British Journal of Nutrition (2009), **102**, S87–S117
doi:10.1017/S0007114509993163






# Dietary assessment methods for micronutrient intake in infants, children and adolescents: a systematic review

Adriana Ortiz-Andrellucchi[1], Patricia Henríquez-Sánchez[1], Almudena Sánchez-Villegas, Luis Peña-Quintana[1], Michelle Mendez[2] and Lluís Serra-Majem[1]*

[1]*Nutrition Research Group, Department of Clinical Sciences, Centre for Health Sciences, University of Las Palmas de Gran Canaria, PO Box 550, 35080 Las Palmas de Gran Canaria, Spain*

[2]*Center for Research in Environmental Epidemiology, Municipal Institute of Medical Research. Biomedical Research Park, Barcelona, Spain*

*(Received 15 June 2009 – Revised 2 October 2009 – Accepted 1 November 2009)*

A systematic literature search identified studies validating the methodology used for measuring the usual dietary intake in infants, children and adolescents. The quality of each validation study selected was assessed using a European micronutrient Recommendations Aligned-developed scoring system. The validation studies were categorised according to whether the study used a reference method that reflected short-term intake (<7 d), long-term intake (≥7 d) or used biomarkers. A correlation coefficient for each nutrient was calculated from the mean of the correlation coefficients from each study weighted by the quality of the study. Thirty-two articles were included in the present review: validation studies from infants (1–23 months); child preschool (2–5 years); children (6–12 years); adolescents (13–18 years). Validation of FFQ studies in infants and preschool children using a reference method that reflected short-term intake showed good correlations for niacin, thiamin, vitamins $B_6$, D, C, E, riboflavin, Ca, K, Mg, Fe and Zn (with correlations ranging from 0·55 for vitamin E to 0·69 for niacin).Regarding the reference method reflecting short-term intake in children and adolescents, good correlations were seen only for vitamin C ($r$ 0·61) and Ca ($r$ 0·51). Using serum levels of micronutrient demonstrated that the 3 d weighed dietary records was superior to the FFQ as a tool to validate micronutrient intakes. Including supplement users generally improved the correlations between micronutrient intakes estimated by any of the dietary intake methods and respective biochemical indices.

**Infants: Children: Adolescents: Dietary assessment methods: Systematic review: Validation: Micronutrients**

Growth in children from birth through adolescence is an extremely complex process. It is influenced not only by the genetic make-up of the individual but also by environmental factors, medical illnesses and nutritional status[1]. Dietary assessments among infants and preschool children are complicated by the facts that dietary habits change rapidly in infancy, parents may share the responsibility for the child with other adults, e.g. in day-care, and finally not all food served to the infants are consumed, resulting in their disposal[2].

In the school age years, children experience enormous cognitive, emotional and social growth and development. Children transition from consuming most food intake under adult control and supervision to taking increasing responsibility for their food choices. The cognitive abilities required to self-report food intake include an adequately developed concept of time, a good memory and attention span and knowledge of the names of food[3,4]. The need for adult assistance in dietary reporting is also driven by the limited scope of the child's experience and knowledge of food preparation[5].

During adolescence, children undergo profound biological, emotional, social and cognitive changes to reach adult maturity. Adolescents' need for energy and all nutrients significantly increases to support the rapid rate of growth and development. Moreover, although appetite and food intake tend to increase, psychosocial characteristics often lead to the development of high-risk nutritional behaviours such as excessive dieting, adoption of fad diets or excessive alcohol consumption. The high prevalence of overweight and obesity, eating disorders, adolescent pregnancy and the lack of consumption of five fruits and vegetables a day constitute some of the nutritional challenges facing adolescents[6].

Research conducted as part of the European Commission's European micronutrient Recommendations Aligned Network of Excellence[7] has focused on extensive literature reviews addressing the validation of methods used to assess intake of micronutrients, $n$-3 fatty acids and of special population groups, including pregnant women, infants, children, adolescents and elderly people. In this review, studies validating

---

**Abbreviations:** BM, biomarker; EDR, estimated dietary records; 24HR, 24 h dietary recall; WDR, weighed dietary records; YAQ, Youth/Adolescent Questionnaire.

On behalf of EURRECA's RA.1.1 'Intake Methods' members: Serra-Majem L (Coordinator), Cavelaars A, Dhonukshe-Rutten R, Doreste JL, Frost-Andersen L, García-Álvarez A, Glibetic M, De Groot L, De Vries J, Gurinovic M, Henríquez-Sánchez P, Naska A, Ngo J, Novakovic R, Ortiz-Andrellucchi A, Øverby NC, Pijls L, Ranic M, Ribas-Barba L, Ristic-Medic D, Román-Viñas B, Ruprich J, Saavedra-Santana P, Sánchez-Villegas A, Tabacci G, Tepsic J, Trichopoulou A, van 't Veer P, Vucic V, Wijnhoven TMA.

* **Corresponding author:** Lluis Serra-Majem, fax +34 928 453475, email lserra@dcc.ulpgc.es

dietary methods for assessing micronutrient intake in infants, children and adolescents are presented.

