" clusters consumed significantly higher snack food intake. "High involvement and supportive" was found to be the most favorable in terms of children's intake.
Hendy, 2008, [49]	Cross-sectional study of n = 2008 mothers of children in 1st-4th grade (mean age: 8.3 years) in Pennsylvania; analysis part of a larger study to develop a tool to asses parental mealtime behaviors.			•	Parent Mealtime Action Scale developed in this study identified multiple dimensions of parental feeding (e.g. snack limits, unhealthy modeling, positive persuasion, too many food choices, fat reduction/ restriction, etc.)	Parent report using FFQ about child's daily intake of 12 commonly consumed high fat/sugar/salty snack foods (Cusatis & Shannon, 1996).	Good	Modeling consumption of unhealthy snacks, allowing excessive food choices, and positive persuasion were all positively associated with intake of snacks. Restriction of child's intake/consumption of fatty foods was negatively associated with child snack intake.

Table 2 Narrative Summary of Studies Examining Food Parenting Practices and Child Snacking (n = 47) *(Continued)*

Author, Year, Citation	Design & Sample Characteristics	Caregiver Behaviors Assessed[a]			Measure(s) Used to Assess Food Parenting	Measure(s) Used to Assess Child Snacking	Study Quality Rating[b]	Relevant Results Summary
		Parenting style	Feeding style	Feeding practices				
Luszczynska, 2013, [54]	Cross-sectional study of n = 2764 adolescents aged 10–17 years from schools in the Netherlands, Poland, Portugal, and theUnited Kingdom.			•	Selected items based upon existing measures assessed perceived parental pressure to limit snack consumption and snack accessibility. Multiple measures cited.	Child report using combined FFQ measures of sugar-sweetened beverage (SSB) intake with measures of snack intake to study snacking as one combined variable, "Snack/SSB intake". Multiple measures cited.	Good	At-home accessibility of snacks/ SSBs was positively associated with consumption. Parental pressure to limit snacks/SSBs was negatively associated with consumption. These factors were all mediated by the child's self-reported ability to self-regulate their snack intake.
Martens, 2010, [55]	Cross-sectional analysis of data collected as part of an intervention study of n = 502 parent-adolescent pairs (mean age 12.7 years) in the Netherlands	•		•	Parenting style was assessed using dimensions of involvement and strictness based upon an existing tool. Food rules and snack home availability were assessed using items from an existing tool. Multiple measures cited.	Parent and child report using one question from a validated tools to assess "sweets/savory snacks" (Van Assema, 2001).	Good	There was no significant association between parenting style, food rules about snacks, or snack food availability/ accessibility and adolescent self-reported snack intake.
Palfreyman, 2012, [59]	Cross-sectional study of n = 484 mothers with a child aged 18 months - 8 years in the United Kingdom.			•	Parental modeling of eating behaviors were assessed using the Parental Modelling of Eating Behaviours Scale developed for this study.	Parent report using adapted existing FFQ (Cooke et al., 2003), to include additional categories such as "savoury snacks".	Good	Verbal monitoring of healthy eating behaviors (e.g. encouragement, talking about foods) was not associated with child snack intake. Parental perception of a child mimicking their undesirable eating habits (labelled as "unintentional modeling") was positively associated with savory snack intake.
Pearson, 2010, [60]	Cross-sectional study of n = 328 adolescents aged 12–16 years in East Midlands, United Kingdom.	•			Items assessing parenting styles using the four dimensions of parenting (e.g. authoritative, indulgent). Multiple measures were adapted and cited.	Child report using 30-item validated Youth/AdolescentFood Frequency Questionnaire (Rockett et al., 1997) to assess "unhealthy snacks".	Good	Parenting style significantly associated with the frequency of snack intake among their children. Adolescents who described their parents as authoritative or authoritarian consumed fewer unhealthy snacks than peers who described parents as neglectful.
Rodenburg, 2014, [64]	Longitudinal study of n = 1275 parent-child pairs, with children aged 7–10 years in the Netherlands.	•	•		Parenting style assessed using an adapted instrument to assess Support, Behavioral Control, and Psychological Control. Parental Feeding Style Questionnaire assessed instrumental feeding, emotional feeding, encouragement to eat,	Parent report using validated FFQ items assessed energy-dense snack intake servings per week, collected at baseline and one year later. Multiple measures cited.	Good	Instrumental feeding and emotional feeding were positively related to increased energy-dense snack intake over one year. Encouragement, overt/covert control were negatively associated with energy-dense snack intake over time.

Table 2 Narrative Summary of Studies Examining Food Parenting Practices and Child Snacking (n = 47) *(Continued)*

Author, Year, Citation	Design & Sample Characteristics	Caregiver Behaviors Assessed[a]			Measure(s) Used to Assess Food Parenting	Measure(s) Used to Assess Child Snacking	Study Quality Rating[b]	Relevant Results Summary
		Parenting style	Feeding style	Feeding practices				
					and control over eating. Multiple measures cited.			
Sleddens, 2010, [66]	Cross-sectional study of n = 135 parents of children aged 6–7 years in the Netherlands		•		The Parental Feeding Style Questionnaire translated into Dutch assessed four styles: instrumental feeding, emotional feeding, encouragement to eat, and control over eating.	Parent report using validated FFQ items assessed sugar-sweetened and energy-dense food products consumed between meals. Multiple measures cited.	Good	Instrumental feeding (e.g. food as a reward) and emotional feeding (e.g. feeding in response to child's feelings) styles were positively related to children's snack consumption. Encouragement to eat was negatively associated with children's snacking behavior.
Vaughn, 2016, [70]	Cross-sectional study of n = 129 parents of children aged 3–12 years in North Carolina; data part of the development and psychometric testing of a questionnaire.			•	Home-STEAD family food practices survey assessed coercive control, autonomy support, and structure.	Parent report using food frequency items assessed weekly consumption of snacks and sweets. Source of measure undefined.	Good	Greater parental rules and limits around unhealthy foods, planning and preparation of healthy meals, and modeling were associated with decreased consumption of sweets and snacks. Frequent use of television during meals was significantly associated with increased consumption of sweets and snacks.
New Measures/Undefined Source								
Blaine, 2015, [18]	Cross-sectional study of n = 271 parents of children aged 2–12 years in low-income Massachusetts communities.			•	Items developed for study assessed the frequency with which snacks (not defined) were offered to children for nutritive (e.g. growth/feeding) and non-nutritive (e.g. behavior management, reward) reasons.	Parent report using items taken from validated FFQ measures of preschooler diets assessing frequency of different food groups, analyzed as compliance with dietary guidelines. Multiple measures cited.	Good	Offering snacks for non-nutritive reasons (e.g. behavior management, rewards) was negatively associated with adherence to dietary guidelines (e.g. sugar sweetened beverage consumption). Parents provided more snacks for non-nutritive reasons than for nutritive ones; younger children received more non-nutritive snacks than older children.
Brown, 2004, [33]	Cross-sectional study of n = 112 parent-child pairs, with children aged 9–13 years recruited from schools in southern England.			•	Source of measure undefined. Parents completed items assessing attempts to control child's food intake and using food as a tool for controlling behavior.	Child self-reported intake of both healthy (e.g. grapes, toast, apples) and unhealthy snacks (e.g. chocolate, crisps). Source of measure undefined.	Good	Parent attempts to control a child's diet were positively associated with higher intakes of child reported intake of both healthy and unhealthy snack foods.
Fisher, 1999, [41]	Experimental study of n = 71 parent-child pairs in			•	Items developed for study assessed restriction of snack foods; Interviews with children	Weighed intake of unrestricted snack foods offered in an observed	Moderate	Maternal restriction of access to snack foods among girls was positive associated with

Table 2 Narrative Summary of Studies Examining Food Parenting Practices and Child Snacking (*n* = 47) *(Continued)*

Author, Year, Citation	Design & Sample Characteristics	Caregiver Behaviors Assessed[a]			Measure(s) Used to Assess Food Parenting	Measure(s) Used to Assess Child Snacking	Study Quality Rating[b]	Relevant Results Summary
		Parenting style	Feeding style	Feeding practices				
	Pennsylvania, with children aged 3–5 years.				assessed perceived restricted access to food.	laboratory setting using a protocol.		child intake of these foods when free access was provided. Null findings observed among fathers or male children.
Fisher, 1999, [42]	Experimental study of n = 31 parent-child pairs in Pennsylvania, with children aged 3–5 years.			•	Items developed for study assessed restriction of snack foods. Source of measure undefined.	Child behavioral response and selection of restricted snacks foods observed using a protocol.	Moderate	Parental self-reported restriction of children's access to snack foods was associated with increased child behavioral response (e.g. requests for the food, attempts to obtain it, or comments about liking it) to the food compared with similar periods in which the snack food was freely available.
Gubbels, 2009, [47]	Cross-sectional study of *n* = 2578 parents of 2-year old children in the Netherlands.			•	Parents were asked if they prohibited children from eating any of the following snack foods: 'Sweets', 'Cookies', 'Cake', 'Soft drinks', 'Crisps' and 'Sugar'. Source of measure undefined.	Parent report using 65-item FFQ assessing daily consumption of specific foods. Source of measure undefined.	Good	Parent restriction of snack foods was negatively associated with unhealthy snack food consumption and positively associated with fruit and vegetable consumption
Karimi-Shahanjarini, 2012, [51]	Cross-sectional study of *n* = 739 female adolescents aged 12–15 years in Iran.			•	Items developed for the study assessed perceived parental control over junk food consumption (e.g. "My parents tell me how much junk food I may consume").	Child report using modified Iranian FFQ (Mirmiran et al., 2007) assessing snacking behaviors over a 1-week period and classified into healthy and unhealthy snacks, or "junk food".	Good	Adolescents who perceived stricter parental control reported less frequent consumption of "junk food", or unhealthy snacks. The relationship was partially mediated by the child's perceived own behavioral control over snack consumption.
Ogden, 2006, [58]	Cross-sectional study of *n* = 297 parents of children aged 4–11 years in Southern England.			•	New measure of parental overt control (detectable by child) and covert control (undetectable by child) of child eating adapted from previous tool (Brown & Ogden, 2004).	Parent report of child intake of healthy (e.g. grapes, yogurt, toast) and unhealthy (e.g. sweets, crisps) snacks using existing tool (Brown & Ogden, 2004)	Good	Greater covert control was associated with less child intake of unhealthy snacks. Greater overt control associated with greater child intake of healthy snacks.
Pearson, 2010, [61]	Longitudinal study over a 2-year period of *n* = 1850 adolescents aged 12–15 years in Victoria, Australia.			•	At baseline, perceived modeling of healthy eating by child's mother was assessed using items developed for the study. Perceived home availability of snack foods and family support for healthy eating were assessed using an existing tool (Neumark-Sztainer et al., 2003).	Child report of change in energy dense snack consumption assessed using a validated FFQ (Marks et al., 2001) at baseline and 2-year follow-up.	Good	Home availability of snacks at baseline was associated with increased energy-dense snack intake after 2 years; family support for healthy eating was inversely associated. Maternal modeling of healthy eating was not associated with a change in snack intake.
van Ansem, 2015, [67]	Cross-sectional study of *n* = 1203 parent-child pairs,			•	One binary item assessed presence of snack consumption	Child report using validated FFQ assessed energy-dense	Good	Home availability of snacks was positively associated with

Table 2 Narrative Summary of Studies Examining Food Parenting Practices and Child Snacking (n = 47) *(Continued)*

Author, Year, Citation	Design & Sample Characteristics	Caregiver Behaviors Assessed[a]			Measure(s) Used to Assess Food Parenting	Measure(s) Used to Assess Child Snacking	Study Quality Rating[b]	Relevant Results Summary
		Parenting style	Feeding style	Feeding practices				
	with children aged 8–12 years in the Netherlands.				rules (e.g. limits on number of snacks) adapted from existing measures. Items adapted from the Home Environment Survey assessed home availability of snacks. Multiple measures cited.	foods consumed between meals. Children also reported on purchasing snacks outside of the home using items developed for the study. Multiple measures cited.		child snack consumption. Parent rules on snack consumption were not associated with child snack intake.
van Assema, 2007, [68]	Cross-sectional study of n = 502 parent-child pairs, with children aged 12–14 years in the Netherlands.			•	Three binary items developed for the study assessed the presence of parent-imposed snack rules about number of snacks, timing of snacks, and which snacks child may eat.	Child report using items adapted from validated FFQs assessing sweet and savory snack consumption. Multiple measures cited.	Good	Presence of rules regarding the quantity and timing of child snack consumption was positively associated with the child's snack intake, based upon child self-report.
Verstraeten, 2016, [71]	Cross-sectional study of n = 784 adolescents aged 10–16 years in southern Ecuador.			•	Two items developed for study based on qualitative data assessed child report of parental permissiveness (e.g. fast food/ snacks allowed any time).	Child report using 2 days of 24-h recalls with "unhealthy snacks" identified as foods high in sodium, fat, or sugar.	Good	Parental permissiveness (e.g. no limits) was not associated with unhealthy snacking among adolescents.
Xu, 2013, [73]	Cross-sectional study of n = 242 first-time mothers and their 2-year-old children in Sydney, Australia.	•			Parenting style was assessed using two constructs: parental warmth (e.g. affectionate behaviors) and parental hostility towards child (e.g. irritable and angry behaviors). Source of measure undefined.	Parent report using items from the New South Wales Child Health Survey identifying snacks, which were defined as hot chips, crisps, confectionery.	Good	High levels of parental hostility were positively associated with children's snack consumption after adjusting for household income; parental warmth was not associated with snacking.

CFQ child feeding questionnaire, *FFQ* food frequency questionnaire, *EAH* eating in the absence of hunger

[a]Black dot indicates study measured caregiver behavior(s) [b]Study quality rating using the National Institutes of Health Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies (Range: Good, Fair, Poor) and the Quality Assessment Tool for Quantitative Studies Tool for experimental studies (Range: Strong, Moderate, Weak)

Table 3 Characteristics of $n = 47$ Eligible Studies of Food Parenting and Child Snacking Published Between 1980 and 2017

Year of Study Publication (n, %)		
Prior to 2000	2	4.3
2000–2004	2	4.3
2005–2009	12	25.5
2010–2014	19	40.4
2015-present	12	25.5
Country (n, %)		
United States	14	29.8
The Netherlands	12	25.5
Australia	8	17.0
United Kingdom	8	17.0
Other	5	10.6
Study Design (n, %)		
Cross-sectional	34	72.3
Longitudinal	6	12.8
Experimental	7	14.9
Participants Recruited (n, %)		
Caregiver only	15	31.9
Caregiver-child dyad	21	44.7
Child only	11	23.4
Number of Participants/Dyads (mean, SD)	693	789
Age Ranges of Children Included in Study (n, %)		
Preschool (2–5 years)	20	42.6
Elementary (6–10 years)	30	63.8
Middle School (11–13 years)	21	44.7
High School (14–18 years)	10	21.3
Reported Caregiver Attributes (n, %)		
Caregiver Race/Ethnicity	20	42.6
Non-white participants ≥60% sample[a]	6	30.0
Caregiver Gender	29	55.3
Female-only sample	12	41.3
Female participants ≥80% sample[b]	26	89.6
Fathers explicitly identified in sample[b]	10	34.5
Caregiver Level of Education	34	72.3
College educated ≥60% sample[c]	23	67.6

[a]Among participants that reported caregiver race/ethnicity
[b]Among participants that distinguished between male and female caregivers
[c]Among participants that reported caregiver level of education

noticeable differences in trends based on feeding practices versus feeding or parenting styles were observed. There was a notable range in the measurement of types of food parenting practices and in the definition of child snacking, thus creating opportunities for improvement in future exploration of these topics. Restrictive feeding and access to unhealthy foods were most consistently associated with increases in children's snack intake, though the frequency of cross-sectional study designs limits the ability to determine causality. Few studies described autonomy-supporting (e.g. praise, encouragement) or permissive (e.g. feeding to comfort) food parenting behaviors.

Inconsistent definition of snacks

Describing child snack intake presents several challenges. First, there appears to be no consensus on a universally accepted definition of child snacking in the literature we examined. Snacks were described both as a food type and as foods consumed in between meals. In most studies the word "snack" was a catch-all phrase to describe energy-dense, nutrient poor food types similar to "junk food"; few studies distinguished between unhealthy (e.g. chips, cookies) and healthy snacks (e.g. fruits and vegetables) [31, 58, 59]. Additionally, multiple dimensions were included in the definitions: half of the studies included beverages as snacks, while one third specified the timing when a snack food was consumed (e.g. between meals).

Another measurement challenge is that many studies defined "snacks" post-hoc, meaning the definition of snacks was often developed after data were collected, introducing possible bias depending on how or why certain foods were grouped together (e.g. relevance in the diet, statistical viability). There was great variation regarding which unhealthy foods were included or excluded across studies of similar populations. Additionally, beverages, though likely consumed alongside snack foods, often received their own separate category for analysis since timing of their intake was not routinely assessed.

Our findings that snacking definitions vary within food parenting literature are reflected elsewhere. A 2010 review of general snacking definitions concluded that studying the impact of snacking on various dietary and health outcomes was limited by the variation in definitions [76]. In another review of child snacking patterns, authors reported limited evidence of association between snacking behaviors and weight status, but emphasized that methodological limitations in the measurement of snacking might have severely limited their ability to conduct the analysis [7].

Relationship between food parenting and child snacking

Despite a doubling in the number of studies describing food parenting and child snacking over the previous decade, the lack of consistency in methodology limits generalizability of findings across studies. On one hand, some of our findings appear consistent with existing literature on food parenting and general dietary intake. We found that restriction was positively associated with child snack intake in a majority of studies, which included experimental and cross-sectional designs. In other studies of food parenting, restriction of food has been linked with

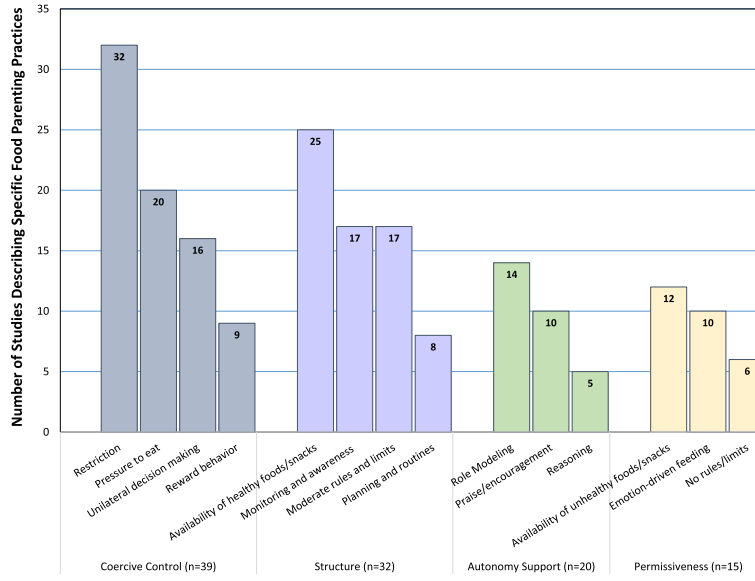

Fig. 2 Number of Studies Describing Various Food Parenting Practices in the Context of Child Snacking (n = 41). The total number of studies that described specific food parenting practices related to child snacking. Practices are arranged within 4 dimensions of child snack feeding derived from a theoretically guided conceptual model of food parenting around child snacking [14]

both increased caloric intake and elevated body mass index in children [11, 77]. The underlying basis for this association is likely bidirectional, complex, and mediated by multiple factors such as a child's weight status (e.g. parents may restrict out of concern if a child is overweight). Additionally, how parents restrict (i.e. with warmth and supportive structure versus with hostility and coercive controlling practices), which may lead children to more disinhibited eating and interest in high-calorie, or "off limits" foods [10, 77]. We also found that home availability of unhealthy foods was positively associated with snack intake in 10 out of 11 studies. The home food environment has been discussed as an important risk factor for childhood obesity. However, it is not clear if this is explicitly due to the presence of the food or represents a proxy, such as role modeling or that fact that parental food and beverage intake strongly predicts that of their children [78, 79]. Our review did not yield enough studies of parental role modeling using consistent methods (n = 2) to determine what impact it might have on child snacking.

Mixed findings were obtained regarding associations of pressure to eat and snacking. In the wider literature on child feeding, parental pressure to eat has been associated with both lower energy intake and body mass index in children in some studies, and increased energy intake in others, possibly because parents may be trying to encourage underweight or picky children to eat [22, 80, 81]. It is also possible that this construct is less

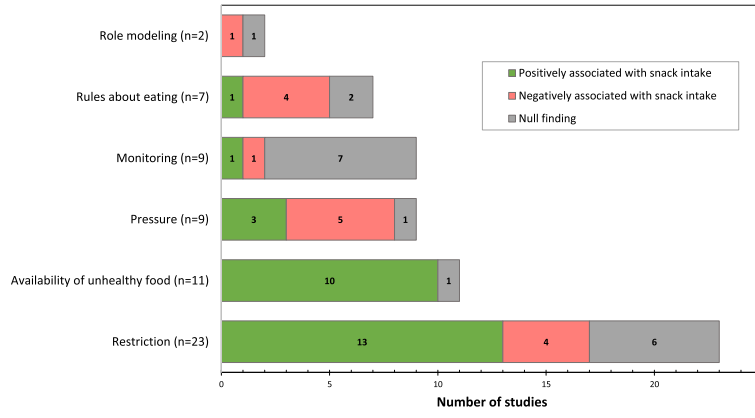

Fig. 3 Summary of Commonly Described Food Parenting Practices and Their Association with Child Snack Intake (n = 33). Number of studies describing positive, negative, or null associations between specific food parenting practices and child snack intake

Table 4 Characteristics of Child Snacking Measures

	(n)	%
Source of Child Snacking Data		
Parent report	20	42.6
Child report	17	36.2
Both parent and child reports	2	4.3
Observed	8	17.0
Type of Instrument		
Food Frequency Questionnaire	22	46.8
Survey items	14	29.8
Observed/weighed intake	9	19.1
24-Hour Recall	2	4.3
Use of Existing Measure		
Adapted from existing measure	33	70.2
Reported use of "validated" measure	10	21.3
Items developed for study	9	19.1
Source of measure undefined	5	10.6
Measure of Snacking		
Specific food item (e.g. chips, soda, cookies)	34	72.3
Categorical (e.g. "desserts", "salty", "unhealthy" foods)	8	17.0
"Snacks" – word undefined[a]	3	6.4
Other	2	4.3
Snack Intake Defined In Analysis		
Same as in the measure	21	44.6
Defined post-hoc (e.g. group specific foods as "snack")	26	55.3
Specificity in Definition of "Snack"		
Beverages included (e.g. soda is a snack food)	26	55.3
Timing (e.g. foods consumed between meals)	14	29.7
Healthy snacks identified (e.g. a fruit could be a snack)	3	6.4
Beverage timing (e.g. differentiate soda with snack vs. dinner)	2	4.3
Snacking Factors Assessed		
Frequency	38	80.9
Energy intake (total calories)	11	23.4
Child preference	2	4.3
Rationale (e.g. why snack offered)	1	2.1
Fat intake	1	2.1

[a]Used the word "snack" in the instrument (e.g. "When do you give snacks"..) without a definition

utilized in the context of child snacking, as parents may be more likely to pressure children to eat foods deemed "healthy." This is consistent with a qualitative conceptual study of food parenting around child snacking that found very few low-income parents identified pressure as part of their schemas around snacking [10, 14].

We also found monitoring food intake bore null findings in a majority of studies [81]. One possible reason for this may be that monitoring can be characterized as controlling when paired with other behaviors (e.g. restriction) and may be positive if it is paired with structure-supporting behaviors (e.g. reasonable limits, offering healthy foods) [14]. Additionally, few studies employed measures that focused specifically on snack food parenting, which may reduce their relevance for some food parenting practices.

Although a number of validated tools exist to assess food parenting practices [9], few studies in our review utilized complete measures, and instead took specific items or partial subscales from tools like the Child Feeding Questionnaire [74] to assess specific controlling feeding practices (e.g. restriction). Measurement of food parenting presents a challenge, as many child feeding tools have numerous items and subscales, which affects participant burden. However, adaptation presents a threat to validity, as psychometric properties of validated scales do not necessarily apply when subsets of items are administered. It is possible such adaptations contributed to mixed findings when we examined associations between food parenting practices and child snacking.

Recommendations for future research

Recommendation #1: Investigate parenting specific to child snacking

In general, the literature presents negative food parenting practices like restriction and pressure to eat, compared with role modeling, healthy limit-setting, or encouragement. Therefore, it would be beneficial for future studies to include positive parenting behaviors to identify how these can be supported and translated into public health interventions. At present, there are a limited number of tools that exist to measure food parenting specific to snacking. The Toddler Snack Food Feeding Questionnaire [36] assesses both negative and positive food parenting dimensions and is validated for use with caregivers of children aged 1–2 years. The Parent Mealtime Action Scale [49] measures overall parent mealtime behavior, but does present two dimensions that are specifically positive and snack focused (e.g. snack limits and snack modeling); this tool was validated with caregivers of children in 1st-4th grade (aged 6–9 years). In the future, it would be beneficial to expand these measures or create a new tool to assess the full spectrum of food parenting practices around snacking.

Recommendation #2: Increase diversity in caregiver perspectives

Our review found that mothers almost exclusively represented caregivers of interest with respect to food parenting around child snacking. We noted that a vast majority of studies either did not mention fathers or male caregivers (e.g. stepfather, live-in partner of mother), and if mentioned, they comprised 10% or less of samples. Increasingly, men are playing a greater role in child rearing, and

their absence in studies of food parenting [28] and childhood obesity-related risk factors [82, 83] presents a major gap in the literature. Thus, it is important to intentionally recruit men in studies of snack food parenting and examine whether their practices conflict with or support that of female partners, or female caregivers as a whole. Future studies should define a parent or caregiver, and clearly convey the number of female and male caregivers included in the sample. Additionally, there is evidence that other informal caregivers, such as grandparents, may play an increasingly important role in the provision of snacks to children [84, 85].

Caregivers in the studies reviewed were typically white and highly educated, consistent with other literature exploring parenting and obesity-related risk factors in children [11, 86]. In light of the health disparities that low-income children from racial/ethnic minority groups face with respect to food quality, healthy food availability, and childhood obesity [87, 88], an intentional approach towards recruiting diverse families is warranted. Additionally, recent qualitative work suggests that low-income parents may use snack foods specifically as an affordable way to comfort children or provide treats in the absence of other costly pleasures (e.g. vacations, movies) [17, 89, 90]. Therefore, more quantitative studies are also needed to identify differences in food parenting intentions and practices based upon such sociodemographic factors.

Recommendation #3: Describe child snacking contexts and purposes

The context in which child snacking occurs is poorly defined in the literature. Although most quantitative studies described the number of snacks children consume, only one described the purpose, or parent rationale for providing snacks (e.g. reward, to promote health) [18]. No studies in our review described the physical context or timing in which snacking occurred. There is reason to believe that timing may also be an important factor, as a recent review of American children's snacking patterns found that afternoon snacks might be more energy dense and nutrition-poor that morning snacks [91].

One qualitative study of low-income multi-ethnic caregivers of 2–5-year-old children provides additional insight, revealed that snacking timing and location were important parts of their definition of a snack [92]. Parents reported that children were often fed in response to environmental stimuli (e.g. ice cream truck, while grocery shopping) or that physical context dictated their child's snacking habits (e.g. whenever the TV was turned on) [14, 89]. Another analysis from the same study found that nutritional quality of snacks varied greatly based upon self-reported purposes; children received healthier snacks when parents were addressing their hunger and less healthy snacks when they were being rewarded [93]. Therefore, understanding both context and the underlying purpose of snack feeding is critical to developing effective public health messages for parents and may also help to identify environmental triggers for food parenting practices that are most obesogenic.

Recommendation #4: Move toward more consistent terminology and detailed definitions around child snacking

The current heterogeneity in definitions of child snacking limits the field in progressing towards greater understanding of snacking behaviors. Given that measurement of snacking varies based upon populations, research aims, and methodologies, it is not likely feasible to provide one universal definition of child snack foods. However, we propose the use of consistent terminology and dimensions of snacking (Table 5).

Primarily, we suggest that snack foods be defined as foods or beverages consumed between meals in order to standardize language across studies. Within this definition, nutrient-rich items like fruits, vegetables, and whole grains consumed between meals may also qualify as snacks, thus leading the field towards including more healthful eating behaviors in research. If items are defined as "unhealthy" snack foods, we recommend providing explicit details about all food/beverages assessed and the specific rationale for such categorization. Nutrient-poor foods assessed without the context of the timing (e.g. junk food or soda consumed at any time of day) would not be considered snack foods within this proposed definition.

Some studies may use qualitative research to define snacking within a population in order to identify the full range of foods consumed between meals as "snacks". For example, one caregiver-defined definition of snacking

Table 5 Suggested Standardized Terminology and Definitions for Future Research on Child Snacking

Terminology	Suggested Definition
Snack foods (and beverages, if applicable)	Foods and/or beverages that are consumed by children between meals. Researchers may provide their own specific qualifiers (e.g. "energy-dense snack foods", "sugary snack foods") along with explicit criteria for these classifications. Terminology may be shortened to "snack" or "snacks" after it has been defined.
Snacking occasions	The number of between-meal eating episodes in a given day.
Snacking purposes	Reasons that parents offer foods between meals (e.g. child request, reward, special occasion, routine).
Snacking contexts	Places where between-meal eating occurs (e.g. at home, in the car, at church).

among preschool-aged children that was recently presented by Younginer et al. [92] is, "A small portion of food that is given in-between meals, frequently with an intention of reducing or preventing hunger until the next mealtime." When parents in this population were asked about why or when they give their children "snacks", this definition is useful to properly interpret the findings.

Measuring all dimensions of snacking certainly has implications for participant burden and is not likely to be feasible in most studies. A smaller-scale study that utilizes high-burden measures to validate a lower burden questionnaire-based assessment of various snacking dimensions would be a promising strategy to enable large-scale assessment of associations with food parenting and other factors in the future.

Strengths and limitations

Our review presents several strengths. First, we provide transparent and replicable methods using PRISMA guidelines. We provide our search protocol, detailed search strategy, and data extraction tool with our findings. We also utilized double coding of all data extracted, including screening and full-text analysis in order to increase validity of our results. Additionally, we built our review upon a theoretically guided conceptual model of food parenting around child snacking so that our findings could be presented in the context of the current momentum within the literature. We use the same terminology and definitions of food parenting practices presented in the model in order to maximize construct operationalization.

Our review also has limitations. Due to the vast number of studies requiring screening, we did not review the bibliographies of full-texts to identify additional articles. We also did not include grey literature in our search, which could have increased the number of possible publications. The cross-sectional design of most studies we present also limits our ability to assess causality or temporality of the relationship between food parenting and child snacking. Due to the lack of standardization across measures of food parenting and child snacking, our review is limited to a descriptive, narrative summary of the state of the research, rather than a meta-analysis. However, our hope is that providing recommendations to improve future methodology will allow for such analysis in the future.

Conclusions

Snacking among children is nearly universal and significantly contributes to children's intake of energy and other nutrients. Parents play an important role in shaping children's dietary behaviors, including snacking. This study is the first to systematically describe food parenting specifically in the context of child snacking. Restrictive feeding and child access to unhealthy foods have been most consistently associated with increases in children's snack intake. Pressure to eat and monitoring have yielded mixed and null findings. With mounting attention paid to the role of child snacking on obesity risk in recent years, a universal definition of snacking that addresses both food type and timing is needed to maximize generalizability across studies and advance findings within the field. Future research should include positive food parenting behaviors around child snacking that may be used as targets for health promotion.

Additional files

Additional file 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist indicating standardized procedures for data collection and analysis

Additional file 2: Protocol containing inclusion and exclusion criteria, along with an electronic search strategy for the study

Additional file 3: Pre-defined list of items to be coded from articles that were included in the review. Includes the complete tool used in SurveyGizmo

Abbreviations

CFQ: Child Feeding Questionnaire; EAH: Eating in the absence of hunger; FFQs: Food Frequency Questionnaires; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Acknowledgements

None.

Funding

No funding sources to declare.

Authors' contributions

REB designed the study, contributed to article screening, data extraction, coding, and analysis, and drafted the complete manuscript. AK screened abstracts, extracted and coded data, and assisted in analysis. KKD contributed to study conceptualization and design. RK contributed to article identification, data extraction, and coding. JOF contributed to study conceptualization, design, development of the coding scheme, and interpretation of the data. All authors read, provided edits, and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Department of Family and Consumer Sciences, California State University, Long Beach, 1250 Bellflower Blvd, FCS FA-15, Long Beach, CA 90840-0501, USA. [2]Department of Social and Behavioral Sciences, Center for Obesity Research and Education, Temple University, 3223 N. Broad Street, Suite 175, Philadelphia, PA 19140, USA. [3]Department of Nutrition, Harvard T.H. Chan School of Public Health, 655 Huntington Ave, Boston, MA 02115, USA. [4]Department of Global Health & Population, Harvard T.H. Chan School of Public Health, 655 Huntington Ave, Boston, MA 02115, USA.

References

1. Ogden CL, Carroll MD, Lawman HG, Fryar CD, Kruszon-Moran D, Kit BK, Flegal KM. Trends in obesity prevalence among children and adolescents in the United States, 1988-1994 through 2013-2014. JAMA. 2016;315:2292–9.
2. Wang Y, Lim H. The global childhood obesity epidemic and the association between socio-economic status and childhood obesity. Int Rev Psychiatry. 2012;24:176–88.
3. Ford CN, Slining MM, Popkin BM. Trends in dietary intake among US 2-to 6-year-old children, 1989-2008. J Am Diet. 2013;113:35–42. e36
4. Adair LS, Popkin BM. Are child eating patterns being transformed globally? Obesity. 2005;13:1281–99.
5. Piernas C, Popkin BM. Trends in snacking among US children. Health Aff. 2010;29:398–404.
6. Samuelson G. Dietary habits and nutritional status in adolescents over Europe. An overview of current studies in the Nordic countries. Eur J Clin Nutr. 2000;54:S21.
7. Larson N, Story M. A review of snacking patterns among children and adolescents: what are the implications of snacking for weight status? Child Obes. 2013;9:104–15.
8. Evans EW, Jacques PF, Dallal GE, Sacheck J, Must A. The role of eating frequency on total energy intake and diet quality in a low-income, racially diverse sample of schoolchildren. Public Health Nutr. 2015;18:474–81.
9. Vaughn AE, Tabak RG, Bryant MJ, Ward DS. Measuring parent food practices: a systematic review of existing measures and examination of instruments. Int J Behav Nutr Phys Act. 2013;10:61.
10. Vollmer RL, Mobley AR. Parenting styles, feeding styles, and their influence on child obesogenic behaviors and body weight. A review. Appetite. 2013;71:232–41.
11. Sleddens EF, Gerards SM, Thijs C, NK VRIES, Kremers SP. General parenting, childhood overweight and obesity-inducing behaviors: a review. Int J Pediatr Obes. 2011;6:e12–27.
12. Dovey TM, Staples PA, Gibson EL, Halford JC. Food neophobia and 'picky/fussy'eating in children: a review. Appetite. 2008;50:181–93.
13. Kiefner-Burmeister AE, Hoffmann DA, Meers MR, Koball AM, Musher-Eizenman DR. Food consumption by young children: a function of parental feeding goals and practices. Appetite. 2014;74:6–11.
14. Davison KK, Blake CE, Blaine RE, Younginer NA, Orloski A, Hamtil HA, Ganter C, Bruton YP, Vaughn AE, Fisher JO. Parenting around child snacking: development of a theoretically-guided, empirically informed conceptual model. Int J Behav Nutr Phys Act. 2015;12:109.
15. Blissett J. Relationships between parenting style, feeding style and feeding practices and fruit and vegetable consumption in early childhood. Appetite. 2011;57:826–31.
16. Shloim N, Edelson LR, Martin N, Hetherington MM. Parenting styles, feeding styles, feeding practices, and weight status in 4–12 year-old children: a systematic review of the literature. Front Psychol. 2015;6:–1849.
17. Fisher JO, Wright G, Herman AN, Malhotra K, Serrano EL, Foster GD, Whitaker RC. "snacks are not food". Low-income, urban mothers' perceptions of feeding snacks to their preschool-aged children. Appetite. 2015;84:61–7.
18. Blaine RE, Fisher JO, Taveras EM, Geller AC, Rimm EB, Land T, Perkins M, Davison KK. Reasons low-income parents offer snacks to children: how feeding rationale influences snack frequency and adherence to dietary recommendations. Nutrients. 2015;7:5982–99.
19. Hughes SO, Power TG, Orlet Fisher J, Mueller S, Nicklas TA. Revisiting a neglected construct: parenting styles in a child-feeding context. Appetite. 2005;44:83–92.
20. Hughes CC, Sherman SN, Whitaker RC. How low-income mothers with overweight preschool children make sense of obesity. Qual Health Res. 2010;20:465–78.
21. Vaughn AE, Ward DS, Fisher JO, Faith MS, Hughes SO, Kremers SP, Musher-Eizenman DR, O'Connor TM, Patrick H, Power TG. Fundamental constructs in food parenting practices: a content map to guide future research. Nutr Rev. 2016;74:98–117.
22. Loth KA. Associations between food restriction and pressure-to-eat parenting practices and dietary intake in children: a selective review of the recent literature. Curr Nutr Rep. 2016;5:61–7.
23. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6:e1000097.
24. Cutting TM, Fisher JO, Grimm-Thomas K, Birch LL. Like mother, like daughter: familial patterns of overweight are mediated by mothers' dietary disinhibition. Am J Clin Nutr. 1999;69:608–13.
25. Grove RW. An analysis of the constant comparative method. Int J Qual Stud Educ. 1988;1:273–9.
26. National Heart L, Institute B. Quality assessment tool for observational cohort and cross-sectional studies. Bethesda: MD: National Institutes of Health, Department of Health and Human Services; 2014.
27. Thomas H: Quality assessment tool for quantitative studies. Effective public health practice project Toronto: McMaster University 2003.
28. Khandpur N, Blaine RE, Fisher JO, Davison KK. Fathers' child feeding practices: a review of the evidence. Appetite. 2014;78:110–21.
29. Ayala GX, Baquero B, Arredondo EM, Campbell N, Larios S, Elder JP. Association between family variables and Mexican American children's dietary behaviors. J Nutr Educ Behav. 2007;39:62–9.
30. Ball K, MacFarlane A, Crawford D, Savige G, Andrianopoulos N, Worsley A. Can social cognitive theory constructs explain socio-economic variations in adolescent eating behaviours? A mediation analysis. Health Educ Res. 2009;24:496–506.
31. Boots SB, Tiggemann M, Corsini N, Mattiske J. Managing young children's snack food intake. The role of parenting style and feeding strategies. Appetite. 2015;92:94–101.
32. Brown KA, Ogden J, Vogele C, Gibson EL. The role of parental control practices in explaining children's diet and BMI. Appetite. 2008;50:252–9.
33. Brown R, Ogden J. Children's eating attitudes and behaviour: a study of the modelling and control theories of parental influence. Health Educ Res. 2004;19:261–71.
34. Campbell KJ, Crawford DA, Ball K. Family food environment and dietary behaviors likely to promote fatness in 5-6 year-old children. Int J Obes. 2006;30:1272–80.
35. Campbell KJ, Crawford DA, Salmon J, Carver A, Garnett SP, Baur LA. Associations between the home food environment and obesity-promoting eating behaviors in adolescence. Obesity (Silver Spring). 2007;15:719–30.
36. Corsini N, Wilson C, Kettler L, Danthiir V. Development and preliminary validation of the toddler snack food feeding questionnaire. Appetite. 2010;54:570–8.
37. Couch SC, Glanz K, Zhou C, Sallis JF, Saelens BE. Home food environment in relation to Children's diet quality and weight status. J Acad Nutr Diet. 2014;
38. Dickens E, Ogden J. The role of parental control and modelling in predicting a child's diet and relationship with food after they leave home. A prospective study. Appetite. 2014;76:23–9.
39. Entin A, Kaufman-Shriqui V, Naggan L, Vardi H, Shahar DR: Parental Feeding Practices in Relation to Low Diet Quality and Obesity among LSES Children. *J Am Coll Nutr* 20141–9.
40. Farrow CV, Haycraft E, Blissett JM. Teaching our children when to eat: how parental feeding practices inform the development of emotional eating–a longitudinal experimental design. Am J Clin Nutr. 2015;101:908–13.
41. Fisher JO, Birch LL. Restricting access to foods and children's eating. Appetite. 1999;32:405–19.
42. Fisher JO, Birch LL. Restricting access to palatable foods affects children's behavioral response, food selection, and intake. Am J Clin Nutr. 1999;69:1264–72.
43. Fisher JO, Birch LL. Eating in the absence of hunger and overweight in girls from 5 to 7 y of age. Am J Clin Nutr. 2002;76:226–31.
44. Gebremariam MK, Henjum S, Terragni L, Torheim LE. Correlates of fruit, vegetable, soft drink, and snack intake among adolescents: the ESSENS study. Food Nutr Res. 2016;60:32512.
45. Gevers DW, Kremers SP, de Vries NK, van Assema P. Patterns of food parenting practices and Children's intake of energy-dense snack foods. Nutrients. 2015;7:4093–106.
46. Gevers DW, van Assema P, Sleddens EF, de Vries NK, Kremers SP. Associations between general parenting, restrictive snacking rules, and adolescent's snack intake. The roles of fathers and mothers and interparental congruence. Appetite. 2015;87:184–91.
47. Gubbels JS, Kremers SP, Stafleu A, Dagnelie PC, Goldbohm RA, de Vries NK, Thijs C. Diet-related restrictive parenting practices. Impact on dietary intake of 2-year-old children and interactions with child characteristics. Appetite. 2009;52:423–9.
48. Harris H, Mallan KM, Nambiar S, Daniels LA. The relationship between controlling feeding practices and boys' and girls' eating in the absence of hunger. Eat Behav. 2014;15:519–22.
49. Hendy HM, Williams KE, Camise TS, Eckman N, Hedemann A. The parent

