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Relative validity of the Children's Eating Habits Questionnaire–food frequency section among young European children: the IDEFICS Study

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Abstract

Objective: To compare, specifically by age group, proxy-reported food group estimates obtained from the food frequency section of the Children's Eating Habits questionnaire (CEHQ-FFQ) against the estimates of two non-consecutive 24 h dietary recalls (24-HDR).
Design: Estimates of food group intakes assessed via the forty-three-food-group CEHQ-FFQ were compared with those obtained by a computerized 24-HDR. Agreement on frequencies of intakes (equal to the number of portions per recall period) between the two instruments was examined using crude and de-attenuated Pearson's correlation coefficients, cross-classification analyses, weighted kappa statistics (κ_w) and Bland–Altman analysis.
Setting: Kindergartens/schools from eight European countries participating in the IDEFICS (Identification and prevention of Dietary- and lifestyle-induced health EFfects In Children and infantS) Study cross-sectional survey (2007–2008).
Subjects: Children aged 2–9 years (*n* 2508, 50·4 % boys).
Results: The CEHQ-FFQ provided higher intake estimates for most of the food groups than the 24-HDR. De-attenuated Pearson correlation coefficients ranged from 0·01 (sweetened fruit) to 0·48 (sweetened milk) in children aged 2–<6 years (mean = 0·25) and from 0·01 (milled cereal) to 0·44 (water) in children aged 6–9 years (mean = 0·23). An average of 32 % and 31 % of food group intakes were assigned to the same quartile in younger and older children, respectively, and classification into extreme opposite quartiles was ≤12 % for all food groups in both age groups. Mean κ_w was 0·20 for 2–<6-year-olds and 0·17 for 6–9-year-olds.
Conclusions: The strength of association estimates assessed by the CEHQ-FFQ and the 24-HDR varied by food group and by age group. Observed level of agreement and CEHQ-FFQ ability to rank children according to intakes of food groups were considered to be low.

Keywords
Relative validation
FFQ
24 h Dietary recall
Children
Proxy reports

Accurate assessment of food intake in children is essential to conduct epidemiological research on diet–health links[1]. Indeed, the importance of valid methods of diet and food intake assessment in epidemiological studies has increasingly been recognized[2–4] given the increasing prevalence of obesity, cardiovascular risk factors and other diseases with long-term consequences even in young populations[5,6]. Therefore, evidence produced for young population groups could benefit from the use of valid dietary assessment tools in terms of an early identification and primary prevention of diet-related chronic diseases.

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FFQ have often been used in large-scale epidemiological studies, because of their ease of administration and time and cost efficiency[7] compared with other dietary assessment methods[8]. However, all self-reporting methods of food intake and consumption are prone to measurement error leading to bias[9] suggesting that estimates may not represent the 'true' usual intake. More specifically, methods are affected by random and systematic errors leading to erroneous associations between diet and disease[10–12]. Validation studies are therefore necessary to indicate the effect of measurement error and to prevent incorrect estimations[13]. Validity refers to the ability of the instrument to discriminate between individuals with true exposure differences[14], where the test instrument is compared against a 'reference method'[15] when available.

Intervention trials have shown that whole foods rather than individual nutrients may best indicate the potential role of the diet in disease prevention[16], which additionally emphasizes the importance of validating dietary assessment methods in terms of food groups rather than nutrients. However, the ability of FFQ to quantify food intakes is not as well documented as their ability to quantify nutrient intakes[9]. The food frequency section of the Children's Eating Habits Questionnaire (CEHQ-FFQ) was designed to investigate the consumption of foods, not of nutrients, previously shown to be consistently associated with overweight and obesity in children. Therefore, the aim of the present study was to evaluate the ability of the CEHQ-FFQ in estimating, specifically by age group, proxy-reported intakes of obesity-related foods. Food estimates obtained from the CEHQ-FFQ were compared with those obtained from two non-consecutive 24 h dietary recalls (24-HDR) as part of the IDEFICS (Identification and prevention of Dietary- and lifestyle-induced health EFfects In Children and infantS) Study.

Experimental methods

Study design and population

The IDEFICS Study is a prospective cohort study with an embedded intervention study carried out in eight European countries (Italy, Estonia, Cyprus, Belgium, Sweden, Germany, Hungary and Spain) with the aim of investigating the aetiology of diet- and lifestyle-related diseases and disorders in European children[17]. A total of 16 224 children fulfilled the general IDEFICS inclusion criteria: complete information on sex, age, height and weight. The design and methodology of the IDEFICS Study have been described previously[17]. Data for the current analysis were obtained from the baseline survey conducted between September 2007 and June 2008 among children aged 2–9 years. For the purposes of the present analysis, only children with two 24-HDR and a CEHQ-FFQ were included (*n* 2508; 1264 boys, 1244 girls). The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved before the start of the examinations by the appropriate local ethics committees in each of the eight survey centres (Belgium: Ethical Committee of the Ghent University Hospital; Cyprus: Cyprus National Bioethics Committee; Estonia: Tallinn Medical Research Ethics Committee; Germany: Ethics Committee of the University of Bremen; Hungary: Egészségügyi Tudományos Tanács Tudományos és Kutatásetikai Bizottság in Budapest; Italy: Comitato Etico ASL in Avellino; Spain: Comité Ético de Investigación Clínica de Aragón (CEICA); Sweden: Regional Ethics Review Board, University of Gothenburg). Written informed consent was obtained from all children's parents.

Data on age, sex and parental education level were recorded by means of parental report on a questionnaire. Height and weight measurements were also taken by trained fieldworkers[17,18].