## Material and methods

The research question applied to the systematic review was 'which dietary methods are reliable for the assessment of micronutrient intake in infants, children and adolescents?' The main stages of the review are illustrated in Fig. 1. The review included English, Spanish, French, Italian, Portuguese and German articles, without limits on time frame or country published before April 2008. Stage 1 of the review involved searching for publications using electronic databases (MEDLINE and EMBASE). The MeSH terms used in the general search were: nutritional assessment, diet, nutritional status, dietary intake, food intake, validity, validation study, reproducibility, replication study, correlation coefficient and correlation study in the title and abstract. As a second specific search, the following words were included: infants (1–23 months), preschool child (2–5 years), children (6–12 years), adolescents (13–18 years), 'dietary assessment', 'dietary intake', 'nutrition assessment', 'diet quality', reliability, reproducibility, validit* and correlate* as free text in the title and abstract. Additional publications were identified from references published in the original papers. At stage 2 of the review, the titles and abstracts were analysed by two independent reviewers and the exclusion criteria were applied (Table 1). At stage 3, studies that fulfilled the inclusion criteria were analysed for relevance to the research question.

The selected studies were then classified into three different types according to the reference method applied in the validation studies: (1) reference method assessing intake of <7 d (including 24 h dietary recall (24HR), estimated dietary records (EDR) and weighed dietary records (WDR)), classified as reflecting short-term intake; (2) reference method assessing intake of ≥7 d, reflecting more long-term intake; (3) reference method that employed the use of a biomarker (BM). Furthermore, the different studies included in this review were scored according to a quality score system developed by European micronutrient Recommendations Aligned. The studies were rated according to the sample size, the statistics used to validate the method, the procedure of data collection, the consideration or not of seasonality and the inclusion or not of vitamin supplement use. (For details see the article in this supplement 'Evaluating the quality of dietary intake validation studies'). A total score was calculated according to the mean of the correlation coefficients weighted by the quality score of the validation study. It was considered a poor method for assessing specific nutrient intake when the correlation between methods was <0·30. Methods whose correlations were between 0·30 and 0·50 were regarded as acceptable for assessing nutrient intake. Good methods were those whose correlations were between 0·51 and 0·70, and finally, when the correlation was >0·70 the method was considered very good.

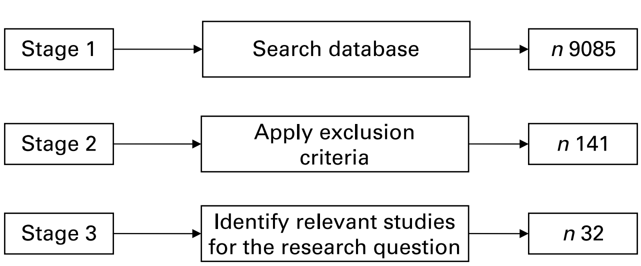


**Fig. 1.** Main stages of the systematic review process.

**Table 1.** Inclusion and exclusion criteria

Inclusion criteria
1. Studies on micronutrient intake in infants, children and adolescents
2. Validation study in human subjects

Exclusion criteria
1. Studies describing the content of foods in nutrients, additives or contaminants.
2. Studies exclusively focused on diseased or institutionalised persons.
3. Articles presenting reference values for food consumption, nutrient intake, biochemical markers and anthropometric measurements.
4. Articles establishing associations between food consumption, nutrient intake, biological variables, biochemical markers and anthropometric measurements.
5. Studies relating diseases to food consumption or nutrient intake.
6. Intervention studies and other therapeutic studies with nutrients or drugs related to the metabolism of these nutrients.
7. Calibration studies and those discussing statistical methods.
8. Studies evaluating the physiological effects of foods, nutrients and in relation to their genetic determinants.
9. Studies in animals.
10. Studies written in other languages than English, Spanish, French, Italian, Portuguese and German and those without abstract.

## Results

A total of thirty-two publications[2,8–39] were selected for inclusion, with information on each validation study, ordered by publication year, summarised in Table 2. Fifteen of the publications showed results from European countries (Norway, Greece, Belgium, Italy, Denmark, United Kingdom and Finland), fifteen from American countries (United States of America, Brazil and Canada), one study from Australia and one study from New Zealand. The number of participants varied from 17 to 741 in the selected studies. In eight of the studies presented[11,13–16,26,34,36], only one type of micronutrient was analysed, while in the rest of the publications included in this review, correlations for a wide variety of micronutrients were observed, and a total of twenty micronutrients were analysed. Tables 3 and 4 show information on the correlation between methods and other statistics in the validation studies in infants, children and adolescents for twelve vitamins and eight minerals, respectively.

