

Can the EPIC food-frequency questionnaire be used in adolescent populations?

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Submitted 19 October 2001; Accepted 11 March 2002

Abstract

Objective: To assess the validity of the food-frequency questionnaire used in the European Prospective Investigation of Cancer (EPIC FFQ) for estimating nutrient intake in an adolescent population.

Design: Sixty-seven schoolchildren (mean age: 12.3 ± 0.3 years) were recruited to complete a 7-day weighed dietary record (7-day WDR), the EPIC FFQ and supply one 24-hour urine collection.

Setting: Harris Academy in Dundee (UK).

Results: Fifty subjects completed both dietary assessment methods. Thirteen of these were classified as underreporters with energy intake/basal metabolic rate < 1.14 . The EPIC FFQ showed higher estimates than the 7-day WDR for all nutrients. The median Spearman correlation coefficient for the nutrients examined was found to be 0.31 and increased to 0.48 after adjustment for total energy. The limits of agreement were as far apart as 13.4 MJ, 120 g, 270 g, 120 g and 1170 mg for energy, fat, sugar, protein and calcium, respectively. Correlations between urine and 7-day WDR dietary nitrogen and potassium were found to be statistically significant with $r = 0.45$ ($P < 0.05$) and $r = 0.78$ ($P < 0.001$), respectively. The median proportion of subjects that appeared in the same and opposite third of intake was found to be 45.9% and 10.8%, respectively.

Conclusions: The EPIC FFQ seems adequate to correctly classify low, medium and high consumers and might therefore be used to identify adolescent population groups at risk or for differences between populations. However, agreement between the EPIC FFQ and the 7-day WDR was very poor on both a group and an individual basis, and demonstrates that the EPIC FFQ is not an appropriate method for estimating absolute intakes in this age group.

Keywords

Adolescent
Food-frequency questionnaire
Weighed food records
Urine

The food – and therefore the nutrient – intake of adolescents is important not only for growth and development, but also for present and future health including the prevention of chronic diseases of adulthood, such as cardiovascular disease¹ and certain cancers². Moreover, eating habits developed in adolescence may endure in adulthood³ and therefore it is important for healthful eating practices to be established in this age group.

Adolescents are a group whose eating habits are characterised by factors such as irregular meals, snacking or 'grazing', and meal-skipping^{3–6}. These eating habits are not easily conducive to assessment of diet by prospective methodology. Whilst it is likely that intensive survey procedures can be used to obtain accurate 7-day weighed dietary records (7-day WDR) in small numbers from this age group, the use of 7-day WDR may be limited for the general adolescent population since this method is

generally considered to be a burden and associated with incomplete recording⁷. Moreover, girls of this age may be concerned with body image and weight⁶, resulting in underreporting of intake⁸ or changed dietary habits during the study period. The retrospective food-frequency questionnaire (FFQ) is a method that has been used in large studies because of its ease of administration and relatively low cost⁹, and has been found to be valid and reproducible in adolescent subjects^{10,11}. Willett and colleagues¹² reported good agreement of nutrient densities in validation of food-frequency questionnaires using weighed dietary records. The European Prospective Investigation of Cancer food-frequency questionnaire (EPIC FFQ) has been validated for use in adults in the UK^{13,14} and provided a reasonable assessment of habitual diet.

The aim of the present study was to assess the validity of the EPIC FFQ in Scottish adolescents, using biological

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markers (urinary potassium and nitrogen) and a 7-day WDR as the reference method.

Methods

Subjects

Between November 2000 and February 2001, secondary school pupils (aged 11–13 years) from Harris Academy in Dundee (UK) were invited to take part in the study. Sixty-seven pupils consented to take part in the study, but this number was further reduced to 54 due to withdrawals. No exclusions were made on the grounds of ill health. The protocol was approved by the Tayside Committee on Medical Ethics.

