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ORIGINAL ARTICLE

An international comparison of dietary patterns in 9–11-year-old children

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OBJECTIVES: Dietary pattern is defined as a combination of foods and drinks and the frequency of consumption within a population. Dietary patterns are changing on a global level, which may be linked to an increased incidence of chronic diseases. The aim of this study was to identify and compare the dietary patterns among 9–11-year-old children living in urban regions in different parts of the world.
METHODS: Participants were 7199 children (54% girls), aged 9–11 years, from 12 countries situated in all major world regions. Food consumption was assessed using a 23-item Food Frequency Questionnaire (FFQ). To identify dietary patterns, principal components analyses (PCA) were carried out using weekly portions as input variables.
RESULTS: Both site-specific and pooled PCA resulted in two strong components. Component 1 ('unhealthy diet pattern') included fast foods, ice cream, fried food, French fries, potato chips, cakes and sugar-sweetened sodas with >0.6 loadings. The loadings for component 2 ('healthy diet pattern') were slightly weaker with only dark-green vegetables, orange vegetables, vegetables in general, and fruits and berries reaching a >0.6 loading. The site-specific diet pattern scores had very strong correlations with the pattern scores from the pooled data: $r=0.82$ and 0.94 for components 1 and 2, respectively.
CONCULSIONS: The results suggest that the same 'healthier' and 'unhealthier' foods tend to be consumed in similar combinations among 9–11-year-old children in different countries, despite variation in food culture, geographical location, ethnic background and economic development.

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INTRODUCTION

The global burden of non-communicable diseases is continuously increasing, particularly in low-to-middle-income countries.[1,2] Non-communicable diseases risk factors can be encountered at all ages, and risk-associated behaviors may be adopted already early in life.[3] It is particularly alarming that childhood obesity is becoming more prevalent in low-to-middle-income countries.[4] Interventions on the prevention of obesity in children have been conducted, but they are mostly small scale.[5] Little is known about the costs and effectiveness in upscaling these studies to the population level.[4] Moreover, the translation of the findings across populations with different geographic and/or sociocultural backgrounds is uncertain.[6]

Diet is an important determinant of the non-communicable diseases risk.[1] Food consumption has been in rapid transition during the recent decades, for example, the consumption of meat and sugar has increased in many low- and middle-income countries.[7] Modifying eating behaviour on a population level requires both individual- and environment-based policies and actions.[8] There is a need to understand and compare broader dietary patterns between countries representing different geographical regions and developmental stages. Similarities offer possibilities for joint strategies and learning from other populations, whereas dissimilar dietary determinants call for more population-specific strategies.

Dietary patterns can be identified by theory-driven and data-driven methods. In the former, the participants are given a dietary index score based on theoretical assumptions, for example, components of a healthy diet.[9,10] Although this score can be adapted to different cultural settings,[11] it is unlikely that a single theory-driven score could be used for a global comparison of countries. Data-driven methods are not *per se* based on assumptions of the relationships between diet and health and are hence likely to be more suitable for international comparisons. In these methods, scores are obtained by identifying underlying correlation matrices of dietary behaviors by principal component analysis (PCA) or cluster analysis.[12] The results show existing and common dietary patterns which may or may not have an association with health.

The present study has taken a global view on food habits in children by comparing dietary patterns in >7000 boys and girls at 12 research sites situated in all major world regions. The data are

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from the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE) which is a unique multi-national study designed to determine the relationships between lifestyle behaviors and obesity in children.[13] The main aim was to identify, evaluate and compare dietary patterns among 9–11-year-old children living in urban regions in different parts of the world. Moreover, we show the reliability of this approach. Dietary pattern in this paper is defined as a combination of foods and drinks and the frequency of consumption within the study population.

MATERIALS AND METHODS

Setting

ISCOLE is a multi-national cross-sectional study. The rationale, design and methods have previously been published in detail.[13] The participating 12 study sites come from low-, middle- and high-income countries spanning a wide range of the Human Development Index. The site-specific samples were not intended to be nationally representative. Rather, the primary sampling frame was schools, typically stratified by an indicator of socioeconomic status in order to maximize variability within sites. The sample consisted of schools from urban and semi-urban areas. A standard protocol was used to collect data across all sites, and all study personnel underwent rigorous training and certification before and during data collection.