Children's Eating Habits Questionnaire–food frequency section (CEHQ-FFQ)

The self-administered CEHQ-FFQ was designed as a screening tool to assess eating behaviours associated with risk of overweight, obesity and general health in children. Children's proxies, mainly the parents, filled it in at home by reporting the number of times the child consumed the food groups included in the questionnaire during a typical week over the previous month.

The whole CEHQ was pre-tested prior to the IDEFICS baseline survey in all involved centres[19]. Country-specific food examples were included to facilitate correct comprehension of the food groups included. The CEHQ-FFQ consisted of forty-three food groups which were clustered into thirty-six according to their nutritional profiles, as similarly done in other studies[20–22]: (i) vegetables (cooked vegetables and legumes); (ii) fried potatoes; (iii) raw vegetables; (iv) fruit; (v) sweetened fruit; (vi) water; (vii) manufactured fruit juices; (viii) soft drinks; (ix) light soft drinks; (x) breakfast cereals; (xi) sweetened breakfast cereals; (xii) milk; (xiii) sweetened milk; (xiv) yoghurt; (xv) sweetened yoghurt; (xvi) fish; (xvii) fried fish; (xviii) fried eggs; (xix) eggs; (xx) mayonnaise; (xxi) cold cuts; (xxii) meat (raw and cooked meat); (xxiii) cheese (sliced, spreadable and grated cheese); (xxiv) jam & honey; (xxv) chocolate/nut-based spread; (xxvi) butter & margarine; (xxvii) ketchup; (xxviii) white bread; (xxix) wholemeal bread; (xxx) pasta & rice; (xxxi) milled cereal; (xxxii) pizza; (xxxiii) fast food (hamburgers, hot dogs, kebabs, etc.); (xxxiv) nuts; (xxxv) snacks (crisps, popcorn, savoury pastries and fritters, etc.); and (xxxvi) sweets (chocolates, candy bars, biscuits, cakes, puddings, ice creams, etc.). To facilitate the proxy's responses, a frequency scale was adopted from the US Department of Agriculture eating habits questionnaire of the Early Childhood Longitudinal Survey[23], consisting of the following categories of consumption: 'never/less than once a week', '1–3 times a week', '4–6 times a week', '1 time per day', '2 times per day', '3 times per day', '4 or more times per day' and 'I have no idea'. These were converted into times per week ranging from 0 up to 30 and thereafter into daily. No portion size estimates were obtained. The CEHQ-FFQ showed acceptable reproducibility comparable to others[24]. Furthermore, previous findings evaluating the CEHQ-FFQ[25] found a positive correlation between milk consumption frequencies and respectively K and Ca urinary excretion ratios.

24 h Dietary recall

The 'reference' method was a computerized version of a 24-HDR, namely SACINA (Self Administered Children and Infants Nutrition Assessment). Two recalls were collected in 2508 participants. Children's proxies were interviewed by trained survey personnel. Each interview lasted an average of 20–30 min. Non-consecutive dietary recalls were conveniently distributed across weekdays and weekend days in an effort to capture intakes spread throughout the week. For the present analysis, average food intakes were computed as the mean of the two 24-HDR. Both the CEHQ-FFQ and the two 24-HDR were administered during the same time span.

The SACINA software is based on the HELENA-DIAT Dietary Assessment Tool software developed for European adolescents within the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) project[26,27]. The program consists of a single 24-HDR structured according to six meal occasions (breakfast, mid-morning snack, lunch, afternoon snack, dinner and evening snack) embedded in questions related to a range of chronological daily activities[26–29]. Proxies were asked to recall all food and drinks consumed the previous day by their child. Survey personnel registered school meals data by direct observation. Portion size estimation was assessed mainly by photos of serving sizes, standard portions, customary packing size and foods in pieces or slices in order to reduce reporting bias. When a specific food was not available within the software it was entered manually specifying the total amount consumed. In Hungary, the procedure of collecting 24-HDR was different from that of the rest countries. Proxies were asked to complete a self-administered 24-HDR at home. This information was thereafter entered in the SACINA software by fieldwork personnel when received. Considering these methodological differences in the application of the 24-HDR, results excluding Hungary (*n* 1418) are presented as Supplementary Materials. The validity of SACINA was previously tested by means of the doubly labelled water method. Findings indicated the 24-HDR to be a valid instrument in assessing energy intake at group level (total energy intake – total energy expenditure = −0·23; C Börnhorst, S Bel-Serrat, I Pigeot *et al.*, unpublished results).

To relate CEHQ-FFQ estimates of food consumption to those of the 24-HDR and to enable comparisons, it was assumed that 'number of times per day' as reported in the CEHQ-FFQ could be equated to 'number of portions per day'[30]. Each reported 24-HDR food item was mapped and subsequently matched to one of the forty-three food groups initially included in the CEHQ-FFQ.

Statistical methods

Statistical analyses included all countries and were performed by age group (2–<6 years, 6–9 years) using the Predictive Analytics SoftWare (PASW) version 18. Means, medians and standard deviations were calculated for food group estimates obtained from the CEHQ-FFQ and 24-HDR. Crude data were log-transformed ($\log_{10}$) to improve normality for all thirty-six food groups. Food groups rarely consumed (<5 %) were excluded (i.e. meat replacement & soya products) from subsequent comparisons. Participants exceeding 25 % of missing values in the CEHQ-FFQ (*n* 43) were also excluded from the analysis[21].