Demographic data

Date of birth, gender, height and weight were obtained from each of the subjects. Height was measured using a SECA portable height measure (Leicester model, SECA, Birmingham, UK) accurate to 1 mm, and weight was recorded in light indoor clothing using a Soehnle portable scale (Soehnle, Germany) accurate to 0.1 kg.

Dietary assessment methods

The EPIC FFQ was completed on an interview basis one day before the 7-day WDR, with the research assistant giving minimal assistance in order to prevent interview bias. To conduct the weighed dietary record, each pupil was given a set of dietary scales with accuracy to ± 1 g (model 2001, Salter, UK), a 7-day food diary in which to record all food/drinks consumed as well as verbal and written instructions. Pupils were encouraged to weigh as much of the food/drinks consumed as possible during the recording period. When this was not possible, food weights were estimated using wrappers/labels of packaged foods and drinks, from standard weights of school dinner portions and from The Ministry of Agriculture, Fisheries and Food's photographic food atlas and food portion size book^{15,16}. Subjects were asked to read through the instructions with their parents or guardians before starting to complete the food diary the next day, to ensure that they fully understood the protocol.

24-Hour urine collection

Subjects were instructed on the technique of 24-hour urine collection on recruitment and asked to make the collection on the Sunday during the 7-day weighed dietary record study. Pupils were asked to give details of the time of the beginning and end of the collections, and whether or not they had any problems or missed specimens.

Analysis was carried out by the Department of Biochemical Medicine at Ninewells Hospital and Medical School, Dundee. A Roche/Hitachi 917 analyser (Roche Diagnostics Ltd, Lewes, UK) was used for the determination of sodium, potassium, urea and creatinine using standard procedures (indirect ion-selective electrode

method for sodium and potassium (Boehringer Mannheim), HiCo Creatinine Jaffé method (Roche) and kinetic UV assay for urea (Roche)). The within- and between-day coefficients of variation for analytical results of sodium, potassium, urea and creatinine were found to be 1.2%, 1.4%, 1.4%, 1.3% and 2.5%, 2.2%, 3.3%, 3.5%, respectively.

Urine collections were checked for completeness using creatinine excretion. Collections were designated incomplete when the creatinine excretion was outside two standard deviations from the mean. From 46 samples, eight were recorded incomplete and a further two assessed as incomplete. Urinary nitrogen was calculated from urinary urea using standard formulas¹⁷.

Data analysis

Demographic details, food-frequency questionnaires, weighed dietary records and urine results were entered and checked. The dietary data from the EPIC FFQs were analysed by the Institute of Public Health, University of Cambridge. Food diaries were entered into ARMIS Version 2.0 (Tinuviel Software Ltd, Warrington, UK). All data were transferred into the Statistical Package for Social Sciences Version 10.0 (SPSS Inc., Chicago, IL, USA) for further statistical analysis.

The estimate of a subject's daily habitual food intake was considered to be underreported if his/her ratio of energy intake to basal metabolic rate (EI/BMR) was less than 1.14, or overreported if greater than 2.5¹⁸. BMR was calculated from standard formulas based on weight¹⁹, with formulas for males and females aged 10–17 years being used.

Results are given for energy, macronutrients, Englyst fibre, calcium, sodium and potassium. Means and standard deviations are presented, and Spearman rank correlation analyses were performed on both unadjusted and energy-adjusted macronutrients and minerals. The correlations between the EPIC FFQ and the 7-day WDR were adjusted for energy by replacing nutrient values with their respective residuals from a regression model with the nutrient intake as the dependent variable and the energy intake as the independent variable²⁰. Furthermore, the agreement on category between the EPIC FFQ and the 7-day WDR was examined by classification of intakes divided into thirds. Limits of agreement between the methods were examined using Bland–Altman plots²¹.

Results

Fifty children completed both the EPIC FFQ and the 7-day WDR. Thirty-six per cent of these were boys and 64% were girls. The mean age, height, weight and body mass index (BMI) are given in Table 1. Based on internationally based cut-off points for overweight (BMI > 25 kg m⁻²) and obesity (BMI > 30 kg m⁻²)²², 10% of the study subjects were classified as overweight and 2% as obese.