The institutional review board at the Pennington Biomedical Research Center (coordinating center) approved the overarching ISCOLE protocol, and the institutional/ethical review boards at each participating institution also approved the local protocol. Written informed consent was obtained from parents or legal guardians, and child assent was also obtained as required by local institutional/ethical review boards before participation in the study. Data were collected from September 2011 through December 2013.

Participants

Out of 7806 consented ISCOLE participants, a total of 7372 participated in the data collection and were included in the overall study sample.[14] We used data from those 7199 children (54% girls) who had an adequately completed diet questionnaire (Table 1). The age of participants was similar in all countries (9–11 years); whereas the prevalence of obesity (BMI *z*-score >+2 from the WHO reference[15]) varied by site from 5.8 (Colombia) to 23.7% (China).

Data for the reliability analysis were collected as part of a sub-study of ISCOLE in a sub-sample of 321 children from Colombia ($n=112$), Finland ($n=98$) and the United States ($n=111$). The main objective of the sub-study was to assess the reliability and validity of the FFQ applied in ISCOLE.[16]

Table 1. Description of the participants included in the analysis

Site	n *(% girls)*	*Age, years mean (s.d.)*	*Percentage obese*[a]
Australia (Adelaide)	519 (54)	10.7 (0.4)	10.8
Brazil (Sao Paulo)	567 (51)	10.5 (0.5)	21.5
Canada (Ottawa)	560 (58)	10.5 (0.4)	12.0
China (Tianjin)	546 (47)	9.9 (0.5)	23.7
Colombia (Bogota)	918 (51)	10.5 (0.6)	5.8
Finland (Helsinki, Espoo and Vantaa)	535 (53)	10.5 (0.4)	6.0
India (Bangalore)	620 (53)	10.4 (0.5)	10.5
Kenya (Nairobi)	555 (54)	10.2 (0.7)	6.7
Portugal (Porto)	755 (54)	10.4 (0.3)	17.9
South Africa (Cape Town)	509 (61)	10.3 (0.7)	10.6
UK (Bath and NE Somerset)	518 (55)	10.9 (0.5)	10.1
USA (Baton Rouge)	597 (57)	10.0 (0.6)	18.0
Total	7199 (54)	10.4 (0.6)	12.6

[a]Obesity defined as BMI *z*-score >+2 from the WHO reference.

Measurements

Food consumption. Food consumption was assessed using a FFQ adapted and modified from the Health Behaviour in School-aged Children Survey.[17] In the FFQ, the participants reported their 'usual' consumption frequency of 23 different food groups, with response categories from 'never" to "more than once a day'. For this paper, the reported consumption frequencies were converted into weekly portions as follows: 'never' into 0, 'less than once a week' into 0.5, 'once a week' into 1, 'on 2–4 days a week' into 3, 'on 5–6 days a week' into 5.5, 'every day' into 7, and 'more than once a day' into 10 portions a week. The reliability and validity of the FFQ has been reported elsewhere in this supplement.[16]

Statistical analyses

To identify dietary patterns among the study population, PCA were carried out using the weekly portions as input variables. Fruit juices were excluded from these analyses owing to low validity.[16]

The PCAs were performed first by using the total data set, and then for each site separately. The scree plot curve showed a decline with a clear elbow between the second and third components, thus two components were eventually chosen for each analysis. The components were then rotated with an orthogonal varimax transformation to force non-correlation of the components ($r=0.000$) and to enhance their interpretation. The component scores were assessed by summing the products of a multiplication of optimal regression weights by the subject's food consumption variables; this was done for each participant for both diet pattern scores, which were standardized to ensure normality. Version 9.3 of the SAS statistical package for Windows (SAS Institute, Cary, NC, USA, 2011) was used for the analyses.

Pearson correlations were determined to examine the associations between the two diet pattern scores, and also between the site-specific and overall diet pattern scores. A two-sample *t*-test was used to test the sex differences in pattern scores.

For the reliability analysis, the FFQ was applied twice (FFQ1 and FFQ2). The time interval between the first and second administration was on average 4.9 (s.d. 1.6) weeks. We used the loadings of the two diet patterns resulting from the PCA performed for the total data set (12 sites) and calculated the component scores for the FFQ1 and FFQ2 using the 3-site (Colombia, Finland, the United States) validation data.[16] The reliability was assessed by comparing component scores for FFQ1 and FFQ2 using Spearman correlation coefficients and intra-class correlation coefficients. The reliability analysis was conducted for all three sub-study sites both together and separately.