Pearson's and Spearman's rank correlation coefficients were calculated for all participants. Results were similar between Pearson and Spearman correlation coefficients, therefore only Pearson coefficients are shown. Correlation coefficients were corrected for attenuation due to random error in the 24-HDR by taking into account the ratio of within-person variance to between-person variance (variance ratio). De-attenuation of crude correlation coefficients was computed according to the equation from Willett[31]:

$$r_{\text{adjusted}} = r_{\text{observed}}\sqrt{1 + \lambda_x/n_x}$$

where λ_x is the variance ratio for x and n_x is the number of replicates for the x variables (here $n = 2$).

Agreement of the CEHQ-FFQ and 24-HDR in ranking individuals was examined by the construction of quartiles for each food group (non-adapted food groups). An alternative approach was used to address the issue of zero consumption observed for >25 % of the participants[21]. Non-consumers were considered as one group and the remaining participants were grouped into tertiles (adapted food groups)[32]. Cross-classification analyses were finally applied in fourteen (fifteen in younger children) out of the thirty-six food groups: vegetables, fruit, milk, cold cuts, meat, cheese, white bread and sweets (non-adapted food groups) and, on the other hand, raw vegetables, fruit juices, soft drinks, breakfast cereals (only for younger children), sweetened milk, butter & margarine and wholemeal bread (as the adapted food groups). The proportion of individuals who fell into the same (correct classification) or into the extreme category (misclassification) was examined. The weighted kappa statistic (κ_w) was calculated with a linear set of weights[33] as a measurement of agreement. Bland–Altman limits of agreement (LOA)[35] were calculated for frequently consumed foods to examine the agreement between the CEHQ-FFQ and the two 24-HDR. The mean differences (bias) between the two measurements ($CEHQ\text{-}FFQ_{log} - 24\text{-}HDR_{log}$) were plotted *v.* their means ($(CEHQ\text{-}FFQ_{log} + 24\text{-}HDR_{log})/2$). The LOA define the limits within which 95 % of the differences are expected to fall (mean ± 2 SD of the difference).

Results

The general characteristics of the 2508 participants are shown in Table 1. Included participants were older, taller and heavier compared with the rest of the IDEFICS participants not included in the present analysis (data not shown).

At the group level, the CEHQ-FFQ provided higher estimates of number of portions than the 24-HDR for the majority of the food groups in both younger and older children (Tables 2 and 3). Significant differences across means were found for all food groups except for fried potatoes, sweetened fruit, milled cereal and fast food in children aged 2–<6 years (Table 2) and breakfast cereals and pizza in children aged 6–9 years (Table 3). Pearson correlation coefficients ranged from 0·01 for sweetened fruit to 0·45 for sweetened milk in younger children (Table 4) and from 0·01 for milled cereal to 0·42 for water in older children (Table 5) in absolute values. After correction for within-person variation, the de-attenuated Pearson correlation coefficients were slightly higher than the crude values (0·01 for sweetened fruit to 0·48 for sweetened milk in younger children and 0·01 for milled cereals to 0·44 for water in older children). The average de-attenuated coefficient for all food groups was 0·25 and 0·23 for younger and older children, respectively. Low de-attenuated coefficients values (<0·20) were observed in thirteen and fourteen out of the thirty-six food groups, respectively, for 2–<6-year-olds and 6–9-year-olds. A higher association (>0·40), however, was observed for fruit, water, breakfast cereals and sugared milk in young children and for raw vegetables, butter & margarine and water in older children. The average de-attenuated correlation coefficient was 0·25 and 0·23, respectively, for younger and older children.

Cross-classification agreement and κ_w values are presented in Tables 6 and 7, showing the ability of the CEHQ-FFQ to classify individuals into the same quartile of intake estimated by the 24-HDR. Among the non-adapted groups, the proportion classified in the same quartile varied from 26 % for sweets to 39 % for milk in children aged 2–<6 years (mean = 32 %) and from 28 % for meat to 34 % for fruit in children aged 6–9 years

Table 1 Baseline characteristics of study participants: children aged 2–9 years from eight European countries participating in the IDEFICS Study (2007–2008)

	All (*n* 2508)		Boys (*n* 1264)		Girls (*n* 1244)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	6·3	1·8	6·3	1·8	6·3	1·8
Height (cm)	119·2	7·5	119·9	12·6	118·6	12·7
Weight (kg)	24·0	7·5	24·4	7·6	23·6	7·4
BMI (kg/m^2)	16·5	2·7	16·6	2·7	16·4	2·6
	n	%	*n*	%	*n*	%
BMI†						
Thinness (BMI < 18·5 kg/m^2)	305	12·2	164	13·0	141	11·3
Normal weight (18·5 ≤ BMI < 25·0 kg/m^2)	1689	67·3	840	66·5	849	68·2
Overweight (25·0 ≤ BMI < 30·0 kg/m^2)	333	13·3	163	12·9	170	13·7
Obesity (BMI ≥ 30·0 kg/m^2)	181	7·2	97	7·7	84	6·8
Age group						
2–<6 years	993	39·6	492	38·9	501	40·3
6–9 years	1515	60·4	772	61·1	743	59·7
Parental education level‡						
Low	213	10·9	112	11·5	101	10·3
Medium	1012	51·8	505	52·0	507	51·7
High	727	37·2	355	36·5	372	38·0
Country						
Italy	398	15·9	217	17·2	181	14·5
Estonia	15	0·6	5	0·4	10	0·8
Cyprus	28	1·1	12	0·9	16	1·3
Belgium	11	0·4	5	0·4	6	0·5
Sweden	97	3·9	47	3·7	50	4·0
Germany	366	14·6	180	14·2	186	15·0
Hungary	1418	56·5	699	55·3	719	57·8
Spain	175	7·0	99	7·8	76	6·1

ISCED, International Standard Classification of Education.
†According to Cole *et al.*'s categories[45]. Thinness includes: thinness grade III, thinness grade II and thinness grade I.
‡Low = ISCED Levels 1 and 2; medium = ISCED Levels 3 and 4; high = ISCED Level 5. ISCED is an indicator of socio-economic level[46].