### *Infants*

This group included infants aged 1–23 months. Of the thirty-two articles included in the present review, seven showed data on the validation of methods used to assess micronutrient intake in infants[2,8,9,17,21,22,24]. Evaluating the quality of these validation studies resulted in quality scores ranging from 2·5 to 5. All the studies evaluated micronutrient intake in infants using a FFQ, and only one article applied four 24HR as an additional dietary assessment method[22]. Different FFQ were validated for which wide variations in


https://doi.org/10.1017/S0007114509993163 Published online by Cambridge University Press

**Table 2.** Characteristics of included studies

| Author/year publication and country | Participants/age group | Dietary method | Reference method | Micronutrient | Conclusions |
|---|---|---|---|---|---|
| Marriott *et al.* (2008)[8,9] UK | Fifty infants aged 6 months & fifty infants aged 12 months Infants | FFQ Previous 7 (6 months) or 28 (12 months) days intake; thirty-four items at 6 months (including ten categories of commercial baby foods); seventy-eight items at 12 months Portion size estimated using household measures. Exact frequencies Interviewer-administered | 4 d weighed dietary records (within 15 days following FFQ completion) For breast-fed infants, the length of each feeding was recorded. | Na, K, Ca, Mg, P. Fe, Zn, Cu, retinol, vitamins D, E, C, $B_6$, $B_{12}$, thiamin, riboflavin, niacin, folic acid | The interviewer-administered FFQ are useful tools for assessing energy and nutrient intakes of healthy infants at 6 and 12 months. |
| Holmes *et al.* (2008)[10] UK | 124 children aged 2–17 years Preschool children Children Adolescents | (i) Four multipass 24 h dietary recalls. Portion size in household measures or using colour photographs Interviewer-administered (ii) 4 d food checklist or daily record of foods eaten; portion size in household measures (iii) 4 d semi-weighed method Food consumed at home weighed and estimated intake allocated to members; supplemented with diary for consumption away from home | 4 d weighed dietary records (weighed inventory). Foods consumed and leftovers weighed for each participant individually. | Ca, Fe, retinol, thiamin, vitamin C | Four 24 h recalls were recommended as the most appropriate method to estimate dietary intakes in low-income households based in part on data to be presented in future publications. |
| Moore *et al.* (2007)[11] Canada | 162 male children aged 9–12 and 14–16 years Children Adolescents | Rapid assessment method (RAM) FFQ thirty-two food items; intakes refer to a ‘typical day’. Included supplements. Visual aids to approximate portion size. Interviewer-administered | Single 24 h dietary recalls Visual aids Interviewer-administered during same interview as RAM | Ca | Correlations between questionnaire and recalls were significant but moderate, though the RAM overestimates daily Ca intake as compared with the 24 h recall method in both children and adolescent males. |
| Lillegaard *et al.* (2007)[12] Norway | Forty-five girls and fifty-five boys 9 years old Children | 4 d pre-coded food diaries (PFD) 277 food items Portion size in household measures or using colour photographs | 4 d weighed dietary records (same days of week as PFD, 1 week later) Records included supplements | Retinol, vitamins D, C, thiamin, riboflavin, Ca, Fe | The PFD method is promising as a tool for assessing food intake in large surveys among children. |
| Magkos *et al.* (2006)[13] Greece | 351 children (189 girls and 162 boys) Mean age 11·9 years Children | 30-item FFQ Past 12 months intake Standard reference portions Self-administered | Single Multipass 24HR Interviewer-administered subsequent to FFQ. Standard household measures (cups, tablespoons, etc) & Picture food models | Ca | The FFQ can be used to discriminate high *v.* low Ca intakes, but results do not support its use in epidemiological studies for the quantitative assessment of individual Ca intake. |
| Harnack *et al.* (2006)[14] USA | 248 children Aged 11–14 years Children Adolescents | 10-item FFQ Past month’s intake. Portion size alternatives included. Frequency categories up to 3/d. Self-administered. | Three 24 hour dietary recalls by phone subsequent to FFQ. 2D food model visual aids mailed | Ca | The Ca FFQ evaluated in this study may be useful where a brief instrument is needed, with a moderate association with estimates from dietary recalls. |
| Huybrechts *et al.* (2006)[15] Belgium | 509 preschool children (2·5–6·5 years) Preschool children | FFQ Past 12 months intake six frequency categories up to one | 3 d estimated dietary records (three consecutive days) | Ca | This FFQ tended to underestimate preschool children’s Ca intake but had a fairly good ability to |