mealtime action scale (PMAS). Development and association with children's diet and weight. Appetite. 2008;52:328–39.
50. Jansen E, Mulkens S, Jansen A. Do not eat the red food!: prohibition of snacks leads to their relatively higher consumption in children. Appetite. 2007;49:572–7.
51. Karimi-Shahanjarini A, Rashidian A, Majdzadeh R, Omidvar N, Tabatabai MG, Shojaeezadeh D. Parental control and junk-food consumption: a mediating and moderating effect analysis. J Appl Soc Psychol. 2012;42:1241–65.
52. Liang J, Matheson BE, Rhee KE, Peterson CB, Rydell S, Boutelle KN. Parental control and overconsumption of snack foods in overweight and obese children. Appetite. 2016;100:181–8.
53. Loth KA, MacLehose RF, Larson N, Berge JM, Neumark-Sztainer D. Food availability, modeling and restriction: how are these different aspects of the family eating environment related to adolescent dietary intake? Appetite. 2016;96:80–6.
54. Luszczynska A, de Wit JB, de Vet E, Januszewicz A, Liszewska N, Johnson F, Pratt M, Gaspar T, de Matos MG, Stok FM. At-home environment, out-of-home environment, snacks and sweetened beverages intake in preadolescence, early and mid-adolescence: the interplay between environment and self-regulation. J Youth Adolesc. 2013;42:1873–83.
55. Martens M, van Assema P, Knibbe R, Engels RC, Brug J. Family environmental factors do not explain differences in the behavioral effect of a healthy diet promotion program in lower vocational schools among 12- to 14-year-old adolescents. Am J Health Promot. 2010;24:182–5.
56. McGowan L, Croker H, Wardle J, Cooke LJ. Environmental and individual determinants of core and non-core food and drink intake in preschool-aged children in the United Kingdom. Eur J Clin Nutr. 2012;66:322–8.
57. Moens E, Braet C. Predictors of disinhibited eating in children with and without overweight. Behav Res Ther. 2007;45:1357–68.
58. Ogden J, Reynolds R, Smith A. Expanding the concept of parental control: a role for overt and covert control in children's snacking behaviour? Appetite. 2006;47:100–6.
59. Palfreyman Z, Haycraft E, Meyer C. Development of the parental Modelling of eating Behaviours scale (PARM): links with food intake among children and their mothers. Matern Child Nutr. 2012;10:617–29.
60. Pearson N, Atkin AJ, Biddle SJ, Gorely T, Edwardson C. Parenting styles, family structure and adolescent dietary behaviour. Public Health Nutr. 2010;13:1245–53.
61. Pearson N, Ball K, Crawford D. Predictors of changes in adolescents' consumption of fruits, vegetables and energy-dense snacks. Br J Nutr. 2010;105:795–803.
62. Reina SA, Shomaker LB, Mooreville M, Courville AB, Brady SM, Olsen C, Yanovski SZ, Tanofsky-Kraff M, Yanovski JA. Sociocultural pressures and adolescent eating in the absence of hunger. Body Image. 2013;10:182–90.
63. Rhee KE, Boutelle KN, Jelalian E, Barnes R, Dickstein S, Wing RR. Firm maternal parenting associated with decreased risk of excessive snacking in overweight children. Eat Weight Disord. 2015;20:195–203.
64. Rodenburg G, Kremers SP, Oenema A, van de Mheen D. Associations of parental feeding styles with child snacking behaviour and weight in the context of general parenting. Public Health Nutr. 2014;17:960–9.
65. Sleddens EF, Kremers SP, Stafleu A, Dagnelie PC, De Vries NK, Thijs C. Food parenting practices and child dietary behavior. Prospective relations and the moderating role of general parenting. Appetite. 2014;79:42–50.
66. Sleddens EFC, Kremers SPJ, De Vries NK, Thijs C. Relationship between parental feeding styles and eating behaviours of Dutch children aged 6–7. Appetite. 2010;54:30–6.
67. van Ansem WJ, Schrijvers CT, Rodenburg G, van de Mheen D. Children's snack consumption: role of parents, peers and child snack-purchasing behaviour. Results from the INPACT study. Eur J Pub Health. 2015;25:1006–11.
68. van Assema P, Glanz K, Martens M, Brug J. Differences between parents' and adolescents' perceptions of family food rules and availability. J Nutr Educ Behav. 2007;39:84–9.
69. Van Strien T, van Niekerk R, Ouwens MA. Perceived parental food controlling practices are related to obesogenic or leptogenic child life style behaviors. Appetite. 2009;53:151–4.
70. Vaughn AE, Dearth-Wesley T, Tabak RG, Bryant M, Ward DS. Development of a Comprehensive Assessment of Food Parenting Practices: The Home Self-Administered Tool for Environmental Assessment of Activity and Diet Family Food Practices Survey. Journal of the Academy of Nutrition and Dietetics. 2017;117(2):214–27.
71. Verstraeten R, Leroy JL, Pieniak Z, Ochoa-Aviles A, Holdsworth M, Verbeke W, Maes L, Kolsteren P. Individual and environmental factors influencing Adolescents' dietary behavior in low- and middle-income settings. PLoS One. 2016;11:e0157744.
72. Wijtzes AI, Jansen W, Jansen PW, Jaddoe VWV, Hofman A, Raat H. Maternal educational level and preschool children's consumption of high-calorie snacks and sugar-containing beverages: mediation by the family food environment. Int J Prev Med. 2013;57:607–12.
73. Xu H, Wen LM, Rissel C, Flood VM, Baur LA. Parenting style and dietary behaviour of young children. Findings from the healthy beginnings trial. Appetite. 2013;71:171–7.
74. Birch LL, Fisher J, Grimm-Thomas K, Markey C, Sawyer R, Johnson SL. Confirmatory factor analysis of the child feeding questionnaire: a measure of parental attitudes, beliefs and practices about child feeding and obesity proneness. Appetite. 2001;36:201–10.
75. Musher-Eizenman D, Holub S. Comprehensive feeding practices questionnaire: validation of a new measure of parental feeding practices. J Pediatr Psychol. 2007;32:960–72.
76. Johnson GH, Anderson GH. Snacking definitions: impact on interpretation of the literature and dietary recommendations. Crit Rev Food Sci Nutr. 2010;50:848–71.
77. Joyce JL, Zimmer-Gembeck MJ. Parent feeding restriction and child weight. The mediating role of child disinhibited eating and the moderating role of the parenting context. Appetite. 2009;52:726–34.
78. Hanson NI, Neumark-Sztainer D, Eisenberg ME, Story M, Wall M. Associations between parental report of the home food environment and adolescent intakes of fruits, vegetables and dairy foods. Public Health Nutr. 2005;8:77–85.
79. Wang Y, Beydoun MA, Li J, Liu Y, Moreno LA. Do children and their parents eat a similar diet? Resemblance in child and parental dietary intake: systematic review and meta-analysis. J Epidemiol Community Health. 2011;65:177–89.
80. Taylor CM, Wernimont SM, Northstone K, Emmett PM. Picky/fussy eating in children: review of definitions, assessment, prevalence and dietary intakes. Appetite. 2015;95:349–59.
81. Rodgers RF, Paxton SJ, Massey R, Campbell KJ, Wertheim EH, Skouteris H, Gibbons K. Maternal feeding practices predict weight gain and obesogenic eating behaviors in young children: a prospective study. Int J Behav Nutr Phys Act. 2013;10:24.
82. Davison KK, Gicevic S, Aftosmes-Tobio A, Ganter C, Simon CL, Newlan S, Manganello JA. Fathers' representation in observational studies on parenting and childhood obesity: a systematic review and content analysis. Am J Public Health. 2016;106:e14–21.
83. Morgan PJ, Young MD, Lloyd AB, Wang ML, Eather N, Miller A, Murtagh EM, Barnes AT, Pagoto SL. Involvement of fathers in pediatric obesity treatment and prevention trials: a systematic review. Pediatrics. 2017;139:e20162635.
84. Moore DA, Goodwin TL, Brocklehurst PR, Armitage CJ, Glenny A-M. When are caregivers more likely to offer sugary drinks and snacks to infants? A qualitative thematic synthesis. Qual Health Res. 2017;27:74–88.
85. Li B, Adab P, Cheng KK. The role of grandparents in childhood obesity in China-evidence from a mixed methods study. Int J Behav Nutr Phys Act. 2015;12:91.
86. Gicevic S, Aftosmes-Tobio A, Manganello J, Ganter C, Simon C, Newlan S, Davison K. Parenting and childhood obesity research: a quantitative content analysis of published research 2009–2015. Obes Rev. 2016;17:724–34.
87. Taveras EM, Gillman MW, Kleinman KP, Rich-Edwards JW, Rifas-Shiman SL. Reducing racial/ethnic disparities in childhood obesity: the role of early life risk factors. JAMA Pediatr. 2013;167:731–8.
88. Caprio S, Daniels SR, Drewnowski A, Kaufman FR, Palinkas LA, Rosenbloom AL, Schwimmer JB, Kirkman MS. Influence of race, ethnicity, and culture on childhood obesity: implications for prevention and treatment. Obesity. 2008;16:2566–77.
89. Blaine RE, Fisher JO, Blake CE, Orloski A, Younginer N, Bruton Y, Ganter C, Rimm EB, Geller AC, Davison KK. Conditioned to eat while watching television? Low-income caregivers' perspectives on the role of snacking and television viewing among pre-schoolers. Public Health Nutr. 2016;19:1598–605.
90. Pescud M, Pettigrew S. Treats: low socioeconomic status Australian parents' provision of extra foods for their overweight or obese children. Health Promot J Austr. 2014;25:104–9.
91. Wang D, van der Horst K, Jacquier E, Eldridge AL. Snacking among US children: patterns differ by time of day. *J Nutr Educ Behav* 2016;48. 369-375:e361.
92. Younginer NA, Blake CE, Davison KK, Blaine RE, Ganter C, Orloski A, Fisher JO. "what do you think of when I say the word 'snack'?" towards a cohesive definition among low-income caregivers of preschool-age children. Appetite. 2016;98:35–40.

The impact of an innovative web-based school nutrition intervention to increase fruits and vegetables and milk and alternatives in adolescents: a clustered randomized trial

Karine Chamberland[1], Marina Sanchez[2], Shirin Panahi[1,4], Véronique Provencher[3], Jocelyn Gagnon[1,5] and Vicky Drapeau[1,2,3,5*]

Abstract

Background: The increase in overweight and obesity in adolescents and its health-related consequences highlight the need to develop strategies, which could help them adopt healthy eating habits. The objective of this study was to evaluate the impact of an innovative web-based school nutrition intervention (Team Nutriathlon) aimed at promoting the consumption of vegetables and fruit (V/F) and milk and alternatives (M/A) in high school students and to identify facilitators and/or barriers influencing its success.

Methods: Ten classes of first and second year secondary students (grades 7 and 8) from the Québec City region were randomized into two groups (control $n = 89$ and intervention $n = 193$). Participants in the intervention (Team Nutriathlon) were to increase their consumption of V/F and M/A using an innovative web-based platform, developed for this study, over 6 weeks. The control group followed the regular school curriculum. The number of servings of V/F and M/A consumed by students per day was compared between the two groups before, during, immediately after and 10 weeks after the intervention using a web-based platform. Main outcome measures included V/F and M/A servings and facilitators and/or barriers of program success. Repeated measures linear fixed effects models were used to assess the impact of Team Nutriathlon on V/F and M/A consumption. A P-value of <0.05 was considered significant.

Results: Students in the intervention reported a significant increase of 3 servings and 1.8 servings per day of V/F and M/A, respectively, compared to the control group ($P < 0.05$); however, this was only observed in the short-term. Some factors contributing to the success of Team Nutriathlon included the team aspect of the program, use of the technology and recording results outside of classroom hours.

Conclusion: Team Nutriathlon represents an innovative web-based nutrition program which positively impacts V/F and M/A consumption among high school students. Using web-based or technological platforms may help youth adopt healthy eating habits that will have implications later in adulthood; however, further studies are needed to determine their long-term effects.

(Continued on next page)

* Correspondence: vicky.drapeau@fse.ulaval.ca
[1]Département de l'éducation Physique, Faculté des Sciences de l'éducation, Université Laval, Québec City, QC G1V 0A6, Canada
[2]Centre de recherche de l'Institut Universitaire de Cardiologie et de Pneumologie de Québec, Québec City, QC, Canada
Full list of author information is available at the end of the article

(Continued from previous page)

Trial registration: NCT03117374 (retrospectively registered).

Keywords: Adolescents, School-based nutrition intervention, Vegetables and fruit, Milk and alternatives, Dairy products, Web-based platform, Eating behaviours

Background

The prevalence of obesity has doubled in the last 30 years and affects more than one in three children and adolescents in Canada [1]. Obesity has also been associated with increased physical and psychosocial problems that may have repercussions later in life [2, 3]. Adolescence is recognized as a critical period characterized by rapid and significant growth with high energy requirements [4]. During this period adolescents learn to adopt healthy lifestyles that play a key role in their current and future health [5]. Although adolescence is synonymous with the development of autonomy, the environment remains an important influence on lifestyle habits [5]. This may partly explain why the dietary habits of adolescents are suboptimal. Among the food groups, a lack of consumption of vegetables and fruit (V/F) and milk products (M/A) and alternatives (such as enriched soy beverages) may lead to suboptimal dietary intakes. According to a Québec survey on the health of youth, more than 50% of adolescents do not consume the recommended Canada Food Guide servings for V/F and M/A [6]. Considering that youth attend school regularly and continuously, and that V/F and M/A consumption is not optimal in this population, establishing initiatives targeting V/F and M/A habits in the youth school environment has great potential for success.

In addition to possessing high nutrient density, V/F and M/A may play an important role in childhood obesity treatment and prevention. In a previous study, we observed that among 41 food groups, an increase in whole fruit and low-fat milk intake appeared to be the two specific groups consistently associated with better weight control; however, this was observed in adults [7]. Acute studies have demonstrated that the incorporation of V/F into children's meals can decrease energy intake by lowering energy density [8]. One intervention also showed a beneficial effect of increasing V/F on children's eating habits compared to a more restrictive intervention that included a reduction in fat [9]. This is line with studies showing that an increase in V/F or dairy products often results in a concomitant decrease in unhealthy snacks/foods [10–13]. Furthermore, inverse associations have been observed between consumption of dairy products and body weight in children [14]. Thus, a high consumption of these two food groups appears to represent a useful strategy to prevent or treat obesity.

Several studies confirm that nutrition intervention initiatives in schools offer a promising approach for reaching adolescents and influencing changes in their eating behaviours [15–20]. More specifically, previous studies highlight that most efficient intervention to improve VF in children/adolescents are based on a variety of approaches, including nutrition education, increased availability of healthy foods, free or subsidized food programs, environmental changes, and parental involvement [16, 18, 21]. Although these studies have shown an increase in the consumption of V/F, few have focused on increasing the variety of these foods, including the consumption of M/A and engage youth in a specific behavioural change process.

In line with these observations, our research team recently evaluated the impact of a nutrition program called "Team Nutriathlon" where the objective was to improve the consumption and diversification of V/F and M/A in primary school children by helping them to develop autonomy in the management of a healthy diet [22]. The implementation of the first version of the program resulted in a significant increase in the consumption of V/F and M/A in children suggesting a role for nutrition programs in schools. Although this study used paper and pencil to record, methods utilizing internet and game technologies have been increasingly used approaches designed to promote health behaviour changes. Accordingly, school-based intervention programs which incorporate technology (e.g. internet use) in obesity prevention in youth have been suggested to influence eating behaviours and increase the consumption of V/F and M/A, particularly when integrated into the school environment [23–27]. However, none of these interventions have included team challenges which support peer influence and motivation as well as a web-based component combined with a face-to-face regulation process that supports the development of autonomy in food choices and may lead to sustained behavioural changes. Therefore, the objective of the present study was to (1) assess the impact of a web-based version of Team Nutriathlon, an innovative web-based nutrition intervention, on the consumption of V/F and M/A and (2) identify facilitators and/or barriers influencing its success among high school students. Since adolescents have been raised with the evolution of technology and are more receptive to using new tools [28], it was hypothesized that the web-

based version of Team Nutriathlon would be a practical way to increase the consumption V/F and M/A in this population.

Methods

Participants and recruitment

This randomized, clustered intervention was conducted between 2011 and 2013 and included 10 classes of grades secondary I and II (grades 7 and 8) from three different high schools in Québec City, Canada. These classes were randomized into an intervention (n = 6) or control group (n = 4). The number of classes and students per class varied from one school to another. The selected schools were of medium to high socioeconomic levels according to the Deprivation Index of the Ministry of Education of Québec.

Schools were recruited on a voluntary basis via email invitation and sent across the region of Québec. Teachers interested in participating and whose environment matched the inclusion criteria of the study (i.e. be a school consisting of at least two secondary I or II classes corresponding to 13 and 14 year-old youth) were invited to contact the leaders of the study. Classes were randomized to either the intervention (i.e. Team Nutriathlon) or control (i.e. regular school curriculum) group. To better control for different school environments and seasonal influences on eating habits, both groups were randomized in the same school and during the same season. Because of the efficacy of the intervention in our previous study and to increase the motivation of teachers to participate in the current study, more participants were included in the current intervention. Only data for which parents and students gave their consent and assent, respectively, were used for the compilation and analysis of the results. This study was approved by the Ethics Committees for Research in Psychology and Educational Sciences at Université Laval.

Team Nutriathlon intervention

The current study examined the impact of an innovative web-based version of Team Nutriathlon aimed at improving the quality of each participant's diet by increasing and diversifying their consumption of V/F and M/A. The initial Team Nutriathlon "paper and pencil" version was designed as an 8-week school-based nutrition intervention and team challenge [22]. This version was shortened over a 6-week period and adapted for secondary school students (13–14 years old) and for compatibility with the characteristics of the school environment to provide remote management via an interactive web interface.

Web-based team Nutriathlon platform

The web-based platform was secured by an information technology specialist who developed a password secured website to allow online participation by recording the daily consumed portions of V/F and M/A. Thus, in order to participate in Team Nutriathlon, each participant was provided with a USERID and password to login. The website provided a six-week calendar where each participant was asked to record, twice a day, their consumption of V/F and M/A from Monday to Friday. Specifically, each day on the calendar included two icons (an apple and a milk carton) representing V/F and M/A, respectively. By clicking on each of these icons, participants were able to add their servings of the various foods at each meal (breakfast, morning snack, lunch, afternoon snack, dinner, and evening snack) which were divided further into various categories. Thus, V/F and M/A were separated into colors based on their nutritional density: (1) green (vegetables rich in folic acid such as broccoli); (2) orange (V/F rich in beta-carotene such as carrots); (3) purple (vegetables rich in potassium and folic acid such as red cabbage); (4) yellow (fruits rich in vitamin C such as oranges); (5) red (fruits rich in potassium and vitamin C such as cranberries); and (6) blue (M/A rich in calcium and vitamin D including milk, cheese and yogurt). The web-based Team Nutriathlon platform automatically calculated the means of V/F and M/A consumed by each participant. It also allowed the presentation of "summary reports" which presented the team totals for the quantity and variety of V/F and M/A that were recorded and compared these results with the Team Nutriathlon goals. These summary reports were essential for the "regulation periods" that were held every 2 weeks. The web-based platform also indicated the individual and team symbolic prizes that were attributed to participants at the end of the program.

Although Team Nutriathlon is not a theory-based intervention, it includes key behaviour change techniques related to self-determination models. These include goal settings, providing feedback, identifying barriers and solutions, reinforcement and social support [29] which can positively influence one's extrinsic and intrinisic motivation, a strong determinant of the adoption of healthy eating habits. Team Nutriathlon was also aimed at promoting the development of the students' autonomy which means to promote their decision-making and control over their behaviors relating to their food choices. Development of autonomy fostered by the Team Nutriathlon is one important element of the self-determination theory [30] and has been associated with the adoption of healthy eating behaviors [31]. The regulation periods aimed to improve student's autonomy allowed them to self-manage their progress toward individual and team objectives. More specifically, it provided time for students to reflect on their recent V/F and M/A consumption, to analyze their progress and to find individual- and team-based strategies to help them increase their servings in the following weeks. In this context, Team Nutriathlon,

although not a theory-based intervention, appears to promote key components of the self-determination theory such as competence and autonomy [30].

Since the program was geared towards the development of autonomy, students decided when to use the platform; however, teachers also invited them to access two 5-min periods during the day to record their information. Furthermore, although parents were not directly involved, materials such as pamphlets describing the details of Nutriathlon and its goals were shared with them. Participants were also able to request purchasing V/F and M/A from the various food categories from their parents.

Implementation phases of team Nutriathlon

The implementation of Team Nutriathlon consisted of three distinct phases including the preparatory, implementation and balance sheet phases. During the preparatory phase, the program co-ordinator provided training and instruction to teachers on the implementation and execution of the web-based program modalities. In line with the competence of "adopting a healthy and active lifestyle" from the Québec Education Program [32], they also learned how to help Nutriathlon participants apply various strategies to reach Team Nutriathlon individual and team goals. A program implementation guide was provided to each teacher to help identify tasks related to the program.

During the six-week implementation phase, students were encouraged to increase their consumption of V/F and M/A in order to satisfy the individual and team requirements of Team Nutriathlon. In the individual component, students were challenged to reach an average daily consumption of the recommended servings of V/F (6 servings/day) and M/A (3 servings/day) based on Canada's Food Guide by age group [33]. In the team component, comprising of three to five students, success depended on two important factors including the "quantity" and "variety" of the foods eaten. For the "quantity" team goal, team members must have accumulated, after 6 weeks, a total number of portions of V/F and M/A, which varied by number of participants in the team. To reach the "variety" team goal, this consumption must have been equally distributed into the six categories of foods associated with colors. The aim of the "variety" goal was to increase the likelihood that students would taste new foods during the program. The individual goals required students to attain a specific "quantity" of servings and team goals were based on both "quantity" of intake and "variety". Follow-ups, also known as "regulation periods", were planned after the second, fourth and 6 weeks of Team Nutriathlon in order to specifically develop the autonomy of youth regarding their food choices. Regulation periods are based on an analysis of summary reports provided by the website. The summary report includes two-week cumulative intakes of V/F and M/A servings for each student and team (week 2 = mean of weeks 1 and 2; week 4 = mean of weeks 3 and 4, etc.) and indicates the students and teams that attained the goals. During the regulation periods, students analyzed their consumption over the previous 2 weeks, the effectiveness of their strategies and planned new strategies that enabled them to adjust their consumption to better meet the requirements of Team Nutriathlon with the help of their teachers.

Finally, during the last regulation period (seventh week), a final phase was organized by the project managers in order to determine the final results of the 6-week changes in the consumption of V/F and M/A of students and to provide a balance sheet. During this phase, individuals and teams were provided with symbolic prizes on the website and were characterized into "Goûteur" (taster) for reaching the individual goals based on the "quantity" and into "Gastronome" (1st place); "Gourmet" (2nd place) "Dégustateur" (3rd place) for reaching team goals based on the "quantity" or "variety" of foods consumed.

Control group

The control group was not exposed to the Nutriathlon challenge objectives (i.e. no team) or Nutriathlon website access. They were only exposed to the usual school curriculum which did not include a specific nutrition program. Throughout the study, participants had access to a plain website in order to record their consumption of V/F and M/A at specific periods. It should be noted that the data collection on the web-based platform for the control group in no way referred to Team Nutriathlon. In addition, to reduce the emphasis on V/F, M/A, eating behaviours and body weight, the research objective that was presented to the participants was "to explore the effects of different lifestyle interventions on health and well-being".

Data collection

Quantitative data

Quantitative data was collected to compare the consumption of V/F and M/A among students participating in Team Nutriathlon and the control group. Each group underwent an initial evaluation period (week 0, pre-) where baseline consumption of V/F and M/A using a plain web-based platform was obtained without referring to Team Nutriathlon in any way. With the assistance of a study co-ordinator, teachers explained to students the concept of servings and modalities on how to use the web-based platform. Anthropometric measurements were taken during the first week of data collection. Participants were weighed using a bioimpedance balance and height was measured using a stadiometer by the study co-ordinator. Overweight/obesity was determined using BMI z-scores according to the criteria of the World Health Organization [34].

Following this initial evaluation, the experimental group participated in Team Nutriathlon while the control group was exposed to the usual school curriculum program. Consumption of V/F and M/A during the intervention was collected using the Team Nutriathlon web-based platform daily during a six-week period (Monday to Friday) for the intervention and at two different times for the control group on the plain web-based platform (weeks 3 and 5, Monday to Friday). Consumption of V/F and M/A after Team Nutriathlon (week 9, post-1) and 10 weeks after the end of the program (week 17, post-2) was also obtained on a plain web-based platform. It is important to note that the web-based platform used for collecting pre- and post-consumption data of V/F and M/A for both groups and during the study for the control group was similar to the Team Nutriathlon web-based platform, but did not include any information or references on Team Nutriathlon procedures. Anthropometric measurements were also taken at the end of Team Nutriathlon (post-1). Finally, although the intervention was 6 weeks, the post-1 assessment period was postponed until week 9 due to a 1 week spring break. The research protocol is shown in Fig. 1.

Qualitative data

The semi-structured group interview method was conducted among a subgroup of students to document the barriers and facilitators related to program success. Qualitative data were collected using a grid adapted to the interview with students. This grid contained 12 open-ended questions on five different themes: barriers and facilitators to the success of Team Nutriathlon, motivation, perception of results, appreciation and future benefits (Table 1). All interviews were conducted only in the intervention group. Among the intervention groups, four Nutriathlon teams were included and selected on the basis of their Team Nutriathlon performance (i.e. the two teams who performed the best and two teams who performed poorly). Their performance was evaluated based on their final summary reports. These interviews were conducted with the teams (four to five students per interview) by one research assistant trained in the analysis of qualitative studies. In these interviews, barriers and facilitators related to the success of the program were discussed with open-ended questions.

Statistical analyses

Statistical analyses were performed using JMP analysis software (JMP 7.0, SAS Institute, Cary, NC, USA). The sample size was calculated based on our previous studies to detect significant differences in consumption of V/F of 0.5 servings per day with an alpha level of 0.01 and a power (1-β error probability) of 0.90. For the quantitative data analysis, the primary variable was the daily servings of V/F and M/A consumed as reported by youth on the web-based platform. The repeated measures linear fixed effects models were used to assess the impact of Team Nutriathlon (independent variable) on the consumption of V/F and M/A (dependent variable). These analyses took the clustering randomization effect into account using the fixed effects model (i.e. random effect for classes). Tukey-Kramer's post hoc test was performed to determine between-group differences at each time. In the analysis, results with greater than 15 portions of V/F (n = 23% female, 96% intervention) and 10 servings of M/A (n = 9% female, 100% intervention) were excluded since their values were greater than twice the standard deviation. Body weight and BMI z-scores were analyzed using the Student's t-test for paired samples to assess the weight status of students before and after Team Nutriathlon. The data were reported by means ± standard deviation and a P-value of <0.05 was considered significant.

Analysis of the interviews was done using the manual content analysis method and the open-content analysis model [35]. According to L'Ecuyer (1990), three steps are essential to achieving a content analysis: a) preliminary reading and establishment of a list of statements; b) choice and definition of the classification units; and c) a categorization process. Verbatim transcripts of each of the four interviews were therefore necessary. The content analysis resulted in six categories: Nutriathlon logistics, student's Team Nutriathlon perceptions, factors that facilitate or inhibit the success of Nutriathlon, impact of Team Nutriathlon on students and their families, student engagement during Team Nutriathlon and student's future involvement in the program. Analysis of the information collected from students was carried out by a research professional qualified in qualitative analysis methods. To ensure scientific validity, another research

Fig. 1 Research protocol (AM: Anthropometric measures; RP: Regulation Periods; SR: Summary Reports). Consumption of V/F and M/A were collected for all participants at pre-test, weeks 3 and 5, Post-1 and Post-2. Anthropometric measures were taken at pre-test and Post-1

Table 1 Interview questions for students containing 12 open-ended questions on five different themes

Theme 1: Barriers and Facilitators	
Question 1	In your opinion, what facilitated (people, environment, personal skills, etc.) your success in Nutriathlon? How did these things help you? What did your teacher to do to facilitate success?
Question 2	In your opinion, what inhibited (people, environment, personal skills, etc.) your success in Nutriathlon? How did these things keep you from successfully achieving your goal? How did you manage to overcome these obstacles? How did your teacher help you overcome these obstacles?
Theme 2: Motivation	
Question 3	What influenced you to get involved in Nutriathlon?
Question 4	What prevented you from getting involved in Nutriathlon?
Question 5	How did you motivate yourself? What did your teacher do to motivate you?
Theme 3: Perception of Results	
Question 6	Did you learn something in the area of physical activity/ nutrition?
Question 7	Are there tips/strategies that you will remember in the future to help you do physical activity and/or consume V/F and M/A?
Theme 4: Appreciation	
Question 8	What did you like in Nutriathlon? (e.g. activities, time and effort required, level of difficulty, teammates, etc.)
Question 9	What did you not like in Nutriathlon? (e.g. activities, time and effort required, level of difficulty, teammates, etc.)
Question 10	Would you want to redo Nutriathlon if you had the chance? Why?
Theme 5: The Future	
Question 11	Following Nutriathlon, do you think it is important to do physical activity and/or eat V/F and M/A?
Question 12	Following Nutriathlon, do you feel like doing physical activity and/or eating V/F and M/A? If so, do you think you will be able to?

professional also qualified in qualitative analyses external to the project also repeated the analyses in order to confirm the categories resulting from the content analysis. Subsequently, the two professionals met to discuss the results and form a consensus.

Results

A total of 282 students (61% female) participated in the study with 193 students (62% female) in the intervention and 89 students (58% female) in the control group (Figure 2). Initially, 42 students (18%) were overweight (48% female, 67% intervention) and 25 (11%) students were obese (64% female, 68% intervention). No significant differences were observed between groups at baseline (pre-test, Table 2). Moreover, body weight change (post-1-baseline) was not significantly different between the intervention and control groups (1.3 ± 1.9 kg vs 1.1 ± 1.9 kg, P = 0.37, respectively). Similar results were observed for changes in BMI z-scores (–0.09 ± 0.02 kg for the intervention group and –0.04 ± 0.03 kg for the control group, P = 0.12).

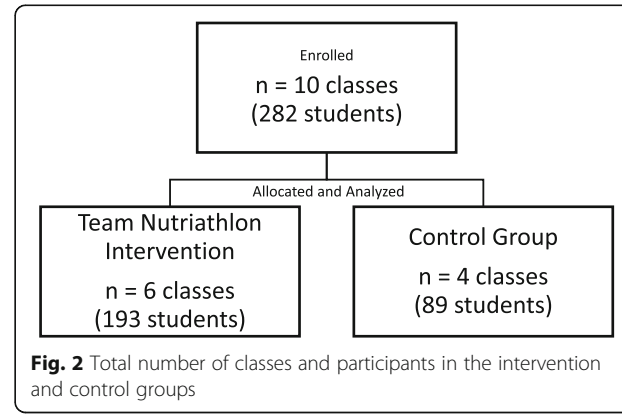

Fig. 2 Total number of classes and participants in the intervention and control groups

Impact of team Nutriathlon on the consumption of V/F and M/a

At baseline (pre-test), there were no significant differences between the control and intervention groups on the consumption of V/F and M/A (Figure 3). An effect of time, group and an interaction (time x condition) was observed for the consumption of V/F (F = 17.8, P < 0.0001, F = 12.6, P = 0.01 and 6.6. P < 0.0001, respectively) and M/A (F = 12.80, P < 0.0001, F = 22.99, P = 0.002 and 9.8, P < 0.0001, respectively). At weeks three and five and at the end of Nutriathlon (post-1), the intervention group reported a higher consumption of V/F and M/A compared to the control group (Figure 3). In contrast, 10 weeks after the end of the intervention (post-2), there were no significant differences in the consumption of V/F (P = 0.64) and M/A (P = 0.40) between the intervention and control groups.

Table 2 Baseline participant characteristics

	Group	
	Intervention (n = 193)	Control (n = 89)
Age	13.7 ± 0.9	13.4 ± 0.8
Weight (kg)	54.0 ± 12.5	52.7 ± 12.9
BMI z-scores[a]	0.4 ± 0.1	0.4 ± 0.1
Female (%)	62	58
Male (%)	38	42
Overweight (%)[b]	17	19
Obese (%)[b]	10	11

[a]38 students (53% female; 71% intervention) had missing data for weight. Analyses of data related to BMI are based on information from 244 students (62% female, 68% intervention)

[b]45 students (53% female, 69% intervention) had missing data for weight (n = 38) or age (n = 7). Analyses of data related to overweight and obesity percentages are based on information from 237 students (62% female, 68% intervention)

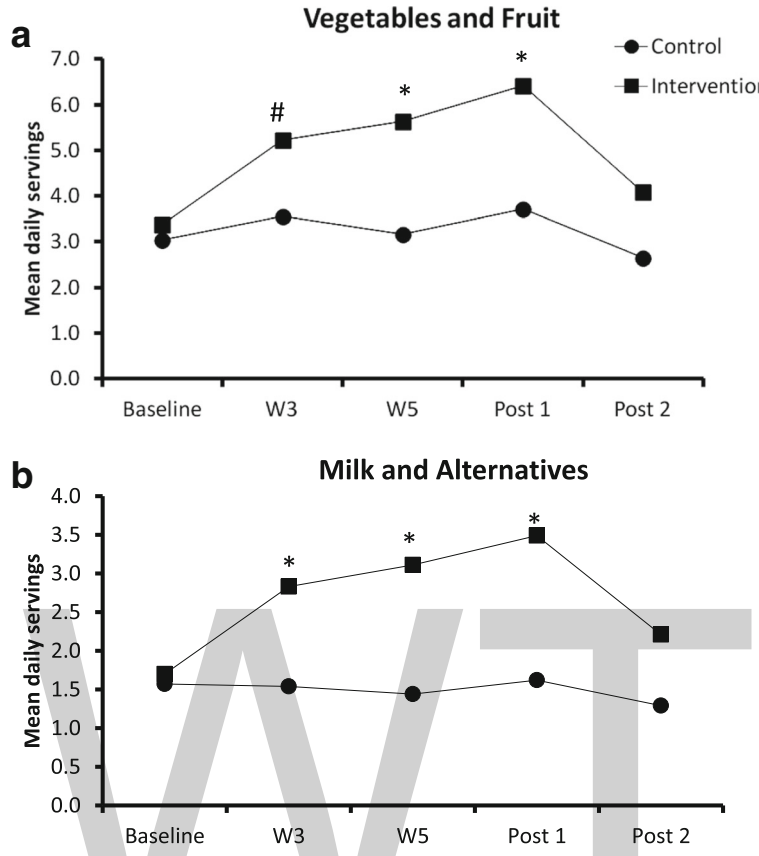

Fig. 3 A comparison of intervention (Team Nutriathlon) and control groups on the consumption of (**a**) V/F and (**b**) M/A for the different data collection periods (W = week). *Significant differences between the intervention and control groups (V/F: W5 $P = 0.0002$; Post-1 $P = 0.002$ and M/A: W3 $P = 0.0005$; W5 $P < 0.0001$; Post-1 $P < 0.0001$, respectively). #Trend for a difference between the intervention and control groups (V/F: W3 $P = 0.08$)

Moreover, there was no effect of sex on the consumption of V/F and M/A ($P < 0.48$; data not shown).

The consumption of V/F between the pre-test and post-1 was increased to 0.39 servings for the control and 3.4 for the intervention group. Students in the intervention group consumed on average 6.4 daily servings of V/F while the control group consumed an average of 3.7 servings at the end of the intervention (post-1).

Milk and alternative consumption between the pre-test and post-1 was increased to 0.14 servings in the control and 1.9 servings in the intervention group. Students in the intervention group consumed an average of 3.5 daily servings while the control group consumed an average of 1.6 servings per day after the intervention (post-1).

Facilitators and barriers to success in team Nutriathlon perceived by students

During interviews, students identified factors facilitating the success of the program (Table 3). Because Nutriathlon promotes teamwork, it has been identified as a good strategy to encourage program participation. For the majority of students, the involvement of teachers proved to be a facilitating factor because they reminded students to record the consumed servings of V/F and M/A on the web-based platform. Moreover, to encourage students to participate in Team Nutriathlon, teachers helped students achieve their goals by providing tips to increase their consumption of V/F and M/A. Some strategies provided to students during the "regulation periods" also came from the research team, other students and/or parents. Several students mentioned the importance of parental input during the program. Moreover, parents were involved in different ways with the adolescents by encouraging them to eat more V/F and M/A, reminding them to note their results on the website, increasing the amount of V/F during meals at home and in lunch boxes and buying more healthy foods at the grocery store.

Table 3 Facilitators and barriers contributing to the success of Team Nutriathlon according to students

Facilitators	Barriers
• Entering data on a web-based platform • Team aspect of the program • Involving teachers • Obtaining strategies • Family environment	• Lack of attendance for recording data on the website • Technological aspects (dysfunction of the user code and incompatibility with other technological tools)

As for barriers to the success of Team Nutriathlon two major themes emerged: one related to "attendance" and the other to the "technological aspect". Attendance at school for entering data on the website was identified as one important factor influencing success of the program. Some students experienced difficulty in attendance for completing their compilation sheets on the web-based platform. Several students struggled to take responsibility outside of school hours to record their data. Barriers related with the "technological aspect" included problems with personal code entry which provided access to the Team Nutriathlon website and incompatibility of the web-based platform with some devices such as the tablet.

Discussion

This study aimed to evaluate the impact of an innovative web-based school nutrition intervention (i.e. Team Nutriathlon) on the consumption of V/F and M/A in high school students, a population where there is a need to improve eating habits and develop nutrition programs. The results of this study suggest that Team Nutriathlon is a promising strategy that promotes the consumption of V/F and M/A in this population, at least in the short-term.

Quantitative results confirmed the positive impact of Team Nutriathlon among youth by the significant increase observed in the consumption of V/F and M/A in the intervention group at weeks 3, 5 and 9 (post-1) even though consumption returned to initial levels 10 weeks after the intervention (post-2). Similarly, several studies have documented the effectiveness of school-based interventions in increasing the consumption of V/F in youth in the short-term [15–20]. In a systematic review on school-based interventions aimed at promoting V/F intake among children and adolescents, 10 out of 15 studies demonstrated an increase in V/F consumed from 0.3 to 1 serving/day for the intervention groups [18]. However, Team Nutriathlon observed an additional average 2.7 servings of V/F consumed per day which represents a 53% increase in V/F consumption between pre- and post-1 for the intervention group suggesting a significant impact of the web-based version of this program. Of note, the majority of the previously cited studies are interventions focusing on nutrition education and environmental change while the emphasis of Team Nutriathlon is on the modification of behaviour and development of skills, which may also explain the positive results observed.

As indicated earlier, the effectiveness of school-based interventions targeting M/A consumption is less documented than V/F. The short-term effectiveness of an intervention that encouraged consumption of a specific number of M/A servings in children compared to a control group [36] and the inclusion of nutrition education interventions in the school curriculum has been suggested to be beneficial in increasing M/A [37]. Studies on interventions encouraging M/A consumption in a healthy eating environment have achieved significant results and represent an increase by one serving a day which is similar to our results (two servings more for the intervention group following Team Nutriathlon) [38].

Team Nutriathlon participants identified various factors facilitating the success of the program. Students suggested that the use of technology (i.e. web-based platform) in the framework of this program facilitated its implementation. A meta-analysis of interventions using computer technology in the form of computer games that increase motivation in youth was shown to be effective in increasing the consumption of V/F [21] and may be an effective way to encourage students to change and adopt behavior that may be beneficial to their health [39]. These results are not surprising considering that youth learn more by using a fun platform. The majority of students who participated in Team Nutriathlon found it simple and appreciated being "part of a team". Moreover, teachers and peer support also contributed to the success of Team Nutriathlon. Several studies have found that social dynamics are a key element to the adoption of healthy lifestyles [40–42] and the involvement of teachers and peers encourage the consumption of V/F and M/A in youth [43]. The family environment was another facilitating factor important for students and has been shown to positively impact eating habits [44–47]. Parents, through their influence on food accessibility [48, 49], support and being a role model [49, 50] may directly influence the consumption of certain foods. Throughout the duration of Team Nutriathlon, students were introduced to strategies that enabled them to more easily achieve their goals. In our study, students reported that the strategies provided by teachers, parents, researchers and those discovered by themselves were factors facilitating the consumption of V/F and M/A. Developing strategies or "practical skills" (e.g. adding more V/F in the lunch box) and obtaining support from teachers and parents would allow students to increase their V/F consumption [51].

Students also identified some barriers to the success of Team Nutriathlon. First, students did not find it convenient to use the platform to enter their consumption of V/F and M/A outside of school hours. This may have been due to a lack of motivation or because students were not in the school environment. Second, students identified technical difficulties with the use of the user code and incompatibility of the platform with certain technological tools such as tablets. However, these latter factors remained out of the control of students and should be modified and considered further in the continuation of this research and other web-based intervention studies.

Although the long-term impact of this type of intervention on the health and behavior of young adolescents is

difficult to assess, our study shed some light on the short-term beneficial effects of a program that promotes the adoption of healthy eating habits. Some factors may partly explain the impact of Team Nutriathlon in the longer term. Participation in a team was a factor facilitating engagement in the program and peer and/or teacher support were important elements in increasing the consumption of V/F and M/A. Thus, the little access to the support of peers and teachers after completion of the program may have contributed to the decrease in consumption 10 weeks after. A second factor was the lack of follow-up with participants after the intervention. Frequent contact with the participants has been suggested to ensure success of a program [52]. Since the daily monitoring and control periods offered by teachers and the research team had ended after Team Nutriathlon, students found themselves in a less structured environment and it was more difficult for them to continue. Finally, it is possible that the duration of Team Nutriathlon was not long enough to change behavior. Because of the high-school agenda, Team Nutriathlon was implemented over a 6-week period, which is less than the original 8-week period that was found to be effective in younger children in the short and longer terms (10 weeks post) [22]. Since the proportion of different weight categories of the participants in this study was consistent with Canadian population statistics, weight issues less likely to explain the results of the study. More research is needed to establish a significant link between the decrease in consumption of V/F and M/A 10 weeks after the end of Team Nutriathlon and the various factors discussed.