RESULTS

The median of consumption of fruit and berries indicated daily frequency and the consumption frequency of vegetables was also close to daily (Table 2). Food groups consumed closer to once or a couple of times weekly were, for example, ice cream, cakes, sodas, energy drinks and sports drinks. The between-site variation in some of the food groups was remarkable. For instance, skimmed and low-fat milk were used on average once a day in Finland and Portugal, but only around once a week in India and Colombia. In contrast, India had the most frequent mean consumption of whole milk (7.2 times weekly), and Canada, Finland, the United Kingdom and Portugal the lowest (1.5 to 1.7 times a week). The consumption frequencies for each site are shown in Supplementary Table 1.

The component loadings indicating the two strongest dietary patterns across all sites are shown in Table 3. Pattern 1 was the stronger out of these two; this is indicated by the number of food groups with moderate or strong loading (>0.3) and the variance explained. Loadings for fast foods, ice cream, fried food, French fries, potato chips, cakes and sugar-sweetened sodas were >0.6. The component loadings for pattern 2 were slightly weaker with only dark-green vegetables, orange vegetables, vegetables in general, and fruits and berries reaching a >0.6 loading. After considering the characteristics of the identified patterns, we named them 'unhealthy diet pattern' (pattern 1) and 'healthy diet pattern' (pattern 2) to reflect known associations between food consumption and health.[18,19]

Table 2. Description of food consumption weekly frequencies. The range of site-specific mean values illustrates the between-site variability

Food item	*Mean (s.d.)*[a]	*Median*[a]	*Range of site-specific mean values*	
			Lowest	*Highest*
Vegetables	5.43 (3.48)	5.5	3.8	7.3
Dark-green vegetables	3.55 (3.42)	3.0	1.8	5.6
Orange vegetables	4.07 (3.41)	3.0	2.6	5.4
Fruits and berries	5.84 (3.35)	7.0	4.5	7.3
Beans, lentils, bean curd, eggs	4.09 (3.34)	3.0	1.4	5.3
Whole grains	4.51 (3.69)	3.0	2.5	6.2
Fish	2.03 (2.60)	1.0	1.1	3.8
Skimmed milk, low-fat milk	3.85 (4.07)	1.0	0.6	7.0
Whole milk	3.54 (3.93)	1.0	1.5	7.2
Cheese	2.93 (3.19)	1.0	0.9	4.7
Other milk products	4.09 (3.39)	3.0	2.7	5.5
Fast foods	1.71 (2.51)	0.5	0.8	3.9
French fries	1.73 (2.39)	1.0	0.8	3.8
Fried food (nuggets, fish sticks)	2.45 (2.91)	1.0	1.2	5.3
Potato chips	2.28 (2.82)	1.0	0.9	4.6
Ice cream	2.09 (2.70)	1.0	1.1	4.4
Sweets (candy/chocolate)	2.99 (3.01)	1.0	1.7	4.5
Cakes, pastries, donuts	1.78 (2.46)	0.5	0.9	3.4
Sugar-sweetened sodas	2.29 (2.83)	1.0	1.0	4.2
Sports drinks	1.68 (2.88)	0.5	0.4	4.8
Energy drinks	0.81 (2.21)	0.0	0.1	2.8
Diet sodas	1.30 (2.41)	0.5	0.5	2.6

[a]Calculated from individual values.

The site-specific analyses (PCA done for each site separately) yielded two strong patterns which were characterized almost identically with food groups already loaded in the pooled data (Supplementary Table 2). Indicating the global similarities in children's dietary patterns, the site-specific diet pattern scores had a very strong correlation with the pattern score from the pooled data: correlations for site-specific versus pooled scores were $r = 0.82$ and 0.94 for patterns 1 and 2, respectively.

We calculated the site-specific mean score values from the pooled analyses to compare sites and sexes. A negative score indicates that the dietary pattern is less predominant in that particular site, compared with the overall average across sites, whereas a positive score indicates stronger predominance.

The unhealthy diet pattern score was highest in South Africa and the United States, and lowest in Canada and Finland (Figure 1 and Supplementary Table 3). The between-site differences in the healthy diet pattern scores were smaller. This pattern was most predominant in Canada and least in Brazil and Colombia. The sex differences in the unhealthy diet pattern scores were significant ($P < 0.05$) in eight sites; in all these, boys had higher scores. Fewer sex differences were found for the healthy diet pattern; the only significant difference (Portugal) showed higher healthy diet pattern scores in girls. However, the numerical difference was in the same direction in all sites, except for Brazil, namely a tendency for the healthy diet pattern to be more common among girls than among boys.