**Table 2.** *Continued*

| Author/year publication and country | Participants/age group | Dietary method | Reference method | Micronutrient | Conclusions |
|---|---|---|---|---|---|
| | | daily intake. Forty-seven food items. Completed by the child's parent or guardian. Portion size alternatives included. Self-administered. | | | classify subjects. |
| Bertoli *et al.* (2005)[16] Italy | Eighteen children aged 6–10 years nineteen adolescents aged 16–20 years Children Adolescents | FFQ 136 food items (period of intake not reported). Included supplements. Portion size estimated using colour photographs (small, medium, large). Seven frequency categories. Interviewer-administered; children aided by parents as needed. | 7 d weighed dietary records | Ca | The FFQ has proved adequate to rank a paediatric population in terms of Ca intake. |
| Williams & Innis (2005)[17] Canada | 148 infants aged 8–26 months Infants | FFQ 191 foods Previous 2 weeks intakeIncluded supplements Interviewer-administered | (i) 3 d estimated dietary records (3 consecutive weekdays and 1 weekend day). Household measuring utensils provided Completed 1 week before food records (ii) Biomarkers: Serum markers of Fe status (ferritin, haemoglobin) | Fe, vitamin C, Ca | FFQ need further development before they can be used to advance assessment of Fe intake and status in infants (poor correlations with biomarkers). |
| Andersen *et al.* (2004)[18,19] Norway | 187 2-year-old children Preschool children | Semi-quantitative FFQ (SFFQ) Previous 14 days intake. 125 food items Included supplements. Portion size estimated using food photographs or household measures Self-administered | 7 d weighed dietary records (7 consecutive days) For breast-fed infants: how often breast milk was given. | Vitamins A, D, E, C, thiamin, riboflavin, Ca, Fe | The SFFQ may be a valuable tool for measuring average intakes of energy, macronutrients and several food items for a 2-year-old population in Norway. |
| Slater *et al.* (2003)[20] Brazil | Seventy-nine adolescents Aged 14–18 years Adolescents | FFQ for adolescents (AFFQ) Seventy-six food items. Past 6 months intake seven frequency category. Single reference portion sizes listed. Use of interviewers not reported | Three 24 h dietary recalls At intervals of 45 days before FFQ administration | Retinol, vitamin C, Ca, Fe | The FFQ provides a reliable scale for categorising individuals by level of past intake of most nutrients, excluding retinol and Fe. |
| Marshall *et al.* (2003)[21] USA | 240 children 6 &12 months3 & 5 years Infants Preschool children | Quantitative beverage FFQ; seven food items or groups described. Intakes in preceding week: at 6 and 12 months parents reported average daily intake; at 3 and 5 years average number of servings per week and usual serving size for each beverage Self-administered. | 3 d weighed dietary records (2 weekdays and 1 weekend day) Intakes from food and beverages (reported here) as well as beverages only (similar results) analysed | Ca, vitamin D | A quantitative beverage frequency questionnaire can provide a relative estimate of beverage, Ca and vitamin D intakes |

**Table 2.** *Continued*

| Author/year publication and country | Participants/age group | Dietary method | Reference method | Micronutrient | Conclusions |
|---|---|---|---|---|---|
| Andersen *et al.* (2003)[2] Norway | Sixty-four infants 12-month-old Infants | Semi-quantitative FFQ; Forty-four questions about 140 food items and supplements Parents asked to keep in mind past 14 days intake. Food photographs or household measures to estimate portions. For breast-fed infants: how often breast milk was given per 24 h Self-administered | 7 d weighed dietary records (four consecutive days, 1-week interval, and three consecutive days) For breast-fed infants: how often breast milk was given. | Vitamins A, D, E, C, thiamin, riboflavin, Ca, Fe | The capability of the questionnaire to rank infants according to intake of nutrients and food items was moderate. |
| Parrish *et al.* (2003)[22] USA | Sixty-eight children aged 1–3 years (biomarker *n* 38) Infants Preschool children | (i) FFQ; Past 12 months intake. 111 food items. Completed by the child's parent or guardian at end of study period (self-administered). Standard reference portions. (ii) Four 24 h dietary recalls Interviewer-administered to parent and alternate caregiver every 3 months before FFQ | Biomarkers Plasma levels of vitamins C, D, retinol, β-carotene and α-tocopherol (vitamin E) | Vitamins D, C, retinol, β-carotene, α-tocopherol (vitamin E) | The FFQ shows mostly good agreements with multiple 24 h recalls and some biomarkers in preschool children. |
| Lietz *et al.* (2002)[23] UK | Fifty children aged 11–13 years (biomarker *n* 27) Children | (i) EPIC FFQ; 130 items. Interviewer-administered. Past 12 months intake; nine frequency categories. Standard reference portions used. (ii) 7 d weighed dietary records subsequent to FFQ. Food photographs to estimate portions when weighing not possible. | (i) 7 d weighed dietary records After FFQ. Food photographs (ii) Biomarkers: 24 h urine K | Ca, Na, K | The EPIC FFQ is not an appropriate method for estimating absolute intakes in adolescent population. However, it seems adequate to classify low, medium and high consumers and might therefore be used to identify population groups at risk. |
| Blum *et al.* (1999)[24] USA | 233 children Aged 1–5 years Infants Preschool children | Harvard Service FFQ (HFFQ) eighty-four food items + nineteen items on supplements, food habits. Past 4-week intakes. Age-appropriate portions applied (not shown on FFQ). Completed by the child's parent or guardian (self-administered). Mean of two FFQ 1 month apart. | Three 24 h dietary recalls at 7–10 d intervals between 1st and 2nd FFQ. Two recalls on weekdays and one recall on weekend. Interviewer-administered by telephone or in person. | Vitamins A, E, C, $B_6$, $B_{12}$, thiamin, riboflavin, niacin, folate, Ca, Zn, Mg, Fe | The HFFQ is a simple self-administered questionnaire completed by the child's parent or guardian and is useful in assessing the diets of Native American and Caucasian children. |
| Field *et al.* (1999)[25] USA | 109 students from fourth to seventh grade Children | FFQ Past 12 months intake Self-administered (read aloud by teachers) ninety-seven food items, standard reference portions used. | Four 24 h dietary recalls (collected on non-consecutive days approximately 3 months apart) Interviewer-administered before FFQ Portion size in household measures or using colour photographs | Vitamin C, P, Ca, Fe | Sixth and seventh grade students demonstrated the ability to provide valid estimates of intake, but children in the fourth and fifth grades experienced some difficulty in completing the FFQ. |
| Taylor & Goulding (1998)[26] New Zealand | Forty-one girls and twenty-six boys aged 3–6 years | FFQ Past 12 months intake thirty-five food and | 4 d estimated dietary records | Ca | The short Ca FFQ tended to overestimate actual Ca intakes in young children. However, the |