Table 1 Characteristics of the participants in the study ($n = 50$)

	Mean	SD	Range
Age (years)	12.3	0.3	11.8–13.2
Weight (kg)	48.3	11.2	31.2–89.8
Height (cm)	154.0	7.5	141.2–175.7
Body mass index (kg m^{-2})	20.3	4.0	15.3–38.1

Table 2 compares the daily intakes of energy and nutrients calculated from the tested dietary methods. Thirteen participants were classified as underreporters with $\text{EI/BMR} < 1.14^{18}$ based on energy intake calculated from the 7-day WDR. Energy, macronutrients and minerals were normally distributed and are therefore presented as mean \pm standard deviation (SD). The EPIC FFQ showed higher estimates than the 7-day WDR for all nutrients before and after truncation for overreporters with $\text{EI/BMR} > 2.5^{18}$. However, if macronutrients were calculated as % energy, these differences were minimal. The validity of the EPIC FFQ was further evaluated by determination of the Spearman correlation coefficients. Unadjusted correlation coefficients ranged from 0.17 for carbohydrate to 0.54 for fat, with an overall median of 0.31. Correlations for the nutrients calcium, sugar, energy, protein and total fat were found to be significant. Adjustment for total energy increased the correlation coefficient for all nutrients except for sodium. Adjusted values ranged from 0.19 for sodium to 0.67 for total fat, with an overall median of 0.48. Correlations for the nutrients potassium, calcium, Englyst fibre, sugar, total carbohydrate and total fat were found to be significant. Agreement between all macronutrients based on the Spearman correlation coefficients was good. However,

protein showed a poor correlation after energy adjustment for truncated EPIC FFQ data.

Bland–Altman plots were used to further examine the limits of agreement between the EPIC FFQ and the 7-day WDR by plotting the individual differences between the two methods against the mean of both methods (Figs 1–5). The nutrients chosen for the analysis were energy, total fat, sugar, protein and calcium intake, since these demonstrated a significant unadjusted correlation between the two dietary assessment methods depending on the truncation of the EPIC FFQ data. The mean difference between the two measurements for energy, total fat, sugar, protein and calcium was found to be 2.4 MJ, 22 g, 53 g, 31 g and 203 mg, respectively, indicating that the EPIC FFQ has a bias towards overestimating nutrient intake when compared with the 7-day WDR. More importantly, the 95% confidence intervals for the bias for energy, total fat, sugar, protein and calcium were 1.3–3.6 MJ, 10–33 g, 29–77 g, 22–41 g and 105–301 mg, respectively. The limits of agreement (mean difference between EPIC FFQ and 7-day WDR, $\pm 2\text{SD}$) for energy, total fat, sugar, protein and calcium ranged from 9.3 MJ to -4.5 MJ, 92 g to -49 g, 194 g to -88 g, 90 g to -27 g and 791 mg to -384 mg, respectively. Together, these data indicated a poor agreement between the two dietary methods on both a group and an individual basis.

To assess the validity of the 7-day WDR, average dietary nitrogen and potassium intakes from the 7-day WDR were compared with the 24-hour urine nitrogen and potassium outputs (Table 3). Only 27 samples were available for this analysis due to missing and incomplete urine samples as well as underreporting in the 7-day WDR. Average nitrogen and potassium intakes from the 7-day WDR were 712 and 94 mmol day^{-1} , and average nitrogen and

Table 2 Daily intakes of energy and nutrients based on the EPIC FFQ and 7-day WDR