This study has several strengths. First, the large mixed sample increases the generalizability of the results. The inclusion of a mixed methodology (quantitative and qualitative measurements) highlights both the impact of Team Nutriathlon on V/F and M/A consumption and student perceptions. This study was therefore able to identify the facilitating factors and barriers perceived by students to adopt healthy habits as part of a school nutrition intervention. Accordingly, it is mainly an extracurricular program, which means that it takes minimal class time to implement (about 4 h for a 6-week period). It also requires minimal human resources such as one coordinator to enter the team's name and give a password to each student and a teacher to introduce the Team Nutriathlon at the beginning and supervise the "regulation periods". Even though the Team Nutriathlon is not a multi-level intervention (i.e. targets not only the individual, but also the environment), it could well be integrated into a school setting that has implemented a nutrition education program in the curriculum or increased the availability of V/F and M/A in their environment. It is also important to highlight that Team Nutriathlon focuses on modifying a single behaviour (i.e. eating habits such as V/F and M/A consumption). Although this has not been extensively studied, this approach has been suggested to be more effective compared to interventions that focus on changing multiple behaviours [53]. Finally, the innovative aspect of this intervention stems from the combination of a team challenge and a web-based component combined with face-to-face interactions that include regulation periods, with the goal of developing autonomy in food choices.

This study is not without some limitations. The program was carried out in schools where it is difficult to analyze the long-term results due to school holidays, changes in the cohort of students every year and departure of some students. Second, the results are not generalizable to all high school students, particularly those with low socio-economic statuses, since the study was conducted in a population of high school students from relatively high socio-economic backgrounds. Third, participation in Team Nutriathlon on a voluntary basis may lead to possible bias already present related to the motivation of students and teachers of the schools involved in the project. Although the level of motivation was not measured in this study, it is clear that this factor could influence the success of the Nutriathlon. This has been highlighted in Team Pentathlon, the physical activity version of the Nutriathlon program [54]. A higher level of motivation among teachers participating in this study could be due to different factors such a better knowledge of nutrition and health and/or personal beliefs. Future studies may include implementation of training programs in schools aimed to increase the level of motivation or influence beliefs related to these behaviours. Fourth, as the servings of V/F and M/A consumed were self-reported by students, social desirability may have influenced their consumption. Students may be encouraged to include more portions of V/F and M/A than actually consumed, because they are aware that this is what is best for their health; however, it is difficult to control this bias. Fifth, due to budgetary constraints and the design of the study, this project did not include process evaluation which is essential for capturing what is delivered and how it is carried out in practice, in comparison to the planned theoretical intervention. This process also allows one to know which adaptations have been made in order to fit the intervention into different contexts and determine its impact on the outcomes. However, in the context of the present study, a step-by-step guide was provided to each teacher to help them standardize the implementation of Nutriathlon and thus, increase intervention fidelity. Moreover, information on participant compliance was available. Students were encouraged to access the platform 80% of the time (4 out of 5 days). This information was available to teachers throughout the intervention period allowing them to encourage students that were less using the platform (less than 80% of the time). Finally, because dietary intakes were not assessed using 24-h food recalls or direct observations, it was not possible to document if V/F and M/A changed the overall

diet quality. Nevertheless, because no differences in z-BMI scores were observed, it may be hypothesized that the increase in V/F and M/A did not result in an increase in total energy intake over the course of the study. One possible explanation is that the increase in V/F and M/A may have helped to decrease the consumption of unhealthy snacks. This is supported by our previous study demonstrating that the implementation of Team Nutriathlon in primary schools result in an increase in V/F and M/A at snack time [22], and by other results showing that the introduction of a V\F program in schools is associated with a decrease in the consumption of unhealthy snacks [10, 11, 13]. Together, these results indicate that Team Nutriathlon increases the consumption of V/F and M/A more specifically between meals which may help to decrease the consumption of less healthy foods.

Conclusion

In conclusion, this study indicates that Team Nutriathlon is an innovative web-based nutrition program which positively impacts V/F and M/A consumption among high school students, at least in the short term. Web-based technologies favouring the development of autonomy in food choice seems thus to represent an interesting avenue to promote healthy eating in adolescents. Although educational institutions are a good choice for implementing web-based intervention in youth, it may be relevant to implement Team Nutriathlon in other types of environments popular among youth including summer camps or daycare. Furthermore, using web-based or technological platforms may help youth adopt healthy eating habits that will have implications later in adulthood; however, further studies are needed to determine their long-term effects.

Abbreviations

M/A: Milk and alternatives; V/F: Vegetables and fruit

Acknowledgements

We thank Mr. Christian Couture for management of the database and assistance with statistical analyses, the study participants for their time.

Funding

We thank the Danone Institute for funding this research.

Authors' contributions

KC analyzed the data and wrote the manuscript. MS carried out the study. SP contributed to statistical analysis and writing of the manuscript. VP and JG contributed to data interpretation and writing of the manuscript. VD conceived the idea, carried out the study, analyzed and interpreted the data and contributed to writing the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Département de l'éducation Physique, Faculté des Sciences de l'éducation, Université Laval, Québec City, QC G1V 0A6, Canada. [2]Centre de recherche de l'Institut Universitaire de Cardiologie et de Pneumologie de Québec, Québec City, QC, Canada. [3]Institut sur la Nutrition et les Aliments Fonctionnels, Université Laval, Québec City, QC, Canada. [4]Département de Kinésiologie, Université Laval, Québec City, QC G1V 0A6, Canada. [5]Centre de Recherche Interuniversitaire sur la Formation et la Profession Enseignante (CRIFPE-Laval), Université Laval, Québec City, QC, Canada.

References

1. Statistics Canada, Body mass index of children and youth, 2012 to 2013, 2015.
2. Daniels SR. Complications of obesity in children and adolescents. Int J Obes. 2009;33(Suppl 1):S60–5.
3. Lambert M, Delvin EE, Levy E, O'Loughlin J, Paradis G, Barnett T, McGrath JJ. Prevalence of cardiometabolic risk factors by weight status in a population-based sample of Quebec children and adolescents. Can J Cardiol. 2008;24(7):575–83.
4. Health Canada. Do Canadian adolescents meet their nutrient requirements through food intake alone? 2012 [cited 2016 August 20]; Available from: http://www.hc-sc.gc.ca/fn-an/surveill/nutrition/commun/art-nutr-adol-eng.php.
5. Institut national de santé publique du Québec. Sociocultural, environment and lifestyle of adolescents: Better understanding for better action. 2014 [cited 2016 August 15]; Available from: https://www.inspq.qc.ca/pdf/publications/1774_EnvSocioCultHabVieAdos.pdf.
6. Institute of Statistics Quebec. Québec Health Survey of High School Students (QHSHSS) 2010–11. 2012 [cited 2016 August 15]; Available from: http://www.stat.gouv.qc.ca/enquetes/sante/eqsjs_an.html.
7. Drapeau V, Despres JP, Bouchard C, Allard L, Fournier G, Leblanc C, Tremblay A. Modifications in food-group consumption are related to long-term body-weight changes. Am J Clin Nutr. 2004;80(1):29–37.
8. Pourshahidi LK, Kerr MA, McCaffrey TA, Livingstone MB. Influencing and modifying children's energy intake: the role of portion size and energy density. Proc Nutr Soc. 2014;73(3):397–406.
9. Epstein LH, Gordy CC, Raynor HA, Beddome M, Kilanowski CK, Paluch R. Increasing fruit and vegetable intake and decreasing fat and sugar intake in families at risk for childhood obesity. Obes Res. 2001;9(3):171–8.
10. Tak NI, Te Velde SJ, Singh AS, Brug J. The effects of a fruit and vegetable promotion intervention on unhealthy snacks during mid-morning school breaks: results of the Dutch Schoolgruiten project. J Hum Nutr Diet. 2010;23(6):609–15.
11. Overby NC, Klepp KI, Bere E. Introduction of a school fruit program is associated with reduced frequency of consumption of unhealthy snacks. Am J Clin Nutr. 2012;96(5):1100–3.
12. Bere E, te Velde SJ, Smastuen MC, Twisk J, Klepp KI. One year of free school fruit in Norway–7 years of follow-up. Int J Behav Nutr Phys Act. 2015;12:139.
13. Andersen LB, Arnberg K, Trolle E, Michaelsen KF, Bro R, Pipper CB, Molgaard C. The effects of water and dairy drinks on dietary patterns in overweight adolescents. Int J Food Sci Nutr. 2016;67(3):314–24.
14. Lu L, Xun P, Wan Y, He K, Cai W. Long-term association between dairy consumption and risk of childhood obesity: a systematic review and meta-analysis of prospective cohort studies. Eur J Clin Nutr. 2016;70(4):414–23.
15. Cohen JF, Kraak VI, Choumenkovitch SF, Hyatt RR, Economos CD. The CHANGE study: a healthy-lifestyles intervention to improve rural children's diet quality. J Acad Nutr Diet. 2014;114(1):48–53.
16. Evans CE, Christian MS, Cleghorn CL, Greenwood DC, Cade JE. Systematic review and meta-analysis of school-based interventions to improve daily fruit and vegetable intake in children aged 5 to 12 y. Am J Clin Nutr. 2012;96(4):889–901.
17. Howerton MW, Bell BS, Dodd KW, Berrigan D, Stolzenberg-Solomon R, Nebeling L. School-based nutrition programs produced a moderate increase in fruit and vegetable consumption: meta and pooling analyses from 7 studies. J Nutr Educ Behav. 2007;39(4):186–96.
18. Knai C, Pomerleau J, Lock K, McKee M. Getting children to eat more fruit and vegetables: a systematic review. Prev Med. 2006;42(2):85–95.
19. Reynolds KD, Franklin FA, Binkley D, Raczynski JM, Harrington KF, Kirk KA, Person S. Increasing the fruit and vegetable consumption of fourth-graders: results from the high 5 project. Prev Med. 2000;30(4):309–19.
20. Siega-Riz AM, El Ghormli L, Mobley C, Gillis B, Stadler D, Hartstein J, Volpe SL, Virus A, Bridgman J. The effects of the HEALTHY study intervention on middle school student dietary intakes. Int J Behav Nutr Phys Act. 2011;8:7.
21. Delgado-Noguera M, Tort S, Martinez-Zapata MJ, Bonfill X. Primary school

interventions to promote fruit and vegetable consumption: a systematic review and meta-analysis. Prev Med. 2011;53(1–2):3–9.
22. Drapeau V, Savard M, Gallant A, Nadeau L, Gagnon J. The effectiveness of a school-based nutrition intervention on Children's fruit, vegetables, and dairy product intake. J Sch Health. 2016;86(5):353–62.
23. Hamel LM, Robbins LB. Computer- and web-based interventions to promote healthy eating among children and adolescents: a systematic review. J Adv Nurs. 2013;69(1):16–30.
24. Di Noia J, Contento IR, Prochaska JO. Computer-mediated intervention tailored on transtheoretical model stages and processes of change increases fruit and vegetable consumption among urban African-American adolescents. Am J Health Promot. 2008;22(5):336–41.
25. Mauriello LM, Ciavatta MM, Paiva AL, Sherman KJ, Castle PH, Johnson JL, Prochaska JM. Results of a multi-media multiple behavior obesity prevention program for adolescents. Prev Med. 2010;51(6):451–6.
26. Winett R, Roodman A, Winett S, Bajzek W, Rovniak L, Whiteley J. The effects of the Eat4Life internet-based health behavior program on the nutrition and activity practices of high school girls. J Gend Cult Health. 1999;4(3):239–54.
27. Randi Schoenfeld E, Ng P, Henderson K, Wu SY. Using the internet to educate adolescents about osteoporosis: application of a tailored web-education system. Health Promot Pract. 2010;11(1):104–11.
28. Burstein GR, Lowry R, Klein JD, Santelli JS. Missed opportunities for sexually transmitted diseases, human immunodeficiency virus, and pregnancy prevention services during adolescent health supervision visits. Pediatrics. 2003;111(5 Pt 1):996–1001.
29. Michie S, Richardson M, Johnston M, Abraham C, Francis J, Hardeman W, Eccles MP, Cane J, Wood CE. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. Ann Behav Med. 2013;46(1):81–95.
30. Ryan RM, Patrick H, Deci EL, Williams GC. Facilitating health behaviour change and its maintenance: interventions based on self-determination theory. Eur Health Psychologist. 2008;10:2–5.
31. Pelletier LG, Dion SC, Slovinec-D'Angelo M, Reid R. Why do you regulate what you eat? Relationships between forms of regulation, eating behaviors, sustained dietary behavior change, and psychological adjustment. Motiv Emot. 2004;28(3):245–77.
32. Ministère de l'Éducation du Québec, Programme de formation de l'école québécoise (Quebec Education Training Program). 2001.
33. Health Canada. Eating Well with Canada's Food Guide. 2011 [cited 2016 August 30]; Available from: http://www.hc-sc.gc.ca/fn-an/food-guide-aliment/index-eng.php.
34. World Health Organization. Facts and Figures on Childhood Obesity. 2014; Available from: http://www.who.int/end-childhood-obesity/facts/en/.
35. L'Écuyer R, Méthodologie de l'analyse développementale de contenu (Method of developmental content analysis) Méthode GPS et concept de soi (GPS method and self-concept). 1990, Québec: Presses de l'Université du Québec. 490.
36. Albala C, Ebbeling CB, Cifuentes M, Lera L, Bustos N, Ludwig DS. Effects of replacing the habitual consumption of sugar-sweetened beverages with milk in Chilean children. Am J Clin Nutr. 2008;88(3):605–11.
37. Nicklas TA. Calcium intake trends and health consequences from childhood through adulthood. J Am Coll Nutr. 2003;22(5):340–56.
38. Abreu S, Santos R, Moreira C, Santos PC, Vale S, Soares-Miranda L, Autran R, Mota J, Moreira P. Relationship of milk intake and physical activity to abdominal obesity among adolescents. Pediatr Obes. 2014;9(1):71–80.
39. Casazza K, Ciccazzo M. The method of delivery of nutrition and physical activity information may play a role in eliciting behavior changes in adolescents. Eat Behav. 2007;8(1):73–82.
40. Teyhen DS, Aldag M, Centola D, Edinborough E, Ghannadian JD, Haught A, Jackson T, Kinn J, Kunkler KJ, Levine B, Martindale VE, Neal D, Snyder LB, Styn MA, Thorndike F, Trabosh V, Parramore DJ. Key enablers to facilitate healthy behavior change: workshop summary. J Orthop Sports Phys Ther. 2014;44(5):378–87.
41. Baggio A, Kispal L, Woodruff S. Associations between Encouraging Peers or Receiving Teacher/Principal Encouragement and Fruit/vegetable Intake among Students in Grades 5-8 in Northern Ontario, Canada. Edinburgh: The International Society for Behavioral Nutrition and Physical Activity Abstract Book June 3-6 2015.
42. Mcdonald D. Evaluating the Effectiveness of a Youth Peer-education Intervention for Increasing Physical Activity and Consumption of Fresh Fruits and Vegetables. Edinburgh: The International Society for Behavioral Nutrition and Physical Activity Abstract Book June 3-6 2015.
43. Agence de la santé publique du Canada. La santé des jeunes Canadiens: un accent sur la santé mentale. 2012; Available from: http://www.phac-aspc.gc.ca/hp-ps/dca-dea/publications/hbsc-mental-mentale/school-ecole-fra.php. Accessed Jan 2017.
44. Dietz WH, Gortmaker SL. Preventing obesity in children and adolescents. Annu Rev Public Health. 2001;22:337–53.
45. Pearson N, Biddle SJ, Gorely T. Family correlates of fruit and vegetable consumption in children and adolescents: a systematic review. Public Health Nutr. 2009;12(2):267–83.
46. Rasmussen M, Krolner R, Klepp KI, Lytle L, Brug J, Bere E, Due P. Determinants of fruit and vegetable consumption among children and adolescents: a review of the literature. Part I: quantitative studies. Int J Behav Nutr Phys Act. 2006;3:22.
47. Van Der Horst K, Oenema A, Ferreira I, Wendel-Vos W, Giskes K, van Lenthe F, Brug JA. Systematic review of environmental correlates of obesity-related dietary behaviors in youth. Health Educ Res. 2007;22(2):203–26.
48. Olson BH, Chung KR, Reckase M, Schoemer S. Parental influences on dairy intake in children, and their role in child calcium-fortified food use. J Nutr Educ Behav. 2009;41(1):53–7.
49. Sharma SV, Hoelscher DM, Kelder SH, Diamond P, Day RS, Hergenroeder A. Psychosocial factors influencing calcium intake and bone quality in middle school girls. J Am Diet Assoc. 2010;110(6):932–6.
50. Gillman MW, Rifas-Shiman SL, Frazier AL, Rockett HR, Camargo CA Jr, Field AE, Berkey CS, Colditz GA. Family dinner and diet quality among older children and adolescents. Arch Fam Med. 2000;9(3):235–40.
51. Henderson M, Gray-Donald K, Rabasa-Lhoret R, Bastard JP, Barnett TA, Benedetti A, Chaput JP, Tremblay A, Lambert M. Insulin secretion and its association with physical activity, fitness and screen time in children. Obesity (Silver Spring). 2014;22(2):504–11.
52. Hendrie GA, Brindal E, Baird D, Gardner C. Improving children's dairy food and calcium intake: can intervention work? A systematic review of the literature. Public Health Nutr. 2013;16(2):365–76.
53. Sweet SN, Fortier MS. Improving physical activity and dietary behaviours with single or multiple health behaviour interventions? A synthesis of meta-analyses and reviews. Int J Environ Res Public Health. 2010;7(4):1720–43.
54. Michaud V, Nadeau L, Martel D, Gagnon J, Godbout P. The effect of team pentathlon on ten- to eleven-year-old childrens' engagement in physical activity. Phys Educ Sport Pedagog. 2012;17(5):543–62.

Child and parent predictors of picky eating from preschool to school age

Silje Steinsbekk[1*], Arielle Bonneville-Roussy[2], Alison Fildes[3], Clare H. Llewellyn[4] and Lars Wichstrøm[1,5]

Abstract

Background: Picky eating is prevalent in childhood. Because pickiness concerns parents and is associated with nutrient deficiency and psychological problems, the antecedents of pickiness need to be identified. We propose an etiological model of picky eating involving child temperament, sensory sensitivity and parent-child interaction.

Methods: Two cohorts of 4-year olds (born 2003 or 2004) in Trondheim, Norway were invited to participate (97.2% attendance; 82.0% consent rate, *n* = 2475) and a screen-stratified subsample of 1250 children was recruited. We interviewed 997 parents about their child's pickiness and sensory sensitivity using the Preschool Age Psychiatric Assessment (PAPA). Two years later, 795 of the parents completed the interview. The Children's Behavior Questionnaire (CBQ) was used to assess children's temperament. Parent- child interactions were videotaped and parental sensitivity (i.e., parental awareness and appropriate responsiveness to children's verbal and nonverbal cues) and structuring were rated using the Emotional Availability Scales (EAS).

Results: At both measurement times, 26% of the children were categorized as picky eaters. Pickiness was moderately stable from preschool to school age (OR = 5.92, CI = 3.95, 8.86), and about half of those who displayed pickiness at age 4 were also picky eaters two years later. While accounting for pickiness at age 4, sensory sensitivity at age 4 predicted pickiness at age 6 (OR = 1.25, CI = 1.08, 2.23), whereas temperamental surgency (OR = 0.88, CI = 0.64, 1.22) and negative affectivity (OR = 1.17, CI = 0.75, 1.84) did not. Parental structuring was found to reduce the risk of children's picky eating two years later (OR = 0.90, CI = 0.82, 0.99), whereas parental sensitivity increased the odds for pickiness (OR = 1.10, CI = 1.00, 1.21).

Conclusions: Although pickiness is stable from preschool to school age, children who are more sensory sensitive are at higher risk for pickiness two years later, as are children whose parents display relatively higher levels of sensitivity and lower levels of structuring. Our findings suggest that interventions targeting children's sensory sensitivity, as well as parental sensitivity and structuring, might reduce the risk of childhood pickiness. Health care providers should support parents of picky eaters in repeatedly offering unfamiliar and rejected foods to their children without pressure and acknowledging child autonomy.

Keywords: Picky eating, Pickiness, Fussiness, Sensory sensitivity, Parenting, Structuring, Sensitivity, Temperament

Background

The unwillingness to eat certain familiar or unfamiliar types of food, known as picky eating [1], is most prevalent in early childhood, with rates ranging from 5.6 to 59.3% depending on the definition and assessment methods used [2]. Pickiness is of great concern for parents [3]. Although knowledge of the health-related outcomes of picky eating is limited due to a lack of longitudinal studies [2], research suggests that picky eating is associated with nutrient deficiency [4], underweight [5], behavioral problems [6] and symptoms of anxiety and depression [7]. Even though pickiness may decrease somewhat during the late preschool and early school years [2], evidence suggests a substantial number of children continue to be picky into school age [3], whereas others first display picky eating after starting school [8]. Further, pickiness also seems to be more persistent with later onset, while early onset cases recover more quickly [3]. Therefore, identifying the predictors of

* Correspondence: silje.steinsbekk@svt.ntnu.no
[1]Department of Psychology, Norwegian University of Science and Technology (NTNU), Dragvoll, 7491, Trondheim, Norway
Full list of author information is available at the end of the article

pickiness in the period of transition from preschool to school would be especially valuable.

Two longitudinal studies have examined socio-demographic predictors of picky eating [8, 9], and one investigation focused on parental negativity [10]. However, research into modifiable risk factors (e.g., breastfeeding, parenting) has been cross sectional, limiting the possibility of causal inferences between those risk factors and picky eating [11]. Children's eating is influenced by their dispositional qualities such as temperament [12–14], but also by parenting practices and the way parents feed and react to their child's eating [15, 16]. We therefore propose an etiological model of picky eating involving child temperament, sensory sensitivity and parent-child interaction. We test this model in a large and representative sample of Norwegian children followed from 4 to 6 years of age.

Temperament, sensory sensitivity and pickiness

Individual differences in temperament may explain why some children develop eating problems whereas others do not [12, 17]. According to Rothbart's work, three overarching factors of temperament can be found: Surgency/extraversion, negative affectivity and effortful control [18]. Surgency, the tendency to be approached-oriented and sensation-seeking, may cause children to be more open to new food experiences. Studies conducted with adults show sensation seeking to be negatively associated with food neophobia, i.e. the avoidance of novel foods, which is closely related to pickiness [19–21]. Notably though, Hafstad et al. [10] did not find that level of sociability (akin to surgency) predicted decreased pickiness in very young children (1.5 to 4.5 years of age), but it is not known whether this also applies to older children. Negative affectivity, which is characterized by mood instability, angry reactivity and dysregulated negative emotions [22, 23], is also associated with picky eating in cross-sectional [9, 12], and prospective studies [10]. We therefore examine both surgency and negative affectivity as predictors of pickiness from preschool to school age.

Effortful control, the third overarching temperamental dimension comprising inhibition and planning [18], does not intuitively appear relevant to picky eating. However, perceptual sensitivity, one of its sub dimensions may be pertinent. Perceptual or sensory sensitivity is conceptualized as low neurological thresholds for responding to sensory events and passive response strategies [24]. Individuals high in sensory sensitivity not only notice *more* sensory events (from taste, touch, vision, and smell) than others, but they notice sensory stimuli, such as food textures, more *rapidly* [24]. As the sensory properties of foods vary, it is reasonable to assume that sensory sensitivity will affect food acceptance [25]. In fact, sensory sensitive children have been found to be more reluctant to try new foods (food neophobia), eat fewer fruits and vegetables [26], and display higher levels of pickiness in cross-sectional studies [7, 27]. However, it is not yet clear whether sensory sensitivity *prospectively* predicts picky eating.

Parenting as a predictor of pickiness

Simply stated, picky eating is characterized by one defining behavior; avoidance of food. Thus, picky eating manifests itself through avoidant behavior, as in anxiety disorders, and may similarly persist by means of negative reinforcement. Parents are concerned about picky eating [3] but may respond to this behavior differently. We propose two parenting pathways that potentially drive pickiness in early childhood, described below.

Protective pathway: parental structuring

Parents who adopt a structuring/scaffolding parenting style, who teach and help the child while acknowledging the child's autonomy [28], may offer their child unfamiliar or disliked foods in a gentle, yet firm way, encouraging the child to try. This parental approach is comparable to an authoritative feeding style, characterized by emotional warmth and responsiveness as well as high dietary expectations [29]. Indeed, authoritative parenting (i.e. high involvement and high control) is associated with healthy eating behavior [16], including higher fruit and vegetable consumption [29], and has been shown to reduce the negative association between pickiness and fruit intake [30]. Parenting behavior characterized by non-aversive, reinforcing parent-child-interactions, the caregiver being proactive and structuring, has further shown to prospectively predict children's dietary quality [31]. In sum, research supports a link between general parenting and dietary practices [32, 33], structuring and autonomy support being considered two of the most important parenting constructs as regards parent's impact on children's diet and eating habits [34]. Although relatively little is known about the management of pickiness [11], repeated exposure to a novel and/or disliked food has been shown to increase children's acceptance of the food [35]. However, in order for exposure interventions to be effective, caregivers have to be systematic in their effort to familiarize their child with foods, for instance, by repeatedly and methodically offering certain rejected foods on multiple occasions and praising or rewarding the child for tasting [36, 37]. Such behavior requires structuring of the child's environment and scaffolding the child's learning. We therefore expect high parental structuring/scaffolding to reduce the risk of the child becoming a picky eater, whereas little or no structure and scaffolding is expected to increase the risk of prospective pickiness.

Risk pathway: parental sensitivity

A child's negative response to food can be distressing for parents [3]; however, some parents may be more distressed than others. Parental sensitivity, defined as awareness and appropriate responsiveness to children's verbal and nonverbal cues, is generally thought to be psychologically beneficial [38]. However, high sensitivity may have its drawbacks. Because the picky child needs to endure uneasiness, or even anxiety to try a rejected food, the parent similarly needs to endure their child's uneasiness. Highly sensitive parents may be more affected by their child's distress and therefore more inclined to avoid confrontation or to abort efforts to encourage their child to try new foods when s/he protests or becomes distressed. This is the proposed *sensitive pathway* to picky eating, whereby high parental sensitivity leads to decreased food exposure, and thereby negatively reinforces the child's avoidance. Of note, highly sensitive parents also tend to be structuring [39]. Therefore, we do not expect structuring and sensitivity, which we hypothesize to work in opposite ways, to be bivariately associated with pickiness, because these opposite effects may cancel each other out. However, when adjusted for each other, the 'true colors' of structuring and sensitivity may appear.

Current study

Pickiness is associated with several negative physical and psychological health outcomes and can cause parental distress. Identification of predictors is pertinent to inform interventions aimed at reducing picky eating in childhood. We aim to extend existing research by examining child- and parenting factors as predictors of pickiness from age 4 to 6. Specifically, we will explore child temperament, sensory sensitivity, parenting sensitivity and structuring as predictors of pickiness. This study extends earlier findings by applying a psychiatric interview to capture pickiness rather than single items or questionnaires used in earlier cross-sectional [2] and longitudinal studies [8, 10]. We hypothesize that pickiness at age 6, adjusted for pickiness at age 4, would be predicted by: 1) higher levels of child negative affectivity and lower levels of surgency; 2) higher levels of sensory sensitivity; and 3) greater parental sensitivity (i.e., the ability to effectively read and act upon the child's cues) and lower levels of parental structuring. Gender differences are also explored.

Methods

Participants and procedure

A letter of invitation to participate in the study, together with the Strengths and Difficulties Questionnaire (SDQ) 4–16 version [40], was sent to the homes of all children born in 2003 and 2004 living in Trondheim, Norway (N = 3456). The parents brought the completed SDQ when attending the regular health check-up for 4-year olds, where a health nurse informed parents about the study and asked them to participate (n = 3016). Of the eligible parents, 97.2% (n = 3358) met for the appointed health check-up, 2475 gave informed consent, and 1250 children were drawn to participate. Children were allocated to four strata according to their SDQ scores to oversample for mental health problems (cut-offs: 0–4, 5–8, 9–11, and 12–40) and the probability of selection increased with increasing SDQ scores (.37, .48, .70, and .89 in the four strata, respectively). The sample is comparable to the Norwegian parent population for the parents' level of education [41]. We succeeded in interviewing parents of 997 children at Time 1 (T1), when the children's mean age was 4.7 years (SD = 0.30). At follow up two years later, 795 children participated (mean age = 6.7 years, SD = 0.17). Further details of the recruitment procedure is presented in Wichstrøm et al. [42]. All procedures were approved by the Regional Committee for Medical and Health Research Ethics Mid Norway.

Measures

Pickiness

A semi-structured psychiatric interview, The Preschool Age Psychiatric Assessment (PAPA) [43], was used to assess children's picky eating at both measurement points. The PAPA assesses symptoms of psychiatric disorders in preschool children, but also includes items related to picky eating. More specifically, parents are interviewed about their child's food preferences and appetite over the last three months, whether the child consumes only restricted types of foods, and whether food selectivity impairs functioning. The interviewer had at least a bachelor's degree in a relevant field in addition to extensive prior experience in working with children and parents. The PAPA includes both required and optional follow-up questions and the administrator decides whether the symptom is present and probes until she or he can make a decision. Based on the interview, the participating children were categorized according to their level of pickiness: no pickiness; moderate pickiness (the child only eats food s/he likes); and severe pickiness (pickiness is substantial and comprehensive, separate meals must be made for the child). Using the same measure of pickiness as in the present inquiry, Zucker et al. (2015) found that even moderate levels of pickiness are associated with psychiatric symptoms and thus need to be identified. We therefore used a dummy variable including both moderate and severe pickiness as the main outcome (0 = no pickiness; 1 = moderate/severe pickiness). Nine percent of videotaped recordings of the PAPA interviews were recoded by blinded interviewers which revealed high inter-rater reliability, ICC = 0.92.

Sensory sensitivity

The PAPA [43] was used to capture sensory sensitivity at age 4, assessing seven sensory modes of sensitivity: (1) tactile (e.g. sensitive to special kinds of clothes/fabrics, tags, seams, etc); (2) oral (e.g. sensitive to crisp, hard, soft consistencies); (3) taste; (4) smell; (5) sounds (e.g. sensitive to sharp, loud sounds); (6) visual (e.g. sensitive to bright sunlight); and (7) "other" forms of sensitivity ("sensitive to other kinds/modes of perceptual sensations?"). The interviewer categorized the child as hypersensitive if impairment was reported (e.g. gets emotionally upset, tries to get away from the sensory stimuli) (0 = no sensitivity; 1 = sensitivity). A sum score of the 7 sensory modes was calculated ranging from 0 to 7.

Temperament

The Norwegian version of the parent-reported Children's Behavior Questionnaire (CBQ) long version [22] was used to assess Negative Affectivity (α = .88) and Surgency (α = .92). The CBQ consists of 195 items, rated on a 7-point Likert scale (1 = "Extremely untrue of your child"; 7 = "Extremely true of your child").

Parental sensitivity and structuring

Parent and child interactions were videotaped at T1 during four consecutive 5-min sequences (free play, child lead play, parent led play, and a clean-up task). Parental sensitivity and structuring were rated based on the emotional availability scales (EAS) [44]. Sensitivity captures a parent's ability to develop and maintain a positive and healthy emotional connection with the child. Highly insensitive parents display few areas of strength in interactions with their child, e.g. only traumatic signals may elicit parental attention, the parent might appear to "forget" that his/her child is around, whereas highly sensitive parents are attentive and responsive (e.g., positive statements, smiling, interest). Structuring refers to the parent's capacity to support the child's learning, and an optimally structuring parent teaches or helps the child at the same time as s/he permits a degree of autonomy so that the child can learn independently [28]. Overall assessment of sensitivity and structuring are made across the four sequences using seven subscales for each construct (sensitivity: α = .82; structuring: α = .83). All raters were trained and certified as reliable by Biringen, who developed the EAS-scales. The inter-rater reliability between multiple blinded coders on a random 10% sample of the videotapes was ICC = .62 for both sensitivity and structuring.

Socioeconomic status

Socioeconomic status was measured by parental occupation, coded according to the International Classification of Occupations [45] on a 6-point scale (1 = Manual workers, 6 = Leaders). If parents were living together the parent with the highest occupation was chosen.

Statistical analyses

Logistic regression analyses were used to estimate stability of pickiness from age 4 to 6. In this multivariate model, pickiness at age 6 was regressed on pickiness, temperament, sensory sensitivity and parenting at age 4, allowing predictors to covary. The proposed pathways tested are illustrated in Additional file 1: Figure S1. Because research has shown that low income predicts pickiness [8], analyses were adjusted for parental socioeconomic status. Gender specific analyses were conducted and Wald tests of parameter constraints were used to test if the predictors were different for boys and girls.

Models were performed in Mplus version 7.0 [46]. We applied a robust maximum likelihood estimator, which is robust to moderate deviations from multivariate normality and provides robust standard errors. A full information maximum likelihood procedure was used to handle missing data. This procedure means that analyses are performed on all available data, provided that cases have values for the dependent variable (pickiness) (n = 1035). Because we used a screen-stratified sample, all analyses were performed using probability weights, which were the inverse of the drawing probability (i.e. low scorers on the SDQ were weighted up and high scorers were weighted down) to produce accurate population estimates. Analyses revealed that none of the study variables predicted attrition.

Results

Preliminary analyses

Preliminary analyses using multinomial logistic regressions between three categories of pickiness (no, moderate and severe pickiness) at age 4 and 6 revealed no difference in predictors of moderate and severe pickiness, supporting the decision to treat pickiness as a dichotomous variable (no versus moderate/severe pickiness).

Table 1 displays the estimated means and SD of all study variables at baseline, as well as the multivariate correlations between the variables. Diagnostic tests to detect multicollinearity issues were run with pickiness at age 6 regressed on pickiness and all predictors at age 4 (children's negative affectivity, surgency, sensory hypersensitivity, parental structuring and sensitivity) [47]. We did not find any multicollinearity issues with the data (tolerance > .50, VIF < 1.99).

Prevalence and stability of pickiness

At age 4, 25.7% of the boys and 26.1% of the girls were categorized as picky eaters. At age 6, 24.8% of the boys and 26.6% of the girls displayed pickiness. There was no significant difference in the proportions of girls and boys categorized as picky eaters at either measurement point

Table 1 Means, standard deviations and correlation coefficients between all study variables at baseline

	Mean (SD)	Children's negative affectivity	Children's surgency	Children's sensory sensitivity	Parental sensitivity	Parental structuring	Socio-economic status
Pickiness	0.28 (0.45)	.13***	−.01	.16***	−.02	−.02	−.01
Children's negative affectivity	3.70 (0.47)		−.18***	.17***	−.08**	−.07*	−.10***
Children's surgency	3.55 (0.61)			−.04	−.03	−.07*	−.02
Children's sensory sensitivity	0.23 (0.98)				−.06*	−.05	−.04
Parental sensitivity	25.18 (3.02)					.71***	.15***
Parental structuring	25.69 (3.18)						.13***
Socioeconomic status	4.41 (0.98)						

Biserial correlations are estimated for the dichotomous pickiness variable. *$p < .05$. **$p < .01$. *** $p < .001$

(Age 4: z = .13, $p = .90$; Age 6: z = .55, $p = .58$). Further, as shown in Table 2, there was moderate stability of pickiness from age 4 to age 6. No gender difference in persistence of pickiness was found (Wald $\chi^2 = 1.49$, df = 1, $p = .22$). In the overall sample, 13.9% displayed pickiness at both ages, thus half of those who were picky eaters at age 4 were also categorized as picky eaters two years later.

Predictors of pickiness

Table 2 displays the results of the logistic regression analyses for the whole sample. The model fit information is as follows: Akaike Information Criterion (AIC) = 18,230.69; Bayesian Information Criterion (BIC) = 18,443.21. AIC and BIC are parsimony-adjusted comparative fir indices and models with smaller AIC and BIC are usually considered more parsimonious [48]. As can be seen in the table, higher levels of parenting sensitivity were found to increase the risk for pickiness at age 6, even when pickiness at age 4 was accounted for. Parental structuring predicted comparatively less pickiness at age 6. More sensory sensitive children were at increased risk for persistent pickiness at age 6, whereas temperamental traits did not predict changes in pickiness over time.

Because SES was unrelated to pickiness in the overall model, SES was not included in the multivariate subgroup model and thus the model fit improved (AIC = 15,651.270, BIC = 15,888.447). Wald tests of parameter constraint revealed that the regression slopes from each predictor to pickiness at age 6, accounting for pickiness at age 4, did not significantly differ between genders (Negative affectivity: Wald $X^2 = 1.53$, df = 1, $p = .212$; Surgency: Wald $X^2 = .88$, df = 1, $p = .35$; Sensory sensitivity: Wald $X^2 = 2.32$, df = 1, $p = .13$; Parental sensitivity: Wald $X^2 = 1.14$, df = 1, $p = .29$; Parental structuring: Wald $X^2 = 1.69$, df = 1, $p = .19$).

Discussion

In light of the high prevalence of picky eating in children and the related negative health outcomes, we aimed to identify predictors of pickiness by following a large and representative sample of Norwegian children from 4 to 6 years of age. Our study adds to existing research by using a semi-structured interview rather than single items or questionnaires thus also capturing impairment of pickiness, and by examining potentially modifiable child and parent predictors. One in four 4 year olds displayed pickiness and the same prevalence was found when they were 6. Pickiness was moderately stable from preschool to school age, and about half of those who displayed pickiness at age 4 were also picky eaters two years later. As expected, our study showed that children who are more sensory sensitive at age 4 are at higher risk for pickiness two years later. As further hypothesized, children who showed high levels of sensory sensitivity and had parents who were high on sensitivity and low on structuring were most likely to display more pickiness over time. Individual differences in temperament did not

Table 2 Multivariable predictors at age 4 of picky eating at age 6 ($n = 1035$)

	Age 6				
Age 4:	B	95% CI	OR	95% CI	*p*
Pickiness	1.78	1.37, 2.18	5.92	3.95, 8.86	≤.001
Children's negative affectivity	0.16	−0,29, 0.61	1.17	0.75, 1.84	.485
Children's surgency	−0.12	−0.45, 0.20	0.88	0.64, 1.22	.455
Children's sensory sensitivity	0.22	0.04, 0.40	1.25	1.08, 2.23	.019
Parental sensitivity	0.10	0.00, 0.19	1.10	1.00, 1.21	.049
Parental structuring	−0.10	−0.19, −0.01	0.90	0.82, 0.99	.024

The OR's are adjusted for all other variables

predict pickiness and there were no gender differences in the prediction of pickiness.

Sensory sensitivity

This is the first study to show that sensory sensitivity prospectively predicts picky eating, adding to earlier cross-sectional findings. Not only taste and smell sensitivity, but also tactile sensitivity is associated with pickiness in children [49, 50]; we therefore included it in the overall sensory sensitivity variable in our study. It is well known that taste exposure increases acceptance and even liking of rejected food in children [35], but tactile exposure might add to this effect [49], as might visual exposure [51].

Parental structuring

As hypothesized, parental structuring reduced the risk of children's picky eating two years later. This result concurs with a previous cross-sectional study examining parental monitoring [52] and a prospective study of parental pressure to eat [53]. Although our study does not reveal the underlying mechanisms, it might be hypothesized that because parents high in structuring facilitate children's learning and exploration within the child's zone of proximal development [54], they are better able to systematically promote exposure of unfamiliar and possibly also previously rejected food, thereby challenging the child within the limits of his/her autonomy.

Parental sensitivity

Although parental sensitivity is a desirable parenting quality associated with a healthy psychosocial development in children (e.g. social competence, emotion regulation) [38], our results indicate that children of highly sensitive parents are at increased odds of future pickiness. Sensitivity captures parents' physical and emotional responses to children's signals and communications, emphasizing affective interactions and negotiation of conflict [54]. As hypothesized in our *sensitive pathway* to pickiness, a plausible explanation of the current finding is that highly sensitive parents may accept the child's reluctance to try new or rejected food and not offer it again, thus reinforcing the child's pickiness. In contrast, less sensitive parents might not be so responsive to children's negative reaction to a food, which could potentially promote exposure.

Gender differences

We did not find gender differences in the stability of pickiness, in contrast to Cano et al. [8] who found boys to be more persistent picky eaters than girls. This inconsistency may be due to different measurement methods (semi-structured interview vs. pickiness operationalized by two items) and length of follow up, but it should be noted that the gender effect detected by Cano et al. [8] was rather small (relative risk ratio [RRR] = .43, p = .05). There was also no difference between genders regarding the predictors of pickiness in our study, but gender differences in the persistence of picky eating are worthy of further exploration.

Limitations

Although the present inquiry has several strengths, such as the longitudinal design, relatively large sample and an interview-based measure of pickiness and sensory sensitivity, some limitations should be noted. Twin studies have shown that pickiness has a strong genetic basis, with >70% of the individual differences in this behavior being accounted for by genetic variation in young children [55]. Although twin studies also show environmental factors to influence interindividual differences in pickiness [21], accounting for genetics may have altered the present results. Because the same instrument (semi-structured parental interview) was used to capture both pickiness and sensory sensitivity, common methods may have inflated the association between the two constructs. In the present study, we adjusted for pickiness at age 4, thereby limiting the common method effect between sensory sensitivity at age 4 and pickiness at age 6. Because the present inquiry is embedded within the larger Trondheim Early Secure Study (TESS), which aims to examine factors related to psychosocial development and development of mental health problems in children, a global measure of parent-child interaction was required and therefore used here. It is plausible that specific parental approaches in response to early signs of picky eating influence the development of pickiness, over and above general aspects of parenting. Future studies should assess specific parent-child interactions around food. To tease out parenting predictors of picky eating future studies should also be powered to examine high vs. low levels of sensitivity and structuring. Since the inter-rater reliability of the parenting variables was moderate, the strengths of the predictions from parenting may be underestimated. It should further be noted that observations of parent-child interactions took place at the University lab, thus reactivity to a novel environment might have affected the results. Finally, to extend the current study, future research should capture longer developmental periods.