**Table 2.** *Continued*

| Author/year publication and country | Participants/age group | Dietary method | Reference method | Micronutrient | Conclusions |
|---|---|---|---|---|---|
| | Preschool children Children | drink items | | | FFQ demonstrated good ability to classify subjects into extremes of Ca intake. |
| Mølgaard *et al.* (1998)[27] Denmark | Twenty-three children aged 13–14 years Adolescents | FFQ Self-administered together with their parents. Past 1 month's intake eighty-eight food items. Exact frequencies used Portion size in household measures | 3 d weighed dietary records Completed after FFQ 2 weekdays, 1 weekend day | Ca, P | The FFQ is able to rank children according to their intake of Ca and P. |
| Green *et al.* (1998)[28] Canada | 105 adolescent females aged 16–19 years Adolescents | (i) FFQ Self-administered 116 food items. Included supplements Past 12 months intake. Standard reference portion sizes in household measures (ii) 3 d weighed records (weekdays, weekends) | Biomarkers Serum folate and serum vitamin $B_{12}$ | Folate, vitamin $B_{12}$ | The FFQ and 3 d-WDR are valid measure of assessing folate intakes in young women compared with biomarkers. Both appear useful in determining vitamin $B_{12}$ intake, but only when supplement users are included. |
| Rockett *et al.* (1997)[29] USA | 261 children and adolescents (aged 9–18) Children Adolescents | Youth/Adolescent Questionnaire (YAQ) Self-administered 131 items; standard reference portions. Past 12 months intake. Mean of two questionnaires administered approximately 1·5 years apart | Three 24 h dietary recalls at approximately 5-month intervals, with detailed probing. Administered between 1st and 2nd FFQ. | Vitamins A, E, C, $B_6$, $B_{12}$, retinol, thiamin, riboflavin, niacin, folate, Ca, P, Mg, Fe, Zn, Cu, K, Na | A simple self-administered questionnaire completed by older children and adolescents can provide nutritional information about this age group. |
| Bellù *et al.* (1996)[30] Italy | 333 children (158 girls, 165 boys) aged 8–10 years Children | FFQ 116 food items | 24 h dietary recalls Interviewer-administered (children's mothers) 3D-food models | Ca, Fe | Average estimates with the FFQ agree with findings obtained by 24 h recalls for most nutrients. The FFQ we designed is appropriate in the northern Italian paediatric population. |
| Arnold *et al.* (1995)[31] Canada | 707 girls aged 7–12 years Children | FFQ 160 food items. Adapted from Block FFQ (intakes in past year). Standard reference portions. Exact frequencies Interviewers reviewed reponses. | Two 7 d estimated dietary records | Vitamins A, C, riboflavin, thiamin, retinol, β-carotene | 70 % of subjects were categorised in the highest or lowest quartile by both FFQ and 7 d EDR for energy and several nutrients. |
| Bellù *et al.* (1995)[32] Italy | Eighty-eight children (forty-nine girls, thiry-nine boys) aged 9–12 years Children | FFQ 116 food items. Reference portion sizes Self-administered | 7 d estimated dietary records 3D-food models Completed after FFQ | Vitamins A, C, E, $B_6$, riboflavin, thiamin, Ca, Fe | Intake estimates for most nutrients were comparable, but there were significant differences in estimates for several nutrients. Use of nutrient density reduced misclassification. |
| Andersen *et al.* (1995)[33] Norway | Forty-nine adolescents (17–18 years) Adolescents | FFQ 190 food items. Portion size in household measures, variable portion sizes included. Meal-based reporting Exact frequencies. Past 12 months intake | 7 d weighed dietary records 4 consecutive days, 1-week interval and three consecutive days (five week days and two week-end days) Completed 2–3 months after FFQ | Retinol, vitamins D, C, thiamin, riboflavin, Ca, Fe, Mg | The questionnaire is able to rank subjects according to the tested nutrients (0–8 % classified in extreme quartiles), except vitamin D (12 % in extreme quartile). |