	7-day WDR ($n = 37$)†		EPIC FFQ ($n = 37$)†		EPIC FFQ truncated for overreporters ($n = 34$)‡		Spearman's r (EPIC FFQ and 7-day WDR)		Spearman's r (EPIC FFQ truncated and 7-day WDR)	
	Mean	SD	Mean	SD	Mean	SD	Unadjusted	Energy-adjusted	Unadjusted	Energy-adjusted
Energy (MJ)	8.0	0.9	10.4	3.6	9.6	2.6	0.33*		0.25	
Protein (g)	62.1	12.6	93.5	30.1	88.9	26.6	0.30	0.31	0.35*	0.27
Total fat (g)	76.5	12.4	98.0	39.8	89.7	29.1	0.52**	0.66**	0.54**	0.67**
Total CHO (g)	257.8	40.7	327.0	122.8	302.7	93.3	0.28	0.50**	0.17	0.51**
Sugar (g)	114.2	33.8	167.1	77.5	152.5	60.4	0.33*	0.57**	0.27	0.55**
Englyst fibre (g)	10.6	5.1	17.9	7.5	17.3	7.4	0.28	0.49**	0.25	0.44**
Calcium (mg)	813	218	1016	273	979	251	0.34*	0.47**	0.40*	0.45**
Sodium (mg)	2634	522	3768	1341	3577	1178	0.29	0.26	0.26	0.19
Potassium (mg)	2347	619	3660	1288	3460	1106	0.27	0.60**	0.35*	0.54**
% Energy										
Protein	13.0	1.9	15.5	2.9	15.7	2.9	0.29		0.25	
Fat	36.2	4.6	35.3	5.4	35.1	5.6	0.61**		0.66**	
CHO	50.8	4.8	49.3	5.6	49.3	5.8	0.47**		0.48**	
Sugar	22.6	6.0	24.9	5.7	24.7	5.8	0.56**		0.56**	

CHO – carbohydrate.

*Correlation significant at $P < 0.05$ (two-tailed); **correlation significant at $P < 0.01$ (two-tailed).

† Excluding underreporters with $\text{EI/BMR} < 1.14$.

‡ Excluding underreporters and overreporters with $\text{EI/BMR} < 1.14$ and $\text{EI/BMR} > 2.5$, respectively.

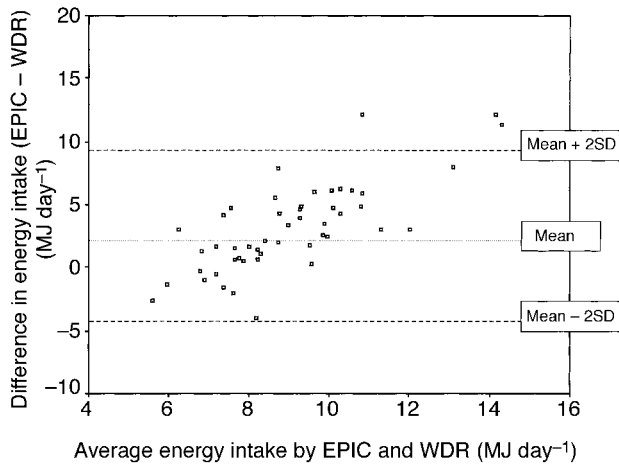


Fig. 1 Individual differences between energy intake from the EPIC FFQ and the 7-day WDR plotted against the mean of energy intake from both the EPIC FFQ and the 7-day WDR

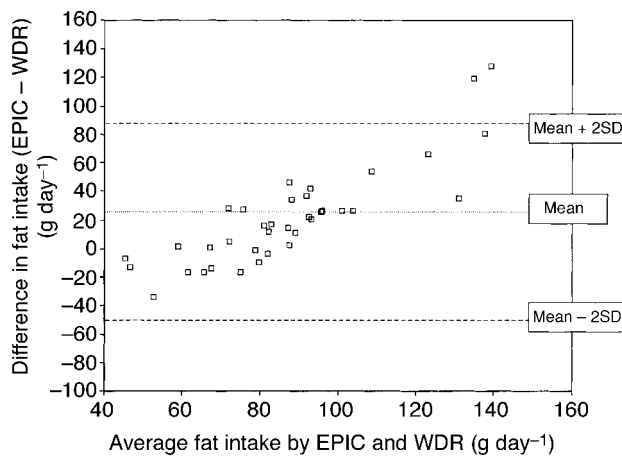


Fig. 2 Individual differences between fat intake from the EPIC FFQ and the 7-day WDR plotted against the mean of fat intake from both the EPIC FFQ and the 7-day WDR