Results on the reliability of the scores for all three participating sites combined are presented in Table 4. Both Spearman correlation and the intra-class correlation coefficients indicated moderate-to-strong reliability for both scores; slightly stronger for the unhealthy diet score. The reliability scores for each of the three sites separately are presented as Supplementary Table 4.

Table 3. Factor loadings per food group/item in the two strongest patterns (all sites combined)

	Pattern 1	*Pattern 2*
Fast foods	0.73	0.06
Ice cream	0.70	0.04
Fried food (nuggets, fish sticks)	0.69	0.08
French fries	0.68	0.05
Potato chips	0.66	0.01
Cakes, pastries, donuts	0.64	0.03
Sugar-sweetened sodas	0.61	−0.13
Sports drinks	0.59	0.20
Energy drinks	0.56	0.17
Sweets (candy/chocolate)	0.53	−0.16
Diet sodas	0.44	0.18
Other milk products	0.40	0.33
Dark-green vegetables	−0.01	0.73
Orange vegetables	0.06	0.73
Vegetables	−0.16	0.70
Fruits and berries	0.00	0.61
Whole grains	0.17	0.51
Beans, lentils, bean curd, eggs	0.25	0.40
Fish	0.34	0.39
Skimmed milk, low-fat milk	−0.05	0.37
Cheese	0.24	0.35
Whole milk	0.25	0.13
Eigenvalue	4.8	3.1
Percentage of variance explained	22	14

DISCUSSION

The main and novel finding in the present report was that very similar dietary patterns were identified in children from 12 countries, representing a wide variation in terms of development, culture, geography, socioeconomic status and ethnic background. It is important to emphasize what the patterns are: dietary patterns are defined as existing combinations of foods and drinks and the frequency of consumption that maximally explain the variation within the study population. However, the pattern scores are relative to other countries. Hence, it is not contradictory to identify scores indicating similar dietary patterns which yet have a different predominance in different sites.

We named the identified dietary patterns as 'unhealthy diet pattern' and 'healthy diet pattern' to illustrate them comprehensively. The naming was not based on any observed health-related associations among these participants; however, the foods most strongly characterizing the 'unhealthy' or 'healthy' diet patterns can be found among the recommended foods for consumption or restriction, as in dietary guidelines set by authorities in many countries.[20,21] Moreover, the classification of food items and groups as potentially healthy and unhealthy is also based on data from population-based cohort studies and systematic reviews.[18,19]

PCA yields rotated patterns which are neither exclusive nor reverse to each other. In theory a child can simultaneously have high (or low) scores in both healthy and unhealthy diet patterns. Canada, for instance, scored high in healthy and low in unhealthy, whereas Finland had low mean scores in both. What the data indicate, however, is that the two most evident dietary patterns were characterized by very similar foods, despite the great variance in socio-demographic and cultural background in the ISCOLE sites. Foods often regarded as 'empty calories', that is, fast foods, ice cream, fried foods, French fries, potato chips, cakes and sugar-sweetened sodas, do certainly not represent culturally traditional foods in many of the ISCOLE countries. The strong correlation of these foods corroborate the globalization of eating trends, especially in low-to-middle-income countries.[7]

Although PCA is a purely data-driven approach and the identified dietary patterns therefore truly exist in the studied

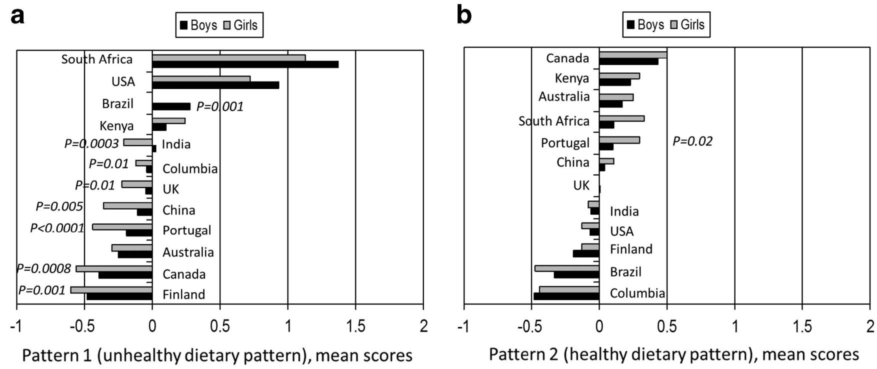

Figure 1. Site-specific mean scores for the unhealthy (**a**) and healthy (**b**) dietary patterns. Significant ($P < 0.05$) site-specific difference between the sexes are shown.