Implications and future directions

Our results suggest that interventions reducing sensory sensitivity or the way it is handled by parents might decrease the risk of picky eating, although clinical trials are needed to test this assumption. One observational study of novel fruit introduction in 2–4 year olds showed that verbal pressure to eat did not affect intake,

whereas physical prompting predicted child swallowing and enjoying the new fruit [25]. The authors suggest that moving the fruit towards the child, holding it under the child's nose or up to the line of sight to encourage smelling, looking at and holding the fruit, increases sensory exposure, which might be the mechanism facilitating acceptance. Thus, encouragement and gentle exposure may work, but there is no indication that enforcement would. Because picky eating varies by age [1], our findings cannot be generalized to other age groups and also needs to be replicated in other cultures.

Conclusions

We found that highly sensory sensitive children whose parents were high on sensitivity and low on structuring were the ones most likely to display more pickiness over time, even if pickiness seems to be relatively stable between the ages of 4 and 6. It is important to increase the awareness of healthcare providers about the predictors of picky eating, especially those that are modifiable, such as parenting. Although parental sensitivity indeed should be encouraged, sensitive parents may profit from support to increase their adaptive behavior (e.g., expose the child and handle the child's potential uneasiness) in order to reduce their child's pickiness. Repeatedly offering unfamiliar and rejected foods in a firm way without pressure while acknowledging child autonomy seems a promising avenue for future research and intervention.

Abbreviations

AIC: Akaike information criterion; BIC: Bayesian information criterion; CBQ: Children's behavior questionnaire; EAS: Emotional availability scales; ICC: Intraclass correlation; PAPA: Preschool age psychiatric assessment; SDQ: Strengths and difficulties questionnaire; SES: Socioeconomic status

Acknowledgements

We would like to thank the participants of the Trondheim Early Secure Study (TESS), which the current inquiry is based on, and the research assistants who collected the data applied.

Funding

This research was funded by the Research Council of Norway, grants 213,793 and 191,144/V50.

Authors' contributions

SS participated in the design of the study, drafted the original manuscript, performed the data analysis, and approved the final manuscript as submitted. AR-B contributed to the statistical analyses, reviewed and revised the original manuscript, and approved the final manuscript as submitted. AF participated in the design of the study, reviewed and revised the original manuscript, and approved the final manuscript as submitted. CHL participated in the design of the study, reviewed and revised the original manuscript, and approved the final manuscript as submitted. LW conceptualized and designed the study, contributed to the data analyses, reviewed and revised the original manuscript, and approved the final manuscript as submitted.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Department of Psychology, Norwegian University of Science and Technology (NTNU), Dragvoll, 7491, Trondheim, Norway. [2]Grove House, Roehampton Lane, Roehampton University, London SW15 5PJ, UK. [3]School of Psychology, University of Leeds, Leeds LS2 9JT, UK. [4]Department of Behavioural Science & Health, University College London, 1-19 Torrington Place, London WC1E 7HB, UK. [5]NTNU Social Research, 7491 Trondheim, Norway.

References

1. Dovey TM, Staples PA, Gibson EL, Halford JCG. Food neophobia and 'picky/fussy' eating in children: a review. Appetite. 2008;50:181–93.
2. Taylor CM, Wernimont SM, Northstone K, Emmett PM. Picky/fussy eating in children: Review of definitions, assessment, prevalence and dietary intakes. Appetite. 2015;95:349–59.
3. Mascola AJ, Bryson SW, Agras WS. Picky eating during childhood: a longitudinal study to age 11 years. Eat Behav. 2010;11:253–7.
4. Galloway AT, Fiorito L, Lee Y, Birch LL. Parental pressure, dietary patterns, and weight status among girls who are 'picky eaters. J Am Diet Assoc. 2005;105:541–8.
5. Tharner A, Jansen PW, Kiefte-de Jong JC, Moll HA, van der Ende J, Jaddoe VWV, Hofman A, Tiemeier H, Franco OH. Toward an operative diagnosis of fussy/picky eating: a latent profile approach in a population-based cohort. Int J Behav Nutr Phys Act. 2014;11
6. Jacobi C, Schmitz G, Agras WS. Is picky eating an eating disorder? Int J Eat Disord. 2008;41:626–34.
7. Zucker N, Copeland W, Franz L, Carpenter K, Keeling L, Angold A, Egger H. Psychological and psychosocial impairment in preschoolers with selective eating. Pediatrics. 2015;136:E582–90.
8. Cano SC, Tiemeier H, Van Hoeken D, Tharner A, Jaddoe VWV, Hofman A, Verhulst FC, Hoek HW. Trajectories of picky eating during childhood: a general population study. Int J Eat Disord. 2015;48:570–9.
9. Jacobi C, Agras WS, Bryson S, Hammer LD. Behavioral validation, precursors, and concomitants of picky eating in childhood. J Am Acad Child Adolesc Psychiatry. 2003;42:76–84.
10. Hafstad GS, Abebe DS, Torgersen L, von Soest T. Picky eating in preschool children: The predictive role of the child's temperament and mother's negative affectivity. Eat Behav. 2013;14:274–7.
11. Cano SC, Hoek HW, Bryant-Waugh R. Picky eating: the current state of research. Curr Opin Psychiatry. 2015;28:448–54.
12. Haycraft E, Farrow C, Meyer C, Powell F, Blissett J. Relationships between temperament and eating behaviours in young children. Appetite. 2011;56:689–92.
13. Anzman-Frasca S, Stifter CA, Birch LL. Temperament and childhood obesity risk: a review of the literature. J Dev Behav Pediatr. 2012;33:732–45.
14. Bergmeier H, Skouteris H, Horwood S, Hooley M, Richardson B. Child temperament and maternal predictors of preschool children's eating and body mass index. A prospective study. Appetite. 2014;74:125–32.
15. Ventura AK, Birch LL. Does parenting affect children's eating and weight status? Int J Behav Nutr Phys Act. 2008;5
16. Vollmer RL, Mobley AR. Parenting styles, feeding styles, and their influence on child obesogenic behaviors and body weight. A review. Appetite. 2013; 71:232–41.
17. Lucarelli L, Cimino S, D'Olimpio F, Ammaniti M. Feeding disorders of early childhood: An empirical study of diagnostic subtypes. Int J Eat Disord. 2013;46:147–55.
18. Rothbart MK, Derryberry D, Posner MI. A psychobiological approach to the development of temperament. In: JEBTD W, editor. Temperament: Individual differences at the interface of biology and behavior. Washington, DC: American Psychological Association; 1994. p. 83–116. APA science volumes.
19. Pliner P, Hobden K. Development of a scale to measure the trait of foof neophobia in humans. Appetite. 1992;19:105–20.
20. Alley TR, Willet KA, Muth ER. Motion sickness history, food neophobia, and sensation seeking. Percept Mot Skills. 2006;102:683–90.
21. Smith A, Herle M, Fildes A, Cooke L, Steinsbekk S, Llewellyn CH: Food fussiness and food neophobia share a common etiology in early childhood. J Child Psychol Psychiatry. 2016;58(2):189–96.
22. Rothbart MK, Ahadi SA, Hershey KL, Fisher P. Investigations of temperament at three to seven years: the children's behavior questionnaire. Child Dev. 2001;72:1394–408.

23. Rothbart MK, Ahadi SA, Hershey KL. Temperament and social-behavior in childhood. Merrill Palmer Quart. 1994;40:21–39.
24. Dunn W. The sensations of everyday life: Empirical, theoretical, and pragmatic considerations. Am J Occup Ther. 2001;55:608–20.
25. Blissett J, Fogel A. Intrinsic and extrinsic influences on children's acceptance of new foods. Physiol Behav. 2013;121:89–95.
26. Coulthard H, Blissett J. Fruit and vegetable consumption in children and their mothers. Moderating effects of child sensory sensitivity. Appetite. 2009;52:410–5.
27. Farrow CV, Coulthard H. Relationships between sensory sensitivity, anxiety and selective eating in children. Appetite. 2012;58:842–6.
28. Saunders H, Kraus A, Barone L, Biringen Z. Emotional availability: theory, research, and intervention. Front Psychol. 2015;28(6):1069. doi: 10.3389/fpsyg.2015.01069.
29. Blissett J. Relationships between parenting style, feeding style and feeding practices and fruit and vegetable consumption in early childhood. Appetite. 2011;57:826–31.
30. Rodenburg G, Kremers SPJ, Oenema A, van de Mheen D. Associations of children's appetitive traits with weight and dietary behaviours in the context of general parenting. PLoS One. 2012;(12):e50642, doi: 10.1371/journal.pone.0050642. epub 2012 dec. 5.
31. Montano Z, Smith JD, Dishion TJ, Shaw DS, Wilson MN. Longitudinal relations between observed parenting behaviors and dietary quality of meals from ages 2 to 5. Appetite. 2015;87:324–9.
32. Kremers SP, Brug J, de Vries H, Engels R. Parenting style and adolescent fruit consumption. Appetite. 2003;41:43–50.
33. Sleddens EFC, Kremers SPJ, Stafleu A, Dagnelie PC, De Vries NK, Thijs C. Food parenting practices and child dietary behavior. Prospective relations and the moderating role of general parenting. Appetite. 2014;79:42–50.
34. Vaughn AE, Ward DS, Fisher JO, Faith MS, Hughes SO, Kremers SPJ, Musher-Eizenman DR, O'Connor TM, Patrick H, Power TG. Fundamental constructs in food parenting practices: a content map to guide future research. Nutr Rev. 2016;74:98–117.
35. Cooke L. The importance of exposure for healthy eating in childhood: a review. J Hum Nutr Diet. 2007;20:294–301.
36. Remington A, Anez E, Croker H, Wardle J, Cooke L. Increasing food acceptance in the home setting: a randomized controlled trial of parent-administered taste exposure with incentives. Am J Clin Nutr. 2012;95:72–7.
37. Fildes A, van Jaarsveld CHM, Wardle J, Cooke L. Parent-administered exposure to increase children's vegetable acceptance: a randomized controlled trial. J Acad Nutr Diet. 2014;114:881–8.
38. Biringen Z, Derscheid D, Vliegen N, Closson L, Easterbrooks MA. Emotional availability (EA): Theoretical background, empirical research using the EA Scales, and clinical applications. Dev Rev. 2014;34:114–67.
39. Wichstrom L, Belsky J, Berg-Nielsen TS. Preschool predictors of childhood anxiety disorders: a prospective community study. J Child Psychol Psychiatry. 2013;54:1327–36.
40. Goodman R. The strengths and difficulties questionnaire: a research note. J Child Psychol Psychiatry. 1997;38:581–6.
41. Population's level of education [http://www.ssb.no/en/utdanning/statistikker/utniv/aar].
42. Wichstrøm L, Berg-Nielsen TS, Angold A, Egger HL, Solheim E, Sveen TH. Prevalence of psychiatric disorders in preschoolers. J Child Psychol Psychiatry. 2012;53:695–705.
43. Egger HL, Erkanli A, Keeler G, Potts E, Walter BK, Angold A. Test-retest reliability of the Preschool Age Psychiatric Assessment (PAPA). J Am Acad Child Adolesc Psychiatry. 2006;45:538–49.
44. Biringen, Z. The Emotional Availabiity (EA) Scales Manual, 4th Edn. Boulder: International Center for Excellence in Emotional Availability; 2008.
45. International Labour Office. ISCO-88 international standard classification of occupation. Genève: International Labour Office; 1990.
46. Muthèn LK, Muthèn BO: Mplus user's guide. Sixth Edition. Los Angeles: Muthen & Muthen; 1998–2010.
47. Cohen J, Cohen P, West SG, Aiken LS. Applied multiple regression/correlation analysis for the behavioral sciences. New York: Lawrence Erlbaum Associates; 2003.
48. Kline R. Principles and practice of structural equation modeling. 4th ed. New York: Guilford Press; 2016.
49. Werthmann J, Jansen A, Havermans R, Nederkoorn C, Kremers S, Roefs A. Bits and pieces. Food texture influences food young children. Appetite. 2015;84:181–7.
50. Nederkoorn C, Jansen A, Havermans RC. Feel your food. The influence of tactile sensitivity on picky eating in children. Appetite. 2015;84:7–10.
51. Heath P, Houston-Price C, Kennedy OB. Increasing food familiarity without the tears. A role for visual exposure? Appetite. 2011;57:832–8.
52. Jani R, Mallan KM, Daniels L. Association between Australian-Indian mothers' controlling feeding practices and children's appetite traits. Appetite. 2015;84:188–95.
53. Jarman M, Ogden J, Inskip H, Lawrence W, Baird J, Cooper C, Robinson S, Barker M. How do mothers manage their preschool children's eating habits and does this change as children grow older? A longitudinal analysis. Appetite. 2015;95:466–74.
54. Biringen Z. Emotional availability: Conceptualization and research findings. Am J Orthop. 2000;70:104–14.
55. Fildes A, van Jaarsveld CHM, Cooke L, Wardle J, Llewellyn CH. Common genetic architecture underlying young children's food fussiness and liking for vegetables and fruit. Am J Clin Nutr. 2016;103:1099–104.

Effects of a physical activity and nutrition program in retirement villages: a cluster randomised controlled trial

Jonine Jancey[1*], Anne-Marie Holt[1], Andy Lee[1], Deborah Kerr[1], Suzanne Robinson[2], Li Tang[2,3], A.S. Anderson[4], Andrew P. Hills[5] and Peter Howat[2]

Abstract

Background: This cluster randomised controlled trial aimed to determine if a 6- month home-based intervention could improve the physical activity and dietary behaviours of adults aged 60 to 80 years living in retirement villages located in Perth, Western Australia.

Methods: Participants (n = 363) from 38 retirement villages were recruited into the trial and allocated to the intervention (n = 197: 17 sites) or control (n = 166: 21 sites) group and were blinded. Previously validated instruments-Fat and Fibre Barometer and International Physical Activity Questionnaire, along with anthropometric measures (weight, height, waist and hip circumferences) and blood pressure were collected at baseline and 6 -month time period. Comparisons between intervention and control groups were undertaken pre- and post- intervention using univariate chi-square and t-tests. Multi-level mixed regression analyses were then conducted to ascertain the effects of the intervention on changes in the outcome variables over time and between groups.

Results: A total of 139 (70.5%) intervention and 141 (84.9%) control group participants completed the program and post-test assessments. The intervention group demonstrated significant increases in time (80 min more per week on average) devoted to moderate-intensity physical activity, engagement in strength exercises (from 23.7% to 48.2%), frequency of fruit consumed as well as fat avoidance and fibre intake scores, in addition to a 0.5 kg mean reduction in weight post program, whereas no apparent changes were observed in the control group. Mixed regression results further confirmed statistically significant improvements in weight loss ($p < 0.05$), engagement in strength exercises ($p < 0.001$) and fruit intake ($p = 0.012$) by the intervention participants at post-test relative to their controls.

Conclusions: Retirement offers a time to reassess lifestyle, and adopt positive health enhancing physical activity and dietary behaviours. This intervention was successful in improving weight, engagement in strength exercises, increasing levels of moderate-intensity physical activity and consumption of fruit among retirement village residents. Further investigation is needed on how to better engage retirement village managers in such programs.

Trial registration: Australia and New Zealand Clinical Trial Registry (ACTRN12612001168842) registered November 2, 2012.

Keywords: Retirement villages, Physical activity, Strength exercise, Walking, Fruit and vegetable intake, Weight management

* Correspondence: j.jancey@curtin.edu.au
[1]Collaboration for Evidence, Research and Impact in Public Health, School of Public Heath, Curtin University, GPO Box U1987, Perth, WA 6845, Australia
Full list of author information is available at the end of the article

Background

As with other developed countries, Australia's population is aging, with the proportion of adults aged over 65 predicted to increase to 25% by the year 2025 [1]. Worldwide, older adults are currently amongst the least physically active population group [2], with almost 50% of Australians aged over 60 years not meeting the recommended physical activity guidelines [1]. In addition, Australians consume a diet high in saturated fat, sugar and salt and low in fibre, fruit and vegetables [3], with between 8 and 10% of those aged 65–74 years not meeting the recommended intake for fruit and vegetables [1, 4]. This sedentary lifestyle combined with a less than optimal diet contributes to the increasing proportion of older adults being overweight and obese (more than 60%) [5].

Participation in regular physical activity, both aerobic and resistance training, along with the consumption of a healthy diet can counter functional decline and the associated chronic disease [6, 7]. Combining physical activity with dietary management can build muscle mass, increase metabolic rate while contributing to weight loss [4, 8]. Evidence also supports longer-term adherence to programs that are multi-component, such as a combination of physical activity and nutrition, as this type of program is more challenging and less repetitious [9]. However, reaching and motivating people to increase their level of physical activity and improve their dietary intake can be demanding, and even more so when these habits are well established, as with older adults.

In Australia, 'retirement village' refers to a range of housing types where adults live independently. Retirement villages are becoming an increasingly popular residential choice for older age groups [10]. An estimated 5.7% of Australian adults aged 65 years and over reside in over 2000 retirement villages, and demand for this type of accommodation is projected to rise to 7.5% in the next decade [10–13].

Retirement villages target functionally mobile and independent older adults, requiring no or very low level of domiciliary care [13–16]. The communities are usually 'gated' with housing purpose-built for an older population group, which offer a range of accommodation options, such as group housing and independent living units (ILUs) that are usually apartments or villas. Although there are often recreational and social facilities available [17, 18], the older adults residing in retirement villages tend to have sedentary lifestyles [12, 19, 20]. This makes retirement villages an ideal setting to target those with low levels of physical activity and less than optimum dietary behaviours [13, 21], as despite the inclusion of light recreation or therapy-based activities such as falls prevention [12], these activities offered to residents are poorly attended. [13, 21].

Retirement is a major life change that provides an opportunity for older adults to modify their eating and activity behaviours [22]. However, to date few randomised controlled trials have been undertaken [15, 23] to understand the impact of tailored physical activity and nutrition programs for older adults in retirement villages. This is surprising, considering the steady increase in the aging population and demand for this type of accommodation [10, 24, 25]. This study presents the results of a physical activity and nutrition intervention for adults aged 60 to 80 years living in retirement villages located in Perth, Western Australia. This study aimed to determine changes in retirement village residents' levels of physical activity, dietary behaviours and anthropometry of the intervention group participants at the end of the 6- month intervention period, in comparison to the control group participants.

Methods

Study design

The protocol for this trial has been described in detail previously [10], in accordance with the Consolidated Standards of Reporting Trial (CONSORT) Statement (see Fig. 1 for Consort flow chart and Additional file 1 for the Consort Check list). This study was a cluster randomised controlled trial of a 6-month individual physical activity and nutrition intervention. Data were collected from the intervention and control participants at baseline and post-test (6-month time period). Ethical approval of the study was obtained from the Curtin University Human Research Ethics Committee (approval number HR 128/2012). Trial registration was lodged with the Australia and New Zealand Clinical Trial Registry (ACTRN12612001168842). All participants were informed of the study objectives, their rights and provided written informed consent prior to being included in the baseline data collection.

Intervention

The retirement village physical activity and nutrition intervention program was guided by Social Cognitive Theory and Motivational Interviewing. The six-month intervention program was designed to support participants through personal goal setting, monitoring and feedback on progress, skill building as well as the provision of social support via group participation [26]. The program incorporated a number of educational resources (booklet, calendar, exercise chart, resistance bands and bi-monthly newsletters) based on the National Physical Activity and Dietary Guidelines [4, 27], and trained program ambassadors of a similar age. The program ambassadors were responsible for two face-to-face meetings whereby they introduced the program, and distributed and explained the program resources. This face-to- face introduction

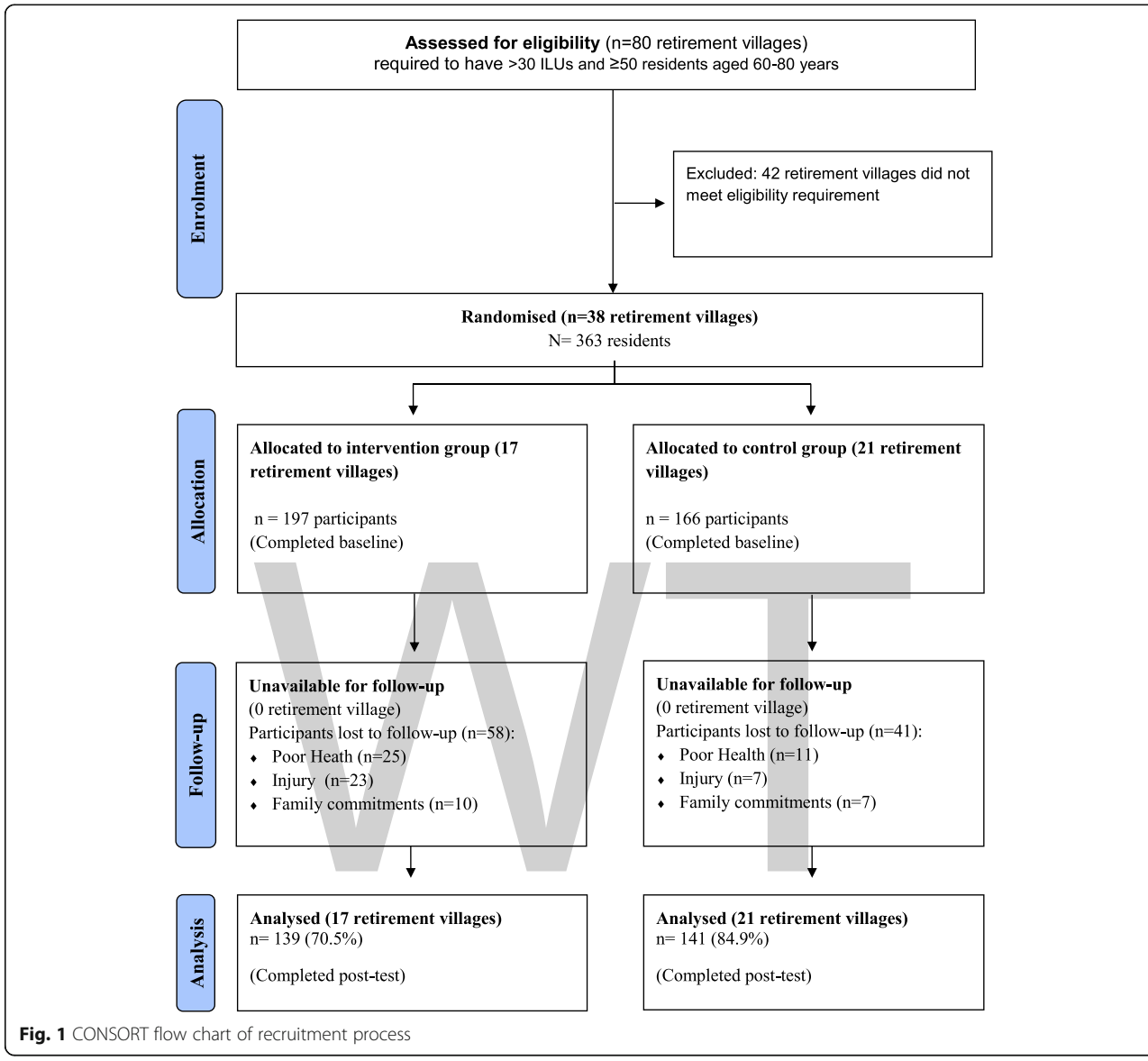

Fig. 1 CONSORT flow chart of recruitment process

discussed goal setting, included a demonstration of the exercise program and responded to any questions. This was then followed-up by regular telephone contact by the program ambassadors. The frequency of the telephone contact was tailored to the needs of participants, which varied between weekly to monthly contact depending on individual preference, as was the motivational interviewing upon agreement with the participants. Motivational interviewing by these ambassadors via telephone contact supported participant goal setting, adherence and program sustainability [28]. Full details of the intervention have been reported elsewhere [12].

Procedure

The study was conducted within a 75-km radius of metropolitan Perth, the capital of Western Australia. Retirement villages with over 30 ILUs were eligible for inclusion if they had at least 50 residents aged between 60 and 80 years. Initial contact was made with the village management and resident committees via telephone and followed up with an email describing the project and its aims. Upon agreement, the retirement village residents were informed of the project through an onsite information session promoted by the managers, and/or a reply paid postcard placed in their letterbox. The postcard explained the program, provided the researchers' contact details and invited residents to return the postcard if they were interested in being involved in the program. This recruitment procedure had been used successfully in other settings with the same age group [29, 30]. Once informed consent was obtained, participants completed the Physical Activity Readiness Questionnaire (PARQ) at baseline [31].

Participants

The 38 retirement villages located over a 75 km radius to avoid contamination, were randomly allocated to control (21 sites) or intervention (17 sites) groups using a table of random numbers, while taking into account the relative size of these retirement villages and the expected lower response rate of the controls. There were 1680 residents in total. From the 583 blinded residents who registered to participate in the study, 363 (intervention n = 197, control n = 166) met the selection criteria (reported undertaking less than 150 min of moderate-intensity physical activity per week, on no special diet and not participating in any other physical activity program).

Measurement instruments

The International Physical Activity Questionnaire-Short Version [32] enabled collection of information on physical activity (walking, moderate- and vigorous-intensity activity) and sitting time in minutes per week. Definitions and examples of moderate- and vigorous-intensity physical activity were provided on the paper based self-complete questionnaire. Muscle strength exercise questions were taken from the American Heart Association guidelines [33].

Dietary habits were assessed via the validated Fat and Fibre Barometer [34]. This questionnaire contains 20 food behaviour items to assess an individual's fat-related food intake (fried foods, dairy foods, meat, chicken and butter) and fibre-related food intake (whole grain foods, fruit and vegetables). Response values for each item range from 1 to 5, with '1' representing food behaviour associated with the high fat intake or low fibre intake, to '5' representing the low fat or high fibre intake. Fat and fibre scores were calculated by summing the scores from the corresponding fat and fibre foods consumed. Individual items on frequency of fruit and vegetables servings (servings were defined and depicted in the questionnaire), were also recorded.

Guided by a measurement protocol, anthropometric measurements were undertaken by a trained researcher and included height, weight, waist and hip circumferences using a portable stadiometer, calibrated electronic scale, and tape measure, respectively. Blood pressure was measured using an Omron M5–1 electronic sphygmomanometer. A mean value was obtained after for all three consecutive measurements. All measurements were taken at baseline and post-intervention (6- months) following standard protocols and guidelines. Demographic information recorded included gender, age, education level, relationship status, smoking status and presence of co-morbidities.

Statistical analysis

Descriptive statistics were used to summarise the baseline demographic, health and lifestyle characteristics. Comparisons between intervention and control groups were undertaken across the two time points using independent samples and paired t-tests for continuous variables and chi-square test for categorical variables.

Co-primary outcomes of interest were physical activity level (for walking, sitting time, moderate- and vigorous-intensity activity and strength exercises) and dietary intake behaviours (fruit intake, vegetables intake, fibre intake, fat intake and fat avoidance), along with a host of secondary outcomes that included anthropometric status (weight, body mass index (BMI), waist-to-hip ratio (WHR)) and blood pressure. In the presence of many zeros, strength exercise and vigorous physical activity were dichotomised to indicate participation status (yes; no), whereas walking, sitting time and moderate-intensity physical activity remained as continuous variables (minutes per week). In terms of dietary behaviours, consumption of at least two servings of fruit (vegetables) on three to seven days per week was classified as frequent intake, and otherwise as infrequent. The fibre intake, fat intake and fat avoidance scores were calculated by summing individual item scores (range 1–5) for all corresponding applicable questions; the sum of each component was then divided by the number of applicable items.

To accommodate the correlation of repeated pre- and post- measures from the same person and the clustering of observations within retirement villages, multilevel mixed regression models with random effects (participants and retirement villages) [35] were fitted to assess the intervention effect on changes in outcome variables over time, while accounting for the influence of potential confounders (age, gender, height, education level, relationship status, smoking status, and presence of co-morbidity). All binary outcomes (strength exercise, vigorous-intensity physical activity, frequent fruit intake and frequent vegetable intake) were analysed using logistic mixed regression models, whereas linear mixed regressions were applied to anthropometric outcomes (weight, BMI, WHR), blood pressure, walking time, fibre intake, fat intake and fat avoidance scores. The walking variable was logarithmicly transformed prior to regression analysis due to its positively skewed distribution. Gamma mixed regression was considered appropriate for modelling the highly skewed sitting variable and moderate activity [26]. All statistical analyses were performed in the SPSS Statistical Package Version 22.0 [36]. Sample size calculations are reported elsewhere [10].

Results

Thirty-eight (47.5%) of the 80 eligible retirement villages agreed to participate in the study. The retirement village on-site information sessions were the preferred and most effective mechanism to promote the program and recruit residents (66.4%), with the postcard distribution

recruitment method being less effective (33.6%). Of the 363 residents who entered the program (intervention: n = 197, control: n = 166), 280 (intervention: n = 139, control: n = 141) remained at post-test, resulting in an overall retention rate of 77.7% (intervention: 70.5%, control: 80.9%). Of the 83 participants who withdrew, 43.4% (intervention: n = 25, control: n = 11) nominated poor health, 36.1% (intervention: n = 23, control: n = 7) were due to injury and 20.5% (intervention: n = 10, control: n = 7) because of family commitments (See Fig. 1).

The average age of the 280 program completers was 72 (SD 5.2) years, with a mean height of 1.6 (SD 0.1) metres. Nearly half had attained tertiary education (48.9%). The majority of participants were female (74.6%), had never smoked (61.1%) and experienced health conditions common to this age group (85.4%). Compared to controls, the intervention participants tended to live with a partner (p = 0.024). There were no statistically significant differences in demographic characteristics between those who completed the study (n = 280) and those who dropped out (n = 83). Table 1 presents the characteristics of the sample at baseline.

Changes in physical activity

No significant differences were recorded in mean walking, sitting time ($p > 0.05$) and prevalence of vigorous-intensity activity ($p > 0.10$) in both groups, but a significant improvement in moderate-intensity activity was evident in the intervention group, an increase of 80-min per week on average, in contrast to only 8-min per week in the controls. Similarly, intervention participants exhibited significantly higher levels of engagement in strength exercise from baseline (23.7%) to post-program (48.2%) ($p < 0.001$) compared to a small increase (2%) in the control group (p = 0.693). Furthermore, significant differences were found in the time devoted to moderate-intensity physical activity (p = 0.004) and the prevalence of strength exercise (p = 0.002) between the two groups at 6- months.

Changes in dietary behaviours

Although both groups reported similar fruit intake at baseline, the intervention participants showed a significant increased intake than controls post-program (p = 0.007). The intervention group also showed a significant increase in mean fibre (p = 0.006) and significant decrease in fat intake scores ($p < 0.001$). As expected, there was little change in dietary habits among controls over the 6-month period.

Changes in anthropometry

Mean BMI, WHR and blood pressure scores at 6-months did not differ from baseline for either group. However, a 0.5 kg reduction in mean weight was evident among the intervention participants from baseline to

Table 1 Baseline characteristics of intervention participants and controls

Variables	Tota (n = 280)	Intervention group (n = 139)	Control group (n = 141)	p[a]
Gender				0.449
Female	209 (74.6%)	101 (72.7%)	108 (76.6%)	
Male	71 (25.4%)	38 (27.3%)	33 (23.4%)	
Education level				0.326
Secondary school or below	143 (51.1%)	77 (55.4%)	66 (46.8%)	
Trade certificate/diploma	57 (20.4%)	27 (19.4%)	30 (21.3%)	
University	80 (28.5%)	35 (25.2%)	45 (31.9%)	
Relationship status				0.024
No partner	103 (36.8%)	42 (30.2%)	61 (43.3%)	
With partner	177 (63.2%)	97 (69.8%)	80 (56.7%)	
Smoking status				0.827
Never	171 (61.1%)	84 (60.4%)	87 (61.7%)	
Former/current	109 (38.9%)	55 (39.6%)	54 (38.3%)	
Co-morbidity [b]				0.116
No	41 (14.6%)	25 (18.0%)	16 (11.3%)	
Yes	239 (85.4%)	114 (82.0%)	125 (88.7%)	
Age: mean (SD) years	72 (5.2)	72.71 (5.02)	71.88 (5.39)	0.186
Height: mean (SD) m	1.6 (0.1)	1.63 (0.09)	1.64 (0.10)	0.504

SD standard deviation
[a]Chi-square or *t*-test between intervention and control groups
[b]Presence of at least one of eight common health conditions

post-program (p = 0.027), whereas no change was recorded in the control group. Table 2 summarises between-group comparisons of all outcomes.

Regression analysis

Table 3 presents results from mixed regression analyses which confirmed a marginal improvement in weight (p = 0.047) and a significant increase in engagement in strength exercise (p < 0.001) across the intervention relative to controls. There was also an increase in time spent on moderate-intensity physical activity for both groups at post-test (p = 0.011), yet the intervention group committed significantly more minutes per week than controls (p = 0.008). The likelihood of frequent fruit intake significantly increased in the intervention group at post-test (p = 0.012) relative to controls, whereas no change was apparent in vegetable or fibre intake, fat intake and fat avoidance scores for both groups (p > 0.10).

Discussion

Recruitment and retention

This study investigated the impact of a semi-tailored physical activity and nutrition intervention on adults aged 60 to 80 years living in retirement villages, an increasingly popular residential choice for the aging population. The program's retention rate was high (77.7%) and compared well with similar community-based programs [26, 37]. However some community-based programs for older adults have reported attrition rates of 50%, suggesting this population may be more prone to attrition [30]. Aspects of program tailoring, increasing acceptability and access [38] should be considered as loss of participants may introduce bias and reduce the representativeness of findings. It was reassuring that the demographic characteristics of dropouts in this study did not differ from those of program completers.

The initial recruitment of the retirement villages was challenging as only 38 of the 80 village managers contacted agreed to participate. This was despite several personal contacts made by telephone to explain the study purpose, the feasibility of residents participating and their preferred process for contacting residents. Over half (n = 42) of the retirement village managers chose not to take part, despite the program being free, managed by trained professionals and readily available to residents. Further investigation into reasons for their rejection is important in order to optimise response rates in future replications of the program.

This research also highlighted the key role retirement village manager's play as 'gate keepers'. The support of managers for recruitment information sessions was essential, with the majority of participants (66.4%) being recruited via this approach. Involvement by managers may have led to perceived ownership of the intervention and therefore more promotion and ongoing support during the study period, thereby increasing program adherence and the likelihood of long-term sustainability after external funding ceased. Independent living is considered a core value of retirement villages [16] and our program was developed to support this core value.

Physical activity

By the end of the 6-month program, the intervention group showed significant improvements in moderate-intensity physical activity, a mean increase of ~80-min per week. This equated to an extra ~11-min per day and exceeding the recommended physical activity guidelines of 150-min per week for health benefits [27]. Consistent with previous research, very few participated in vigorous-intensity activity [26]. The increase in moderate-intensity physical activity compares favourably with similar physical activity programs for older adults [26, 39] and further demonstrates the substantial gains possible via a low-dose semi-tailored intervention. The retirement village setting may offer even greater potential to influence behaviour change through the use of 'social norms,' due in part to the close living proximity of residents within these gated communities. For example, if a culture of involvement in regular walking was seen, it might encourage other like-minded residents to participate and became more active. Further research is recommended to better understand how social norms can be utilised to support positive health behaviours in this setting [40].

Participation rate in strength exercise had doubled at post-test in the intervention group, in contrast to a small (2%) increase in the control group. Participation in strength exercises has the potential to provide many benefits to aging adults including a contribution to muscular strength and endurance with likely improvement in mobility and reduction in the risk of falls and related injuries [41]. Strength exercises were carried out with low-cost resistance bands and body weight exercises, acceptable to the target group and relatively safe [26, 42]. The combination of strength exercises and aerobic activity has the potential to maximise positive health effects [43] and should be considered for any community-based program.

Dietary behaviours

Lack of knowledge about foods and changing dietary needs may influence the types of foods consumed [4, 44, 45]. This intervention aimed to increase knowledge of appropriate food types and meals through the provision of educational resources and motivational interviewing to support behaviour change. It appears to have had a positive impact in certain dietary behaviours, with the intervention group significantly increasing frequency of fruit intake across the program, along with fibre intake and fat avoidance. These changes are moderately encouraging

Table 2 Comparison of outcomes intervention and controls at baseline and post-program

Outcomes	Intervention group (n = 139)		Control group (n = 141)		
	Baseline	Post	Baseline	Post	
Weight: mean (SD) kg	75.57	75.07	76.84	76.86	$p_2 = 0.515$
	(14.97)	(14.78)	(17.36)	(17.67)	$p_3 = 0.359$
	$p_1 = 0.027$		$p_1 = 0.924$		
Body mass index: mean (SD) kg/m^2	28.38	28.31	28.62	28.59	$p_2 = 0.688$
	(4.59)	(4.97)	(5.63)	(5.74)	$p_3 = 0.667$
	$p_1 = 0.660$		$p_1 = 0.669$		
Waist-to-hip ratio: mean (SD)	0.89	0.89	0.89	0.90	$p_2 = 0.910$
	(0.09)	(0.09)	(0.09)	(0.09)	$p_3 = 0.254$
	$p_1 = 0.727$		$p_1 = 0.093$		
Systolic blood pressure: mean (SD) mmHg	141.01	141.39	141.26	142.42	$p_2 = 0.909$
	(18.17)	(18.92)	(18.30)	(17.88)	$p_3 = 0.640$
	$p_1 = 0.797$		$p_1 = 0.434$		
Diastolic blood pressure: mean (SD) mmHg	78.40	77.22	78.28	79.23	$p_2 = 0.915$
	(9.57)	(9.57)	(9.55)	(10.45)	$p_3 = 0.096$
	$p_1 = 0.089$		$p_1 = 0.199$		
Walking time: mean (SD) minutes per week	239.72	231.59	216.01	224.45	$p_2 = 0.510$
	(324.68)	(260.27)	(275.02)	(270.35)	$p_3 = 0.822$
	$p_1 = 0.769$		$p_1 = 0.712$		
Sitting time: mean (SD) minutes per week	2398.13	2223.38	2426.40	2463.25	$p_2 = 0.812$
	(905.68)	(1089.16)	(1074.20)	(1103.47)	$p_3 = 0.069$
	$p_1 = 0.064$		$p_1 = 0.697$		
Moderate activity: mean (SD) minutes per week	139.79	219.53	129.18	137.83	$p_2 = 0.683$
	(165.88)	(280.90)	(257.86)	(174.48)	$p_3 = 0.004$
	$p_1 = 0.003$		$p_1 = 0.692$		
Vigorous activity: [a] n (%)	23	27	17	25	$p_2 = 0.283$
	(16.5%)	(19.4%)	(12.1%)	(17.7%)	$p_3 = 0.716$
	$p_1 = 0.532$		$p_1 = 0.181$		
Strength exercise: [a]n (%)	33	67	39	42	$p_2 = 0.453$
	(23.7%)	(48.2%)	(27.7%)	(29.8%)	$p_3 = 0.002$
	$p_1 < 0.001$		$p_1 = 0.693$		
Fruit intake: [b]n (%)	96	104	92	84	$p_2 = 0.497$
	(69.1%)	(74.8%)	(65.2%)	(59.6%)	$p_3 = 0.007$
	$p_1 = 0.286$		$p_1 = 0.325$		
Vegetable intake: [b]n (%)	126	127	123	118	$p_2 = 0.363$
	(90.6%)	(91.4%)	(87.2%)	(83.7%)	$p_3 = 0.052$
	$p_1 = 0.834$		$p_1 = 0.398$		
Fibre intake score: mean (SD)	3.51	3.60	3.48	3.50	$p_2 = 0.715$
	(0.58)	(0.55)	(0.63)	(0.56)	$p_3 = 0.138$
	$p_1 = 0.006$		$p_1 = 0.616$		
Fat intake score: mean (SD)	3.50	3.59	3.58	3.63	$p_2 = 0.162$
	(0.51)	(0.52)	(0.47)	(0.44)	$p_3 = 0.527$
	$p_1 < 0.001$		$p_1 = 0.092$		

Table 2 Comparison of outcomes intervention and controls at baseline and post-program *(Continued)*

Fat avoidance score: mean (SD)	3.65	3.70	3.51	3.62	$p_2 = 0.195$
	(0.85)	(0.88)	(0.94)	(0.91)	$p_3 = 0.444$
	$p_1 = 0.290$		$p_1 = 0.049$		

SD standard deviation
[a]participation of at least 10 min
[b]consumption of at least two servings on 3 to 7 days per week
p_1: *p* value for baseline versus post
p_2: *p* value for baseline intervention versus baseline control
p_3: *p* value for post intervention versus post control

as many older Australians are not aware of their nutritional needs [4]. However, there was no statistically significant change in vegetable intake, which may require further investigation. These participants may already maintain adequate vegetable consumption, which may have reduced the opportunity for dietary gain [24].

Weight loss

The 0.5 kg mean reduction in body weight of the intervention group was also encouraging and the adoption of a diet high in fruit and vegetables and low in fats is associated with a lower BMI in older adults [7]. Weight reduction in older adults may be unhealthy if skeletal muscle tissue as opposed to adipose tissue is preferentially lost. We are unable to quantify changes in tissue composition however participants in this intervention were involved in a balanced combination of strength exercises, aerobic activity and dietary education. Considering that approximately 60% of the target population are overweight or obese [46], attempts to improve body composition should involve maximising fat loss and preserving lean tissue and thereby supporting functional and independent living.