Table 2 Food group intakes (daily number of portions) from the CEHQ-FFQ and 24-HDR: younger children aged 2–<6 years from eight European countries participating in the IDEFICS Study (2007–2008)

		CEHQ-FFQ			24-HDR (SACINA)				
Food group (portions/d)	*n*	Mean	Median	SD	Mean	Median	SD	Mean Δ	*P* value
Vegetables	983	0·57	0·29	0·47	0·91	1·00	0·68	−0·34	0·000*
Fried potatoes	976	0·11	0·00	0·19	0·09	0·00	0·22	0·02	0·101
Raw vegetables	979	0·67	0·29	0·66	0·55	0·50	0·70	0·12	0·000*
Fruit	971	1·07	1·00	0·76	0·87	0·50	0·79	0·20	0·000*
Sweetened fruit	914	0·19	0·00	0·46	0·04	0·00	0·14	0·15	0·648
Water	955	3·06	4·29	1·51	1·72	1·50	1·12	1·34	0·000*
Fruit juices	979	1·08	0·71	1·57	0·60	0·50	0·76	0·48	0·000*
Soft drinks	978	0·37	0·00	0·81	0·53	0·50	0·72	−0·16	0·000*
Light soft drinks	959	0·15	0·00	0·61	0·01	0·00	0·09	0·14	0·000*
Sweetened breakfast cereals	976	0·33	0·29	0·42	0·17	0·00	0·33	0·16	0·000*
Breakfast cereals	936	0·20	0·00	0·46	0·17	0·00	0·43	0·03	0·000*
Milk	940	0·88	0·71	0·93	0·79	0·50	0·77	0·09	0·000*
Sweetened milk	969	0·70	0·29	0·79	0·41	0·00	0·62	0·29	0·000*
Yoghurt	940	0·20	0·00	0·39	0·07	0·00	0·23	0·13	0·000*
Sweetened yoghurt	971	0·51	0·25	0·50	0·30	0·00	0·45	0·21	0·000*
Fish	941	0·13	0·00	0·18	0·07	0·00	0·20	0·06	0·000*
Fried fish	956	0·14	0·00	0·24	0·07	0·00	0·21	0·07	0·000*
Cold cuts	982	0·60	0·29	0·54	0·88	1·00	0·72	−0·28	0·000*
Meat	989	0·70	0·57	0·59	0·71	0·50	0·56	−0·01	0·047*
Fried eggs	976	0·15	0·00	0·20	0·07	0·00	0·20	0·08	0·000*
Eggs	959	0·11	0·00	0·15	0·07	0·00	0·19	0·04	0·000*
Mayonnaise	967	0·08	0·00	0·18	0·03	0·00	0·12	0·05	0·000*
Cheese	986	0·83	0·61	0·70	0·47	0·50	0·56	0·36	0·000*
Jam & honey	966	0·26	0·29	0·36	0·16	0·00	0·34	0·10	0·000*
Chocolate/nut-based spread	977	0·26	0·00	0·39	0·14	0·00	0·31	0·12	0·000*
Butter & margarine	966	0·61	0·29	0·74	0·42	0·00	0·61	0·19	0·000*
Ketchup	971	0·21	0·29	0·10	0·11	0·00	0·25	0·10	0·000*
White bread	978	1·07	1·00	0·94	1·37	1·50	0·84	−0·30	0·000*
Wholemeal bread	960	0·47	0·29	0·65	0·39	0·00	0·61	0·08	0·000*
Pasta & rice	974	0·43	0·29	0·35	0·66	0·50	0·50	−0·23	0·000*
Milled cereal	959	0·07	0·00	0·18	0·00	0·00	0·02	0·07	0·674
Pizza	963	0·06	0·00	0·13	0·09	0·00	0·23	−0·03	0·000*
Fast food	982	0·26	0·00	0·41	0·04	0·00	0·16	0·22	0·239
Nuts	978	0·16	0·00	0·25	0·04	0·00	0·18	0·12	0·000*
Snacks	988	0·23	0·29	0·34	0·09	0·00	0·24	0·14	0·001*
Sweets	992	1·17	1·00	0·95	1·39	1·50	0·97	−0·22	0·000*

CEHQ-FFQ, Children's Eating Habits Questionnaire–food frequency section; 24-HDR, 24 h dietary recall; SACINA, Self Administered Children and Infants Nutrition Assessment; Δ, difference.
*$P<0·05$.