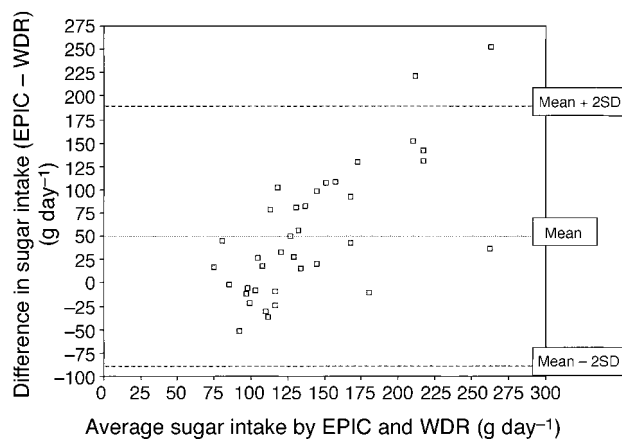


Fig. 3 Individual differences between sugar intake from the EPIC FFQ and the 7-day WDR plotted against the mean of sugar intake from both the EPIC FFQ and the 7-day WDR

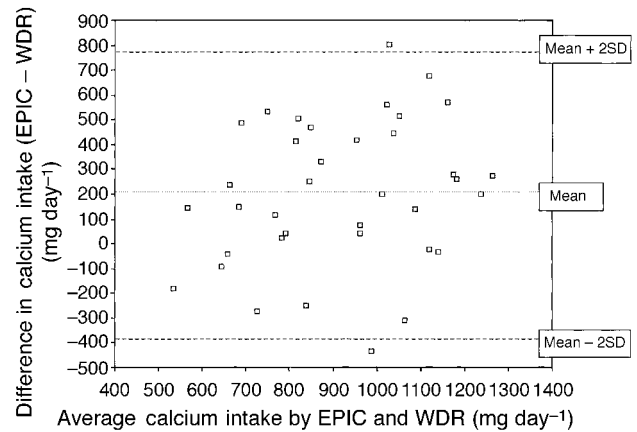


Fig. 4 Individual differences between calcium intake from the EPIC FFQ and the 7-day WDR plotted against the mean of calcium intake from both the EPIC FFQ and the 7-day WDR

potassium excretions in the complete 24-hour urine samples were found to be 482 and 43 mmol day⁻¹, respectively. The average ratio of urinary to dietary nitrogen or potassium was found to be 0.68 and 0.72, respectively. Urinary to dietary ratios of both nitrogen and potassium followed a normal distribution. Correlations between 24-hour urine and dietary nitrogen and potassium from the 7-day WDR were found to be statistically significant (Table 3).

Table 4 shows the ability of the EPIC FFQ to classify individuals into the same third of intake calculated from the 7-day WDR and to misclassify into adjacent and opposite thirds. The proportion of subjects appearing in the same third varied from 37.8% for sodium, calcium and sugar to 48.6% for potassium and carbohydrate, with the median percentage being 45.9%. The percentage of subjects classified into the opposite third varied between 8.1% for potassium and calcium and 16.2% for Englyst fibre, with the median percentage being 10.8%.