Limitations

The present intervention was limited to 6-months in duration due to budget and resource restraints, however it is comparable to other programs for older adults in the literature. This time period may be considered adequate to reflect changes in behaviour [47], taking into account the likelihood of participant attrition over a more extended period, however. Nevertheless, longer

Table 3 Mixed regression analysis of outcomes before and after intervention ($n = 280$)

Outcomes	Group[a] (intervention versus control)			Time[a] (post versus baseline)			Group × time[a]		
	COE	SE	*p*	COE	SE	*p*	COE	SE	*p*
Weight[b]	−1.30	1.61	0.423	0.02	0.20	0.914	−0.54	0.27	0.047
Body mass index[b]	−0.08	0.60	0.893	−0.04	0.08	0.651	−0.03	0.17	0.855
Waist-to-hip ratio[b]	−0.01	0.01	0.468	0.01	0.01	0.143	−0.01	0.01	0.243
Systolic blood pressure[b]	−0.25	2.21	0.910	1.01	1.36	0.457	−0.79	2.41	0.743
Diastolic blood pressure[b]	0.57	1.28	0.658	0.92	0.52	0.077	−2.16	1.01	0.032
Walking time[bc]	0.12	0.14	0.379	−0.02	0.17	0.909	0.23	0.20	0.257
Sitting time[d]	0.02	0.04	0.558	0.02	0.04	0.640	−0.11	0.05	0.027
Moderate activity[d]	0.96	0.36	0.008	0.44	0.17	0.011	0.07	0.21	0.726
Vigorous activity[e]	0.34	0.36	0.347	0.47	0.34	0.170	−0.26	0.40	0.513
Strength exercise[e]	−0.26	0.30	0.387	0.12	0.19	0.515	1.14	0.31	<0.001
Frequent fruit intake[e]	0.24	0.25	0.335	−0.30	0.19	0.118	0.63	0.25	0.012
Frequent vegetable intake[e]	0.42	0.36	0.241	−0.30	0.23	0.190	0.39	0.45	0.378
Fibre intake score[b]	0.05	0.09	0.588	0.02	0.04	0.545	0.07	0.05	0.189
Fat intake score[b]	−0.05	0.05	0.340	0.05	0.03	0.106	0.04	0.04	0.285
Fat avoidance score[b]	0.13	0.12	0.266	0.12	0.05	0.023	−0.06	0.07	0.418

COE coefficient, *SE* standard error
[a]adjusted for age (years), height, gender, education level (secondary school or below, trade certificate/diploma, university), relationship status (no partner, with partner), smoking status (never, former/current) and co-morbidity (no, yes)
[b]linear mixed regression model
[c]logarithmic transformed
[d]gamma mixed regression model
[e]logistic mixed regression model

duration studies are recommended for future interventions to determine program sustainability and effectiveness. The inherent self-selection bias could not be avoided for our voluntary participants but was controlled partially through the cluster-randomisation process. Another limitation concerned the lack of objective physical activity and dietary assessments, despite self-report data deemed to be appropriate for determining behavioural changes over time [48], this method can result in over and under-reporting, recall bias and participant burden [49].

Conclusions

Retirement is a period of time that offers important opportunities for individuals to reassess their lifestyle and adopt health-enhancing behaviours such as positive changes to physical activity and diet. The physical activity and nutrition program outlined was successful in improving body weight, engagement in strength exercises, increasing levels of moderate-intensity physical activity and consumption of fruit among retirement village residents. These behaviour changes, if maintained, may contribute to delaying the onset of chronic diseases, support functional mobility and independent living, a core value of retirement villages. Strategies that enhanced such positive behaviour changes included individual knowledge, skill building and access to appropriate services and facilities. This is important information for those involved in the management of retirement villages, a growing segment of the aging residential population. However, more effective engagement of retirement villages and their managers remains a challenge in future research.

Abbreviations

BMI: Body mass index; ILU: Independent living unit; kg: Kilogram; WHR: Waist hip ratio

Acknowledgements

This study was funded by the Western Australian Health Promotion Foundation. We are grateful to the managers and residents of the retirement villages that participated in the study and the program ambassadors who assisted with the program's implementation.

Funding

This project was funded by Healthway, Australia.

Authors' contributions

AH carried out recruitment and data collection, coordinated the intervention program. LT performed statistical analysis and AL supervised the statistical analysis. JJ, AH, AL, PH, DK, SR, AH & AA participated in the design of the study, development of program materials and measurement instruments. JJ drafted the manuscript and AL, AH, PH, DK, SR, AH & AA reviewed and contributed to the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Collaboration for Evidence, Research and Impact in Public Health, School of Public Heath, Curtin University, GPO Box U1987, Perth, WA 6845, Australia. [2]School of Public Health, Curtin University, GPO Box U1987, Perth, WA 6845, Australia. [3]Chinese Evidence-based Medicine Center, West China Hospital, Sichuan University, No. 37 Guoxue Alley, Chengdu, Sichuan Province 610041, China. [4]Centre for Public Health Nutrition Research, Division of Cancer Research, Ninewells Medical School, Dundee University, Level 7, Mailbox 7, Dundee DD1 9SY, UK. [5]University of Tasmania, 41 Charles St, Launceston TAS, Launceston, TAS 7250, Australia.

References

1. Australian Institute of Health and Welfare. Australia's health 2014: the 14th biennial health report. Canberra: AIHW2014 Contract No.: Australia's health series no.13. Cat. no. AUS 156.
2. Sun F, Norman I, While A. Physical activity in older people: a systematic review. BMC Public Health. 2013;13(1):1–17.
3. Australian Bureau of Statistics. Australian Health Survey 2011–13. Canberra: ABS. 2016; Available from: http://www.abs.gov.au/australianhealthsurvey.
4. Brownie S, Muggleston H, Oliver C. The 2013 Australian dietary guidelines and recommendations for older Australians. Aust Fam Physician. 2015;44(5):311–5.
5. Australian National Preventive Health Agency. Evidence brief - obesity: prevalence trends in Australia. Canberra: ANPHA; 2014.
6. Iolascon G, Di Pietro G, Gimigliano F, Mauro A, Moretti A, Giamettei MT, et al. Physical exercise and sarcopenia in older people: position paper of the Italian Society of Orthopaedics and Medicine (OrtoMed). Clinical cases in mineral and bone metabolism. Official Journal of the Italian Society of Orthopaedics and Medicine (OrtoMed). 2014;11(3):215–21.
7. Miller P, Morey M, Hartman T, Snyder D, Sloane R, Cohen H, et al. Dietary patterns differ between urban and rural older, long-term survivors of breast, prostate, and colorectal cancer and are associated with body mass index. J Acad Nutr Diet. 2012;112(6):824–31. 31.e1
8. Frimel T, Sinacore D, Villareal D. Exercise attenuates the weight-loss-induced reduction in muscle mass in frail obese older adults. Med Sci Sports Exerc. 2008;40(7):1213–9.
9. Hughes S, Seymour R, Campbell R, Whitelaw N, Bazzarre T. Best-practice physical activity programs for older adults: findings from the National Impact Study. Am J Public Health. 2009;99(2):362–8.
10. Miskovski K, Chenoweth L, Moore B. Living with dementia in retirement villages: Alzheimer's Australia2015 Contract No.: NSW Discussion Paper 13.
11. Croucher K. Making the case for retirement villages. York, Joseph Rowntree Foundation; 2006.
12. Holt A, Jancey J, Lee A, Kerr D, Hills A, Anderson A, et al. A cluster-randomised controlled trial of a physical activity and nutrition programme in retirement villages: A study protocol. BMJ Open. 2014;4:e005107. doi:10.1136/bmjopen-2014-005107.
13. Nathan A, Wood L, Giles-Corti B. Exploring socioecological correlates of active living in retirement village residents. J Aging Phys Act. 2014;22(1):1–15.
14. Kerr J, Carlson J, Sallis J, Rosenberg D, Leak C, Saelens B, et al. Assessing health-related resources in senior living residences. J Aging Stud. 2011;25(3):206–14.
15. Rosenberg D, Kerr J, Sallis J, Norman G, Calfas K, Patrick K. Promoting walking among older adults living in retirement communities. J Aging Phys Act. 2012;20(3):379–94.
16. Swanson H. Retirement Living Australia: healthcare and retirement living. 2009.
17. Crisp D, Windsor T, Butterworth P, Anstey K. What are older adults seeking? Factors encouraging or discouraging retirement village living. Australasian Journal on Ageing. 2013;32(3):163–70.
18. Jones A, Howe A, Tilse C, Bartlett H, Stimson B. Service integrated housing for Australians in later life. Melbourne: Australian Housing and Urban Research Institute; 2010.
19. Brubaker P. Steps for improving physical activity orientation among health-care providers of older cardiovascular patients. Current Geriatrics Reports. 2014;3(4):291–8.
20. Mihalko S, Wickley K, Sharpe B. Promoting physical activity in independent living communities. Med Sci Sports Exerc. 2006;38(1):112–5.
21. Nathan A, Wood L, Giles-Corti B. Examining correlates of self-reported and objectively measured physical activity among retirement village residents. Australasian Journal on Ageing. 2014;33(4):250–6.
22. Hector D, Espinel P, King L. Reducing the risk of chronic disease in older adults: a summary report to support obesity prevention planning in

NSW. Sydney: Physical Activity, Nutrition and Obesity Research Group (PANORG); 2012.
23. Kerr J, Crist K, Marshal I, Rosenberg D, Castro C, Sallis J, et al. Comprehensive evaluation of a multilevel physical activity intervention in older adults. San Diego: Active Living Research Annual Conference; 2013.
24. Holt A, Lee A, Jancey J, Kerr D, Howat P. Are retirement villages Promoting active aging? J Aging Phys Act. 2016;24(3):407–11.
25. Wan W, Goodkind D, Kowal P. An aging world: 2015. In: International population reports; 2016.
26. Burke L, Lee A, Jancey J, Xiang L, Kerr D, Howat P, et al. Physical activity and nutrition behavioural outcomes of a home-based intervention program for seniors: a randomized controlled trial. Int J Behav Nutr Phys Act. 2013;10(1):1–8.
27. Australian Government Department of Health. Recommendations on physical activity for health for older Australians. 2013. http://www.health.gov.au/internet/main/publishing.nsf/content/130D93778A64136DCA257BF0001DACF2/$File/pa-guidelines.pdf.
28. Teixeira P, Carraca E, Marques M, Rutter H, Oppert J, De Bourdeaudhuij I, et al. Successful behavior change in obesity interventions in adults: a systematic review of self-regulation mediators. BMC Med. 2015;13:84.
29. Burke L, Jancey J, Howat P, Lee A, Kerr D, Shilton T, et al. Physical activity and nutrition program for seniors (PANS): protocol of a randomized controlled trial. BMC Public Health. 2010;10(1):1–7.
30. Jancey J, Clarke A, Howat P, Lee A, Shilton T, Fisher J. A physical activity program to mobilize older people: a practical and sustainable approach. Gerontologist. 2008;48:2.
31. Cardinal BJ, MK. C. Preparticipation physical activity screening with a racially diverse, older adults sample: comparison of the original and revised physical activity readiness questionnaires. Res Q Exerc Sport. 2000;71:302–7.
32. Craig C, Marshall A, Sjostrom M, Bauman A, Booth M, Ainsworth B, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003;35(8):1381–95.
33. Pollock M, Franklin B, Balady G, Chaitman B, Fleg J, Fletcher B, et al. Resistance exercise in individuals with and without cardiovascular disease: benefits, rationale, safety, and prescription an advisory from the committee on exercise, rehabilitation, and prevention, council on Clinical cardiology, American Heart Association. Circulation. 2000;101(7):828–33.
34. Wright J, Scott J. The fat and fibre Barometer, a short food behaviour questionnaire: reliability, relative validity and utility. Aust J Nutr Diet. 2000;57(1):33–9.
35. Burton N, Haynes M, Wilson L, Giles-Corti B, Oldenburg B, Brown W, et al. HABITAT: a longitudinal multilevel study of physical activity change in mid-aged adults. BMC Public Health. 2009;9(1):1–11.
36. IBM Corp. IBM SPSS statistics for windows, Version 22.0. Armonk: IBM Corp; 2013.
37. McCann J, Ridgers N, Carver A, Thornton L, Teychenne M. Effective recruitment and retention strategies in community health programs. Health Promotion Journal of Australia. 2013 Aug;24(2):104–10.
38. Jancey J, Lee A, Howat P, Clarke A, Wang K, Shilton T. Reducing attrition in physical activity programs for older adults. J Aging Phys Act. 2007 Apr;15(2):152–65.
39. Jancey J, Lee A, Howat P, Clarke A, Wang K, Shilton T. The effectiveness of a physical activity intervention for seniors. Am J Health Promot. 2008;22(5):318–21.
40. Miller E, Buys L. Predicting older Australians' leisure time physical activity. Act Adapt Aging. 2007;31(3):13-30.
41. Zhuang J, Huang L, Wu Y, Zhang Y. The effectiveness of a combined exercise intervention on physical fitness factors related to falls in community-dwelling older adults. Clin Interv Aging. 2014;9:131–40.
42. Burke L, Howat P, Lee A, Jancey J, Kerr D, Shilton T. Development of a nutrition and physical activity booklet to engage seniors. BMC Research Notes. 2008;1:77.
43. Silva N, Oliveira R, Fleck S, Leon A, Farinatti P. Influence of strength training variables on strength gains in adults over 55 years-old: a meta-analysis of dose–response relationships. J Sci Med Sport. 2014;17(3):337–44.
44. Flood V, Burlutsky G, Webb K, Wang J, Smith W, Mitchell P. Food and nutrient consumption trends in older Australians: a 10-year cohort study. Eur J Clin Nutr. 2010;64(6):603–13.
45. Pettigrew S, Pescud M, Donovan R. Older people's diet-related beliefs and behaviours: intervention implications. Nutrition & Dietetics. 2012;69(4):260–4.
46. Australian Bureau of Statistics. 3101.0 - Australian Demographic Statistics. Canberra: ABS; 2015; Available from: http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/3101.0Main+Features1Sep%202014.
47. Stiggelbout M, Hopman-Rock M, Crone M, Lechner L, van Mechelen W. Predicting older adults' maintenance in exercise participation using an integrated social psychological model. Health Educ Res. 2006;21(1):1–14.
48. Dhaliwal S, Howat P, Bejoy T, Welborn T. Self-reported weight and height for evaluating obesity control programs. Am J Health Behav. 2010;34(4):489–99.
49. Ainsworth BE, Caspersen CJ, Matthews CE, Masse LC, Baranowski T, Zhu W. Recommendations to improve the accuracy of estimates of physical activity derived from self-report. J Phys Act Health. 2012;9(1):S76–84.

Disparities in dietary intake and physical activity patterns across the urbanization divide in the Peruvian Andes

Morgan L. McCloskey[1], Carla E. Tarazona-Meza[2], Jessica C. Jones-Smith[3], Catherine H. Miele[1], Robert H. Gilman[1], Antonio Bernabe-Ortiz[4], J. Jaime Miranda[4] and William Checkley[1,2*]

Abstract

Background: Diet and activity are thought to worsen with urbanization, thereby increasing risk of obesity and chronic diseases. A better understanding of dietary and activity patterns across the urbanization divide may help identify pathways, and therefore intervention targets, leading to the epidemic of overweight seen in low- and middle-income populations. Therefore, we sought to characterize diet and activity in a population-based study of urban and rural residents in Puno, Peru.

Methods: We compared diet and activity in 1005 (503 urban, 502 rural) participants via a lifestyle questionnaire. We then recruited an age- and sex-stratified random sample of 50 (25 urban, 25 rural) participants to further characterize diet and activity. Among these participants, diet composition and macronutrient intake was assessed by three non-consecutive 24-h dietary recalls and physical activity was assessed using Omron JH-720itc pedometers.

Results: Among 1005 participants, we found that urban residents consumed protein-rich foods, refined grains, sugary items, and fresh produce more frequently than rural residents. Among the 50 subsample participants, urban dwellers consumed more protein (47 vs. 39 g; $p = 0.05$), more carbohydrates (280 vs. 220 g; $p = 0.03$), more sugary foods (98 vs. 48 g, $p = 0.02$) and had greater dietary diversity (6.4 vs 5.8; $p = 0.04$). Rural subsample participants consumed more added salt (3.1 vs 1.7 g, $p = 0.006$) and tended to consume more vegetable oil. As estimated by pedometers, urban subsample participants burned fewer calories per day (191 vs 270 kcal, $p = 0.03$).

Conclusions: Although urbanization is typically thought to increase consumption of fat, sugar and salt, our 24-h recall results were mixed and showed lower levels of obesity in rural Puno were not necessarily indicative of nutritionally-balanced diets. All subsample participants had relatively traditional lifestyles (low fat intake, limited consumption of processed foods and frequent walking) that may play a role in chronic disease outcomes in this region.

Keywords: Nutrition transition, 24-h recall, Urbanization, Overweight, Low- and middle income countries, Chronic diseases

Background

In recent years, the burden of disease in Peru has started to shift [1]. Generally described as the epidemiologic transition, deaths due to communicable diseases are falling, while deaths due to non-communicable disease are on the rise [1]. At the same time, Peru is undergoing a nutrition transition, which is broadly described as a shift in diet and physical activity patterns that results in an increasing prevalence of overweight and obesity [2–4]. A 2012 study assessed the nutrition transition in each Peruvian administrative region, based on anthropometric data [4]. Authors categorized the nutrition transition into three stages, with Stage 1 representing issues of chronic undernutrition, Stage 2 representing both undernutrition and overweight and Stage 3 representing primarily issues of overweight. Only the poorest region remained in Stage 1 of the nutrition transition [4]. A majority of regions (17) were in Stage 2, and seven regions were in Stage 3 [4]. Overall, it is estimated that

* Correspondence: wcheckl1@jhmi.edu
[1]Division of Pulmonary and Critical Care, School of Medicine, Johns Hopkins University, 1830 Monument St Room 555, Baltimore, MD 21205, USA
[2]Biomedical Research Unit, A.B. PRISMA, Lima, Peru
Full list of author information is available at the end of the article

overweight and obesity rates among adults in Peru currently range from 40 to 68% [3–5]. Increases in the number of individuals with excess weight is particularly concerning because obesity is associated with a substantially increased risk of diabetes, hypertension, coronary artery disease, and sleep apnea [6].

The nutrition transition is characterized by shifts in dietary intake, particularly increases in consumption of oils, caloric sweeteners, and animal products, which are thought to precede changes in disease burdens [2]. Between 1990 and 1999, the number of kilocalories available per capita in Peru increased from less than 2000 kcal per day to over 2500 kcal per day [7]. In the Andean region, there has been a significant decrease in consumption of vegetables, starchy roots, and fruit [7]. There has also been a shift from consumption of milk to greater consumption of soda and other sugar-sweetened beverages [5]. The nutrition transition also involves shifts in physical activity, typically toward more sedentary lifestyles [2]. Physical activity levels have decreased throughout the Latin American region and a national study on adults in all regions of Peru reported that 40% live a sedentary life [8]. Similarly, only 28% of Peruvian adults pursue vigorous physical activity [8].

A commonly cited driver of the nutrition transition and these lifestyle changes is urbanization, as individuals tend to shift from agrarian lifestyles to more sedentary jobs [9, 10]. Urbanization typically increases access to processed foods and street foods that are high in sugar, fat, and salt [9, 10]. The CRONICAS cohort, a longitudinal sample of over 3000 adults in four resource-poor settings in Peru, provides a platform to examine these patterns [11]. Rates of overweight and obesity in this cohort ranged from 76.6% in coastal, peri-urban Lima, 76.1% in urban Puno, 75.3% in coastal, semi-rural Tumbes and 48.1% in rural Puno. To better understand these discrepancies and determine if these lifestyle factors may be contributing to patterns of overweight/obesity, we conducted a pilot study on 50 participants in Puno, Peru to collect more detailed data regarding dietary intake and physical activity. We sought to characterize differences in dietary and physical activity patterns in urban and rural residents through the use of 24-h recalls and pedometers.

Methods

Study setting

This study was conducted in Puno, a city in southern Peru with approximately 150,000 inhabitants, at an elevation of 3825 m above sea level. The study population consisted of adults aged ≥35 years living in urban Puno city and surrounding rural communities. Urban participants commonly worked in commerce or education and lived in the city center, whereas rural participants were typically native subsistence farmers and lived in surrounding villages at varying distance from the city.

Study design

Methods associated with the baseline questionnaire are described elsewhere [11]. A baseline lifestyle questionnaire provided information on general nutrition and physical activity among study participants. For the purpose of this study, we limited our analyses to participants in Puno. A total of 1005 participants answered the lifestyles questionnaire. Of these, we selected an age- and sex-stratified random sample of 25 urban and 25 rural participants for dietary intake (24-h recall) and physical activity (pedometer) measurements. Sample size calculations indicated that differences in macronutrient intakes and physical activity would have to be relatively large (331 kcal, 12 g fat, 12 g protein, 44 g carbohydrates and 3500 steps per day) to detect a significant difference with 50 participants, but dietary and physical activity information from the baseline questionnaire indicated there were substantial differences in consumption between urban and rural residents and we could reasonably expect a large effect size.

Ethics approvals

The CRONICAS cohort study was approved by the internal review boards of the Johns Hopkins Bloomberg School of Public Health in Baltimore, MD, and Universidad Peruana Cayetano Heredia and A.B. PRISMA in Lima, Peru. This ancillary study was also approved by the same ethics boards as above and verbal informed consent was obtained and all participants received their sub-study results and generalized guidelines for improving their diet and physical activity habits.

Dietary intake

Among the 1005 participants completing the lifestyle questionnaire, participants reported how frequently they consumed various food groups. From this, we calculated the average number of times per month participants consumed each food group. Food groups included in the questionnaire were representative of commonly eaten foods in this population as well as food groups that are commonly linked to chronic disease (food groups are listed in Table 1). Among the 50 subsample participants, diet was assessed with three, non-consecutive 24-h recalls, including one weekend day. All data collectors were trained together by a licensed nutritionist in Peru, who oversaw the data collection to ensure quality. Data collectors used one form to list all foods that participants consumed individually and another form to list all foods that participants consumed with others as part of a larger preparation. Participants identified portion sizes visually with a Peruvian standardized book that contained

Table 1 Characterization of body mass index, physical activity and average number of times various food groups were consumed per month among study participants in Puno, Peru

	Urban (n = 503)	Rural (n = 502)	p-value	Difference in multivariable analyses[b]	p-value
Mean age in years (SD)	55.3 (12.1)	55.5 (23.5)	0.76	-	-
% Males (n)	49.5 (249)	47.2 (237)	0.47	-	-
Mean wealth index (SD)	294 (7.95)	96.7 (3.38)	<0.001		
Average BMI in kg/m^2 mean (SD)	27.9 (4.37)	25.2 (3.72)	<0.001		
BMI Categories[a]					
% underweight, (n)	0.59% (3)	1.6% (8)	<0.001	-	-
% normal weight, (n)	23.2 (117)	50.5(253)			
% overweight, (n)	49.7 (250)	37.1 (186)			
% obese, (n)	26.4 (133)	10.8 (54)			
Physical Activity					
Average days walking/week, mean (SD)	5.79 (1.96)	6.49 (1.51)	<0.001	0.75	<0.001
Average hours walking/day, mean (SD)	1.57 (2.08)	2.58 (2.11)	<0.001	0.94	<0.001
Food Groups					
Whole grains	14	12	0.25	0.84	0.47
Fruit	25	12	<0.001	−6.8	<0.001
Green vegetables	14	8.9	<0.001	−1.8	0.11
Cooked Vegetables	36	40	0.015	−0.47	0.77
Raw Vegetables	5.8	3.4	<0.001	−2.0	<0.001
Legume	4.6	6.5	0.001	1.7	0.02
Meat	15	16	0.28	2.1	0.22
Organ	4.2	3.4	0.06	−2.5	<0.001
Poultry	13	3.9	<0.001	−7.0	<0.001
Seafood	4.8	3.9	<0.001	−0.55	0.07
Eggs	12	10	0.06	−0.14	0.88
Potatoes	30.	48	<0.001	15	<0.001
Refined Grains	38	14	<0.001	−20	<0.001
Dairy	19	11	<0.001	−4.3	<0.001
Desserts	4.1	2.3	<0.001	−1.1	0.02
Ice Cream	3.1	2.9	0.51	0.14	0.72
Sugar	64	50	<0.001	−13	<0.001
Soda	7.2	4.6	<0.001	−2.4	0.002
Fruit Juice	9.6	3.1	<0.001	−3.9	<0.001
Fried Food	7.0	6.3	0.14	−0.59	0.325
Snacks	4.0	3.7	0.55	−1.0	0.15

[a]BMI categories defined by World Health Organization; underweight (BMI ≤ 18.5 kg/m2); normal weight (18.5 kg/m^2 ≥ BMI ≤ 24.9 kg/m^2); overweight (25 kg/m^2 ≥ BMI ≤ 29.9 kg/m^2); obese (BMI ≥ 30 kg/m^2)
[b]Models were adjusted for age, sex, BMI and wealth index

to-scale pictures of common food items, plate ware and corresponding gram weights [12]. If participants ate from a restaurant, ingredient weights were estimated using restaurant recipes. Supplement intake was not assessed.

Final gram weights of all food items consumed were calculated using an in-house developed software, which allowed for the calculation of waste factors for any foods not consumed in their entirety as well as individual consumption from larger preparations. All foods were codified according to the Peruvian food composition table, which was built into the software, and average macronutrient intakes were calculated for each participant. Due to limitations of the software and a Peruvian food composition table, micronutrient intakes were not included

in the analysis. Any day in which participants consumed less than 400 cal was considered inaccurate and excluded from our analysis, resulting in the exclusion of 1 day from five urban participants and 1 day from one rural participant. Average macronutrient intake and diet composition were calculated for each individual based on mean consumption across the two (n = 6) or 3 days (n = 41) measured. Dietary diversity scores were calculated on a 0–9 scale based on the Food and Agriculture Organization of the United Nation's guidelines for an individual-level Women's Dietary Diversity Score [13]. Each food item was assigned to one of the following categories: starchy staples (white tubers and cereals); dark green leafy vegetables; vitamin A rich fruits and vegetables; other fruits and vegetables; organ meat; meat and fish; eggs; legumes, nuts and seeds; milk products. Additional categories were created to further assess diet: sugar (manually added); sugary foods (desserts, candy, soda, sugary drink mixes, etc); added salt and oil (vegetable oil, butter).

Physical activity and anthropometrics

In the larger cohort, height and weight were assessed in triplicate using a locally-made stadiometer and a TF-300A body composition analyzer (TANITA Corporation, Japan), respectively, using standard techniques [11]. We re-assessed weight only in duplicate using the same balance in the sub-sample. In the lifestyle questionnaire, 1005 participants reported how much time they spent walking per week. Among the 50 subsample participants, physical activity was assessed with Omron HJ-720itc pedometers (Omron Healthcare, Inc., Bannockburn, USA). It has been shown that 3–5 days can sufficiently predict physical activity in adults, so participants were asked to wear the pedometers 5 days, including at least one weekend day [14–16]. Pedometers were programmed for each individual based on weight and average stride length. Pedometer data, including total steps, aerobic steps, calories burned, fat burned and distance walked, was downloaded into the Omron Health Management Software. The pedometer automatically calculated calories and fat burned based on a proprietary manufacturer formula. Pedometer data was discarded for any day in which participants wore the pedometer for less than 12 h. If this resulted in less than 3 days of usable data for a participant, these data were excluded from the analysis (n = 11). Average physical activity measures were calculated for each participant based on the number of days worn.

Biostatistical methods

Two-sample t-tests with equal variances and multivariable linear regression, adjusted for age, sex, BMI and a wealth index [17] were used to compare baseline measures for the 1005 participants in Puno. Two-sample t-tests with equal variances were used to compare nutrient intakes and average grams consumed of each food group between subsample urban and rural participants. A Wilcoxon rank-sum test was used to compare the average grams consumed of each food group between all urban and rural participants. Due to the small sample size and to avoid parametric assumptions, a Kolmogorov-Smirnov test was used to compare pedometer measures between urban and rural participants. An alpha level of $p < 0.05$ was considered statistically significant. All statistical analyses were conducted in Stata 13 (StataCorp, College Station, Texas, USA).

Results

Participant characteristics

We selected a total of 4941 participants using a simple random sample from our community census, of which 2356 were not available for some reason and 276 did not meet the eligibility criteria. Of these, we contacted 2309 participants, and enrolled 1513 participants, of which 1005 completed all evaluations including lifestyle questionnaires and dietary data.

Among the 1005 participants with complete evaluations, 48.4% were male and average age was 55.4 years (Table 1). Urban participants had a higher average BMI when compared to rural participants (27.9 vs. 25.2 kg/m^2; $p < 0.001$). Characteristics of the subsample were reflective of the entire Puno cohort. Specifically, the subsample was 52% male and the average age was 54.6 years (Table 2). On average, urban participants in the subsample had a slightly higher, albeit non-significant BMI and a higher wealth index (Table 2).

Diet and physical activity in entire Puno cohort

After adjusting for age, sex, BMI and wealth index, urban residents consumed calorie-dense foods, such as refined grains, desserts, sugar, and soda more frequently

Table 2 General characteristics of the 50 urban and rural sub - study participants

	Urban (n = 25)	Rural (n = 25)	p-value
Mean age in years (SD)	57 (12)	51 (15)	0.10
Mean wealth index (SD)	311 (41)	124 (16)	<0.001
% male (n)	52 (13)	52 (13)	-
Average BMI in kg/m^2, mean (SD)	26.9 (4.7)	25.2 (4.4)	0.18
BMI Categories[a]			0.30
% underweight, (n)	0 (0)	4 (1)	
% normal weight, (n)	44 (11)	48 (12)	
% overweight, (n)	32 (8)	40 (10)	
% obese, (n)	24 (6)	8 (2)	

[a]BMI categories defined by World Health Organization; underweight (BMI ≤ 18.5 kg/m2); normal weight (18.5 kg/m^2 ≥ BMI ≤ 24.9 kg/m^2); overweight (25 kg/m^2 ≥ BMI ≤ 29.9 kg/m^2); obese (BMI ≥ 30 kg/m^2)

(Table 1). Urban residents consumed a variety of protein-rich products, including poultry, organ meat and dairy, and fresh produce, including fruits and raw vegetables, more frequently than rural residents (Table 1). The only food groups consumed more frequently by rural residents were potatoes and legumes (Table 1). Rural residents walked more days per week (6.49 vs 5.79, $p < 0.001$) and spent more hours walking per day (2.58 vs 1.56, $p < 0.001$).

Dietary intake in subsample

We obtained 24-h recall data for 47 participants. Urban participants consumed significantly more protein (47 g vs. 39 g, $p = 0.048$) and carbohydrates (280 g vs. 220 g, $p = 0.033$) than rural participants and tended to consume more calories (1600 kcal vs. 1300 kcal, $p = 0.07$). In terms of macronutrient composition, the diet of urban participants was 69.7% carbohydrates, 19.7% fat, and 11.9% protein; and, that of rural participants was 67% carbohydrates, 20.9% fat, and 11.7% protein. Macronutrient intakes did not appear differ between sexes or age categories (data not shown).

Urban participants had a higher average dietary diversity score of 6.4 compared to 5.8 among rural participants ($p = 0.04$) (Table 3). Food group categories utilized for the dietary diversity calculation were also used to characterize overall diet. Compared to rural participants, urban participants tended to consume a wider variety of fruits and protein-rich foods, including significantly more chicken (43 g vs. 14 g, $p = 0.002$) and dairy products (68 g vs. 25 g, $p = 0.001$) (Table 4). All participants consumed both cereal products and potatoes, although location played a significant role when it came to actual amounts consumed. Urban residents consumed significantly more cereal products (230 g vs. 140 g, $p < 0.001$), while rural participants consumed nearly triple the amount of potatoes (350 g vs. 130 g, $p < 0.001$) (Table 4). Rural participants consumed significantly more salt (3.1 g vs. 1.7 g, $p = 0.006$), although all 47 participants added salt to meals prepared at home (Table 4). Nearly all participants also added sugar to their food, with urban residents consuming more than double the amount of added sugar (20 g vs. 8.6 g, $p = 0.11$) and overall sugary products, such as candy, desserts, and sugary drink mixes (98 g vs. 46 g, $p = 0.02$) (Table 4).

We had too small a sample to conduct multivariable analyses. However, in a two variable regression adjusting for wealth index, we found that the direction, magnitude and significance of our findings were unchanged.

Table 3 Average macronutrient intake per day from 3 non-consecutive 24-h recalls among urban and rural subsample participants

	Urban ($n = 22$)	Rural ($n = 25$)	p-value
Calories in kilocalories, mean (SD)	1600 (571)	1300 (445)	0.07
Protein in grams, mean (SD)	47 (15.4)	39 (14.1)	0.05
Fat in grams, mean (SD)	35 (18.9)	31 (21.9)	0.49
Carbohydrate in grams, mean (SD)	280 (111.7)	220 (63.3)	0.03
Dietary Diversity Score	6.4	5.8	0.04

Physical activity in subsample

After accounting for non-compliance with study protocol, 39 participants remained for analysis. There were no significant differences between compliant and non-compliant participants with regard to site (45% vs 51% urban, $p = 0.74$), age (53.7 vs 58.1 years, $p = 0.35$), sex (54.5% vs 48.7% female, $p = 0.74$) or BMI (28.1 vs 25.4 kg/m^2, $p = 0.08$). Among these participants, 20 wore their pedometers for 5 days, 10 wore their pedometers for 4 days and 9 wore their pedometers for 3 days. Rural participants burned more calories and walked longer distances than urban participants (Kolmogrov-Smirnov test $p < 0.05$). Although not statistically significant, rural participants tended to walk more steps per day and burn more fat (Table 5). Age was also a crucial factor influencing physical activity in this population, as all measures were significantly different between participants above and below age 60 years, with younger participants being more physically active (data not shown).

Discussion

In this high-altitude Andean population, location appeared to play an important role in diet and physical activity. In the entire Puno cohort, there were significant differences in the frequency of consumption of key food groups and frequency of physical activity between urban and rural populations. In our analysis of 24-h recalls from subsample participants, we found that urban participants consumed more grams of protein and carbohydrates than did rural participants, and tended to consume more calories. A majority of calories for all participants (67–70%) came from carbohydrates, indicating that participants consumed more than the recommended levels of carbohydrates relative to fat and protein, as this is above the Acceptable Macronutrient Distribution Range (AMDR) of 45–65% calories from carbohydrates [18]. Participants were on the lowest end of AMDR recommendations for fat and protein, with around 20% of calories derived from fat and around 12% of calories derived from protein.

In addition, other dietary studies have been completed in the Puno region [19–23]. Similar to our findings, many reported that rural residents received a substantial portion of their calories from potatoes or chuño, a stored and dehydrated potato [19–21]. In contrast, a study published in 1987 found that a majority of rural families did not have access to store-bought foods such

Table 4 Proportion of participants consuming each food group and average grams consumed per day of each food group overall and among consumers from three non-consecutive 24-h recalls among urban and rural subsample participants

	Proportion Consuming			Average grams consumed overall			Average grams consumed among consumers		
Food Group	Urban (n = 22)	Rural (n = 25)	p-value	Urban (n = 22)	Rural (n = 25)	p-value	Urban (n = 22)	Rural (n = 25)	p-value
All meat	1.00	0.92	0.18	65	55	0.17	65	59	0.65
Chicken	0.91	0.36	0.001	43	14	0.002	47	39	0.61
Red meat	0.68	0.76	0.55	22	41	0.34	33	53	0.12
Fish	0.32	0.44	0.39	11	13	0.54	34	29	0.75
Dairy products	0.95	0.48	0.004	68	25	0.001	71	52	0.42
Eggs	0.55	0.36	0.20	7.5	9	0.29	14	26	0.18
Legumes	0.68	0.84	0.20	7.0	12	0.09	24	42	0.34
Cereals	1.00	1.00	-	230	140	<0.001	230	140	<0.001
White roots & tubers	1.00	1.00	-	130	350	<0.001	130	350	<0.001
Dark green vegetables	0.27	0.28	0.96	0.20	0.81	0.55	0.72	2.9	0.11
Vitamin A vegetables & tubers	0.95	0.96	0.92	43	42	0.96	45	44	0.88
Other vegetable	1.00	1.00	-	36	29	0.95	36	29	0.46
Vitamin A fruits	0.36	0.2	0.21	29	18	0.27	82	90.	0.88
Other fruits	1.00	1.00	-	160	120	0.79	160	120	0.49
Added salt	1.00	1.00	-	1.7	3.1	0.006	1.7	3.1	0.02
Added vegetable oil	0.82	0.88	0.55	6.9	14	0.15	8.5	16	0.08
Added sugar	0.91	0.92	0.89	20	8.6	0.11	22	9.4	0.12
All sugar & sugary foods	1.00	0.96	0.34	98	46	0.02	98	48	0.06

as oatmeal, sugar, canned milk, and vegetable oil [19]. In our study, rural participants regularly consumed these food items, indicating the changes in the rural food landscape that have taken place in recent years. A systematic review on nutrition in the Central Andes region found that fat intakes in the reviewed reports were remarkably low, with multiple reports of percent energy from fat lower than 10% [24]. Although our data was not this extreme, with an average percent energy derived from fat around 20%, it is on the low end of macronutrient recommendations. Low fat intake may be a unique feature of Puno and other Andean populations compared to other regions of Peru. A 1990s study on nearly 800 individuals in urban and rural communities throughout Peru characterized diet based on 24-h recall and weighed record methods [25]. They found an average fat intake of 136 g, nearly quadruple the fat intake that was reported in our sample [25]. However, reported intakes of protein and carbohydrates were very similar to what was seen in our sample [25]. Lower fat intake could be an important factor in evaluating chronic disease risk in Puno adults compared to other individuals in the CRONICAS cohort.

Table 5 Average pedometer results for urban and rural subsample participants

	Urban (n = 20)	Rural (n = 19)	p-value
Steps/day, mean (SD)	7641 (3459)	9519 (4586)	0.09
Aerobic steps/day, mean (SD)	1188 (1075)	1433 (1537)	0.38
Kcal burned/day, mean (SD)	191 (123)	270 (136)	0.03
Miles walked/day, mean (SD)	2.64 (1.51)	3.65 (1.95)	0.03
Grams fat burned/day, mean (SD)	10.71 (6.97)	15.22 (7.84)	0.08

In addition, through the 24-h recalls, we were able to characterize consumption of specific food groups and confirm dietary patterns seen in the entire Puno cohort. As seen in the baseline lifestyles questionnaire, urban residents consumed refined grains in the form of bread while rural residents consumed potatoes. A majority of rural residents received their protein from red meat products, including beef and alpaca. As seen in the baseline data, urban residents also consumed red meat, but tended to consume more chicken and dairy, so likely received protein from a wider variety of sources. Both subsample populations consumed a decent variety of vegetables in similar quantities. In nutrition transition literature, urbanization is often thought to increase consumption of sugar, salt, and fat [9, 10]. However, our results are mixed. As seen in the baseline data, urban residents did tend to consume more added sugar as well as other sugary products like cakes, sodas and chocolate. However, rural residents tended to consume more

vegetable oil and added more salt to meals that they prepared. Overall, urban residents had a higher dietary diversity score, reflecting the greater variety of foods available in the urban environment.

In terms of physical activity, we also found that rural residents, regardless of age, burned more calories and walked longer distances each day. Although not statistically significant, rural residents also tended to complete more aerobic steps, indicating a greater intensity of activity, which could account for the greater caloric output in rural residents. Our findings are consistent with other studies on physical activity in Peru that report rural residents are more active as compared to urban residents. A study on migrants in Peru found that the prevalence of low physical activity was just 2.2% in rural residents, 32.2% in rural-urban migrants and 39.2% in urban residents [26].

An important strength of this study is that trained staff performed three, non-consecutive 24-h recalls, the gold standard for dietary intake assessment, on each participant. Food items were weighed whenever possible and participants used to-scale food pictures to most accurately identify what they had eaten. However, there is always the possibility of under-reporting with the 24-h recall technique, as individuals may not remember everything they consumed. Informal qualitative observations showed that individuals tended to underestimate the portion sizes of foods that they consumed. Authors of the systematic review on nutrition in the Andes reached similar conclusions about their data, supporting the idea that underreporting could be a crucial limitation to 24-h recall data in this region [25]. Another limitation of our study is that it was completed in the pre-harvest season. A study showed that mean energy intake of low socioeconomic status, rural Puno households was lower in the pre-harvest season, which could have contributed to limited dietary diversity and relatively low caloric intake reported by low-income rural residents in our study [23]. In terms of physical activity assessment, a key strength of this study was that participants wore the pedometer for a minimum of 3 days, so as to characterize average physical activity. We confirmed the feasibility of using pedometers in this population and there were no objections to pedometer use among participants. One limitation of pedometers in this setting is that they are not able to capture the full range of physical activities of the participants, particularly in rural areas where participants planted crops and carried extremely heavy loads. Due to the logistics of completing three non-consecutive 24-h recalls with each participant, the sample size was small and may not have been sufficiently powered to detect all differences. Despite large differences in weight status between urban and rural participants in the entire Puno cohort, there were no significant differences in BMI between the urban and rural sub-sample participants, which may have influenced the results. A final limitation is that, because this pilot substudy was conducted only in Puno, generalizability is limited and findings are specific to high-altitude Andean populations.

This pilot study confirms and elaborates on the baseline diet and physical activity patterns identified in the Puno cohort. This study also demonstrates that lower levels of obesity in rural Puno are not necessarily indicative of nutritionally-balanced diets. Dietary diversity is positively associated with nutrient adequacy in both urban and rural populations [27, 28]. Because rural residents had significantly lower dietary diversity scores, it is likely that they are at higher risk of nutrient inadequacy than urban residents. In-field discussions with participants confirmed that rural residents had limited access to fresh produce and both the baseline and 24-h recall data showed that rural residents tended to consume a smaller variety and lower quantity of fruits and fresh vegetables. Additionally, rural residents consumed only 1300 kilocalories per day, well below recommendations for active Peruvian adults [29]. This data, in combination with findings that participants received nearly 70% of their daily calories from carbohydrates, indicates a need for further investigation into food security in rural areas and suggests that improving dietary diversity may be an important intervention target for the future. Future research on a larger number of individuals in this setting or across the entire CRONICAS cohort is necessary to further characterize diet and physical activity patterns and better identify intervention targets.