(mean = 31 %). Extreme misclassification was about or even lower than 12 % for all food groups in both younger and older children; the highest values were observed for white bread (12 %) in young children and cheese (11 %) in older children. Mean κ_w was 0·20 for 2–<6-year-old children and 0·17 for 6–9-year-old children. The κ_w values showed an acceptable agreement for fruit, milk, cold cuts, cheese and white bread, whereas low agreement (<0·20) was seen for vegetables, meat and sweets in both age groups. Results changed when examining the adapted food groups, since the proportion of correct classification ranged from 38 % for wholemeal bread to 49 % for sweetened milk in younger children (mean = 40 %) and from 32 % for wholemeal bread to 52 % for sweetened milk in older children (mean = 38 %). The mean proportion of individuals classified into the opposite tertile, however, was 22 % in both age groups, varying from 10 % and 6 % for sweetened milk to 29 % and 28 % for soft drinks in younger and older children, respectively. Mean κ_w for the adapted food groups was 0·20 for children aged 2–<6 years and 0·17 for those aged 6–9 years. Poor agreement was found except for sweetened milk, which showed acceptable agreement in both younger and older children (κ_w = 0·30 and 0·36, respectively). Among younger children, breakfast cereals and butter & margarine also showed acceptable agreement (>0·20).

Following exclusion of the Hungarian data, de-attenuated correlation coefficients were slightly higher compared with the crude coefficients, with an average of 0·31 in 2–<6-year-old children and 0·28 in 6–9-year-old children (Supplementary Materials, Tables 3 and 4). Average variance ratio increased to 0·64. Supplementary Materials, Tables 5 and 6 show the results of the cross-classification analysis excluding the Hungarian data. The mean percentage of correctly classified subjects increased to 35 % in younger children and to 32 % in older children. Mean extreme misclassification was considerably lower for both younger (5 %) and older children (7 %). The κ_w values

Table 3 Food group intakes (daily number of portions) from the CEHQ-FFQ and the 24-HDR: older children aged 6–9 years from eight European countries participating in the IDEFICS Study (2007–2008)

		CEHQ-FFQ			24-HDR (SACINA)				
Food group (portions/d)	*n*	Mean	Median	SD	Mean	Median	SD	Mean Δ	*P* value
Vegetables	1499	0·52	0·29	0·43	0·86	1·00	0·69	−0·34	0·000*
Fried potatoes	1485	0·15	0·00	0·20	0·09	0·00	0·23	0·06	0·000*
Raw vegetables	1501	0·65	0·29	0·62	0·56	0·50	0·72	0·09	0·000*
Fruit	1498	0·97	1·00	0·81	0·76	0·50	0·77	0·21	0·000*
Sweetened fruit	1377	0·23	0·00	0·56	0·03	0·00	0·12	0·20	0·000*
Water	1455	3·05	4·29	1·54	1·86	2·00	1·10	1·19	0·000*
Fruit juices	1484	1·01	0·71	1·20	0·57	0·50	0·74	0·44	0·000*
Soft drinks	1480	0·48	0·00	0·96	0·61	0·50	0·76	−0·13	0·000*
Light soft drinks	1472	0·15	0·00	0·56	0·01	0·00	0·13	0·14	0·000*
Sweetened breakfast cereals	1495	0·44	0·29	0·45	0·19	0·00	0·36	0·25	0·000*
Breakfast cereals	1411	0·13	0·00	0·29	0·12	0·00	0·30	0·01	0·086
Milk	1422	0·76	0·71	0·83	0·66	0·50	0·64	0·10	0·020*
Sweetened milk	1464	0·64	0·50	0·71	0·32	0·00	0·53	0·32	0·000*
Yoghurt	1426	0·19	0·00	0·37	0·05	0·00	0·18	0·14	0·000*
Sweetened yoghurt	1485	0·45	0·29	0·48	0·23	0·00	0·41	0·22	0·000*
Fish	1432	0·11	0·00	0·17	0·06	0·00	0·19	0·05	0·000*
Fried fish	1446	0·12	0·00	0·16	0·05	0·00	0·17	0·07	0·000*
Cold cuts	1500	0·67	0·71	0·60	0·99	1·00	0·76	−0·32	0·000*
Meat	1505	0·73	0·57	0·54	0·81	0·50	0·62	−0·08	0·002*
Fried eggs	1481	0·16	0·00	0·18	0·07	0·00	0·18	0·09	0·000*
Eggs	1482	0·10	0·00	0·17	0·04	0·00	0·15	0·06	0·000*
Mayonnaise	1475	0·09	0·00	0·20	0·04	0·00	0·17	0·05	0·000*
Cheese	1510	0·89	0·71	0·83	0·46	0·50	0·54	0·43	0·000*
Jam & honey	1486	0·26	0·29	0·37	0·16	0·00	0·34	0·10	0·000*
Chocolate/nut-based spread	1490	0·27	0·29	0·37	0·13	0·00	0·29	0·14	0·000*
Butter & margarine	1490	0·64	0·29	0·71	0·46	0·00	0·64	0·18	0·000*
Ketchup	1490	0·25	0·29	0·34	0·07	0·00	0·22	0·18	0·000*
White bread	1503	1·27	1·00	1·01	1·61	1·50	0·92	−0·34	0·000*
Wholemeal bread	1467	0·40	0·29	0·63	0·24	0·00	0·51	0·16	0·000*
Pasta & rice	1489	0·37	0·29	0·30	0·64	0·50	0·48	−0·27	0·000*
Milled cereal	1471	0·06	0·00	0·20	0·00	0·00	0·01	0·06	0·000*
Pizza	1477	0·07	0·00	0·17	0·06	0·00	0·18	0·01	0·057
Fast food	1500	0·39	0·29	0·52	0·03	0·00	0·14	0·36	0·000*
Nuts	1488	0·14	0·00	0·26	0·04	0·00	0·17	0·10	0·000*
Snacks	1505	0·24	0·29	0·35	0·11	0·00	0·25	0·13	0·000*
Sweets	1511	1·07	0·86	0·93	1·38	1·00	0·94	−0·31	0·000*

CEHQ-FFQ, Children's Eating Habits Questionnaire–food frequency section; 24-HDR, 24 h dietary recall; SACINA, Self Administered Children and Infants Nutrition Assessment; Δ, difference.
$^{*}P < 0·05$.

showed acceptable agreement except for sweets and fruit, for which it was poor (<0·20) and moderate (>0·40), respectively, in both younger and older children. Vegetables, milk and meat also showed poor agreement among 6–9-year-old children. Regarding the adapted food groups, the mean proportion of individuals classified into the same tertile increased in both age groups compared with the non-adapted food groups. Average misclassification of individuals into the opposite tertiles decreased, being 16 % and 20 %, respectively, for 2–<6-year-old and 6–9-year-old children. Higher mean κ_w values were obtained: 0·20 in younger children and 0·14 in older children.