**Table 2.** *Continued*

| Author/year publication and country | Participants/age group | Dietary method | Reference method | Micronutrient | Conclusions |
|---|---|---|---|---|---|
| Iannotti *et al.* (1994)[34] USA | Seventeen preschool children 2–4 years Preschool children | Willett FFQ Previous 7 days intake Self-administered six frequency category | Three 24 h dietary recalls before FFQ. | Na | The questionnaire did not provide an accurate assessment of measured intake and could not replace the dietary recall. |
| Byers *et al.* (1993)[35] USA | Ninety-seven children aged 6–10 years Children | FFQ Past 3 months intake Completed by the child's parent Interviewer-administered. 111 food items Frequency categories based on Willett | Biomarkers Serum levels of vitamins C, A and E | Vitamins C, A, E | Children in the highest *v.* lowest fruit and vegetable intake quartiles had 31 % higher serum vitamin C. Parental reports of young children's diet using FFQ methods are accurate enough to be useful in nutritional screening. |
| Lytle *et al.* (1993)[36] USA | Forty-nine children aged 8 years old Children | 24 h dietary recalls administered to the child, aided by a previous day food record (listing) Interviewer-administered. 3D food models and utensils. | Observed intakes (parents and trained staff) | Na | The 24 h recall assisted by food records is a valid method for assessing the dietary intake of children as young as 8 years old. |
| Stein *et al.* (1992)[37] USA | 224 preschool children (baseline aged 44–60 months) Preschool children | Willett semi-quantitative FFQ Past 6 months intake. Completed by the child's parent. Interviewer-administered. Mean of two FFQ completed at 6 months intervals. Reference portion sizes adapted for children. | Four 24 h dietary recalls Interviewer-administered before each FFQ 3D-food models | Na, K, Ca | Agreement between the two methods in assigning individuals to energy-adjusted quintiles was moderate, as were correlations between energy-adjusted intakes. |
| Jenner *et al.* (1989)[38] Australia | 225 children Aged 11–12 years Children | FFQ 175 food items. Previous 7 days intake. Meal-based reporting. six frequency categories. No portions on FFQ (average portions from records applied). Administered separately to (i) children and (ii) parents. A subset of the first 1–3 diet records were also used as an alternative intake estimate. | Fourteen 24 h dietary records Completed over 3-month period after FFQ | K, Ca | Poor agreement between the diet records and the FFQ completed either by children or parents. In contrast, agreement between the reference method and 1–3 diet records in the series was relatively good. |
| Räsänen L. (1979)[39] Finland | 741 children aged 5–13 years Preschool children Children Adolescents | Single 24 h dietary recalls Interviewer-administered Completed by the child's mothers Included supplements Portion size in household measures | Diet history Past 12 months intake Interviewer-administered | Ca, Fe, vitamins A, C, thiamin, riboflavin, niacin | Neither of the methods can be considered suitable for the measurement of an individual child's dietary intake. |

24 HR, 24 h diet recalls; EPIC, european prospective investigation of cancer; WDR, weighed dietary record; EDR, estimated dietary record.

**Table 3.** Validation studies in infants, children and adolescents: vitamins

| Author/year publication/country/ (quality index) | *n*/age group | Methods/ no FFQ items, portion sizes | Correlation between methods/other statistics | |
|---|---|---|---|---|
| Vitamin A | | | | |
| Andersen *et al.* (2003)[2] Norway (4·5) | *n* 64<br>12 months<br>Infants | FFQ *v.* 7 d WDR<br>140 items. HH measures or food photographs | Absolute intake<br>CC 0·34 | Median ($P_{25}$–$P_{75}$) (μg)<br>FFQ 1358 (1008–3029)<br>WDR 681 (490–834)*** |
| Blum *et al.* (1999)[24] USA (2·5) | *n* 233<br>1–5 years<br>Infants<br>Preschool children | FFQ *v.* three 24 HR<br>eighty-four items. | CC 0·49 | Mean (SD) (RE)<br>24 HR 1035 (569)<br>FFQ 1176 (449) |
| Andersen *et al.* (2004)[18,19] Norway (5) | *n* 187<br>2 years old<br>Preschool children | FFQ *v.* 7 d WDR<br>125 items. HH measures or food photographs | Absolute intake<br>CC 0·59*** | Median ($P_{25}$–$P_{75}$) (μg)<br>FFQ 1586 (1130–2230)<br>WDR 694 (473–1027)*** |
| Räsänen L. (1979)[39] Finland (5) | *n* 741<br>5–13 years<br>Preschool children<br>Children<br>Adolescents | 24 HR *v.* DH | CC 0·20 | Mean DH: 1650; 24 HR: 1061 |
| Byers *et al.* (1993)[35] USA (2·5) | *n* 97<br>6–10 years<br>Children | FFQ *v.* BM<br>111 items | Crude 0·14<br>Adjusted 0·17 | |
| Arnold *et al.* (1995)[31] Canada (3·5) | *n* 707<br>7–12 years<br>Children | FFQ *v.* 14 d EDR<br>160 items. Standard reference portions | Pearson CC 0·49† | |
| Bellù *et al.* (1995)[32] Italy (3·5) | *n* 88<br>9–12 years<br>Children | FFQ *v.* 7 d EDR<br>116 items. Reference portion sizes | Raw nutrient 0·06<br>Nutrient density 0·13 | Mean (SD)<br>EDR 419 (740)<br>FFQ 371 (157) |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261<br>9–18 years<br>Children<br>Adolescents | YAQ *v.* three 24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·39<br>14–18 years CC 0·37 | Mean (SD) (IU)<br>24 HR 6755 (5023)<br>YAQ 9228 (4317) |
| Retinol | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* 50<br>6 months<br>Infants | FFQ *v.* 4 d WDR<br>thirty-four items. HH measures | Energy adjusted<br>CC 0·76 | Median (μg)<br>FFQ 597<br>WDR 531 |
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50<br>12 months<br>Infants | FFQ *v.* 4 d WDR<br>seventy-eight items. HH measures | Energy adjusted<br>CC 0·58 | Median (μg)<br>FFQ 559<br>WDR 400 |
| Parrish *et al.* (2003)[22] USA (3·5) | *n* 38<br>1–3 years<br>Infants<br>Preschool children | FFQ *v.* BM 111 items. Standard reference portions | CC 0·01 | |
| | | 24 HR *v.* BM | CC 0·35 | |
| Holmes *et al.* (2008)[10] UK (3) | *n* 124<br>2–17 years<br>Preschool children<br>Children<br>Adolescents | 24 HR *v.* 4 d WDR | Males-Mean difference<br>2–10 years 77 ($P = 0.058$)<br>11–17 years 65 ($P = 0.280$) | Females-Mean difference<br>2–10 years 155 ($P = 0.008$)<br>11–17 years 57 ($P = 0.633$) |
| | | FC *v.* 4 d WDR | Males-Mean difference<br>2–10 years 68 ($P = 0.135$) | Females-Mean difference<br>2–10 years 75 ($P = 0.076$) |