Conclusions

Overall, both urban and rural subsample participants have relatively traditional lifestyles, with limited consumption of high-fat processed foods, moderate vegetable intake and relatively active lifestyles. Overall fat intakes were quite low and few participants reported consuming fast food or processed items. Both urban and rural adults under the age of 60 years were walking around 10,000 steps per day, meeting widespread guidelines for physical activity [14]. This could, in part, be due to the fact that urban Puno currently has a much lower degree of urbanization than other urban centers in Peru. Future efforts to encourage the maintenance of these traditional lifestyles in the face of increasing urbanization will be important. It is also worth considering that adults in this sample ranged from 37 to 80 years of age, an age group that is more likely to have maintained a traditional diet and lifestyle. In-field observations showed that children often consumed more sweets and processed products, so future research should evaluate dietary patterns among the younger generation.

Acknowledgements
The authors are indebted to all participants who kindly agreed to participate in the study. Special thanks to all field teams for their commitment and hard work, especially to Lilia Cabrera and David Danz for their leadership in each of the study sites, as well as Marco Varela for data coordination.

Funding
This project was funded by the Johns Hopkins Center for Global Health (Checkley), by philanthropic support from Mr. William Clarke III and Mr. Kenneth Banks, and by the United States National Heart, Lung, and Blood Institute, National Institutes of Health, Department of Health and Human Services, under Contract No. HHSN268200900033C. Catherine H Miele was further supported by National Institutes of Health Fogarty International Center (5R25TW009340). Morgan McCloskey was further supported by the Johns Hopkins Center for Global Health.

Authors' contributions
RHG, JJM and WC conceived, designed and supervised the overall study; JJM, ABO and WC coordinated and supervised fieldwork activities in Puno; MM and CTM conducted 24-h dietary recalls and collected pedometer data in Puno; MM, CTM, JJS and CHM analyzed data; MM wrote the first draft and MM, CTM, JJS, CHM and WC participated in writing the manuscript. WC had primary responsibility for final content. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Division of Pulmonary and Critical Care, School of Medicine, Johns Hopkins University, 1830 Monument St Room 555, Baltimore, MD 21205, USA. [2]Biomedical Research Unit, A.B. PRISMA, Lima, Peru. [3]Department of Health Services, University of Washington, Seattle, WA, USA. [4]CRONICAS Center of Excellence in Chronic Diseases, Universidad Peruana Cayetano Heredia, Lima, Peru.

References

1. PAHO-Peru. Health in the Americas. Volume II – Countries. Washington DC: Pan American Health Organization; 2007. p. 577–95.
2. Popkin BM. The nutrition transition and obesity in the developing world. J Nutr. 2001;131(3):871S–3S.
3. Jacoby E, Goldstein J, Lopez A, et al. Social class, family, and life-style factors associated with overweight and obesity among adults in Peruvian cities. Prev Med. 2003;37(5):396–405.
4. Chaparro MP, Estrada L. Mapping the nutrition transition in Peru: evidence for decentralized nutrition policies. Rev Panam Salud Publica. 2012;32(3): 241–4.
5. Ministerio de Salud de Perú (MINSA). Un gordo problema: Sobrepeso y obesidad en el Perú: 2012. http://www.minsa.gob.pe/cino/documentos/publicaciones/Un-Gordo_problema.pdf. Accessed 5 July 2017.
6. Field AE, Coakley EH, Must A, et al. Impact of overweight on the risk of developing common chronic diseases during a 10-year period. Arch Intern Med. 2001;161(13):1581–6.
7. Bermudez OI, Tucker KL. Trends in dietary patterns of Latin American populations. Cad Saude Publica. 2003;19(Suppl 1):S87–99.
8. Ministerio de Salud de Perú (MINSA). Encuesta Nacional de Indicadores Nutricionales, Bioquímicos, Socioeconómicos y Culturales Relacionados con Las Enfermedades Crónicas Degenerativas. 2006. http://www.minsa.gob.pe/portada/Especiales/2007/nutricion/publicaciones/INFORME_FINAL_ENIN.pdf. Accessed 5 July 2017.
9. Popkin BM. Urbanization, lifestyle changes and the nutrition transition. World Dev. 1999;27(11):1905–16.
10. Mendez M, Popkin B. Overview paper, globalization, urbanization and nutritional change in the developing world. In: Globalization of food systems in developing countries: impact on food security and nutrition. Rome: Food and Agriculture Organization; 2004. p. 55–80.
11. Miranda JJ, Bernabe-Ortiz A, Smeeth L, et al. Addressing geographical variation in the progression of non-communicable diseases in Peru: the CRONICAS cohort study protocol. BMJ Open. 2012;2(1):e000610.
12. Asociación Benéfica PRISMA. Laminario de medidas caseras. Lima: PRISMA; 1996.
13. Food and Agriculture Organization. Guidelines for measuring household and individual dietary diversity. Rome: FAO; 2010.
14. Tudor-Locke C, Burkett L, Reis JP, et al. How many days of pedometer monitoring predict weekly physical activity in adults? Prev Med. 2005; 40(3):293–8.
15. Strycker LA, Duncan SC, Chaumeton NR, et al. Reliability of pedometer data in samples of youth and older women. Int J Behav Nutr Phys Act. 2007;4:4.
16. Hart TL, Swartz AM, Cashin SE, et al. How many days of monitoring predict physical activity and sedentary behaviour in older adults? Int J Behav Nutr Phys Act. 2011;8:62.
17. Miele CH, Jaganath D, Miranda JJ, Bernabe-Ortiz A, Gilman RH, Johnson CM, Diette GB, Wise RA, Checkley W. CRONICAS Cohort Study Group. Urbanization and Daily Exposure to Biomass Fuel Smoke Both Contribute to Chronic Bronchitis Risk in a Population with Low Prevalence of Daily Tobacco Smoking. doi:10.3109/15412555.2015.1067765.
18. Trumbo P, Schlicker S, Yates AA, et al. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. J Am Diet Assoc. 2002;102(11):1621–30.
19. Leonard WR, Thomas RB. Changing dietary patterns in the Peruvian Andes. Ecology Food Nutrition. 1988;21(4):245–63.
20. Graham MA. Food allocation in rural Peruvian households: concepts and behavior regarding children. Soc Sci Med. 1997;44(11):1697–709.
21. Kim SW, Kashiwazaki H, Imai H, Moji K, Orias-Rivera J. Food consumption and energy expenditure of Aymara in a herding community of the Bolivian Altiplano. J Hum Ergol (Tokyo). 1991;20(2):181–97.
22. Watt EW, Picon-Reategui E, Gahagan HE, et al. Dietary intake and coronary risk factors in Peruvian Quechua Indians. J Am Diet Assoc. 1976;68(6):535–7.
23. Graham MA. "no somos iguales": the effect of household economic standing on women's energy intake in the Andes. Soc Sci Med. 2004;58(11):2291–300.
24. Berti PR, Fallu C, Cruz Agudo Y. A systematic review of the nutritional adequacy of the diet in the Central Andes. Rev Panam Salud Publica. 2014; 36(5):314–23.
25. Montes C, Segura L, Miranda M, et al. Consumo de alimentos en el Perú: 1990–1995. Lima: Asociación Benéfica PRISMA; 1997.
26. Masterson Creber RM, Smeeth L, Gilman RH, et al. Physical activity and cardiovascular risk factors among rural and urban groups and rural-to-urban migrants in Peru: a cross-sectional study. Rev Panam Salud Publica. 2010; 28(1):1–8.
27. Arimond M, Wiesmann D, Becquey E, et al. Simple food group diversity indicators predict micronutrient adequacy of women's diets in 5 diverse, resource-poor settings. J Nutr. 2010;140(11):2059S–69S.
28. Torheim LE, Ouattara F, Diarra M, et al. Nutrient adequacy and dietary diversity in rural Mali: association and determinants. Eur J Clin Nutr. 2004; 58(4):594–604.
29. Ministerio de Salud de Perú (MINSA). Nutrición por etapa de vida: alimentación de adulto. 2007. http://www.minsa.gob.pe/portada/Especiales/2007/nutricion/adulto.asp. Accessed 5 July 2017.

Determinants of diet and physical activity (DEDIPAC): a summary of findings

Johannes Brug[1], Hidde P. van der Ploeg[2,3], Anne Loyen[2], Wolfgang Ahrens[4], Oliver Allais[5], Lene F. Andersen[6], Greet Cardon[7], Laura Capranica[8], Sebastien Chastin[7,9], Ilse De Bourdeaudhuij[7], Marieke De Craemer[7], Alan Donnelly[10], Ulf Ekelund[11], Paul Finglas[12], Marion Flechtner-Mors[13], Antje Hebestreit[4], Thomas Kubiak[14], Massimo Lanza[15], Nanna Lien[6], Ciaran MacDonncha[16], Mario Mazzocchi[17], Pablo Monsivais[18], Marie Murphy[19], Mary Nicolaou[20], Ute Nöthlings[21], Donal J. O'Gorman[22], Britta Renner[23], Gun Roos[24], Matthijs van den Berg[25], Matthias B. Schulze[26], Jürgen M. Steinacker[13], Karien Stronks[20], Dorothee Volkert[27], Jeroen Lakerveld[28*]
and on behalf of the DEDIPAC consortium

Abstract

The establishment of the Determinants of Diet and Physical Activity (DEDIPAC) Knowledge Hub, 2013–2016, was the first action taken by the 'Healthy Diet for a Healthy Life' European Joint Programming Initiative. DEDIPAC aimed to provide better insight into the determinants of diet, physical activity and sedentary behaviour across the life course, i.e. insight into the causes of the causes of important, non-communicable diseases across Europe and beyond. DEDIPAC was launched in late 2013, and delivered its final report in late 2016. In this paper we give an overview of what was achieved in terms of furthering measurement and monitoring, providing overviews of the state-of-the-art in the field, and building toolboxes for further research and practice. Additionally, we propose some of the next steps that are now required to move forward in this field, arguing in favour of 1) sustaining the Knowledge Hub and developing it into a European virtual research institute and knowledge centre for determinants of behavioural nutrition and physical activity with close links to other parts of the world; 2) establishing a cohort study of families across all regions of Europe focusing specifically on the individual and contextual determinants of major, non-communicable disease; and 3) furthering DEDIPAC's work on nutrition, physical activity, and sedentary behaviour policy evaluation and benchmarking across Europe by aligning with other international initiatives and by supporting harmonisation of pan-European surveillance.

Keywords: Determinants of health behaviours, Dietary behaviour, Europe, Physical activity, Policy evaluation, Sedentary behaviour, Interventions

Background

Unhealthy dietary habits, lack of physical activity, and extensive and uninterrupted sitting are known risk factors for major, non-communicable diseases [1]. However, comparatively little is known about the 'causes of these causes' of non-communicable disease, i.e. about the most important and modifiable determinants of unhealthy dietary, physical activity, and sedentary behaviour. To further such research, the European Determinants of Diet and Physical Activity (DEDIPAC) Knowledge Hub was established.

In brief, DEDIPAC was the first action taken by the European 'Joint Programming Initiative (JPI) Healthy Diet for a Healthy Life (HDHL)' to better align research across Europe in the realm of healthy dietary and physical activity behaviour. DEDIPAC was launched in December 2013 and its mission, purpose, and design were shared with the larger scientific community in a paper published in the *International Journal of Behavioural Nutrition and Physical Activity* in 2014 [2]. DEDIPAC delivered its final report for evaluation and approval on December 1st, 2016.

* Correspondence: j.lakerveld@vumc.nl
[28]Department of Epidemiology and Biostatistics, Amsterdam Public Health research institute, VU University Medical Center, De Boelelaan 1089a, 1081, HV, Amsterdam, The Netherlands
Full list of author information is available at the end of the article

DEDIPAC's aim was to understand the determinants, at both the individual and (sub-)population levels, of dietary, physical activity, and sedentary behaviour using a broad, multidisciplinary approach, and to translate this knowledge into more effective promotion of healthy diet and physical activity. To this end, DEDIPAC first aimed to prepare and build the necessary infrastructure for this mission and work towards aligning and coordinating public health research in relation to behaviour in these areas. Today, the DEDIPAC Knowledge Hub is internationally recognised as a network of scientists from various relevant disciplines, and with different levels of seniority, who work together to collect, gain, advance, exchange, and disseminate scientific knowledge and competences in the area of the topic of interest.

The main text of this paper will cover both the methods employed by DEDIPAC, as well as the results of its efforts. We present further detail regarding the infrastructure of the Knowledge Hub and describe how this helped to align research conducted in the context of DEDIPAC, as well as make better use of expertise and available data. Subsequently, we will outline the mix of different methods that were applied to advance the field within the three thematic areas of the Knowledge Hub, and provide an overview of the results of the research conducted in the context of DEDIPAC. In the discussion, we will specifically focus on future steps that may contribute to advancing research on the underlying determinants of major, non-communicable disease within Europe and beyond.

Methods and results

Joint programming is a process by which European countries define, develop, and implement a common strategic research agenda, based on a shared vision of how to address societal challenges that no country is capable of resolving independently. Such joint programming pools the resources of individual countries such that they can be focused on common goals in an effort to enable more comprehensive, and larger-scale research with more variation in exposure and outcomes. This prevents unnecessary overlap and repetition, thereby enhancing the development and use of standardised research methodology and improving research infrastructure. JPI HDHL's mission is to enable all Europeans to have the motivation, ability, and opportunity to eat a healthy diet, and undertake sufficient physical activity to contribute to the reduction of the incidence of non-communicable, chronic disease [3].

Twelve countries across Europe (Austria, Belgium, Finland, France, Germany, Italy, Ireland, Norway, Poland, Spain, The Netherlands, and The United Kingdom) agreed to support this first joint action in the context of JPI HDHL, and provided funding via their national governmental funding bodies to support participation and research activities of scientists in their countries. Research groups in the participating countries were then invited to submit expressions of interest in joining an international research consortium dedicated to furthering research on the determinants of diet and physical activity behaviour. Based on these expressions of interest, representatives of the interested research groups were invited to a joint kick-off meeting during which the Knowledge Hub was established, the consortium leadership elected, and a first-draft framework for the proposal of the actual research was outlined. This outline was expanded and developed into a full proposal – entitled, DEDIPAC – over the course of a series of face-to-face and online workshops, meetings, and consultations held over the next three months. This proposal was reviewed and, after reviewers' comments were taken into account, it was approved by the HDHL management board. DEDIPAC formally started in December, 2013. The final, approved version of the DEDIPAC proposal put forward three key aims:

1. To enable a more standardised and continuous, pan-European 'needs analysis', i.e. to monitor dietary, physical activity, and sedentary behaviour, and changes in behaviour in these areas across the life course and across populations, in an effort to identify targets and target populations for (policy) interventions;
2. To explore the main correlates and determinants of these behaviours in and across populations to help to tailor policies and interventions seeking to target these determinants;
3. To learn from the successes and failures of previous and on-going interventions and policies in order to improve evaluation, and increase the effectiveness of future interventions and policies, as well as to identify and benchmark best practices across Europe and compare these internationally.

To work towards realising these aims, DEDIPAC was organised into three Thematic Areas (TAs), and each of these TAs was divided further into work packages (WPs) that, in turn, were broken down into specific tasks:

TA 1: Assessment and harmonisation of methods for future research, surveillance, monitoring, and evaluation of interventions and policies regarding diet, physical activity, and sedentary behaviour;
TA 2: Identification of determinants of dietary, physical activity and sedentary behaviour across the life course and in vulnerable groups;
TA 3: Evaluation and benchmarking of public health interventions and policies aimed at improving dietary, physical activity and sedentary behaviour across the life course.

DEDIPAC was organised as a network, as opposed to having a centrally-led, top-down management structure, and coordinators were elected for both for the overall DEDIPAC organisation, as well as for the individual TAs. The central coordinator and the leaders of the TAs acted as the DEDIPAC management team, mandated to make necessary decisions, subject to the approval of the consortium at large, monitor progress, prepare periodical reports, and report to and align with the JPI HDHL organisation.

In total, almost 300 researchers joined forces as part of the DEDIPAC Knowledge Hub. These individuals hailed from 68 research institutes across all of the participating European countries (see Fig. 1). The Finnish organisations withdrew early in the process, as their national funding body was not able to provide the support necessary to carry out DEDIPAC activities planned by the Finnish partners, and a Danish organisation joined with its own resources *after* the formal establishment of the Knowledge Hub.

DEDIPAC aimed to promote and facilitate knowledge exchange and dissemination and aimed to establish collaborations that would lead to new research and last beyond the initial three-year funding period. A main purpose of DEDIPAC was, thus, to bring together researchers from various relevant disciplines from different countries. This is why it was proposed and presented as a Knowledge Hub, rather than a project or program.

Furthermore, because DEDIPAC was specifically aimed at making the best possible use of available evidence, data, and expertise, the three TAs adopted similar strategies and methodologies that encompassed:

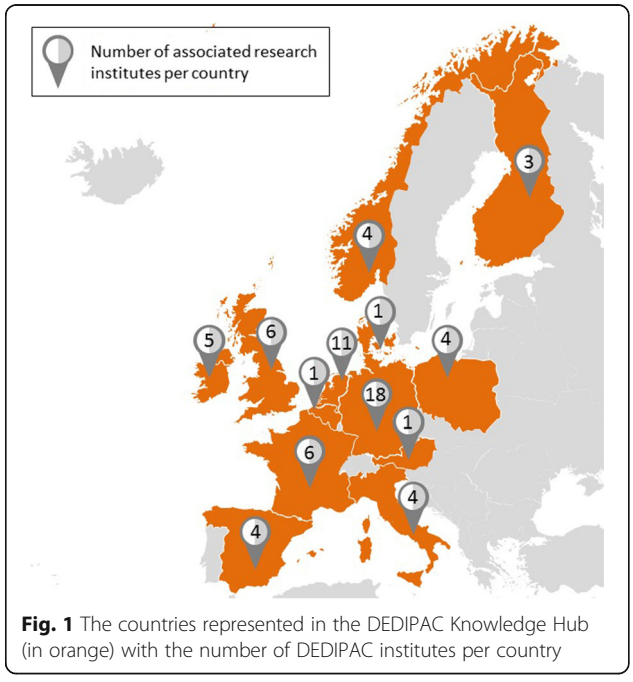

Fig. 1 The countries represented in the DEDIPAC Knowledge Hub (in orange) with the number of DEDIPAC institutes per country

- The provision of methods and a harmonised set of reliable and validated measures to be used for future research, surveillance, and monitoring of the individual, social, and environmental determinants of dietary, physical activity, and sedentary behaviour;
- The provision of state-of-the-art overviews of up-to-date evidence regarding the determinants of these behaviours in different demographic groups by means of series of systematic literature reviews, and mapping/scoping reviews;
- The creation of a level playing field by enabling expert meetings, capacity building, and career development for young researchers, as well as through the creation of integrative frameworks for research;
- Improved use of relevant, existing data through secondary data analyses, including dataset pooling and variable harmonisation;
- Improved dissemination and application of findings and results through the creation of an online platform that provides toolboxes for researchers, practitioners, and policy makers.

Expert consultations with different techniques, such as concept mapping, and some additional, original research complemented these approaches. The literature reviews all complied with the PRISMA guidelines [4], and review protocols were published in PROSPERO [5] where appropriate.

The progress and deliverables have been communicated and disseminated via the DEDIPAC website (https://www.dedipac.eu), scientific publications and non-scientific publications in English and other languages, consortium meetings, as well as in a series of workshops specifically aimed at early-career researchers. DEDIPAC's output includes 36 papers that have been published or accepted for publication to date, and 34 that are still in progress. These papers include systematic (umbrella) literature reviews, publications on integrative – systems-thinking based – frameworks on determinants of dietary, physical activity, and sedentary behaviour. All currently published DEDIPAC manuscripts are listed in Tables 1, 2, 3 and 4, and DEDIPAC's open-access output is available via https://www.dedipac.eu. This website also contains the publicly-available and accessible 'toolboxes' that are designed to guide and aid researchers, policy makers, and health-promotion professionals in the areas of methodology, identifying determinants, and in exploring intervention and policy best practices. The following section will highlight the TAs' objectives, methods, and results in more detail.

Objectives, methods and results of TA1

The overall objective of TA1 was to provide the pan-European research community with a harmonised set of reliable and valid measurement methods to be used for

Table 1 Published manuscripts from DEDIPAC Thematic Area 1

Authors	Subject/independent variable	Behaviour/dependent variable	Age group	Study design	Countries	Main conclusions
Surveillance systems						
Bel-Serrat et al. [6]	Surveillance systems	Dietary, physical activity and sedentary behaviour	Across the life course	Inventory	Cross-European	"Many on-going activities were identified at the national level focussing on adults, but fewer surveillance systems involving vulnerable groups such as infants and pre-school children. Assessment of sedentary and dietary behaviours should be more frequently considered. There is a need for harmonisation of surveillance methodologies, indicators and target populations for between-country and over time comparisons. This inventory will serve to feed future discussions within the DEDIPAC-JPI major framework on how to optimize design and identify priorities within surveillance."
Assessment methods						
Riordan et al. [7]	Assessment methods	Intake of sugar-sweetened beverages	Across the life course	SLR	Cross-European	"The current review highlights the need for instruments to use an agreed definition of sugar-sweetened beverages. Methods that were tested for validity and used in pan-European populations encompassing a range of countries were identified. These methods should be considered for use by future studies focused on evaluating consumption of sugar-sweetened beverages."
Riordan et al. [8]	Assessment methods	Intake of fruits and vegetables	Across the life course	SLR	Cross-European	"The current review indicates that an agreed classification of fruits and vegetables is needed in order to standardise intake data more effectively between European countries. Validated methods used in pan-European populations encompassing a range of European regions were identified. These methods should be considered for use by future studies focused on evaluating intake of fruits and vegetables."
Gebremariam et al. [9]	Assessment methods	Availability and accessibility of food	Youth (≤18y)	SLR	International	"The review identified several measures of food availability or accessibility among youth with satisfactory evidence of reliability and/or validity. Findings indicate a need for more studies including measures of accessibility and addressing its conceptualization. More testing of some of the identified measures in different population groups is also warranted, as is the development of more measures of food availability and accessibility in the broader environment such as the neighbourhood food environment."

Table 1 Published manuscripts from DEDIPAC Thematic Area 1 *(Continued)*

Authors	Subject/independent variable	Behaviour/dependent variable	Age group	Study design	Countries	Main conclusions
Population levels						
Loyen et al. [10]	Variation in population levels	Physical activity	Adults (≥18y)	SLR	Cross-European	"The included studies showed substantial variation in the assessment methods, reported outcome variables and, consequently, the presented physical activity levels. Because of this, absolute population levels of physical activity in European adults are currently unknown. However, when ranking countries, Ireland, Italy, Malta, Portugal and Spain generally appear to be among the less active countries. Objective data of adults across Europe is currently limited. These findings highlight the need for standardisation of the measurement methods, as well as cross-European monitoring of physical activity levels."
Loyen et al. [11]	Variation in population levels	Sedentary time	Adults (≥18y)	SLR	Cross-European	"One third of European countries were not included in any of the studies. Objective measures of European adults are currently limited, and most studies used single-item self-reported questions without assessing sedentary behaviour types or domains. Findings varied substantially between studies, meaning that population levels of sedentary time in European adults are currently unknown. In general, people living in northern Europe countries appear to report more sedentary time than southern Europeans. The findings of this review highlight the need for standardisation of the measurement methods and the added value of cross-European surveillance of sedentary behaviour."
Van Hecke et al. [12]	Variation in population levels	Physical activity	Youth (<18y)	SLR	Cross-European	"Reported levels of physical activity and prevalence of compliance to physical activity recommendations in youth showed large variation across European countries. This may reflect true variation in physical activity as well as variation in assessment methods and reported outcome variables. Standardization across Europe, of methods to assess physical activity in youth and reported outcome variables is warranted, preferably moving towards a pan-European surveillance system combining objective and self-report methods."
Verloigne et al. [13]	Variation in population levels	Sedentary time	Youth (<18y)	SLR	Cross-European	"A substantial number of published studies report on levels of sedentary time in children and adolescents across European countries, but there was a large variation in assessment methods. Questionnaires (child specific) were used most often, but they mostly measured specific screen-based activities and did not assess total sedentary

Table 1 Published manuscripts from DEDIPAC Thematic Area 1 *(Continued)*

Authors	Subject/independent variable	Behaviour/dependent variable	Age group	Study design	Countries	Main conclusions
						time. There is a need for harmonisation and standardisation of objective and subjective methods to assess sedentary time in children and adolescents to enable comparison across countries."
Secondary data analysis						
Steene-Johannessen et al. [14]	Agreement between self-report and objective measurements	Meeting the physical activity recommendations	Adults (≥18y)	Secondary, CS	DK, FR, DE, GR, IT, NL, NO, SP, SW, UK	"The modest agreement between self-reported and objectively measured physical activity suggests that population levels of physical activity derived from self-report should be interpreted cautiously. Implementation of objective measures in large-scale cohort studies and surveillance systems is recommended."
Loyen et al. [20]	Accelerometer pooling	Physical activity and sedentary time	Adults (≥18y)	Secondary, pooled, CS	England, Norway, Portugal, Sweden	"We found high levels of sedentary time and physical inactivity in four European countries. Older people and obese people were most likely to display these behaviours and thus deserve special attention in interventions and policy planning. In order to monitor these behaviours, accelerometer-based cross-European surveillance is recommended."

Table 2 Published manuscripts from DEDIPAC Thematic Area 2

Authors	Subject/independent variable	Behaviour/ dependent variable	Age group	Study design	Countries	Main conclusions
Determinant reviews						
Symmank et al. [28]	Determinants	Food decision making	Across the life course	Systematic Inter-disciplinary Mapping (SIM) review	International	"After applying qualitative and quantitative analyses, this study reveals that most of the research [on food decision making] emphasizes biological, psychological, and product related predictors, whereas policy-related influences on food choice are scarcely considered"
Condello et al. [29]	Behavioural determinants	Physical activity	Across the life course	Umbrella SLR	International	"Although the majority of the evidence was limited and most of the determinants were not associated with PA, this umbrella SLR provided a comprehensive overview of the associations between behavioural determinants and PA. Youth should be physically active in the early years and increase active transport to/from school, independent mobility, and 'free-range activities' without adult supervision, whilst adult PA behaviours are mostly influenced by the life events. Finally, more research is needed that incorporates prospective study designs, standardized definitions of PA, objective measurement methods of PA assessment, and the use of interactionist and mediational approached for the evaluation of different behavioural determinants influencing PA behaviours."
Cortis et al. [31]	Psychological determinants	Physical activity	Across the life course	Umbrella SLR	International	"This umbrella SLR provided a comprehensive overview of the associations between psychological determinants and PA. Most of the evidence resulted probable and limited, mainly due to differences in the definition of PA and of psychological determinants across reviews. Convincing evidence was found for a positive association between self-efficacy and PA in children and adolescents, and a negative association between stress and PA regardless of age. At present, there is a need of a consensus on clear definitions of relevant psychological determinants of PA to allow clear interpretations and generalizability of findings. Furthermore, it is envisaged that psychological determinants should be considered within a larger and multi-level framework of determinants to determine possible interactions or mediations of the effects."
Puggina et al. [32]	Policy determinants	Physical activity	Across the life course	Umbrella SLR	International	"This umbrella systematic literature review summarizes the current evidence on the policy determinants of PA across the life course at individual and population levels. The majority of the reviews resulted of moderate quality. Furthermore, none of the investigated policy determinants had a convincing level of evidence, and very few had a probable level of evidence. At individual level, a clear association between time spent outdoors and PA emerged for children, whereas a limited evidence was found for working hours negatively associated with PA in adults. At the population level, community- and street-scale urban design and land use

Table 2 Published manuscripts from DEDIPAC Thematic Area 2 *(Continued)*

Authors	Subject/independent variable	Behaviour/ dependent variable	Age group	Study design	Countries	Main conclusions
						policies were found to positively support PA levels, although levels of evidence were low. Therefore, further research is needed, preferably by using prospective study designs, standardized definitions of PA and objective measurement of PA."
Carlin et al. [30]	Physical environment determinants	Physical activity	Across the life course	Umbrella SLR	International	"This umbrella systematic literature review provided a comprehensive overview of the physical determinants of PA across the life course. The limited evidence available from longitudinal studies, coupled with the diverse methodologies and definitions of both PA outcomes and physical determinants/factors employed across studies, makes it difficult to draw firm conclusions. It is vital that researchers make a concerted effort to employ harmonised, objective methodologies in the future measurement of PA and its determinants."
Stierlin et al. [33]	Determinants	Sedentary behaviour	Youth (<18y)	SLR	International	"Multiple potential determinants were studied in only one or two studies. Determinants were found at the individual, interpersonal, environmental and policy level but few studies examined acomprehensive set of factors at different levels of influences. Evidence was found for age being positively associated with total sedentary behaviour, and weight status and baseline assessment of screen time being positively associated with screen time (at follow-up). A higher playground density and a higher availability of play and sports equipment at school were consistently related to an increased total sedentary behaviour, although these consistent findings come from single studies. Evidence was also reported for the presence of safe places to cross roads and lengthening morning and lunch breaks being associated with less total sedentary behaviour."
O'Donoghue et al. [34]	Determinants	Sedentary behaviour	Adults (18–65y)	SLR	International	"Results provide further evidence relating to several already recognised individual level factors and preliminary evidence relating to social and environmental factors that should be further investigated. Most studies relied upon cross-sectional design limiting causal inference and the heterogeneity of the sedentary measures prevented direct comparison of findings. Future research necessitates longitudinal study designs, exploration of policy-related factors, further exploration of environmental factors, analysis of inter-relationships between identified factors and better classification of sedentary behaviour domains."
Chastin et al. [35]	Determinants	Sedentary behaviour	Older adults (>65y)	SLR	International	"Few studies have investigated determinants of sedentary behaviour in older adults and these have to date mostly focused on personal factors, and qualitative studies were mostly lacking. More longitudinal studies are needed as well as inclusion of a broader range of personal and

Table 2 Published manuscripts from DEDIPAC Thematic Area 2 *(Continued)*

Authors	Subject/independent variable	Behaviour/ dependent variable	Age group	Study design	Countries	Main conclusions
						contextual potential determinants towards a systems-based approach, and future studies should be more informed by qualitative work."
Osei-Kwasi et al. [36]	Determinants	Dietary behaviour	Across the life course; minority groups	SLR	Cross-European	"This review identified a broad range of factors and clusters influencing dietary behaviour among ethnic minority groups. Gaps in the literature identified a need for researcher to explore the underlying mechanisms that shape dietary behaviours, which can be gleaned from more holistic, systems-based studies exploring relationships between factors and clusters. The dominance of studies exploring 'differences' between ethnic minority groups and the majority population in terms of the socio-cultural environment and food beliefs suggests a need for research exploring 'similarities'. The evidence from this review will feed into developing a framework for the study of factors influencing dietary behaviours in ethnic minority groups in Europe."
Langøien et al. [37]	Determinants	Physical activity and sedentary behaviour	Across the life course; ethnic minority groups	SLR	Cross-European	"Physical activity and sedentary behaviour among ethnic minority groups living in Europe are influenced by a wide variety of factors, especially informed by qualitative studies. More comparative studies are needed as well as inclusion of a larger number of ethnic minority group resettled in different European countries. Few studies have investigated factors influencing sedentary behaviour. It is important in the future to address specific factors influencing physical activity and sedentary behaviour among ethnic minority groups in order to plan and implement effective interventions."
Determinant frameworks						
Stok et al. [38]	Determinants Of Nutrition and Eating (DONE) framework	Dietary behaviour	Across the life course	Multi-phase, multi-method process	International	"In the creation phase, mind mapping, knowledge mapping, and several discussion and consensus rounds were employed to generate a comprehensive, systematically structured set of determinants of nutrition and eating across the lifespan. In the evaluation phase, priorities for research were determined by rating the determinants on the dimensions of modifiability, relationship strength, and population-level effect. Furthermore, the framework's quality, usefulness, and comprehensiveness were empirically evaluated by external experts from different disciplines and countries. In the updating phase, a pilot confirmed the feasibility of the continued evolution of the framework by requesting additional input from external experts. Moreover, the framework was dynamically visualized and made freely available on the Internet."
Condello et al. [39]	European-Physical Activity Determinants (EU-PAD) framework	Physical activity	Across the life course	Concept mapping	Cross-European	"The current framework provides a preliminary overview of factors which may account for physical activity behaviour across the life course and are most relevant to the European community. These insights could potentially be a foundation

Table 2 Published manuscripts from DEDIPAC Thematic Area 2 *(Continued)*

Authors	Subject/independent variable	Behaviour/ dependent variable	Age group	Study design	Countries	Main conclusions
						for future pan-European research on how these factors might interact with each other, and assist policy makers to identify appropriate interventions to maximise physical activity behaviours and thus the health of European citizens."
Chastin et al. [40]	Systems Of Sedentary behaviour (SOS) framework	Sedentary behaviour	Across the life course	Concept mapping	International	"Through an international transdisciplinary consensus process, the SOS framework was developed for the determinants of sedentary behaviour across the life course. Investigating the influence of Institutional and Home Settings was deemed to be the most important area of research to focus on at present and potentially the most modifiable. The SOS framework can be used as an important tool to prioritise future research and to develop policies to reduce sedentary time."
Secondary data analysis						
Stelmach-Mardas et al. [45]	Seasonality	Food and energy intake	Adults (≥18y)	SLR	International	"The winter or the post-harvest season is associated with increased energy intake. The intake of fruits, vegetables, eggs, meat, cereals and alcoholic beverages is following a seasonal consumption pattern and at least for these foods season is a determinant of intake."
Schoen et al. [46]	Notified risk of type 1 diabetes	Dietary quality	Youth (<18y)	Secondary, pooled, CS	Germany	"Nutrient and food intake quality were lower at nine months of age and food intake quality was lower at 24 months of age in at-risk [for type 1 diabetes] than in not-at-risk children ($p = 0.01$ and $p < 0.0001$, respectively). The amount of added sugar was higher in at-risk children at both ages ($p < 0.0001$). In at-risk children, dietary quality was similar between children who were first exposed to gluten at six or 12 months of age. Despite being notified about their child's risk of T1D, the child's mother did not switch to healthier diets compared with not-at-risk mothers."
Wittig et al. [47]	Sex, age, BMI, SES and diet quality	Energy and macronutrient intake	Adults (≥18y)	Secondary, 7CS	Germany	"The presented analyses provide comprehensive descriptions of meal patterns in regard to the distribution of energy intake over the course of the day of selected population groups in Germany. With few differences within the population groups defined by sex, age, BMI, SES, and HEI-NVS-II, the traditional three-main-meal pattern was observed, a result which is also found in other studies. For old adults, meals have an important role for structuring the day as seen in distinct peaks at the three-main-meal periods. In contrast, young adults seem to have a higher variability in energy intake and a less distinct meal pattern. Further, the results show that the highest energy intake was observed in the 'evening' period, especially in young adults, overweight persons, and persons with a high SES, as well as men with a low dietary quality (expressed by HEI-NVS-II). Because a high energy intake in the 'evening' period is associated with health-related factors, such as obesity, higher hypertension

Table 2 Published manuscripts from DEDIPAC Thematic Area 2 *(Continued)*

Authors	Subject/independent variable	Behaviour/ dependent variable	Age group	Study design	Countries	Main conclusions
						prevalence, and a higher blood pressure, in the literature, the distribution of energy intake over the course of the day should be considered by recommendations for the promotion of a healthy nutritional behaviour."
Si Hassen et al. [48]	Socioeconomic indicators	Nutrient intake	Adults (≥18y)	Secondary, CS	France	"Low educated participants had higher protein and cholesterol intakes and lower fibre, vitamin C and beta-carotene intakes. Low income individuals had higher complex carbohydrate intakes, and lower magnesium, potassium, folate and vitamin C intakes. Intakes of vitamin D and alcohol were lower in low occupation individuals. Higher income was associated with higher intakes of fibre, protein, magnesium, potassium, beta-carotene, and folate among low educated persons only, highlighting effect modification. Lower SEP, particularly low education, was associated with lower intakes of nutrients required for a healthy diet. Each socio economic position indicator was associated with specific differences in nutrient intake suggesting that they underpin different social processes."
Gebremariam et al. [49]	Screen-based sedentary time	Soft drink consumption	Youth (<18y)	Secondary, CS	International	"TV viewing appears to be independently associated with soft drink consumption and this association was moderated by parental education in two countries only. Reducing TV time might therefore favorably impact soft drink consumption."
Totland et al. [50]	Correlates	Irregular family meal patterns	Youth (<18y)	Secondary, CS	Cross-European	"The majority of 11-year-old children regularly ate breakfast and dinner with their families. More television viewing and less vegetable consumption were associated with irregular family breakfasts and dinners, respectively. Social differences were observed in the regularity of family breakfasts. Promoting family meals across social class may lead to healthier eating and activity habits, sustainable at the population level."
Lakerveld et al. [51]	Correlates	Sedentary behaviour	Adults (≥18y)	Secondary, CS	Cross-European	"Higher socio-economic status subgroups were generally more likely to sit for extended time as compared to people with a lower socio-economic status. Type of occupation was the primary discriminator. In addition, gender, level or urbanization and internet use were important predictors of sitting >7.5 h/day. Gender differences depended on the specific context."
Loyen et al. [52]	Correlates	Sedentary behaviour	Adults (≥18y), ethnic minority groups	Secondary, CS	Netherlands	"No statistically significant differences in the levels of objectively measured sedentary time or its socio-demographic and lifestyle-related correlates were observed among five ethnic groups in Amsterdam, the Netherlands."

Table 3 Published manuscripts from DEDIPAC Thematic Area 3

Authors	Subject/independent variable	Behaviour/dependent variable	Age group	Study design	Countries	Main conclusions
Quality of policies and interventions						
Horodyska et al. [56]	Good practice characteristics of interventions and policies	Dietary, physical activity and sedentary behaviours	N/A	Umbrella review	International	"The use of the proposed list of 53 good practice characteristics may foster further development of health promotion sciences, as it would allow for identification of success vectors in the domains of main characteristics of interventions/policies, their implementation, evaluation and monitoring processes."
Implementation and transferability						
Horodyska et al. [57]	Evidence-based conditions important for successful implementation of interventions and policies	Dietary, physical activity and sedentary behaviours	N/A	Umbrella review	International	"The use of the proposed list of 83 conditions for successful implementation may enhance the implementation of interventions and policies which pursue identification of the most successful actions aimed at improving diet, physical activity and reducing sedentary behaviours."

future research on dietary, physical activity, and sedentary behaviour and their individual, socio-cultural, and environmental determinants. This objective was translated in four specific goals:

1) To provide an overview of the state-of-the-art in assessment methods and tools in the areas of dietary, physical activity, and sedentary behaviour and make these available in an online toolbox;
2) To provide an overview of the currently available data on dietary, physical activity, and sedentary behaviour and their determinants across Europe;
3) To provide an inventory of state-of-the-art surveillance systems (national, regional, and international) in Europe that assess dietary, physical activity and sedentary behaviours, and to identify gaps in current systems, methods, and tools and formulate recommendations on how to fill these gaps;
4) To develop a roadmap for a state-of-the-art, harmonised, pan-European surveillance system of dietary intake, dietary behaviour, physical activity, and sedentary behaviour and their key determinants, with a focus on children and adolescents. This subgroup was chosen as current surveillance systems do not allow for longitudinal and regional comparisons of the prevalence of overweight/obesity in children and adolescents, the related lifestyle behaviour, and the key determinants of this behaviour. This prioritisation was based on a needs and gaps analysis of the DEDIPAC inventory on existing surveillance systems in Europe [6].

TA1 was further broken down into two WPs that addressed the assessment and harmonisation in the areas of dietary intake and dietary behaviour (WP1.1), and physical activity and sedentary behaviour (WP1.2). A third WP focused on pan-European harmonisation of research and surveillance regarding dietary and physical activity behaviour and their determinants (WP1.3). Harmonisation, in this respect, refers to the process of minimizing differences in measures, variables, and methods, so that outcomes are comparable.

Overview of the state-of-the-art and identification of gaps

For goals 1–3, 19 systematic literature reviews were performed to provide an overview of the state-of-the-art in terms of assessment methods and tools. It was shown that dietary behaviour is usually assessed using food frequency questionnaires (FFQs) in etiologic research and 24-h dietary recalls or food record methods in the context

Table 4 Other published manuscripts from DEDIPAC

Authors	Title
Brug and Chinapaw [63]	Determinants of engaging in sedentary behavior across the lifespan; lessons learned from two systematic reviews conducted within DEDIPAC
Chastin et al. [64]	Development of a Consensus Taxonomy of Sedentary Behaviors (SIT): Report of Delphi Round 1
Lakerveld et al. [43]	Identifying and sharing data for secondary data analysis of physical activity, sedentary behaviour and their determinants across the life course in Europe: general principles and an example from DEDIPAC

of surveillance. These are self-reported, but standardised methods for which validity has been evaluated at the level of selected nutrients using advanced measurement-error models. Over the course of the project, several systematic reviews identified specific dietary assessment tools and methods used in existing pan-European studies to assess dietary intake and behaviour in terms of food (e.g. consumption of sugar-sweetened beverages [7] and fruits and vegetables [8]) and availability and accessibility of food [9], nutrient intake, dietary patterns, and meal patterns.

The systematic assessment of currently available data on the prevalence of physical activity and sedentary behaviour and its determinants across Europe was described in a set of four reviews [10–13] that revealed that physical activity and sedentary behaviour are assessed using a range of methods and measures, most commonly including self-report questionnaires, and less often, the monitoring of wearable technology, including pedometers, heart-rate monitors, accelerometers, inclinometers, or combined sensors. The majority of methodological studies have found that these worn devices are increasingly available, provide increased validity, reliability, and sensitivity, and are therefore potentially useful in terms of improving comparability of surveillance systems across Europe. Conversely, self-reporting tends to overestimate physical activity [14]. Nevertheless, self-reported data still adds essential contextual information, and thus may be used to supplement data extracted from worn devices. In addition, although accelerometers, or other such devices, provide more objective assessment of physical activity and sedentary behaviour, decisions related to data management and analysis still remain somewhat subjective. As such, we do not claim that the use of such devices eliminates subjectivity.