Table 4. Test–retest reliability of the diet pattern scores developed for ISCOLE study (median (25th, 75th percentile))

Category	*Diet score median (25th, 75th percentile)*		*Test–retest results*	
	FFQ1[a]	*FFQ2*[b]	P-*value*[c]	*ICC*[d]
Unhealthy diet pattern	−0.23 (−0.61, 0.47)	−0.33 (−0.68, 0.07)	0.79	0.78
Healthy diet pattern	−0.48 (−0.95, 0.21)	−0.63 (−1.07, −0.15)	0.58	0.56

Abbreviaitons: FFQ, food frequency questionnaire; ISCOLE, International Study of Childhood Obesity, Lifestyle and the Environment. [a]FFQ administered in the period of time 1. [b]FFQ administered 4 weeks after the first FFQ. [c]Spearman correlation coefficient. [d]Intra-class correlation coefficient.

populations, it may still be that we have not been able to capture the most predominant patterns in all sites. This may be reflected in the reported food consumption frequencies; the sum of all frequencies showed differences between sites, indicating that the provided food groups in the questionnaire were more fitting for some food cultures than for others. Other subjective analytical decisions based on the researchers' discretion include conversion of the frequencies into portions, methodological details of the PCA and the criteria with which the number of principal components to be derived was decided. However, the two extracted and identified components explained 22% and 14% of the total variation in the reported food consumption. Given the general difficulty in identifying dietary patterns, the above numbers can thus be considered as a satisfactory description of the underlying true diets among the studied populations.

Identification of dietary patterns has proven to be a useful approach in nutritional epidemiology, complementing the more reductionist single-nutrient or single-food approaches.[22] However, there are several methodological considerations when using data-driven methods, such as PCA. The analysis and its results are strongly dependent on the selection of input variables, that is, food groups. An important question is whether the identified dietary patterns are real, or only artifacts created by the food groups in the FFQ. In the subsequent validation study,[16] we showed that most of the eaten foods were correctly placed in their category. However, and most importantly, the validation study found only a few differences between three culturally different countries (Colombia, Finland and the United States) which gives confidence to assume that the identified dietary patterns are indeed genuine.

The finding that girls had more frequent healthy patterns and less frequent unhealthy diet patterns was expected from previous data from different countries.[23,24] In fact, identifying the anticipated sex-difference gives confidence for the validity of both the FFQ and in particular the pattern analyses. We have also recently used these diet scores in models predicting obesity in children in the ISCOLE sample.[14] In these analyses, the diet pattern scores were not significantly related to obesity. This slightly unexpected finding may be related to the statistical model used (for example, the other variables), to reverse causality (obesity may affect eating) and the fact that the scores describe dietary quality, not energy intake.

In conclusion, our study shows clear evidence on the globalization of diets among children around the world. The results suggest that the same 'healthier' and 'unhealthier' foods tend to be consumed in similar combinations among 9–11-year-old children in different countries despite the huge variation in food culture, geographical location, ethnic background and economic development. The findings give support to internationally mutual targets in improving dietary patterns in children.[3,4,8]

CONFLICT OF INTEREST

MF has received a research grant from Fazer Finland and has received an honorarium for speaking for Merck. AK has been a member of the Advisory Boards of Dupont and McCain Foods. RK has received a research grant from Abbott Nutrition Research and Development. VMa is a member of the Scientific Advisory Board of Actigraph and has received an honorarium for speaking for The Coca-Cola Company. TO has received an honorarium for speaking for The Coca-Cola Company. The remaining authors declare no conflict of interest.

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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**: 2224–2260.

2 International Diabetes Federation. *IDF Diabetes Atlas*, 6th edn. International Diabetes Federation: Brussels, Belgium, 2013.

3 World Health Organization. Global action plan for the prevention and control of noncommunicable diseases 2013–2020. 2013. Available at http://apps.who.int/iris/bitstream/10665/94384/1/9789241506236_eng.pdf?ua = 1 (accessed on 30 April 2015).

4 Lobstein T, Jackson-Leach R, Moodie ML, Hall KD, Gortmaker SL, Swinburn BA *et al*. Child and adolescent obesity: part of a bigger picture. *Lancet* 2015; **385**: 2510–2520.