Figure 1 (Supplementary Materials) illustrates findings of the Bland–Altman analysis representative of the observed trends. For most food groups (vegetables, raw vegetables, breakfast cereals, sweetened milk, cold cuts, meat, cheese, butter and sweets), a systematic increase in difference between the two methods with increasing intake was observed indicating worse agreement at higher intakes. For fruit, fruit juices, soft drinks, milk, white bread and wholemeal bread, however, a double interpretation is possible. When considering intakes within the LOA only, it was observed that the agreement between methods was similar regardless of the average intake. On the other hand, beyond the LOA, it seemed that when mean intake increased the bias also increased up to a certain value, after which it started decreasing.

Discussion

The aim of the present study was to evaluate the ability of the CEHQ-FFQ in estimating age group-specific proxy-reported intakes of obesity-related foods compared with two 24-HDR (SACINA). To the authors' knowledge, the present study is the largest one carried out in children in which relative validity has been evaluated through food group intakes. Results showed wide differences in relative

Table 4 Pearson correlation coefficients between food group intakes (daily number of portions) from the CEHQ-FFQ and the 24-HDR: younger children aged 2–<6 years from eight European countries participating in the IDEFICS Study (2007–2008)

Food group	Pearson correlation coefficient	Variance ratio	De-attenuated correlation coefficient
Vegetables	0·14	0·80	0·17
Fried potatoes	0·05	0·92	0·06
Raw vegetables	0·33	0·58	0·37
Fruit	0·36	0·53	0·40
Sweetened fruit	−0·01	0·95	−0·01
Water	−0·41	0·25	−0·44
Fruit juices	0·32	0·50	0·36
Soft drinks	0·14	0·42	0·15
Light soft drinks	0·17	0·87	0·20
Sweetened breakfast cereals	0·28	0·66	0·32
Breakfast cereals	0·41	0·33	0·44
Milk	0·32	0·33	0·35
Sweetened milk	0·45	0·30	0·48
Yoghurt	0·20	0·63	0·23
Sweetened yoghurt	0·35	0·54	0·39
Fish	0·24	0·72	0·28
Fried fish	0·12	0·86	0·14
Cold cuts	0·27	0·53	0·30
Meat	0·06	0·79	0·07
Fried eggs	0·17	0·81	0·20
Eggs	0·13	0·95	0·16
Mayonnaise	0·11	0·88	0·13
Cheese	0·25	0·52	0·28
Jam & honey	0·29	0·54	0·33
Chocolate/nut-based spread	0·30	0·49	0·33
Butter & margarine	0·35	0·49	0·39
Ketchup	0·22	0·80	0·26
White bread	0·26	0·60	0·30
Wholemeal bread	0·35	0·34	0·38
Pasta & rice	0·24	0·78	0·28
Milled cereal	−0·01	1·00	−0·01
Pizza	0·11	0·85	0·13
Fast food	0·11	0·71	0·13
Nuts	0·18	0·71	0·21
Snacks	0·11	0·83	0·13
Sweets	0·17	0·57	0·19

CEHQ-FFQ, Children's Eating Habits Questionnaire–food frequency section; 24-HDR, 24 h dietary recall.

validity across the different food groups, emphasizing the importance of validating dietary assessment methods in terms of food groups rather than nutrients. It should also be considered that comparison of findings among validation studies is compromised by differences among the type of FFQ administered, sample size, food groups examined, unit of estimates, use of reference method, recall period or number of recorded days[35].

As expected, the CEHQ-FFQ gave higher mean intakes as opposed to the 24-HDR, a tendency also observed in previous studies carried out in adults and/or children[14,22,35–37]. Our findings suggest that episodically consumed food groups such as milled cereal, light soft drinks, fast food and sweetened fruit tended to be over-reported by the CEHQ-FFQ in this population group. This can partly be explained by the difficulty of the 24-HDR to capture infrequently consumed products, especially in children with highly varying diets and rapidly changing food habits[8].

More specifically, the low crude correlations observed increased slightly following correction for attenuation effect in the 24-HDR. Correlations tended to be stronger for foods with higher frequency of consumption, again indicating current problems in the assessment of episodically consumed foods. Respectively for younger and older children, fifteen and ten out of the thirty-six foods groups had correlation coefficients within the range of 0·3–0·8 as shown by others[9,14,22,36,38]. Coefficients for fruit (younger children), water, fish, cheese or white bread were comparable to or even higher (raw vegetables, sweetened milk (younger children), chocolate/nut-based spread, wholemeal bread and pasta & rice) than those found in a validation study conducted with Belgian adolescents[39]. Similarly, low coefficients for cooked vegetables (0·17 in younger children and 0·13 in older children) and for fried potatoes in older children (0·14) were comparable to those of an American validation study in 8–9-year-old students[40].