**Table 3.** *Continued*

| Author/year publication/country/ (quality index) | *n*/age group | Methods/ no FFQ items, portion sizes | Correlation between methods/other statistics | | | |
|---|---|---|---|---|---|---|
| | | | 11–17 years 19 ($P = 0·808$) | 11–17 years −25 ($P = 0·851$) | | |
| | | SW *v.* 4 d WDR | Males-Mean difference<br>2–10 years −4 ($P = 0·935$)<br>11–17 years −21 ($P = 0·821$) | Females-Mean difference<br>2–10 years 44 ($P = 0·299$)<br>11–17 years −27 ($P = 0·826$) | | |
| Arnold *et al.* (1995)[31] Canada (3·5) | *n* 707<br>7–12 years<br>Children | FFQ *v.* 14 d EDR<br>160 items. Standard reference portions | Pearson CC 0·30 | | | |
| Lillegaard *et al.* (2007)[12] Norway (3·5) | *n* 100<br>9 years old<br>Children | PFD *v.* 4 d WDR<br>277 items. HH measures or colour photographs | Boys-Median ($P_{25}$– $P_{75}$) (µg)<br>PFD 854 (489, 1304)<br>WDR 800 (498, 1173)<br>CC 0·62*** | Girls-Median ($P_{25}$– $P_{75}$) (µg)<br>PFD 876 (636, 1323)<br>WDR 695 (506, 987)<br>CC 0·40** | | |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261<br>9–18 years<br>Children<br>Adolescents | YAQ *v.* three 24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·44<br>14–18 years CC 0·51 | Mean (SD) (IU)<br>24 HR 2917 (2442)<br>YAQ 3436 (2109) | | |
| Slater *et al.* (2003)[20] Brazil (4) | *n* 79<br>14–18 years<br>Adolescents | FFQ *v.* three 24 HR<br>76 items. Single reference portion size listed | Non-adjusted 0·28*<br>Energy adjusted 0·06<br>Deattenuated 0·10 | Mean (SD) (µg)<br>24 HR 745 (831)<br>FFQ 614 (243) | | |
| Andersen *et al.* (1995)[33] Norway (3) | *n* 49<br>Adolescents | FFQ *v.* 7 d WDR<br>190 items. HH measures | Unadjusted 0·30<br>Energy adjusted 0·39 | Median FFQ: 1381 (µg)<br>Median WDR: 787 (µg) | | |
| β-Carotene | | | | | | |
| Parrish *et al.* (2003)[22] USA (3·5) | *n* 38<br>1–3 years<br>Infants<br>Preschool children | FFQ *v.* BM<br>111 items. Standard reference portions | CC 0·13 | | | |
| Arnold *et al.* (1995)[31] Canada (3·5) | *n* 707<br>7–12 years<br>Children | FFQ *v.* 14 d EDR<br>160 items. Standard reference portions | Pearson CC 0·53 | | | |
| Vitamin D | | | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* 50<br>6 months<br>Infants | FFQ *v.* 4 d WDR<br>thirty-four items. HH measures | Energy adjusted<br>CC 0·83 | Median (µg)<br>FFQ 9·3<br>WDR 8·3 | | |
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50<br>12 months<br>Infants | FFQ *v.* 4 d WDR<br>seventy-eight items. HH measures | Energy adjusted<br>CC 0·40 | Median (µg)<br>FFQ 6·29<br>WDR 1·54 | | |
| Andersen *et al.* (2003)[2] Norway (4·5) | *n* 64<br>12 months<br>Infants | FFQ *v.* 7 d WDR<br>140 items. HH measures or food photographs | Absolute intake<br>CC 0·18 | Median ($P_{25}$–$P_{75}$) (µg)<br>FFQ 2·3 (1·1–4·2)<br>WDR 1·1 (0·4–1·9)*** | | |
| Marshall *et al.* (2003)[21] USA (4) | *n* 240<br>6–12 months<br>3–5 years<br>Infants<br>Preschool children | FFQ *v.* 3 d WDR<br>seven items. Estimated usual serving size | 6 months<br>CC 0·80***<br>Mean (SD) µg<br>FFQ 6·4 (3·4)<br>WDR 5·6 (2·8) | 12 months<br>CC 0·60***<br>Mean (SD) µg<br>FFQ 6·1 (3·3)<br>WDR 5·6 (2·8) | 3 years<br>CC 0·74***<br>Mean (SD) µg<br>FFQ 3·2 (2·3)<br>WDR 3·7 (2·3) | 5 years<br>CC 0·63***<br>Mean (SD) µg<br>FFQ 3·3 (2·1)<br>WDR 3·4 (1·9) |
| Parrish *et al.* (2003)[22] USA (3·5) | *n* 68<br>1–3 years | FFQ *v.* BM<br>111 items. Standard | CC 0·00 | | | |