In terms of the upstream determinants of this behaviour, the availability of standardised assessment methods lags behind, and knowledge of individual-level psychosocial determinants is largely based on self-reporting, thus limiting international comparability. Pan-European standardisation of methods and instruments is lacking, which also results in data being largely incomparable.

The state-of-the-art assessment methods for dietary, physical activity, and sedentary behaviour and determinants that were identified in the systematic literature reviews were summarised in a publicly available, online toolbox that includes information on the validity, reliability, and acceptability (perceived by participants) of the assessment methods. The toolbox can be found here: https://www.dedipac.eu/toolbox/. Additionally, analyses of secondary data were conducted using existing datasets (e.g. the Attitude Behaviour Change study [15]; the Swedish Neighborhood and Physical Activity study [16]; the Health Survey for England [17]; a Norwegian physical activity prevalence study [18]; and a Portuguese physical activity prevalence study) [19]. The systematic literature reviews and secondary data analyses provided an overview of the state-of-art, and helped identify major gaps with regard to methodology and availability of data on prevalence and determinants, as well as geographical blind spots.

For physical activity and sedentary behaviour, the studies included in the systematic literature reviews of population levels showed substantial variation in the assessment methods, reported outcome variables, and, consequently, the reported physical activity levels and time spent sedentary [10–13]. Because of this, absolute population levels of physical activity and time spent sedentary in European youth and adults are currently largely unknown. Hence, there is a need for harmonisation and standardisation of methods to assess these behaviours and to enable better comparison across European countries. The pooling of accelerometer data in population-based studies provided some data allowing comparisons between countries that revealed, for example, that the most active countries can also be the most sedentary countries [20]. This latter combination is possible within a population, but also for an individual (as one may meet the physical activity guidelines on a particular day, but may also remain sedentary for a great deal of time on the same day). Nevertheless, pooling of accelerometer data does have its own challenges, and the availability of accelerometer data in population-based samples is still very limited (only four European countries have such data for population-based, adult samples).

Finally, an initial step toward bridging the gaps that were identified in assessment methodologies was made by developing and evaluating a new research instrument that assesses sugar-sweetened beverage consumption, as well as a novel instrument that can be used to assess sedentary behaviour and media use for surveillance purposes – both relevant, important, and under-researched topics regarding health behaviour, particularly in young populations. Appropriate existing questionnaires were screened and, where suitable, some of their components were adapted and integrated into the new instrument. This was complemented by a manual containing a Standard Operating Procedure. Another selected and adapted instrument was a smartphone-based method of assessing sugar-sweetened beverage consumption, and an inclinometer to assess physical activity and sedentary behaviour in young adults. The novel instruments were pilot tested in multiple countries.

Development of the roadmap for a harmonised pan-European monitoring system

An inventory was made of national and international European surveillance systems covering diet, physical activity, and sedentary behaviour, and determinants of health behaviour [6]. Based on this inventory, we observed that children and adolescents followed by elderly people were

the age groups that were least well-covered by current surveillance systems. We, therefore, prioritised a roadmap toward a harmonised pan-European surveillance system targeting youth. In particular, sedentary behaviour emerged as the domain that was least assessed in children and adolescents, followed by physical activity. In addition, the European Strategy Forum on Research Infrastructures-Biological and Medical Science Research Infrastructures (ESFRI-BMS RIs) was approached to explore potential synergies between the European RI landscape and DEDIPAC. Working toward a stepwise implementation, we identified currently existing surveillance systems that provide state-of-the-art instruments, or that provide a pan-European infrastructure that could potentially serve as a harmonised surveillance system. Six international surveillance systems were selected as key initiatives: the WHO European Childhood Obesity Surveillance Initiative (COSI) [21]; the Health Behaviour in School-aged Children (HBSC) study [22]; the EU Menu project (aiming to provide standardised information on what people eat in all countries and regions across the EU) [23]; GloboDiet (working towards adapting a standardised international 24-h dietary recall methodology) [24]; European Health Interview Survey [25]; and the Nordic Monitoring of Diet, Physical Activity and Overweight [26]. The German Health Interview and Examination Survey for Children and Adolescents (KiGGS) initiative was selected to serve as a model for the implementation of objective measurement methods [27]. These initiatives contributed to the roadmap.

During an expert meeting, concrete action steps were formulated for the roadmap that were laid down in a conceptual framework. Six action steps with regard to the conceptual framework for implementing the roadmap were proposed: 1) key indicators for dietary intake, dietary behaviour, physical activity, sedentary behaviour, and their determinants should be identified; 2) suitable instruments to assess key indicators across existing surveillance systems should be selected and should a) be valid with the greatest overlap across existing systems; b) prioritise objective measurements over self-reports where feasible; c) use instruments that are robust and easy to apply at a reasonable cost; 3) additional in-depth measurements may be identified and added as optional supplementary modules, e.g. using objective methods in subsamples; 4) a first set of key indicators may be measured using short screening instruments (screeners); 5) the latter could be developed and then implemented by a few select surveillance systems that will superimpose them onto their established instruments as a first step; 6) the stepwise implementation of further screeners may then lead to a gradual replacement of the original, non-harmonised measures, and the successive introduction of newer, and more valid measurements. Methodological studies need to accompany the development, pilot-testing, and implementation of each new module, as well as the calibration of existing instruments.

Objectives, methods and results of TA2

The overall objective of TA2 was to explore the main correlates and determinants of dietary, physical activity, and sedentary behaviour across the life course, and to help to tailor policies and interventions to target these determinants. This objective was specified in two main goals:

1) To review the current state-of-the art, and develop dynamic and evolving frameworks to guide research on the determinants of dietary, physical activity, and sedentary behaviour;
2) To conduct secondary data analyses that contribute to new knowledge to further develop the frameworks on determinants of dietary, physical activity, sedentary behaviour and social inequality.

To realise these goals, TA2 formed four WPs addressing dietary behaviour (WP2.1), physical activity (WP2.2), sedentary behaviour (WP2.3), and social inequality and ethnic minorities (WP2.4). The first three WPs covered all age groups across the life course, with a primary focus on the general population, while WP2.4 had a specific focus on high-risk populations: groups with a lower socioeconomic position, and ethnic minority and immigrant groups, in particular.

Reviewing determinants and developing determinant frameworks

Overall, in the context of TA2, 21 systemic reviews were conducted or are in progress, of which ten have been published at this time: 1 on determinants of diet [28]; 4 on determinants of physical activity [29–32]; 3 on determinants of sedentary behaviour [33–35]; and 2 on ethnic minorities [36, 37] (see Table 2 for the published papers).

For diet, a systematic interdisciplinary mapping (SIM) review of consumer food-decision making and its determinants was conducted using rapid review techniques and the Determinants Of Nutrition and Eating (DONE) framework to explore the state-of-the-art and to identify hot topics and research gaps in this field [28]. This SIM review included 1820 publications from more than ten disciplines (including nutritional science, medicine/health science, psychology, food science and technology, business research, etc.) across a period of 60 years. After applying qualitative and quantitative analyses, this study revealed that most of the research conducted and published to date focused on biological, psychological, and/or product-related predictors, whereas 'upstream' influences (e.g. related to policy or built and social environments) on food choice are scarcely considered. In this way, the SIM study highlighted newly identified determinants for future empirical research

and showed how measurement of known determinants should be embedded in new or different contexts in future studies (e.g., to embed policy determinants in studies with a focus on individual decision making). A further 8 systematic literature reviews were performed that dealt with determinants of dietary behaviour in different age groups (for the published papers see Table 2).

The results of four of the seven systematic umbrella reviews ('reviews of reviews') focusing on the biological, behavioural [29], psychological [31], built environmental [30], socio-cultural, economic, and policy determinants [32] have been published and are summarised in Table 2. In general, the current evidence showed to be of moderate quality. A need for consensus on clear definitions of physical activity and its possible relevant determinants emerged. Furthermore, to allow for clear interpretation and generalisability of findings, determinants of physical activity should be studied within a large and multi-level framework to account for interacting and mediating factors. Finally, further prospective study designs, objective measurement of physical activity, and cohort studies are strongly recommended.

WP2.3 conducted three systematic reviews on determinants of sedentary behaviour across three age groups: youth (<18 years) [33]; adults (18–65 years) [34]; and older adults (>65 years) [35]). The studies included were predominantly conducted in and covered populations from Europe, the US, and Australia. The operationalisation of sedentary behaviour in most studies was limited to TV or 'screen' time, rather than overall sedentary behaviour, and often relied on self-reporting. Furthermore, the systematic literature reviews revealed a lack of studies using qualitative research methodologies, as well as a lack of studies that looked into the more motivational and, as was the case in the reviews dealing with determinants of dietary behaviours, the contextual or 'upstream' potential determinants of sedentary behaviour.

WP2.4 conducted two systematic mapping reviews of the determinants of diet [36], and physical activity/sedentary behaviour [37] in ethnic minority and migrant origin populations in Europe. There were few large-scale, epidemiological studies, and much of the evidence presented was obtained from qualitative studies. Both reviews identified a broad range of factors and clusters influencing diet and physical activity behaviour among minority ethnic groups, but overall there was a predominance of studies exploring 'differences' between minority ethnic groups and the majority population. The studies were mainly conducted in Northern European countries with populations of South Asian origin most often being the object of study. The reviews indicated that there are several gaps in the literature related to the minority populations studied, the countries in which the studies were conducted, the paucity of comparative studies, and lack of attention to sedentary behaviour. In addition, there is a need for interdisciplinary studies to map the interrelationships between different types of determinants (e.g. physical and political environment). Given the diversity of ethnic minorities in many European countries, there is a need for research exploring 'similarities', i.e. the relative importance of factors influencing behaviour in the general population, *as well as* in ethnic minority populations.

The results of these reviews informed the first steps toward the development of three behaviour-specific frameworks for determinants of dietary behaviour [38], physical activity [39], and sedentary behaviour [40]. In addition, WP2.4 developed its own frameworks for determinants of dietary behaviour, and physical activity/sedentary behaviour of ethnic minorities, while also further contributing to the three behaviour-specific frameworks. The other high-risk group in WP 2.4, namely lower socio-economic groups, were covered in the general frameworks. The frameworks were all developed over multiple iterations and fostered multidisciplinary systems thinking in an effort to extend the contents of the framework beyond silos of disciplines and existing ecological models. Structured consensus protocols based on concept mapping were used in those dealing with physical activity and sedentary behaviour, and these behaviours among ethnic minorities [41]. Concept mapping is a standardised mixed method that combines qualitative points of view with multivariate statistical analysis to enable a group to gather and organise ideas into a conceptual framework. This involved five main phases: 1) Preparation included the definition of behavioural outcomes, and the creation of a protocol for structuring and standardising the whole process, which detailed the ways in which participants could contribute; 2) a Delphi-like process followed with the objective of compiling an exhaustive list of all potential determinants based on evidence provided by literature reviews and expert judgements; 3) the potential determinants were then structured into groups/systems; 4) next, the potential determinants were ranked and sorted according to research priority, modifiability, and potential population impact; and 5) determinants were visualised as clusters or systems. The 'data' generated over the course of these five phases - aggregated from individual expert contributions and multiple consensus events - were processed and visualised. This was done using *Tableau* in WP2.1 (www.tableau.com; Web link) and *Ariadne* in WP2.2 and WP2.3 (www.minds21.org Web link for WP2.2, Web link for WP2.3) software.

For potential determinants of dietary behaviour, the DONE framework was developed [38]. This framework is organised according to three main outcome categories: food choice, eating behaviour, and dietary intake/nutrition. The framework includes 441 determinants and is visualised on an interactive website: https://www.uni-konstanz.de/DONE/. The website allows the user to select determinants

by level, including 4 main levels (individual, interpersonal, environment, policy), 11 stem categories (e.g., biology, psychological), and 51 leaf-categories, as well as by different age groups and relevance for ethnic minorities. For all determinants, the degree of modifiability, relationship strength with the respective outcome category, and population-level effect according to expert ratings is visualised. A first systematic interdisciplinary mapping (SIM) review on consumer food decision making using the DONE framework for categorising the identified predictors of food decision making revealed that most of the research emphasises biological, psychological, and product-related predictors, whereas policy-related influences on food choice are barely considered [28].

For physical activity, the EUropean-Physical Activity Determinants (EU-PAD) framework was developed [39]. The WP2.2 research team identified a list of 183 factors based on both expert judgement and empirical evidence. The concept mapping resulted in six distinct clusters, broadly merged in two themes: 1) the 'Person', which included the clusters 'Intra-Personal Context and Well-being' and 'Family and Socioeconomic Status' (42% of all factors), and 2) the 'Society', which included the remaining four clusters 'Policy and Provision', 'Cultural Context and Media', 'Social Support and Modelling', and 'Supportive Environment' (58% of all factors). Overall, 25 factors were rated as the most modifiable and impactful in terms of physical activity behaviour across the life course. They were largely situated in the 'Intra-Personal Context and Well-being' cluster [39].

For sedentary behaviour, the Systems of Sedentary behaviour (SOS) framework was developed [40]. The resulting framework maps the 190 potential factors in a system of six interacting clusters: 'Physical Health and Well-being', 'Social and Cultural Context', 'Built and Natural Environment', 'Psychology and Behaviour', 'Politics and Economics', and 'Institutional and Home Settings'. In addition, priorities were set in terms of focusing research on the most potentially modifiable and impactful parts of the system. Investigating the influence of 'Institutional and Home Settings' was deemed to be the most promising area [40].

In the determinant framework developed specifically for ethnic minorities populations, seven distinct clusters emerged for dietary behaviour (containing 85 factors) and eight for physical activity behaviour (containing 183 factors). Four clusters revealed themselves to be similar across all behaviour: 'Social and cultural environment', 'Social and material resources', 'Psychosocial', and 'Migration context'. The WP2.4 framework was aligned with those of the other three WPs. In general, the clusters of factors that emerged in the ethnic minority determinant framework were somewhat similar to the majority population frameworks for diet and physical activity behaviour, with the exception of 'Migration context'. The importance of factors across all clusters was acknowledged, but their relative importance, or manifestation, differed for ethnic minority versus the majority population [42].

Secondary data analyses

A data pooling taskforce that spanned the WPs in TA1 and TA2 was established to develop a strategy for secondary data analysis. This group devised a five-step methodology covering 1) the identification of relevant datasets across Europe; 2) the development of a dataset compendium that included details on the design, study population, measures, and level of accessibility of data from each study; 3) the definition of key topics and approaches for secondary analyses; 4) the acquisition of access to datasets; and 5) the development of a data harmonisation platform, and pooling and harmonisation of the data [43]. Based on this, a variety of approaches to secondary data analysis were identified, including re-analysis of a single, existing dataset, 'federated' meta-analyses of two or more datasets based on a common data-analytical syntax applied to locally stored data, and the pooling, harmonisation and re-analyses of multiple datasets. To assist with these analytical approaches, a two-day statistical analysis workshop was organised in Amsterdam, the Netherlands, that specifically focused on the challenges associated with conducting secondary data analysis, handling pooling and harmonisation issues, and the provision of support in the area of advanced statistical techniques (e.g., federated data analyses, Bayesian analyses, mediation/moderation analyses, and handling missing data). In addition, WP2.2 and WP2.3 held a combined, three-day writing retreat in Ghent, Belgium to further define approaches, make progress on specific questions, as well as identify unresolved issues regarding the pooling and harmonisation process.

Critical aspects of the FAIR principles of data management and stewardship [44] were monitored throughout the phases of the secondary data analyses, from the identification of potentially relevant datasets to the actual reuse of data. The FAIR principles suggest that each data resource, associated metadata, and complimentary files should be easy to find ('Findable'); provide relevant metadata from these datasets, on the types of variables, age groups under study, study design, measurement instruments used, time frame, etc. ('Accessible'); be 'Interoperable' and thus use a consistent data format and taxonomy for knowledge representation; and, finally, they should be 'Reusable', i.e., made available for further analyses.

The topics and general outcomes of the secondary data analyses are briefly summarised below. We found that many different approaches to handling the multiple data sources were used, as were a wide variety of methods of statistical analysis. Regarding determinants of dietary behaviour, a total of 14 research questions have been or

are currently being addressed using secondary and/or federated meta-analysis [45–50]. The published articles are listed in Table 2.

Compiling the physical activity and sedentary behaviour data resulted in a detailed list of 150 datasets. A total of 14 of these datasets were eventually obtained and reused to address 10 exemplar research questions on determinants of physical activity and sedentary behaviour (Table 2 contains the published papers). So far, these manuscripts have relied on a variety of methods of analysing the data, such as Bayesian Network analysis of the determinants of physical activity and sedentary behaviour provided by the Eurobarometer dataset, meta-regression to examine more complex interactions with selected moderator/mediator variables of physical activity behaviour within harmonised datasets, and Chi-squared automatic interaction detection (CHAID) to examine the hierarchy of socio-demographic correlates of remaining sedentary for an extended period of time [51]. The latter analyses included over 27,000 participants and showed that current occupation was primary discriminator. A deeper profiling revealed that highly educated adults with white-collar jobs, who had no difficulties paying bills, and used the internet frequently were most likely to sit too much.

In WP2.4, due to the limited availability of data on behaviour and determinants across ethnic minorities, specific case studies and secondary data analysis on single datasets were conducted, as opposed to federated meta-analysis or pooled analyses [52]. In general, these efforts revealed a clear lack of indicators of ethnic minority status in the studies that were included in the compendium. Furthermore, quite often the numbers of ethnic minorities included in some of the pan-European studies were too small to enable detailed analysis of specific groups, thus they are often 'lumped' together to increase statistical power.

The DEDIPAC data warehouse proved to be useful for pooling datasets, but in general, the available data -or rather the lack thereof- often restricted harmonisation to just a few core (crude) outcome variables and some individual-level, socio-demographic correlates of these behaviours. The stepwise approach to secondary data analysis used was described in a 'methods' paper [43], as well as in a position paper that draws on the possibilities and impossibilities of secondary data analyses of pooled and harmonised data on determinants of sedentary behaviour. The main gaps identified were lack of datasets that specifically emphasise determinants of behaviour - especially at the more macro level and with a systems approach; too few longitudinal studies examining determinants; and inadequate coverage of European nations and age groups. Most studies investigated the behaviour-disease relationship rather than the determinants of the behaviour.

Objectives, methods, and results of TA3

TA3's overall objective was to contribute to better evaluation and benchmarking of public health interventions and policies related to dietary, physical activity, and sedentary behaviour across the life-course. The specific goals of TA3 were:

1) To improve the quality of public policies and intervention to promote healthy diet, physical activity, and to reduce sedentary behaviour by creating a database with examples of good practice;
2) To improve implementation (from research to practice/policy) and transferability (from practice/policy to practice/policy) of public policies and intervention;
3) To develop and pilot test an online toolbox for developing, monitoring, and evaluating policies and multi-component interventions across Europe.

The work within TA3 was organised into three WPs; the first aimed to realise goals 1 and 2, and the two other WPs focused on the development and pilot testing of the toolbox (goal 3) - one focused on policies, and the other on multi-component interventions. 'Multilevel or multi-component interventions' were defined as theory-based interventions that use knowledge of behavioural determinants at different levels (i.e. individual, socio-cultural, and environmental) to improve dietary, physical activity, and sedentary behaviour in individuals. The focus was specifically on interventions that combined individual-level components with contextual or environmental-change components, as earlier evidence suggested that such combinations are most likely to be effective [53–55]. These interventions have not yet been widely implemented, but have the potential to be translated into health-promoting policies if adopted by governmental agencies in the future. They may thus be regarded as feasibility/pilot interventions to inform future policy making.

Improving quality of public policies and interventions

To contribute to meeting the first objective, an umbrella review (a review of reviews) was conducted first. This umbrella review focused on identifying good-practice characteristics for interventions and policies that aim to promote healthy diets and physical activity, and included systematic reviews, as well as position papers [56]. In this review, 53 good-practice characteristics were identified. Eighteen of these characteristics were related to intervention and policy content and focus, and were related to the use of theory, target populations and target behaviour, content development and management, multidimensionality, and practitioners and settings. Another 18 characteristics were related to monitoring and evaluation and were related to such issues as costs/funding, outcomes and evaluation of

effects, evaluation of reach, and participation. The other characteristics (n = 17) were related to implementation and concerned issues such as participation processes, implementation partnerships, training of practitioners, the use of existing resources, maintenance, adaptation processes, and transferability.

Next, a so-called 'quick scan' was conducted of relevant interventions and policies to identify potential good practices in ten countries involved in DEDIPAC. The 'founders' (N = 79) of the 'good practices' were subsequently approached and asked to complete an online questionnaire to retrieve information related to good-practice characteristics and to provide additional information regarding the main characteristics of the policy or intervention, monitoring and evaluation, and implementation. Finally, based on the 'quick scan' inventory of good practices, and the responses to the online questionnaire, an online database of examples of good practice in terms of public policies and multicomponent interventions (N = 52) was developed. The purpose of creating this database was to increase the use and knowledge of good practices in designing and implementing public policies and multicomponent interventions. A total of 44 examples of good practices of policies and interventions from eight European countries represented in DEDIPAC were included in the database. The database contains information on intervention characteristics (including aim, target population, and behaviour, among others), monitoring and evaluation efforts and accomplishments and implementation, sustainability, and transferability conditions. Most of the interventions in the database focus on children in school settings and address both diet and physical activity. This database is publicly available online (https://www.dedipac.eu/toolbox/) and is supported by a factsheet with background information to support the use and dissemination of the database among policy makers and health-promotion professionals.

Improving implementation and transferability of policies and interventions

To meet the second objective of TA3, an umbrella review was conducted to identify critical implementation and transferability conditions [57]. This review focused on documents aimed at generating empirical evidence and evidence-based recommendations regarding implementation conditions for policies and interventions targeting healthy diet, physical activity, or sedentary behaviour. For the purpose of this umbrella review, so-called 'stakeholder documents' were also considered eligible for inclusion and, as such, the data banks of publications from eight major stakeholders, like the World Health Organization, were searched for relevant documents. Eighty-three conditions that were relevant to successful implementation were identified and these were further grouped according to the RE-AIM (Reach, Effectiveness, Adoption, Implementation, Maintenance) framework [58]. Eight implementation conditions referred to reach in the target population; five addressed efficacy of implementation processes; 24 dealt with adoption issues by staff or institutions; 43 referred to consistency, costs, and adaptations made in the implementation process; and three addressed maintenance. The vast majority of the implementation conditions identified (73 of 83) were relevant in terms of both multi-component interventions and policies. Seven implementation conditions were policy-specific and related to the increasing complexities associated with coexisting policies/legal instruments and their consequences for implementation, as well as politicians' collaboration in implementation.

Additionally, six example interventions and six policies pertaining to diet, physical activity and/or sedentary behaviour were identified in five DEDIPAC countries (Belgium, Germany, Ireland, Norway, and Poland). Face-to-face, semi-structured interviews were held with 40 stakeholders in an effort to ascertain the things that health promotion professionals and policy makers believe are important in terms of factors impacting adoption, implementation, maintenance, and transferability. Analysis of these case studies showed that active involvement of relevant stakeholders from the political, health and education sectors, as well as that of intervention/policy implementers, and good communication between coordinating organisations and the government, private organisations, and settings were important factors contributing to the successful adoption and implementation of both interventions and policies [59]. Additional factors included sufficient training of staff to ensure implementation according to existing intervention/policy protocols, and tailoring of materials to match needs and (language) skills and sociocultural context of various target groups. The respondents also indicated that maintenance of implemented interventions/policies depended on whether or not they were embedded in existing or newly created organisational structures in different settings and whether or not continued funding was secured (which often depends on political support).

Development and testing of the online toolbox

In developing a preliminary toolbox for the development, monitoring, and evaluation of public policies and multicomponent interventions across Europe, so-called 'rapid reviews' were conducted on monitoring and evaluation of public policies and multicomponent interventions aiming to promote healthy dietary, physical activity and/or sedentary behaviour. Additionally, a template for systematically describing relevant policies and multi-component interventions including content, implementation conditions and main characteristics (e.g., aim, target population), and monitoring and evaluation was developed. This enabled

the systematic inventory of standardised measures used to evaluate effects of policies or multi-component interventions (i.e. in terms of changes in determinants, behaviours, and health outcomes). It also enabled the systematic summary of procedures and measures related to economic evaluations, including the application of counterfactual methods to determine *ex post* effectiveness on the basis of quasi-experimental data [60], and process evaluation measures.

All the information and content derived from the reviews, interviews, and inventories were then combined into a preliminary toolbox designed to aid in the development, evaluation, and implementation of public policies and multicomponent interventions. The toolbox was implemented as an online, wiki-based platform and was pilot tested in two rounds by DEDIPAC partners and external stakeholders, including policy makers and practitioners, respectively. Face-to-face interviews, telephone interviews, or written comments using a standardised feedback form were used to obtain feedback on issues such as visual appearance, technical features, functionality, content of the toolbox, as well as questions about omissions, remarks, and suggestions for improvement.

The feedback provided was generally related to three issues. First, the online, wiki-based platform was regarded as being user *unfriendly*. Second, in many cases, the content was regarded as being insufficiently extensive and detailed. The third issue identified was the (lack of) ease of navigation. Based on this feedback, the platform was changed to a web-based format, the content was expanded and made more detailed and more examples were provided, and navigation changes were made. The second draft of the toolbox was then presented, tested, and discussed by DEDIPAC partners during the consensus meeting. At this meeting, additional comments and suggestions regarding further, final changes, improvements, and recommendations pertaining to the current version of the toolbox and its future use were made.

At this stage, the draft toolbox was applied to policy and multi-component activities that were already running or that were soon to be implemented or disseminated in different countries, to test and further enrich the toolbox. Stakeholders involved in these policies and interventions were asked to apply the toolbox and complete structured feedback sheets. The toolbox was tested in the context of five policies and six multicomponent interventions and feedback was provided by the relevant users. Finally, a meeting to reach a consensus on the content, appearance, accessibility, and user-friendliness of the toolbox was organised among the TA3 partners.

Overall, the stakeholder evaluation of the usefulness, feasibility, and applicability of the toolbox was positive; feedback provided indicated that the database part of the toolbox provided good examples of policy and multi-component interventions, and that the toolbox was helpful in terms of planning future policy and multi-component interventions and their evaluation.

Some critical feedback and suggestions for further improvements were provided as well. These concerned a need for additional content and a linkage to other, existing resources, including (other) websites with relevant information; further adaptation of structure, design and navigation throughout the toolbox; and inclusion of more examples, possibly also in other European languages besides English. Based on this feedback, final adaptations were made to the toolbox and it was made publicly available online (https://www.dedipac.eu/toolbox/).

This version of the toolbox is divided into four sections. The first section, DEVELOPMENT, guides users through the process of developing a policy or multi-component intervention. Next, EVALUATION, proposes and explains guidelines and specific instruments geared toward evaluating policies and multi-component interventions. IMPLEMENTATION provides information on the process of implementation and/or process evaluation. Finally, the NATURAL EXPERIMENTS section offers practical examples of policies and multi-component interventions.

Discussion

Over a three-year period, researchers from thirteen countries across Europe joined forces to establish DEDIPAC, the first joint action taken by the Joint Programming Initiative in an effort to foster pan-European research to contribute to more healthful diets and increased physical activity across Europe. This joint action built and pursued a common research agenda aimed at realising collaboration between various scientific disciplines to expand knowledge, develop new insights, and reduce research overlap.

The overall aim of DEDIPAC was to improve the infrastructure and methodology for research on, and gain more insight into the determinants of dietary, physical activity, and sedentary behaviour over the life course. The many outputs that were – and are being – generated, provide an overview of the state of the art, as well as suggestions for further research on multilevel determinants of dietary, physical activity and sedentary behaviour over the life course. The outputs also focus on the interrelation of these determinants, existing and available measurement methods that can be used to assess this behaviour and its determinants, and to inform and evaluate policies and multilevel interventions.

Concrete products developed in the context of DEDIPAC include determinant frameworks for dietary, physical activity, and sedentary behaviour, and comprehensive, open-access toolboxes that provide measurement methods applicable to this behaviour and its determinants, as well as methods and tools to develop, implement, and evaluate interventions and policies.

The main results of DEDIPAC show that the evidence base on determinants of diet, physical activity and sedentary behaviour - and thus on the causes of the causes of non-communicable disease - is fragmented. The series of systematic literature reviews assessed the available evidence on the current nature of dietary, physical activity and sedentary behaviour in Europe, as well as on factors that influence these behaviours over the life course. These revealed a great deal of variation in terms of assessment methods used and reported behavioural outcome variables, such that information on physical activity, sedentary and dietary behaviour across all of Europe is scarce, and such that studies in this area are difficult to compare and findings are difficult to assimilate. The disabling lack of knowledge exposed by the systematic reviews may well stem from the dearth of available data on determinants – at least in Europe. The various secondary data analyses that were undertaken in the context of DEDIPAC highlighted a lack of data that prevents closure of the knowledge gap. The federated meta-analyses, pooling, and harmonisation actions revealed that available studies have focused almost entirely on socio-demographic factors in isolation, and have not yet investigated more distal, contextual factors in the built, social and economic environments. Consequently, the available evidence regarding determinants and correlates of sedentary behaviour, for example, generally says more about *who* is sedentary than *why* people are sedentary. This evidence may help to decide *whom* to target with interventions and policies, but not *what* to target or *how* to do it. Moreover, the 'renewed' and widespread appreciation for systems thinking was reflected in the four frameworks that were developed within DEDIPAC. These frameworks focus on understanding how *clusters* of factors interact synergistically or antagonistically to promote or prevent certain behaviour. As such, this challenges the current practice of reducing determinants of health behaviour to discrete factors organised according to conceptual levels and conducting analysis using linear models, and raises the question of whether or not this advances our understanding of how to intervene effectively.

Regarding the benchmarking and evaluation of policy interventions to address dietary, physical activity, and/or sedentary behaviour, DEDIPAC revealed some best practice information and implementation conditions, as well as a few more detailed examples of policy evaluation. However, the main result was that policy evaluation and benchmarking in our field is in its infancy and needs to progress towards evidence-based policy making. In parallel with DEDIPAC, the INFORMAS network and methodologies were further developed as a global network of public-interest organisations and researchers aiming to monitor, benchmark, and support public and private sector actions to create healthy food environments and reduce obesity and non-communicable disease [61]. Part of INFORMAS is a so-called 'Government Healthy Food Environment Policy Index' (Food-EPI) that is comprised of a 'policy' component with seven domains on specific aspects of food environments, and an 'infrastructure support' component with seven domains geared toward strengthening systems to prevent obesity. A second interesting development in this field of policy evaluation and benchmarking is the NOURISHING framework [62], developed by the World Cancer Research Fund to highlight the areas in which governments need to take action to promote adherence to a healthy diet and reduce overweight and obesity. NOURISHING and INFORMAS are linked and work together, focusing on nutrition environments and policies. DEDIPAC aligned with INFORMAS to push for the application of the Food-EPI in different countries across Europe in order to gain experience with and further develop this instrument, and to actually carry out benchmarking of public policies across Europe. DEDIPAC further pushed for and contributed to initial steps to work towards a similar instrument for benchmarking and monitoring physical activity and sedentary behaviour environments and policies.

DEDIPAC succeeded in forging new collaborations across Europe to align research focus, infrastructure, and funding for this important topic to contribute to furthering behavioural nutrition and physical activity research, as well as translating this research into practice and policy. DEDIPAC can be regarded as a European joint-programming experiment designed to make better use of the limited resources for research by doing more things better together than each country could do separately. We believe that this experiment worked well in the context of DEDIPAC; the series of interrelated reviews, the stepwise generation of comprehensive models, the inventories of best practices, making use of, pooling and harmonising international data, as well as the development of toolboxes to disseminate state of the art research to wider audiences would not have been possible without a joint agenda and governance. Additionally, DEDIPAC worked as a true Knowledge Hub; it has created new collaborations, led to exchanges of people and knowledge, established networks, and resulted in (international) research grant proposals.

Gaps to close

The systematic analyses of existing knowledge in the context of the various systematic literature reviews identified several gaps. First, the definitions used for the outcomes (i.e. dietary behaviour, physical activity) were not consistent, with many different types and terms being used. Second, a wide range of study designs, measurement methods, population groups, investigated determinants, and outcomes emerged from the analysed studies, making it difficult to evaluate and compare the evidence, and to draw definitive conclusions.

Regarding measurement, there is an urgent call for more objective methods. These do start to play a bigger role in behaviour assessment, particularly the measurement of physical activity and sedentary behaviour, but are still subject to limitations of their own. For instance, objective methods still suffer from an inability to assess specific domains of physical activity or sedentary behaviour, and their use can be constrained by price, logistical requirements for data, storage and processing. In addition, there are many devices available to make such measurements nowadays, but these devices also vary in terms of their validity. Therefore, at least for the foreseeable future, more traditional, self-reported data will still need to be collected adjacent to the data collected from mobile devices, for example, to appropriately capture important information on contextual factors affecting the behaviour. However, for surveillance purposes, if we are simply interested in prevalence estimates of adherence to physical activity recommendations, then such context may be less important.

Standardisation of assessment methods for determinants still needs special attention. Even simple determinants, such as education and occupation, are assessed and classified using a plethora of different methods. This impedes comparison between studies, as well as harmonisation and data pooling. Recruitment of population-representative samples, especially for population surveillance, is another challenge; non-response has become a greater and greater issue, as response proportions have decreased steadily over the last few decades.

Third, the most commonly used study design was cross-sectional. This means that the strength of the evidence produced by these studies in inherently limited due to the impossibility of assessing the direction of observed associations, and therefore of identifying the *true* drivers of health behaviour and their quantitative impact. The lack of high-quality longitudinal data on behaviour, as well as potential determinants, is arguably the most glaring research gap. Longevity of surveillance systems and cohort studies needs special attention, especially with regard to funding systems that only provide funding for up to five years. Keeping measurement methods standardised over time is paramount, but it is far from standard practice. There is an obvious tension between keeping methodology constant over time and advances in measurement methods, which might be solved by including new measures adjacent to existing ones in order to maintain longitudinal comparability, while simultaneously improving the surveillance system. Further, surveillance systems that include worn technology to assess trends over time are, with few exceptions, virtually non-existent. Although data pooling has been proposed as a promising way forward, the reality is much more sobering. Harmonisation between measures for both behaviour and determinants is incredibly challenging and often impossible. Hence, the establishment of a pan-European cohort and/or surveillance system focused on dietary, physical activity and sedentary behaviour, and their determinants seems the best way forward to take this research field to the next level.

Fourth, information on relationships between determinants, especially determinants at different socio-ecological levels within systems, are severely lacking. Fifth, there is a lack of studies on this behaviour and its determinants in ethnic minorities. Finally, there is a need to establish links between pan-European research and European Research Infrastructures (RI). One obstacle to establishing synergies between health research and surveillance, and RIs is that in many cases no provisions were made at the time of the creation of the resource to account for sharing/merging/linking with another research community. Therefore, in many instances, the benefits associated with these efforts can only be reaped in the future. As such, future effort will be necessary to make these resources sufficiently useable for surveillance, but also for the research community.

The frameworks developed highlighted areas of priority and modifiability within the dietary, physical activity and sedentary behaviour systems, specific to age groups, and also for ethnic minority populations. For instance, the 'Supportive Environment' cluster was considered to be the highest priority for research out of all the determinant clusters for physical activity. These findings, as well as those from the other DEDIPAC frameworks, support the suggestion, and call for, a shift in focus from individual responsibility, personal commitment, and lifestyle choices, to the influence of social and physical environment on overcoming barriers to healthy behaviour.

The efforts made in the context of the secondary data analyses on determinants of physical activity and sedentary behaviour faced considerable barriers across all FAIR domains: data resources, associated metadata, and complimentary files were often not easy to find ('Findable'). Retrieving relevant metadata from these datasets, on the types of variables, age groups under study, study design, measurement instruments used, time frame, etc., for instance, was a painstaking process ('Accessible'). A consistent data format and taxonomy for knowledge representation was generally lacking ('Interoperable'), and, finally, only a limited number of datasets were eventually found to be 'Reusable', i.e., made available.

Extending beyond FAIR, the harmonisation of independent variables and outcome measures under study was often problematic. The DEDIPAC Compendium of Datasets indicates substantial variation in assessment methods and operationalisation of variables across current European studies. This variation not only hampered the practical harmonisation process, but also presented comparability issues, as estimations of physical activity and sedentary behaviour levels are known to differ based on the assessment method used. The secondary data analyses' focus on ethnic-minority

groups revealed that within current 'mainstream' research on the determinants of health behaviour in Europe, ethnic minorities are often either not included, or their numbers are too small to enable meaningful analysis.

Despite DEDIPAC's significant theoretical and knowledge progress on behaviour and its determinants, the paucity of high quality, EU-wide data collected using standardised methodology on both the behaviour, as well as a wide range of potential determinants, in accordance a systems perspective, is a major barrier that slows this momentum. This data shortage undermines the progress towards informing policy and interventions to tackle key non-communicable chronic disease related to unhealthy behaviour.

Future directions

Regarding policy benchmarking and monitoring, we recommend the further development of the toolbox for policy evaluation and benchmarking by developing and testing an instrument for physical activity and sedentary behaviour similar to the INFORMAS food-EPI; combining and applying this alongside the food-EPI in different countries across Europe to gain hands-on experience with this type of policy monitoring and benchmarking across Europe. This will contribute to the further validation of the methodology, the dissemination of best practices across Europe, and thus to working towards better-informed, evidence-based policy making across Europe.

DEDIPAC was one of the first actions taken in the context of the Joint Programming Initiative in the field of behavioural nutrition and physical activity in Europe. This joint-programming experiment provided better overviews of the field, initiated new collaborations, created new insights, as well as identified directions for further research. DEDIPAC works toward and seeks support for three ways of building upon DEDIPAC to further the field:

1. Sustain and further strengthen the Knowledge Hub in an effort to create a sustainable European network centre for research and expertise on behavioural nutrition and physical activity, which could work under the umbrella of the International Society for Behavioural Nutrition and Physical Activity;
2. Provide longitudinal data on the individual and contextual drivers of the behaviour causing or aggravating non-communicable disease by building a prospective cohort of families across all regions of Europe, making use of the rich diversity in the systems of policies, contextual and individual determinants, as well as the behaviour across Europe from an early age onward. Analysis of the data acquired from this cohort should be subjected to harmonised methodology and measures, and focus on policy, contextual, as well as individual determinants of dietary, physical activity and sedentary behaviour from a life-course perspective. In addition, the cohort should be representative of the whole European population, including those who have migrated from other parts of the world;
3. Build a strong framework for monitoring, evaluation, and benchmarking of dietary, physical activity, and sedentary behaviour policies and environments across Europe.

Conclusions

Europe has the right ingredients for the creation of infrastructure to study the causes of the causes of the chronic disease burden. DEDIPAC has strengthened existing infrastructure by aligning countries, research centres, and scientists from various disciplines across Europe on this crucial topic. It provided further insights into the measurement, the wide range of determinants of dietary, physical activity and sedentary behaviour across the life course and their interplay. However, action is now needed to build on this momentum. At present, we need better cross-European harmonisation of measurement and monitoring, FAIR data management and data sharing, common methodology, as well as (longitudinal) data required to gain more insight into behavioural determinants, as well as policy evaluation and benchmarking. We lack complete data on all of Europe, with data on southern and eastern European regions, in particular, being scarce.

Abbreviations

CHAID: Chi squared automatic interaction detection; COSI: Childhood obesity surveillance initiative; DEDIPAC: Determinants of diet and physical activity; DONE: Determinants of nutrition and eating framework; ESFRI-BMS: European strategy forum on research Infrastructures- Biological and medical science; EU: European Union; EU-PAD: European physical activity determinants framework; FAIR: Findable, Accessible, Inter-operable, Reusable; FFQ: Food frequency questionnaire; Food- EPI: Government healthy food environment policy index; HBSC: Health behaviour in school-aged children; HDHL: A healthy diet for a healthy Life; INFORMAS: International Network for Food and Obesity/ non-communicable Diseases Research, Monitoring and Action Support.; JPI: Joint programming initiative; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PROSPERO: International prospective register of systematic reviews; RE-AIM: Reach, Effectiveness, Adoption, Implementation, Maintenance; RI: Research infrastructure; SIM: Systematic interdisciplinary mapping; SOS: Systems of sedentary behaviour framework; TA: Thematic area; WHO: World Health Organization; WP: Work package

Acknowledgements

Not applicable.

Funding

This work is supported by the Joint Programming Initiative 'Healthy Diet for a Healthy Life'. The funding agencies supporting this work are (in alphabetical order of participating Member States): Austria: Austrian Federal Ministry of Science and Research; Belgium: Research Foundation – Flanders; France: Institut National de la Recherche Agronomique (INRA); Germany: Federal Ministry of Education and Research; Italy: Ministry of Education, University and Research/ Ministry of Agriculture Food and Forestry Policies; Ireland: The Health Research Board (HRB); The Netherlands: The Netherlands Organisation for Health Research and Development (ZonMw); Norway: The Research Council of Norway, Division for Society and Health; Poland: The National Centre for Research and Development; Spain: Carlos III Institute of Health (ISCIII); The United Kingdom: The Medical Research Council (MRC).