5 Peirson L, Fitzpatrick-Lewis D, Morrison K, Ciliska D, Kenny M, Usman Ali M *et al*. Prevention of overweight and obesity in children and youth: a systematic review and meta-analysis. *CMAJ Open* 2015; **3**: E23–E33.

6 Dixon B, Peña M-M, Taveras EM. Lifecourse approach to racial/ethnic disparities in childhood obesity. *Adv Nutr Bethesda Md* 2012; **3**: 73–82.

7 Kearney J. Food consumption trends and drivers. *Philos Trans R Soc Lond B Biol Sci* 2010; **365**: 2793–2807.

8 Roberto CA, Swinburn B, Hawkes C, Huang TT-K, Costa SA, Ashe M *et al*. Patchy progress on obesity prevention: emerging examples, entrenched barriers, and new thinking. *Lancet* 2015; **385**: 2400–2409.

9 Guenther PM, Kirkpatrick SI, Reedy J, Krebs-Smith SM, Buckman DW, Dodd KW *et al*. The Healthy Eating Index-2010 is a valid and reliable measure of diet quality according to the 2010 Dietary Guidelines for Americans. *J Nutr* 2014; **144**: 399–407.

10 Kanerva N, Kaartinen NE, Schwab U, Lahti-Koski M, Männistö S. Adherence to the Baltic Sea diet consumed in the Nordic countries is associated with lower abdominal obesity. *Br J Nutr* 2013; **109**: 520–528.

11 Rauber F, da Costa Louzada ML, Vitolo MR. Healthy eating index measures diet quality of Brazilian children of low socioeconomic status. *J Am Coll Nutr* 2014; **33**: 26–31.

12 Mikkilä V, Räsänen 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**: 923–931.

13 Katzmarzyk PT, Barreira TV, Broyles ST, Champagne CM, Chaput J-P, Fogelholm M *et al*. The International Study of Childhood Obesity Lifestyle and the Environment (ISCOLE): design and methods. *BMC Public Health* 2013; **13**: 900.

14 Katzmarzyk PT, Barreira TV, Broyles ST, Champagne CM, Chaput JP, Fogelholm M *et al*. Relationship between lifestyle behaviors and obesity in 9-11 year old children: results from a 12-country study. *Obesity* 2015; **23**: 1696–1702.

15 De Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ* 2007; **85**: 660–667.

16 Saloheimo T, González S, Erkkola M, Milauskas DM, Meisel JD, Champagne CM *et al*. The reliability and validity of a short food frequency questionnaire among 9-11 year olds: a multinational study on 3 middle income and high income countries. *Int J Obes Suppl* 2015 (this issue).

17 Currie C, Gabhainn SN, Godeau E, Roberts C, Smith R, Currie D *et al*. Inequalities in Children's Health: HBSC International Report from the 2005/2006 Survey. Report No.: 5. WHO Regional Office for Europe: Copenhagen, Denmark, 2008.

18 Fardet A, Boirie Y. Associations between food and beverage groups and major diet-related chronic diseases: an exhaustive review of pooled/meta-analyses and systematic reviews. *Nutr Rev* 2014; **72**: 741–762.

19 Fogelholm M, Anderssen S, Gunnarsdottir I, Lahti-Koski M. Dietary macronutrients and food consumption as determinants of long-term weight change in adult populations: a systematic literature review. *Food Nutr Res* 2012; **56**.

20 Office of Disease Prevention and Health Program. Scientific Report of the 2015 Dietary Guidelines Advisory Committee. Available at http://www.health.gov/dietaryguidelines/2015-scientific-report/ (accessed on 30 April 2015).

21 Nordic Nutrition Recommendations Project Group. Nordic Nutrition Recommendations 2012. *Integrating Nutrition and Physical Activity*, 5th edn. Nordic Council of Ministers: Copenhagen, Denmark, 2014.

22 Jacobs DR, Steffen LM. Nutrients, foods, and dietary patterns as exposures in research: a framework for food synergy. *Am J Clin Nutr* 2003; **78**: 508S–513S.

23 Hiza HAB, Casavale KO, Guenther PM, Davis CA. Diet quality of Americans differs by age, sex, race/ethnicity, income, and education level. *J Acad Nutr Diet* 2013; **113**: 297–306.

24 Torres R, Santos E, Orraca L, Elias A, Palacios C. Diet quality, social determinants, and weight status in Puerto Rican children aged 12 years. *J Acad Nutr Diet* 2014; **114**: 1230–1235.

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