Correlations from food frequency instruments have generally been shown to be lower in child and adolescent populations than among adults[8]. Such observations

Table 5 Pearson correlation coefficients between food group intakes (daily number of portions) from the CEHQ-FFQ and the 24-HDR: older children aged 6–9 years from eight European countries participating in the IDEFICS Study (2007–2008)

Food group	Pearson correlation coefficient	Variance ratio	De-attenuated correlation coefficient
Vegetables	0·11	0·80	0·13
Fried potatoes	0·12	0·79	0·14
Raw vegetables	0·36	0·55	0·41
Fruit	0·30	0·51	0·34
Sweetened fruit	−0·02	0·93	−0·02
Water	−0·42	0·24	−0·44
Fruit juices	0·28	0·48	0·31
Soft drinks	0·21	0·43	0·23
Light soft drinks	0·08	0·47	0·09
Sweetened breakfast cereals	0·23	0·56	0·26
Breakfast cereals	0·18	0·47	0·20
Milk	0·24	0·39	0·26
Sweetened milk	0·33	0·38	0·36
Yoghurt	0·10	0·62	0·11
Sweetened yoghurt	0·32	0·46	0·35
Fish	0·25	0·71	0·29
Fried fish	0·12	0·89	0·14
Cold cuts	0·26	0·56	0·29
Meat	0·15	0·82	0·18
Fried eggs	0·10	0·92	0·12
Eggs	0·08	0·97	0·10
Mayonnaise	0·18	0·77	0·21
Cheese	0·24	0·59	0·27
Jam & honey	0·32	0·53	0·36
Chocolate/nut-based spread	0·31	0·54	0·35
Butter & margarine	0·40	0·47	0·44
Ketchup	0·20	0·85	0·24
White bread	0·23	0·47	0·26
Wholemeal bread	0·35	0·31	0·38
Pasta & rice	0·18	0·76	0·21
Milled cereal	−0·01	1·00	−0·01
Pizza	0·10	0·80	0·12
Fast food	0·12	0·91	0·14
Nuts	0·14	0·63	0·16
Snacks	0·10	0·84	0·12
Sweets	0·18	0·58	0·20

CEHQ-FFQ, Children's Eating Habits Questionnaire–food frequency section; 24-HDR, 24 h dietary recall.

could be partly attributed to the effect of proxy reporting, as proxies are conditioned by their ability to accurately recall their children's food intake[41]. Additionally, parents as proxies seem to be reliable reporters in the home setting[41] but the opposite is true for food intake out of home[41]. This limits parents' suitability as the sole informants of their children's intake.

Findings from the cross-classification analyses varied by food group and at times demonstrated the rather limited ability of the questionnaire to discriminate between quartiles of food groups. A third of the participants were allocated into the same category by both methods and on average only 7 % and 8 % of younger and older children, respectively, were likely to be classified into the opposite quartile. Although among the adapted food groups the proportion of misclassified individuals increased, higher agreement between the methods was found in terms of classification. Percentage agreement and misclassification were within the ranges reported by other authors[14,21,38] for the non-adapted food groups. However, the degree of misclassification observed among the adapted groups was remarkably higher compared with previous studies[14,21,38]. Findings from the κ_w analysis also confirmed fair agreement between the CEHQ-FFQ and 24-HDR.

In general, no great differences were observed by age group in terms of correlation coefficients and agreement between the CEHQ-FFQ and 24-HDR, since values were similar for most of the food groups. It is noteworthy, however, that correlation coefficients for some highly consumed food groups – i.e. fruit, breakfast cereals, milk, sweetened milk and yoghurt – were considerably higher in younger children compared with those obtained among their older peers. Similarly, κ_w values were also higher for milk, white bread, sweetened milk and butter & margarine in 2–<6-year-old children. This can be explained by the fact that younger children are less likely to be unsupervised during in-home and out-of-home eating than older children[1,41]. Consequently, parents become more reliable reporters and more capable of reporting their children's intake in an accurate way.

Table 6 Cross-classification by quartile of food group intakes from the CEHQ-FFQ and the 24-HDR: younger children aged 2–<6 years from eight European countries participating in the IDEFICS Study (2007–2008)

Food group	CEHQ-FFQ *v.* two 24-HDR: Correctly classified (%)	Grossly misclassified (%)	κ_w
Vegetables	30·2	3·6	0·13
Fruit	35·5	4·7	0·34
Milk	38·6	7·8	0·36
Cold cuts	32·0	4·8	0·27
Meat	27·0	10·0	0·10
Cheese	33·7	10·5	0·30
White bread	35·8	12·3	0·29
Sweets	25·9	9·9	0·17
Adapted food groups†			
Raw vegetables	42·1	22·6	0·14
Fruit juices	41·2	17·7	0·17
Soft drinks	42·0	29·2	0·10
Breakfast cereals	45·9	19·4	0·26
Sweetened milk	49·3	10·1	0·30
Butter & margarine	47·0	16·2	0·24
Wholemeal bread	38·2	18·6	0·12

CEHQ-FFQ, Children's Eating Habits Questionnaire–food frequency section; 24-HDR, 24 h dietary recall; κ_w, weighted kappa statistic.

For fried potatoes, sweetened fruit, water, light soft drinks, sweetened breakfast cereals, yoghurt, sweetened yoghurt, fish, fried fish, fried eggs, eggs, mayonnaise, jam & honey, chocolate/nut-based spread, ketchup, pasta & rice, milled cereal, pizza, fast food, nuts and snacks, ranking into quartiles or tertiles was not possible since >25 % of the participants did not consume these foods on each recall day.