Authors' contributions
All authors were closely involved in the initiation and implementation of DEDIPAC. JB, together with HvdP, AL and JL drafted the first version of the manuscript. All authors provided feedback and contributed to further versions. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Amsterdam School of Communication Research (ASCoR), University of Amsterdam, Amsterdam, The Netherlands. [2]Department of Public and Occupational Health, Amsterdam Public Health Research Institute, VU University Medical Center, Amsterdam, The Netherlands. [3]Sydney School of Public Health, University of Sydney, Sydney, NSW, Australia. [4]Leibniz-Institute for Prevention Research and Epidemiology – BIPS, Bremen, Germany. [5]INRA, UR1303 ALISS, F-94205 Ivry-sur-Seine, France. [6]Department of Nutrition, University of Oslo, Oslo, Norway. [7]Department of Movement and Sports Sciences, Ghent University, Ghent, Belgium. [8]Department of Movement, Human and Health Sciences, University of Rome Foro Italico, Rome, Italy. [9]Institute for Applied Health Research, School of Health and Life Science, Glasgow Caledonian University, Scotland, UK. [10]Centre for Physical Activity and Health Research, University of Limerick, Limerick, Ireland. [11]Norwegian Institute of Public Health, Oslo, Norway. [12]Institute of Food Research, Norwich, UK. [13]Department of Internal Medicine II, Division of Sports and Rehabilitation Medicine, University Ulm, Ulm, Germany. [14]Johannes Gutenberg University, Mainz, Germany. [15]Department of Neurosciences, Biomedicine and Movement Sciences, Verona, Italy. [16]Health Research Institute, University of Limerick, Limerick, Ireland. [17]Department of Statistical Sciences of the University of Bologna, Bologna, Italy. [18]Centre for Diet and Activity Research, MRC-Epidemiology Unit, School of Medicine, University of Cambridge, Cambridge, UK. [19]Sport & Exercise Sciences Research Institute, Ulster University, Northern Ireland, UK. [20]Department of Public Health, Amsterdam Public Health research institute, Academic Medical Centre, University of Amsterdam, Amsterdam, The Netherlands. [21]Department of Nutrition and Food Science, Rheinische Friedrich-Wilhelms-Universität Bonn, Bonn, Germany. [22]3U Diabetes, School of Health and Human Performance, Dublin City University, Dublin, Ireland. [23]Department of Psychology, University of Konstanz, Konstanz, Germany. [24]Consumption Research Norway, Oslo and Akershus University College of Applied Sciences, Oslo, Norway. [25]Department of Prevention & Nutrition, National Institute for Public Health and the Environment, Bilthoven, The Netherlands. [26]Department of Molecular Epidemiology, German Institute of Human Nutrition Potsdam-Rehbruecke, Nuthetal, Germany. [27]Institute for Biomedicine of Aging, Friedrich-Alexander-Universität Erlangen-Nürnberg, Nuremberg, Germany. [28]Department of Epidemiology and Biostatistics, Amsterdam Public Health research institute, VU University Medical Center, De Boelelaan 1089a, 1081, HV, Amsterdam, The Netherlands.

References

1. World Health Organization, Global status report on noncommunicable diseases 2014.
2. Lakerveld J, et al. Towards the integration and development of a cross-European research network and infrastructure: the DEterminants of DIet and physical ACtivity (DEDIPAC) knowledge hub. Int J Behav Nutr Phys Act. 2014;11:143.
3. Joint Programming Initiative a Healthy Diet for a Healthy Life, The vision for 2030. 2010.
4. Moher D, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6(7):e1000097.
5. Centre for Reviews and Dissemination. PROSPERO database. 2015; Available from: http://www.crd.york.ac.uk/PROSPERO
6. Bel-Serrat S, et al. Inventory of surveillance systems assessing dietary, physical activity and sedentary behaviours in Europe: a DEDIPAC study. Eur J Pub Health. 2017;27(4):747–55.
7. Riordan F, et al. A systematic review of methods to assess intake of sugar-sweetened beverages among healthy European adults and children: a DEDIPAC (DEterminants of DIet and physical activity) study. Public Health Nutr. 2016:1–20.
8. Riordan F, et al. A systematic review of methods to assess intake of fruits and vegetables among healthy European adults and children: a DEDIPAC (DEterminants of DIet and physical activity) study. Public Health Nutr. 2016:1–32.
9. Gebremariam MK, et al. Measurement of availability and accessibility of food among youth: a systematic review of methodological studies. Int J Behav Nutr Phys Act. 2017;14(1):22.
10. Loyen A, et al. Variation in population levels of physical activity in European adults according to cross-European studies: a systematic literature review within DEDIPAC. Int J Behav Nutr Phys Act. 2016;13:72.
11. Loyen A, et al. Variation in population levels of sedentary time in European adults according to cross-European studies: a systematic literature review within DEDIPAC. Int J Behav Nutr Phys Act. 2016;13:71.
12. Van Hecke L, et al. Variation in population levels of physical activity in European children and adolescents according to cross-European studies: a systematic literature review within DEDIPAC. Int J Behav Nutr Phys Act. 2016;13:70.
13. Verloigne M, et al. Variation in population levels of sedentary time in European children and adolescents according to cross-European studies: a systematic literature review within DEDIPAC. Int J Behav Nutr Phys Act. 2016;13:69.
14. Steene-Johannessen J, et al. Are self-report measures able to define individuals as physically active or inactive? Med Sci Sports Exerc. 2016;48(2):235–44.
15. Hagströmer M, Oja P, Sjöström M. Physical activity and inactivity in an adult population assessed by accelerometry. Med Sci Sports Exerc. 2007;39(9):1502–8.
16. Sundquist K, et al. Neighborhood walkability, physical activity, and walking behavior: the Swedish neighborhood and physical activity (SNAP) study. Soc Sci Med. 2011;72(8):1266–73.
17. Health Survey for England 2008, National Centre for social research and University College London. Department of Epidemiology and Public Health, health survey for England, 2008 [computer file]. 3rd edition. Colchester, Essex: UK data archive [distributor], July 2011. SN: 6397, https://doi.org/10.5255/UKDA-SN-6397-1.
18. Hansen BH, et al. Accelerometer-determined physical activity in adults and older people. Med Sci Sports Exerc. 2012;44(2):266–72.
19. Baptista F, et al. Prevalence of the Portuguese population attaining sufficient physical activity. Med Sci Sports Exerc. 2012;44(3):466–73.
20. Loyen A, et al. Sedentary time and physical activity surveillance through accelerometer pooling in four European countries. Sports Med. 2017;47(7):1421–35.
21. Wijnhoven TM, et al. WHO European childhood obesity surveillance initiative: school nutrition environment and body mass index in primary schools. Int J Environ Res Public Health. 2014;11(11):11261–85.
22. Roberts C, et al. The health behaviour in school-aged children (HBSC) study: methodological developments and current tensions. Int J Public Health. 2009;54(Suppl 2):140–50.
23. European Food Safety Authority. Guidance on the EU Menu methodology. EFSA J. 2014;12(12)
24. Slimani N, et al. Structure of the standardized computerized 24-h diet recall interview used as reference method in the 22 centers participating in the EPIC project. European prospective investigation into cancer and nutrition. Comput Methods Prog Biomed. 1999;58(3):251–66.
25. Eurostat, European Health Interview Survey (EHIS wave 2) - methodological manual. 2013.
26. Rasmussen LB, et al. Nordic monitoring of diet, physical activity and overweight - first collection of data in all Nordic countries. 2012:2011.
27. Kurth BM, et al. The challenge of comprehensively mapping children's health in a nation-wide health survey: design of the German KiGGS-study. BMC Public Health. 2008;8:196.
28. Symmank C, et al. Predictors of food decision making: a systematic interdisciplinary mapping (SIM) review. Appetite. 2017;110:25–35.
29. Condello G, et al. Behavioral determinants of physical activity across the life course: a "DEterminants of DIet and physical ACtivity" (DEDIPAC) umbrella

systematic literature review. Int J Behav Nutr Phys Act. 2017;14(1):58.
30. Carlin A, et al. A life course examination of the physical environmental determinants of physical activity behaviour: a "determinants of diet and physical activity" (DEDIPAC) umbrella systematic literature review. PLoS One. 2017;12(8):e0182083.
31. Cortis C, et al. Psychological determinants of physical activity across the life course: a "DEterminants of DIet and physical ACtivity" (DEDIPAC) umbrella systematic literature review. PLoS One. 2017;12(8):e0182709.
32. Puggina A, et al. Policy determinants of physical activity across the life course: a "DEDIPAC" umbrella systematic literature review. Eur J Pub Health. 2017; in press
33. Stierlin AS, et al. A systematic review of determinants of sedentary behaviour in youth: a DEDIPAC-study. Int J Behav Nutr Phys Act. 2015;12:133.
34. O'Donoghue G, et al. A systematic review of correlates of sedentary behaviour in adults aged 18-65 years: a socio-ecological approach. BMC Public Health. 2016;16(1):163.
35. Chastin SF, et al. Systematic literature review of determinants of sedentary behaviour in older adults: a DEDIPAC study. Int J Behav Nutr Phys Act. 2015;12:127.
36. Osei-Kwasi HA, et al. Systematic mapping review of the factors influencing dietary behaviour in ethnic minority groups living in Europe: a DEDIPAC study. Int J Behav Nutr Phys Act. 2016;13:85.
37. Langoien LJ, et al. Systematic mapping review of the factors influencing physical activity and sedentary behaviour in ethnic minority groups in Europe: a DEDIPAC study. Int J Behav Nutr Phys Act. 2017;14(1):99.
38. Stok FM, et al. The DONE framework: Creation, evaluation, and updating of an interdisciplinary, dynamic framework 2.0 of determinants of nutrition and eating. PLoS One. 2017;12(2):e0171077.
39. Condello G, et al. Using concept mapping in the development of the EU-PAD framework (EUropean-physical activity determinants across the life course): a DEDIPAC-study. BMC Public Health. 2016;16(1):1145.
40. Chastin SF, et al. The SOS-framework (Systems of Sedentary behaviours): an international transdisciplinary consensus framework for the study of determinants, research priorities and policy on sedentary behaviour across the life course: a DEDIPAC-study. Int J Behav Nutr Phys Act. 2016;13:83.
41. Trochim WMK. An introduction to concept mapping for planning and evaluation. Evaluation and Program Planning. 1989;12:1–16.
42. Holdsworth, M., et al., Developing a systems-based framework of the factors influencing dietary and physical activity behaviours in ethnic minority populations living in Europe - a DEDIPAC study. Submitted.
43. Lakerveld J, et al. Identifying and sharing data for secondary data analysis of physical activity, sedentary behaviour and their determinants across the life course in Europe: general principles and an example from DEDIPAC. BMJ Open. 2017;7(10):e017489.
44. Wilkinson MD, et al. The FAIR guiding principles for scientific data management and stewardship. Sci Data. 2016;3:160018.
45. Stelmach-Mardas M, et al. Seasonality of food groups and total energy intake: a systematic review and meta-analysis. Eur J Clin Nutr. 2016;70(6):700–8.
46. Schoen S, et al. Diet quality during infancy and early childhood in children with and without risk of type 1 diabetes: a DEDIPAC study. Nutrients. 2017;9(1)
47. Wittig F, et al. Energy and macronutrient intake over the course of the day of German adults: a DEDIPAC-study. Appetite. 2017;114:125–36.
48. Si Hassen W, et al. Socioeconomic indicators are independently associated with nutrient intake in French adults: a DEDIPAC study. Nutrients. 2016;8(3):158.
49. Gebremariam MK, et al. Screen-based sedentary time: association with soft drink consumption and the moderating effect of parental education in European children: the ENERGY study. PLoS One. 2017;12(2):e0171537.
50. Totland TH, et al. Correlates of irregular family meal patterns among 11-year-old children from the pro children study. Food Nutr Res. 2017;61(1):1339554.
51. Lakerveld J, et al. Sitting too much: a hierarchy of socio-demographic correlates. Prev Med. 2017;101:77–83.
52. Loyen A, et al. Objectively measured sedentary time among five ethnic groups in Amsterdam: the HELIUS study. PLoS One. 2017;12(7):e0182077.
53. De Bourdeaudhuij I, et al. School-based interventions promoting both physical activity and healthy eating in Europe: a systematic review within the HOPE project. Obes Rev. 2011;12(3):205–16.
54. Heath GW, et al. Evidence-based intervention in physical activity: lessons from around the world. Lancet. 2012;380(9838):272–81.
55. Lakerveld J, et al. Sustainable prevention of obesity through integrated strategies: the SPOTLIGHT project's conceptual framework and design. BMC Public Health. 2012;12
56. Horodyska K, et al. Good practice characteristics of diet and physical activity interventions and policies: an umbrella review. BMC Public Health. 2015;15:19.
57. Horodyska K, et al. Implementation conditions for diet and physical activity interventions and policies: an umbrella review. BMC Public Health. 2015;15:1250.
58. Glasgow RE, Vogt TM, Boles SM. Evaluating the public health impact of health promotion interventions: the RE-AIM framework. Am J Public Health. 1999;89:1322–7.
59. Muellmann, S., et al., Views of policy makers and health promotion professionals on factors facilitating implementation and maintenance of interventions and policies promoting physical activity and healthy eating: results of the DEDIPAC project. Submitted.
60. Heckman JJ. Micro data, heterogeneity, and the evaluation of public policy: Nobel lecture. J Polit Econ. 2001;109(4):673–748.
61. The University of Auckland. INFORMAS. 2017; Available from: https://www.fmhs.auckland.ac.nz/en/soph/global-health/projects/informas.html.
62. Hawkes C, Jewell J, Allen K. A food policy package for healthy diets and the prevention of obesity and diet-related non-communicable diseases: the NOURISHING framework. Obes Rev. 2013;14(Suppl 2):159–68.
63. Brug J, Chinapaw M. Determinants of engaging in sedentary behavior across the lifespan; lessons learned from two systematic reviews conducted within DEDIPAC. Int J Behav Nutr Phys Act. 2015;12:134.
64. Chastin SF, Schwarz U, Skelton DA. Development of a consensus taxonomy of sedentary behaviors (SIT): report of Delphi round 1. PLoS One. 2013;8(12):e82313.

Permissions

 Every chapter published in this book has been scrutinized by our experts. Their significance has been extensively debated. The topics covered herein carry significant findings which will fuel the growth of the discipline. They may even be implemented as practical applications or may be referred to as a beginning point for another development.

The contributors of this book come from diverse backgrounds, making this book a truly international effort. This book will bring forth new frontiers with its revolutionizing research information and detailed analysis of the nascent developments around the world.

We would like to thank all the contributing authors for lending their expertise to make the book truly unique. They have played a crucial role in the development of this book. Without their invaluable contributions this book wouldn't have been possible. They have made vital efforts to compile up to date information on the varied aspects of this subject to make this book a valuable addition to the collection of many professionals and students.

This book was conceptualized with the vision of imparting up-to-date information and advanced data in this field. To ensure the same, a matchless editorial board was set up. Every individual on the board went through rigorous rounds of assessment to prove their worth. After which they invested a large part of their time researching and compiling the most relevant data for our readers.

The editorial board has been involved in producing this book since its inception. They have spent rigorous hours researching and exploring the diverse topics which have resulted in the successful publishing of this book. They have passed on their knowledge of decades through this book. To expedite this challenging task, the publisher supported the team at every step. A small team of assistant editors was also appointed to further simplify the editing procedure and attain best results for the readers.

Apart from the editorial board, the designing team has also invested a significant amount of their time in understanding the subject and creating the most relevant covers. They scrutinized every image to scout for the most suitable representation of the subject and create an appropriate cover for the book.

The publishing team has been an ardent support to the editorial, designing and production team. Their endless efforts to recruit the best for this project, has resulted in the accomplishment of this book. They are a veteran in the field of academics and their pool of knowledge is as vast as their experience in printing. Their expertise and guidance has proved useful at every step. Their uncompromising quality standards have made this book an exceptional effort. Their encouragement from time to time has been an inspiration for everyone.

The publisher and the editorial board hope that this book will prove to be a valuable piece of knowledge for researchers, students, practitioners and scholars across the globe.

List of Contributors

Sally E. Barber, Brian Kelly, Paul J. Collings and John Wright
Bradford Institute for Health Research, Bradford Royal Infirmary, Duckworth Lane, Bradford BD9 6RJ, UK.

Liana Nagy
Bradford Institute for Health Research, Bradford Royal Infirmary, Duckworth Lane, Bradford BD9 6RJ, UK.
Faculty of Health Studies, University of Bradford, Richmond Rd, Bradford BD7 1DP, UK.

Tracey Bywater
Department of Health Sciences, Faculty of Sciences, University of York, Area 2, Seebohm Rowntree Building, York YO10 5DD, UK.

Jonathan Y. Bernard
Singapore Institute for Clinical Sciences, Agency for Science, Technology and Research (A*STAR), Singapore, Singapore.
Singapore Institute for Clinical Sciences (SICS), Agency for Sciences, Technology and Research (A*STAR). MD1 Tahir Foundation Building, #12-02/03, 21 Lower Kent Ridge Rd, Singapore 119077, Singapore.

Natarajan Padmapriya and Shirong Cai
Department of Obstetrics and Gynaecology, Yong Loo Lin School of Medicine, National University of Singapore, Singapore, Singapore.

Bozhi Chen
Saw Swee Hock School of Public Health, National University of Singapore, Singapore, Singapore.

Kok Hian Tan
Department of Maternal Fetal Medicine, KK Women's and Children's Hospital, Singapore, Singapore.
Duke-NUS Medical School, Singapore, Singapore.

Fabian Yap
Department of Paediatrics, KK Women's and Children's Hospital, Singapore, Singapore.

Lynette Shek
Singapore Institute for Clinical Sciences, Agency for Science, Technology and Research (A*STAR), Singapore, Singapore.
Department of Paediatrics, Yong Loo Lin School of Medicine, National University of Singapore, Singapore, Singapore.
Division of Paediatric Allergy, Immunology and Rheumatology, Khoo Teck Puat - National University Children's Medical Institute, National University Health System, Singapore

Yap-Seng Chong
Singapore Institute for Clinical Sciences, Agency for Science, Technology and Research (A*STAR), Singapore, Singapore.
Department of Obstetrics and Gynaecology, Yong Loo Lin School of Medicine, National University of Singapore, Singapore, Singapore.

Peter D. Gluckman
Singapore Institute for Clinical Sciences, Agency for Science, Technology and Research (A*STAR), Singapore, Singapore.
Liggins Institute, University of Auckland, Auckland, New Zealand.

Keith M. Godfrey
Medical Research Council Lifecourse Epidemiology Unit, University of Southampton, Southampton, UK.
NIHR Southampton Biomedical Research Centre, University of Southampton and University Hospital Southampton NHS Foundation Trust, Southampton, UK.

Michael S. Kramer
Departments of Pediatrics and of Epidemiology and Biostatistics, McGill University Faculty of Medicine, Montreal, Quebec, Canada.

Seang Mei Saw
Saw Swee Hock School of Public Health, National University of Singapore, Singapore, Singapore.
Duke-NUS Medical School, Singapore, Singapore.
Singapore Eye Research Institute, Singapore, Singapore.

Falk Müller-Riemenschneider
Saw Swee Hock School of Public Health, National University of Singapore, Singapore, Singapore.
Institute for Social Medicine, Epidemiology and Health Economics, Charite University Medical Centre, Berlin, Germany.

Susanna Mills and Heather Brown
Institute of Health & Society, Newcastle University, Baddiley-Clark Building, Richardson Road, Newcastle upon Tyne NE2 4AX, UK.

Wendy Wrieden
Human Nutrition Research Centre, Institute of Health & Society, Newcastle University, M1.151 William Leech Building, Medical School, Framlington Place, Newcastle upon Tyne NE2 4HH, UK.

Martin White
Institute of Health & Society, Newcastle University, Baddiley-Clark Building, Richardson Road, Newcastle upon Tyne NE2 4AX, UK.
Centre for Diet and Activity Research (CEDAR), MRC Epidemiology Unit, School of Clinical Medicine, University of Cambridge, Box 285 Biomedical Campus, Cambridge CB2 0QQ, UK.

Jean Adams
Centre for Diet and Activity Research (CEDAR), MRC Epidemiology Unit, School of Clinical Medicine, University of Cambridge, Box 285 Biomedical Campus, Cambridge CB2 0QQ, UK.

L. N. Signal, J. Stanley, M. Smith, M. B. Barr, T. J. Chambers, C. McKerchar and G. L. S. Jenkin
Department of Public Health, Health Promotion & Policy Research Unit, University of Otago, PO Box 7343, Wellington South, Wellington 6242, New Zealand.

J. Zhou, A. Duane, C. Gurrin and A. F. Smeaton
Insight Centre for Data Analytics, Dublin City University, Belfield, Dublin, Ireland.

A. L. Pearson
Department of Geography, Environment and Spatial Sciences, Michigan State University, 673 Auditorium Rd, East Lansing, MI 48825, USA.

J. Hoek
Department of Marketing, University of Otago, Level 4, Business School, Clyde St, North Dunedin, Dunedin 9016, New Zealand.

C. Ni Mhurchu
National Institute for Health Innovation, University of Auckland, 261 Morrin Road, Glen Innes, Auckland 1072, New Zealand

Fiona Lavelle and Moira Dean
Institute for Global Food Security, School of Biological Sciences, Queen's University Belfast, Belfast BT9 5AG, UK.

Laura McGowan
Centre for Public Health, School of Medicine, Dentistry and Biomedical Sciences, Queen's University Belfast, Belfast, UK.

Lynsey Hollywood and Dawn Surgenor
Department of Hospitality and Tourism Management, Ulster University Business School, Ulster University, Coleraine, UK.

Amanda McCloat, Elaine Mooney
Department of Home Economics, St. Angela's College, Sligo, Ireland.

Martin Caraher
Centre for Food Policy, Department of Sociology, School of Arts and Social Sciences, City University London, London, UK.

Monique Raats
Food, Consumer Behaviour and Health Research Centre, School of Psychology, University of Surrey, England, UK.

Rebecca Byrne and Elena Jansen
Centre for Children's Health Research, School of Exercise and Nutrition Sciences, Queensland University of Technology, 62 Graham St, South Brisbane, QLD 4101, Australia.

Lynne Daniels
School of Exercise and Nutrition Sciences, Queensland University of Technology, Kelvin Grove, QLD 4069, Australia

T. Bucher M. Weltert
Department of Health Sciences and Technology, ETH Zurich, Universitätsrasse 16, 8092 Zurich, Switzerland.
Priority Research Centre for Physical Activity and Nutrition, Faculty of Health and medicine, The University of Newcastle, Newcastle, Australia.

M.E. Rollo and C.E. Collins
Priority Research Centre for Physical Activity and Nutrition, Faculty of Health and medicine, The University of Newcastle, Newcastle, Australia.

S.P. Smith
School of Electrical Engineering and Computing, The University of Newcastle, Newcastle, Australia.

W. Jia and M. Sun
Departments of Neurosurgery, University of Pittsburgh, Pittsburgh, USA.

Jing-Jing Wang
Mass Sports Research Center, China Institute of Sport Science, Beijing, China.

Tzu-An Chen
HEALTH Research Institute, University of Houston, Houston, TX 77204, USA.

Tom Baranowski
Children's Nutrition Research Center, Department of Pediatrics, Baylor College of Medicine, Houston, TX 77030, USA.

Patrick W.C. Lau
Department of Physical Education, Faculty of Social Sciences, Hong Kong Baptist University, Academic and Administration Building, 15, Road, Kowloon Tong, Hong Kong, China

Kimberley M. Mallan
School of Psychology, Australian Catholic University, 1100 Nudgee Road, Banyo, QLD 4014, Australia.
School of Exercise and Nutrition Sciences, Queensland University of Technology, 60 Musk Avenue, Kelvin Grove, QLD 4059, Australia.

Alison Fildes
School of Psychology, University of Leeds, Woodhouse Lane, Leeds LS2 9JT, UK.
Department of Behavioural Science and Health, University College London, Gower St, London WC1E 6BT, UK.

Xochitl de la Piedad Garcia, Jayne Drzezdzon and Matthew Sampson
School of Psychology, Australian Catholic University, 1100 Nudgee Road, Banyo, QLD 4014, Australia.

Clare Llewellyn
Department of Behavioural Science and Health, University College London, Gower St, London WC1E 6BT, UK.

Louis Goffe and Ashley Adamson
Institute of Health & Society, Newcastle University, Newcastle, UK.
Human Nutrition Research Centre, Newcastle University, Newcastle, UK.
Fuse – UKCRC Centre for Translational Research in Public Health, Newcastle, UK.

Stephen Rushton
School of Natural and Environmental Sciences, Newcastle University, Newcastle, UK.

Martin White
Institute of Health & Society, Newcastle University, Newcastle, UK.
Centre for Diet and Activity Research, (CEDAR), MRC Epidemiology Unit, University of Cambridge, Cambridge, UK

Jean Adams
Centre for Diet and Activity Research, (CEDAR), MRC Epidemiology Unit, University of Cambridge, Cambridge, UK

Erica C. Jansen
Department of Nutritional Sciences, School of Public Health, Ann Arbor, MI, USA.
Department of Nutritional Sciences, University of Michigan School of Public Health, 14 15 Washington Heights, Ann Arbor, MI 48109,USA.

Alison L. Miller
Center for Human Growth and Development, University of Michigan, Ann Arbor, MI, USA.
Department of Health Behavior and Health Education, School of Public Health, Ann Arbor, MI, USA.

Julie C. Lumeng
Center for Human Growth and Development, University of Michigan, Ann Arbor, MI, USA.
Department of Pediatrics, University of Michigan, Ann Arbor, MI, USA.

Niko Kaciroti
Center for Human Growth and Development, University of Michigan, Ann Arbor, MI, USA.

Holly E. Brophy Herb
Department of Human Development and Family Studies, Michigan State University, East Lansing, MI, USA.

Mildred A. Horodynski
College of Nursing, Michigan State University, East Lansing, MI, USA.

Dawn Contreras
Department of Human Development and Family Studies, Michigan State University, East Lansing, MI, USA.
Health and Nutrition Institute, Michigan State University Extension, East Lansing, MI, USA.

Karen E. Peterson
Department of Nutritional Sciences, School of Public Health, Ann Arbor, MI, USA.

Rachel E. Blaine
Department of Family and Consumer Sciences, California State University, Long Beach, 1250 Bellflower Blvd, FCS FA-15, Long Beach, CA 90840-0501, USA.

Alexandria Kachurak and Jennifer Orlet Fisher
Department of Social and Behavioral Sciences, Center for Obesity Research and Education, Temple University, 3223 N. Broad Street, Suite 175, Philadelphia, PA 19140, USA.

Kirsten K. Davison
Department of Nutrition, Harvard T.H. Chan School of Public Health, 655 Huntington Ave, Boston, MA 02115, USA.

Rachel Klabunde
Department of Global Health & Population, Harvard T.H. Chan School of Public Health, 655 Huntington Ave, Boston, MA 02115, USA.

Karine Chamberland
Département de l'éducation Physique, Faculté des Sciences de l'éducation, Université Laval, Québec City, QC G1V 0A6, Canada.

Marina Sanchez
Centre de recherche de l'Institut Universitaire de Cardiologie et de Pneumologie de Québec, Québec City, QC, Canada.

Shirin Panahi
Département de l'éducation Physique, Faculté des Sciences de l'éducation, Université Laval, Québec City, QC G1V 0A6, Canada.
Département de Kinésiologie, Université Laval, Québec City, QC G1V 0A6, Canada.

Véronique Provencher
Institut sur la Nutrition et les Aliments Fonctionnels, Université Laval, Québec City, QC, Canada.

Jocelyn Gagnon
Département de l'éducation Physique, Faculté des Sciences de l'éducation, Université Laval, Québec City, QC G1V 0A6, Canada.
Centre de Recherche Interuniversitaire sur la Formation et la Profession Enseignante (CRIFPE-Laval), Université Laval, Québec City, QC, Canada.

Vicky Drapeau
Département de l'éducation Physique, Faculté des Sciences de l'éducation, Université Laval, Québec City, QC G1V 0A6, Canada.
Centre de recherche de l'Institut Universitaire de Cardiologie et de Pneumologie de Québec, Québec City, QC, Canada.
Institut sur la Nutrition et les Aliments Fonctionnels, Université Laval, Québec City, QC, Canada.
Centre de Recherche Interuniversitaire sur la Formation et la Profession Enseignante (CRIFPE-Laval), Université Laval, Québec City, QC, Canada.

Silje Steinsbekk
Department of Psychology, Norwegian University of Science and Technology (NTNU), Dragvoll, 7491, Trondheim, Norway.

Arielle Bonneville-Roussy
Grove House, Roehampton Lane, Roehampton University, London SW15 5PJ, UK.

Alison Fildes
School of Psychology, University of Leeds, Leeds LS2 9JT, UK.

Clare H. Llewellyn
Department of Behavioural Science & Health, University College London, 1-19 Torrington Place, London WC1E 7HB, UK.

Lars Wichstrøm
Department of Psychology, Norwegian University of Science and Technology (NTNU), Dragvoll, 7491, Trondheim, Norway.
NTNU Social Research, 7491 Trondheim, Norway

Jonine Jancey, Anne-Marie Holt, Andy Lee and Deborah Kerr
Collaboration for Evidence, Research and Impact in Public Health, School of Public Heath, Curtin University, GPO Box U1987, Perth, WA 6845, Australia.

Suzanne Robinson and Peter Howat
School of Public Health, Curtin University, GPO Box U1987, Perth, WA 6845, Australia.

Li Tang
School of Public Health, Curtin University, GPO Box U1987, Perth, WA 6845, Australia.
Chinese Evidence-based Medicine Center, West China Hospital, Sichuan University, No. 37 Guoxue Alley, Chengdu, Sichuan Province 610041, China.

A.S. Anderson
Centre for Public Health Nutrition Research, Division of Cancer Research, Ninewells Medical School, Dundee University, Level 7, Mailbox 7, Dundee DD1 9SY, UK.

Andrew P. Hills
University of Tasmania, 41 Charles St, Launceston TAS, Launceston, TAS 7250, Australia.

Morgan L. McCloskey, Catherine H. Miele and Robert H. Gilman
Division of Pulmonary and Critical Care, School of Medicine, Johns Hopkins University, 1830 Monument St Room 555, Baltimore, MD 21205, USA.

Carla E. Tarazona-Meza
Biomedical Research Unit, A.B. PRISMA, Lima, Peru.

Jessica C. Jones-Smith
Department of Health Services, University of Washington, Seattle, WA, USA.

Antonio Bernabe-Ortiz, J. Jaime Miranda
CRONICAS Center of Excellence in Chronic Diseases, Universidad Peruana Cayetano Heredia, Lima, Peru.

William Checkley
Division of Pulmonary and Critical Care, School of Medicine, Johns Hopkins University, 1830 Monument St Room 555, Baltimore, MD 21205, USA.
Biomedical Research Unit, A.B. PRISMA, Lima, Peru.

Johannes Brug
Amsterdam School of Communication Research (ASCoR), University of Amsterdam, Amsterdam, The Netherlands.

Hidde P. van der Ploeg
Department of Public and Occupational Health, Amsterdam Public Health Research Institute, VU University Medical Center, Amsterdam, The Netherlands.
Sydney School of Public Health, University of Sydney, Sydney, NSW, Australia.

Anne Loyen
Department of Public and Occupational Health, Amsterdam Public Health Research Institute, VU University Medical Center, Amsterdam, The Netherlands.

Wolfgang Ahrens and Antje Hebestreit
Leibniz-Institute for Prevention Research and Epidemiology – BIPS, Bremen, Germany.

Oliver Allais
INRA, UR1303 ALISS, F-94205 Ivry-sur-Seine, France.

Lene F. Andersen, Nanna Lien
Department of Nutrition, University of Oslo, Oslo, Norway.

Greet Cardon, Ilse De Bourdeaudhuij and Marieke De Craemer
Department of Movement and Sports Sciences, Ghent University, Ghent, Belgium.

Laura Capranica
Department of Movement, Human and Health Sciences, University of Rome Foro Italico, Rome, Italy.

Sebastien Chastin
Department of Movement and Sports Sciences, Ghent University, Ghent, Belgium.
Institute for Applied Health Research, School of Health and Life Science, Glasgow Caledonian University, Scotland, UK.

Alan Donnelly
Centre for Physical Activity and Health Research, University of Limerick, Limerick, Ireland.

Ulf Ekelund
Norwegian Institute of Public Health, Oslo, Norway.

Paul Finglas
Institute of Food Research, Norwich, UK.

Marion Flechtner-Mors and Jürgen M. Steinacker
Department of Internal Medicine II, Division of Sports and Rehabilitation Medicine, University Ulm, Ulm, Germany.

Thomas Kubiak
Johannes Gutenberg University, Mainz, Germany.

Massimo Lanza
Department of Neurosciences, Biomedicine and Movement Sciences, Verona, Italy.

Ciaran MacDonncha
Health Research Institute, University of Limerick, Limerick, Ireland.

Mario Mazzocchi
Department of Statistical Sciences of the University of Bologna, Bologna, Italy.

Pablo Monsivais
Centre for Diet and Activity Research, MRC-Epidemiology Unit, School of Medicine, University of Cambridge, Cambridge, UK.

Marie Murphy
Sport & Exercise Sciences Research Institute, Ulster University, Northern Ireland, UK.

Mary Nicolaou and Karien Stronks
Department of Public Health, Amsterdam Public Health research institute, Academic Medical Centre, University of Amsterdam, Amsterdam, The Netherlands.

Ute Nöthlings
Department of Nutrition and Food Science, Rheinische Friedrich-Wilhelms-Universität Bonn, Bonn, Germany.

Donal J. O'Gorman
3U Diabetes, School of Health and Human Performance, Dublin City University, Dublin, Ireland.

Britta Renner
Department of Psychology, University of Konstanz, Konstanz, Germany.

Gun Roos
Consumption Research Norway, Oslo and Akershus University College of Applied Sciences, Oslo, Norway.

Matthijs van den Berg
Department of Prevention & Nutrition, National Institute for Public Health and the Environment, Bilthoven, The Netherlands.

Matthias B. Schulze
Department of Molecular Epidemiology, German Institute of Human Nutrition Potsdam-Rehbruecke, Nuthetal, Germany.

Dorothee Volkert
Institute for Biomedicine of Aging, Friedrich-Alexander-Universität Erlangen-Nürnberg, Nuremberg, Germany.

Jeroen Lakerveld
Department of Epidemiology and Biostatistics, Amsterdam Public Health research institute, VU University Medical Center, De Boelelaan 1089a, 1081, HV, Amsterdam, The Netherlands.

Index

A

Added Sugar, 108-111, 113-116, 173-174

Adolescents, 2, 8-11, 21, 29, 32, 34, 42, 74-75, 88-89, 96, 98, 104, 106, 109, 114, 116-117, 138-141, 146-147, 149-150, 188-190, 199

Adults, 3, 12-13, 22-23, 30-32, 42, 47, 55-56, 65-66, 74, 90-91, 93, 95-106, 115, 141, 152, 159-160, 164, 166-168, 170, 172, 174-176, 189, 191, 193, 199-200

Appetite, 30-32, 42, 55, 63-64, 74, 89-91, 94, 96, 106, 115, 117, 119, 121, 138-139, 153, 157-158, 199-200

Appetitive Traits, 90-96, 158

Automated Food Volume Recognition, 65

B

Behavioural Nutrition, 177, 196, 198

C

Cardio-metabolic Health, 22-24, 28-30

Childhood Obesity, 10, 13, 31, 33-34, 41-42, 55, 58, 64, 134, 136, 138-139, 141, 149-150, 157, 190, 198-199

Chronic Diseases, 31, 76, 88, 167, 169, 176

Cohort Studies, 12, 31, 149, 191, 197

Computer, 2, 10, 12, 14, 16, 45, 47, 53-55, 65-67, 74-75, 89, 147, 150, 199

Confirmatory Factor Analysis, 64, 90-93, 96, 139

Cooking Skills, 23, 30, 32, 44-47, 49-55

Cross-sectional, 13, 16, 18, 21-23, 28-34, 44, 54-56, 58, 91, 98, 104-106, 108-109, 114, 117, 120-123, 133, 137-138, 152-153, 156, 176

D

Dairy Products, 24, 141, 173-174

Deprivation, 1-4, 6-9, 11, 35, 42, 104, 106, 142

Determinants of Diet and Physical Activity (DEDIPAC), 177, 199

Determinants of Health Behaviours, 177

Development, 1, 7, 10, 13, 30, 45, 51, 53, 56, 60-62, 64, 74, 90, 96, 105-106, 109-110, 116, 137-139, 141-143, 147, 149, 157, 168, 178-179, 188-196, 198-200

Diet, 22, 32, 34, 38, 46, 56, 64, 75, 77, 88, 94, 98, 106, 111, 117, 119, 123, 133, 138-139, 142, 150, 152, 158, 160, 162, 166-170, 172, 178, 188-194, 196, 198

Dietary Assessment, 31, 65, 117, 120, 123, 189

Dietary Behavior, 139, 150, 158

Dietary Intake, 24-25, 29, 48, 57-63, 66, 74, 98, 106, 117, 119, 133, 138-139, 160, 162, 169-170, 173, 175-176, 188-191

Differential Item Functioning, 76-77, 79, 82, 87-89

E

Early Childhood, 1-2, 8-10, 12-13, 15, 18, 20-21, 64, 74, 109, 138, 151-152, 157-158, 200

Eating Behavior, 64, 96, 152

Eating Behaviors, 64, 76, 87, 96, 117-119, 136, 138-139, 142, 150

Eating Behaviours, 64, 90-91, 95-96, 138-139, 141, 143, 157

Eating Out, 45, 97, 104, 106

Energy Intake, 24, 31, 57, 59-60, 63, 66, 74, 90-91, 95-106, 108, 110-111, 113-114, 118-119, 123, 134-135, 138, 141, 149, 175-176, 200

Ethnic Minority, 1-2, 8-9, 136, 190-193, 197, 200

Externalizing Behavior, 108-112, 114-116

F

Feeding, 32, 57-64, 91, 96, 118-123, 133-139, 152, 157-158

Food Environment, 41, 90, 97, 103, 106, 134, 138-139, 196, 198

Food Intake, 23, 58, 60, 62-63, 65, 95-97, 103, 121, 135, 138-139, 149, 162

Food Intake Reporting, 65

Food Marketing, 33-35, 37-43, 47

Food Parenting, 118-123, 133-139, 158

Food Refusal, 57-58, 60, 63

Food Shape, 65, 70

Food Skills, 31, 44-55

Fussiness, 57-58, 60, 62-64, 90-95, 151, 157-158

Fussy Eating, 57-60, 62-64, 91, 95-96, 139, 157

H

Hand-held Device, 12, 14-16, 18-20

Home Cooking, 22-23, 28-31

I

Intervention, 1-2, 8-9, 11, 20, 41, 44-45, 58, 76, 87-88, 105, 109, 111, 114, 117, 140-150, 157-169, 175, 179, 193-195, 200

Interventions, 1-2, 8-12, 18, 20, 30, 43, 45, 53-55, 57, 62-63, 65-66, 74, 76-77, 97, 105, 109, 116, 135, 141, 143, 147-153, 156, 168, 177-178, 188, 190, 193-196, 198, 200

Item Response Modeling, 76-78, 88-89

L
Low- and Middle Income Countries, 169

M
Maternal Feeding Practices, 57-58, 60-61, 63-64, 96, 139
Maternal Perception, 57-63
Measure, 8, 24, 31, 40, 44-46, 49, 51, 53-55, 57-58, 61-62, 69, 88, 90, 93, 95-96, 99, 104, 110, 116, 120-121, 135, 139, 153, 156-157, 162
Milk and Alternatives, 140-141, 149

N
Ndns, 46, 56, 97-99, 103-104
Non-communicable Disease, 169, 177-178, 196, 198
Nutrition Transition, 169-170, 174, 176

O
Obesity, 2, 11, 13, 23, 28, 31, 34, 41-45, 55, 58, 64, 66, 74, 79, 88, 91, 96, 98, 104-110, 119, 134, 136-141, 143, 145, 150, 157, 167-170, 176, 188, 190, 196, 198-200
Obesogenic Environments, 33, 43
Out-of-home Meals, 97-100, 102-103
Overweight, 5, 11, 22, 24, 26-29, 34, 37, 42, 48, 55, 57, 64, 74, 77, 79, 82, 88, 91, 108, 114, 118, 134, 140, 143, 145, 149, 160, 166, 169-172, 176, 188, 190, 196, 199

P
Physical Activity, 10-14, 18, 21, 25-28, 31-32, 59, 64-65, 74, 76-78, 88-89, 96, 106, 110-113, 117, 145, 148, 150, 159-164, 167-173, 175-179, 188-200
Pickiness, 96, 151-157
Picky Eating, 57, 60, 62, 64, 96, 151-153, 155-158
Policy Evaluation, 177, 196, 198
Portion Size Measurement Aid, 65, 74
Prospective Longitudinal, 1, 7, 9
Psem, 65
Psma, 65

R
Restaurant, 38, 97, 99, 103-106, 171
Retirement Villages, 159-162, 164, 167-168

S
School-based Nutrition Intervention, 141-142, 150
Screen-time, 1
Sedentary Behavior, 10-11, 13, 21, 89, 117, 188, 200
Sedentary Lifestyle, 12-13, 160
Self-efficacy, 29, 32, 55, 64, 76-79, 82, 87-89, 114
Sensitivity, 14-15, 29, 64, 94, 111, 151-158, 189
Sensory Sensitivity, 151-156, 158
Snacks, 34, 109, 114, 118-121, 123, 133, 135-139, 141, 149, 171
Sodium, 24, 35, 106, 108-111, 113-117
Standardisation, 65, 189, 197
State-of-the-art, 177, 179, 188-190
Strength Exercise, 159, 162-165
Structural Equation Modeling, 96, 158
Structuring, 151-157, 191

T
Takeaway, 32, 97-106
Television, 1, 3, 7, 10-16, 18-21, 31, 34, 39-40, 42, 139
Temperament, 64, 117, 151-155, 157-158
Toddlers, 10, 21, 57-58, 60-61, 63-64, 96, 120

U
Urbanization, 169-170, 174-176

V
Validation, 11, 31, 44, 47, 51, 64, 74, 77-78, 87-89, 93-96, 117, 138-139, 157, 198
Vegetables and Fruit, 64, 88, 140-141, 149, 158
Volume and Capacity Training, 65

W
Walking, 159, 162-167, 169, 171-173, 175, 199
Wearable Cameras, 33-34, 40, 43
Web-based Platform, 140-144, 146-147
Weight Management, 159