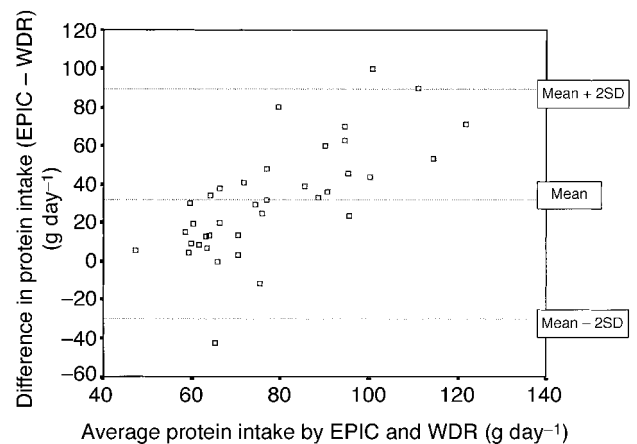


Fig. 5 Individual differences between protein intake from the EPIC FFQ and the 7-day WDR plotted against the mean of protein intake from both the EPIC FFQ and the 7-day WDR

Table 3 Comparison between dietary potassium and nitrogen intakes from different methods of dietary assessment with 24-hour urine potassium and nitrogen

	Potassium			Nitrogen			Correlations	
	Mean (mmol)†	SD	Urine/dietary ratio	Mean (mmol)†	SD	Urine/dietary ratio	24-hour urine and dietary K	24-hour urine and dietary N
24-hour urine	43.4	21.7		481.6	230.7			
7-day WDR	60.1	17.6	0.72	712.1	157.8	0.68	0.78***	0.45*
EPIC FFQ	93.8	35.1	0.46	1066.0	357.1	0.45	-0.04	-0.20

*Correlation significant at $P < 0.05$; ***correlation significant at $P < 0.001$ (two-tailed).

† From 27 samples.

Discussion

Correlation coefficients between the EPIC FFQ and the 7-day WDR on average tended to be small and were only found to be statistically significant for energy, fat, sugar and calcium. However, the performance of the EPIC FFQ was comparable to that of previously evaluated food-frequency questionnaires with reported correlation coefficients for macronutrients in the range 0.3–0.45²³, 0.29–0.54²⁴, 0.13–0.57²⁵, 0.17–0.31²⁶ and 0.39–0.59¹⁴ in adults and 0.35–0.55²⁷ and 0.13–0.33¹¹ in adolescent subjects. Energy adjustment improved the magnitude of the correlation coefficient considerably in the present study. With the exception of protein, the adjustment of all macronutrients improved the correlation significantly.

The EPIC FFQ gave higher mean values for all nutrients than the 7-day WDR. This finding is not unexpected, as earlier studies in Norwegian adolescents²⁷, British adolescents¹¹, British adults^{15,25} as well as Spanish adults²⁶ observed overestimation for most nutrients by food frequency methods over weighed dietary records. In validation studies of nutritional assessment methods, the applied reference method needs to be as accurate and precise as possible. Dietary weighed records are used as the 'gold standard' method in assessing dietary intakes in

free-living individuals. However, Livingstone *et al.*⁶ reported that the 7-day weighed dietary record underestimates food intake in adolescents. The underreported food intake in adolescents was attributed to forgetfulness and lack of compliance, relatively unstructured eating patterns and significant amounts of food eaten away from home. If the 7-day WDR in this study were also biased towards underestimation of habitual food intake, then the validity of the EPIC FFQ would be underestimated.

To examine if the 7-day WDR method gave valid estimates of the usual diet, comparisons were made between the intake values obtained by the 7-day WDR and the biological markers of food intake in 24-hour urine collections. Urinary nitrogen and potassium can be translated into absolute estimates of nitrogen and potassium intake on the basis of 24-hour urine collections²⁸. The 7-day WDR correlated significantly with both the 24-hour nitrogen and potassium values. The correlation coefficient between urinary potassium and dietary intake from the 7-day WDR ($r = 0.78$) was higher than correlations reported in previous studies^{14,29,30}. However, since the urine samples were collected on the same day throughout the study, this result does not reflect a day-to-day variation of the biomarker. The correlation coefficient between urinary nitrogen and dietary intake from the 7-day WDR ($r = 0.45$) was lower than published correlations between urinary and dietary nitrogen^{14,26,29,30}. The average urine N/dietary N ratio of 0.68 in the present study was comparable to the ratio of the lowest quintile in the study of Bingham *et al.*²⁹. Reasons for a low correlation coefficient between dietary and urinary nitrogen could be that (1) the reported protein intake did not represent the true dietary intake, (2) the collected urine did not represent a true 24-hour collection, and (3) only one 24-hour urine collection increases the variation.