†Within that food groups, zero consumers were considered as one group and tertiles were constructed for the remaining participants.

Table 7 Cross-classification by quartile of food group intakes from the CEHQ-FFQ and the 24-HDR: older children aged 6–9 years from eight European countries participating in the IDEFICS Study (2007–2008)

Food group	CEHQ-FFQ *v.* two 24-HDR: Correctly classified (%)	Grossly misclassified (%)	κ_w
Vegetables	28·7	3·9	0·10
Fruit	34·5	7·3	0·31
Milk	33·3	7·4	0·24
Cold cuts	33·9	4·7	0·26
Meat	27·7	7·0	0·14
Cheese	32·6	11·5	0·31
White bread	29·3	7·5	0·23
Sweets	30·4	10·2	0·18
Adapted food groups†			
Raw vegetables	39·6	21·0	0·15
Fruit juices	41·9	18·2	0·16
Soft drinks	38·8	28·0	0·10
Sweetened milk	52·5	5·8	0·36
Butter & margarine	38·0	12·3	0·10
Wholemeal bread	32·3	17·0	0·05

CEHQ-FFQ, Children's Eating Habits Questionnaire–food frequency section; 24-HDR, 24 h dietary recall; κ_w, weighted kappa statistic.

For fried potatoes, sweetened fruit, water, light soft drinks, sweetened breakfast cereals, breakfast cereals, yoghurt, sweetened yoghurt, fish, fried fish, fried eggs, eggs, mayonnaise, jam & honey, chocolate/nut-based spread, ketchup, pasta & rice, milled cereal, pizza, fast food, nuts and snacks, ranking into quartiles or tertiles was not possible since >25 % of the participants did not consume these foods on each recall day.

†Within that food groups, zero consumers were considered as one group and tertiles were constructed for the remaining participants.

The lack of agreement between methods of assessment observed in children has often been attributed to a number of factors[41], including the use of proxy reporting as discussed earlier, the nature of the diet of young age groups and the lack of a gold standard for directly assessing the validity or relative validity of FFQ, among others[13]. Moreover, FFQ validity is highly conditioned by the reference method, which is also subject to instrument-specific limitations. In addition, proxies reported the 24-HDR, who tend to under-report intake[8]. It should be noted that the European Food Consumption Survey Method (EFCOSUM) has recommended the use of two or more non-consecutive 24 h recalls as the best method to assess food consumption in individuals aged 10 years and above in different European countries[42].

Dietary information is affected by high day-to-day variability in children's diets[8], which could explain the lack of agreement between methods. This influence could be minimized by an increase in the number of recording days, but long recording periods reduce the accuracy of recording owing to increasing fatigue and boredom, potential alterations of dietary habits and increasing likelihood of drop-outs[43]. Additionally, the large sample size included in the present study makes up for the small number of replicates to keep the same precision of the corrected correlation coefficient[13]. Moreover, the fact that portion sizes were not assessed in the CEHQ-FFQ might also affect the agreement between both methods; i.e. overestimation of foods consumed in small quantities and underestimation of those consumed in higher quantities. Considering the increased respondent burden however, no attempts were done to capture portion sizes in the current study[13]. Our sample differed from the IDEFICS whole sample in terms of baseline characteristics, which means that these results might not be generalized to all participating children. However, no differences were found for BMI which is considered to be an indicator of misreporting[44].

As stated before, Hungary collected the 24-HDR information differently from the other survey centres and this is considered as one of the study limitations influencing the generalizability of its results. Our findings suggest that when Hungarian data were excluded, the strength of the associations between the CEHQ-FFQ and the 24-HDR increased. In fact, the number of food groups showing moderate correlation coefficients increased and the number of slight correlations decreased. Furthermore, when cross-classification analyses were applied, without considering Hungarian data the degree of agreement in both non-adapted and adapted food groups increased. Indeed, the proportions of correctly classified individuals as well as κ_w values improved towards higher values, whereas the percentages of grossly misclassified individuals decreased.

To our knowledge, the present study is the first one performed in a large sample of European children of (pre)school age in which proxy-reported data obtained from an FFQ were compared with those from two 24-HDR. Another important strength of the study is standardized procedures followed during the data collection of the IDEFICS fieldwork[17]. High-quality control procedures were applied during the different stages of the project, including checks for plausibility already implemented in the database and performed during data entry. In addition, the reference method used in the study was previously validated with the doubly labelled water method considered as the 'gold standard' method for this purpose. Furthermore, portions/d were used instead of g/d offering newer approaches and insights into validation studies using FFQ despite associated limitations.

Conclusions

Findings of the present study suggest that the strength of association estimates assessed by the CEHQ-FFQ and the 24-HDR varied by food group intakes and by age group. In addition, the ability of the CEHQ-FFQ to rank children according to intakes of food groups was lower than expected but in line with other studies. Overall, these results suggest low agreement for the majority of food groups examined by a proxy-estimated FFQ and two 24-HDR in a large sample of 2–9-year-old European children. However, one should consider that both instruments are subject to measurement errors affecting the strength of the association. In that sense, the CEHQ-FFQ could provide acceptable food estimates at group level. It is of great importance to detect true diet–disease relationships with the aim to develop public health strategies to prevent children from suffering chronic diseases. For that reason, validation studies are indispensable to test the validity and appropriateness of dietary assessment methods used within epidemiological surveys to accurately assess food intake.

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Supplementary Materials

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