Protein intake correlated very poorly between the dietary assessment methods in this study, both after energy adjustment and truncation of the EPIC FFQ data. It is possible that both the EPIC FFQ as well as the 7-day WDR did misclassify the true protein intake. On the other hand, it is also possible that the criteria for a 24-hour urine sample were not stringent enough, since samples within two standard deviations from the mean creatinine

Table 4 Percentage of subjects classified by the EPIC FFQ into the same or different third of consumption by the 7-day WDR

Nutrient	Same third	Adjacent third	Opposite third
Energy	40.5	48.6	10.8
Protein	40.5	48.6	10.8
Total fat	45.9	43.2	10.8
Total CHO	48.6	37.8	13.5
Sugar	37.8	48.6	13.5
Englyst fibre	45.9	37.8	16.2
Calcium	37.8	54.1	8.1
Sodium	37.8	48.6	13.5
Potassium	48.6	43.2	8.1
% Energy			
Protein	29.7	56.8	13.5
Fat	51.4	43.2	5.4
CHO	54.1	37.8	8.1
Sugar	51.4	40.5	8.1

CHO – carbohydrate.

concentration were designated complete. Most importantly, we were only able to collect one single 24-hour urine sample from the study subjects. The average coefficient of variation in urine nitrogen excretion is around 13%²⁸, and can be substantially reduced if several samples are obtained. However, pupils were very reluctant to supply even one 24-hour urine sample.

Nevertheless, the correlation between the 7-day WDR and urinary potassium was found to be similar to that in previous studies, and good agreements were found on both a group and an individual basis using the Bland–Altman analysis. This result is reassuring in that, at least in terms of mineral intake, the 7-day WDR did classify individuals correctly.

It is important to recognise that databases for analysis, portion sizes and time periods differ between the two dietary assessment methods. However, the ability of the questionnaire to correctly classify individuals into high, medium or low consumers of individual nutrients was comparable to that in an earlier study, where subjects were classified for macronutrient intake in either the same or opposite third at 41–52% or 9–13%, respectively²³.

Since the EPIC FFQ was designed to be used with an adult population, the contribution of certain foods to the diets of children is undoubtedly very small (i.e. fish roe and *taramasalata*). Furthermore, questions regarding the preparation of foods and the inability of children to split composite meals into food ingredients were other factors that complicated the completion of the EPIC FFQ. Other conditions that would need to be re-evaluated are the portion size estimates used in the EPIC FFQ. It seems obvious that these factors will need to be addressed if the questionnaire should be used with an adolescent population.

Although the ability of the EPIC FFQ to classify individuals into thirds was acceptable, agreement between the EPIC FFQ and the 7-day WDR for energy, total fat, sugar and calcium was very poor on both a group and an individual basis. Furthermore, this finding is contrary to the fact that significant correlation coefficients were observed for these four nutrients and stresses the importance of assessing the between-method differences using the Bland–Altman analysis. The limits of agreement were as far apart as 13.4 MJ, 120 g, 270 g, 120 g and 1170 mg for energy, fat, sugar, protein and calcium, respectively, which is unacceptable for dietary assessment purposes. These results demonstrate that the EPIC FFQ is inappropriate for estimating absolute intakes in adolescents, but that the food frequency method can be applied to correctly classify groups into low, medium and high consumers and therefore identify risk groups.

Acknowledgements

We are very grateful to Harris Academy in Dundee (UK) and to all pupils who participated. We acknowledge

funding from the Chief Scientist Office, Edinburgh (UK) for this project.

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