**Table 3.** *Continued*

| Author/year publication/country/ (quality index) | *n*/age group | Methods/ no FFQ items, portion sizes | Correlation between methods/other statistics | |
|---|---|---|---|---|
| | Infants<br>Preschool children | reference portions<br>24 HR *v.* BM | <br>CC 0·17 | |
| Andersen *et al.* (2004)[18,19] Norway (5) | *n* 187<br>2 years old<br>Preschool children | FFQ *v.* 7 d WDR<br>125 items. HH measures or food photographs | Absolute intake<br>CC 0·48*** | Median ($P_{25}$–$P_{75}$) (μg)<br>FFQ 9·1 (5·8–13·7)<br>WDR 3·9 (1·6–7·3)*** |
| Lillegaard *et al.* (2007)[12] Norway (3·5) | *n* 100<br>9 years old<br>Children | PFD *v.* 4 d WDR<br>277 items. HH measures or colour photographs | Boys-Median ($P_{25-}$ $P_{75}$) (μg)<br>PFD 3·0 (1·5, 6·2)<br>WDR 2·1 (1·2, 3·7)<br>CC 0·51*** | Girls-Median ($P_{25-}$ $P_{75}$) (μg)<br>PFD 3·4 (2·0, 5·9)<br>WDR 2·2 (1·5, 4·2)<br>CC 0·52*** |
| Andersen *et al.* (1995)[33] Norway (3) | *n* 49<br>Adolescents | FFQ *v.* 7 d WDR<br>190 items. HH measures | Unadjusted 0·14<br>Energy adjusted 0·21 | Median FFQ: 4·9 (μg)<br>Median WDR: 2·2 (μg) |
| Vitamin E | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* 50<br>6 months<br>Infants | FFQ *v.* 4 d WDR<br>thirty-four items. HH measures | Energy adjusted<br>CC 0·83 | Median (mg)<br>FFQ 6·0<br>WDR 5·3 |
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50<br>12 months<br>Infants | FFQ *v.* 4 d WDR<br>seventy-eight items. HH measures | Energy adjusted<br>CC 0·27 | Median (μg)<br>FFQ 6·13<br>WDR 4·11 |
| Andersen *et al.* (2003)[2] Norway (4·5) | *n* 64<br>12 months<br>Infants | FFQ *v.* 7 d WDR<br>140 items. HH measures or food photographs | Absolute intake<br>CC 0·32 | Median ($P_{25}$–$P_{75}$) (mg)<br>FFQ 4·0 (3·1–5·6)<br>WDR 2·9 (2·3–4·2)*** |
| Parrish *et al.* (2003)[22] USA (3·5) | *n* 38<br>1–3 years<br>Infants<br>Preschool children | FFQ *v.* BM<br>111 items. Standard reference portions<br>24 HR *v.* BM | CC 0·48<br><br><br>CC 0·30 | |
| Blum *et al.* (1999)[24] USA (2·5) | *n* 233<br>1–5 years Infants<br>Preschool children | FFQ *v.* three 24 HR<br>eighty-four items. | CC 0·56 | Mean (SD) (mg)<br>24 HR 8 (5)<br>FFQ 10 (7) |
| Andersen *et al.* (2004)[18,19] Norway (5) | *n* 187<br>2 years old<br>Preschool children | FFQ *v.* 7 d WDR<br>125 items. HH measures or food photographs | Absolute intake<br>CC 0·48*** | Median ($P_{25}$–$P_{75}$) (mg)<br>FFQ 9·3 (6·2–12·7)<br>WDR 4·7 (2·9–7·2)*** |
| Byers *et al.* (1993)[35] USA (2·5) | *n* 97<br>6–10 years<br>Children | FFQ *v.* BM<br>111 items | Crude 0·32<br>Adjusted 0·32 | |
| Bellù *et al.* (1995)[32] Italy (3·5) | *n* 88<br>9–12 years<br>Children | FFQ *v.* 7 d EDR<br>116 items. Reference portion sizes | Raw nutrient 0·31<br>Nutrient density 0·38 | Mean (SD)<br>EDR 0·67 (0·21)<br>FFQ 0·57 (0·22) |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 26<br>19–18 years<br>Children-Adolescents | YAQ *v.* 3–24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·50<br>14–18 years CC 0·55 | Mean (SD) (mg)<br>24 HR 13 (22)<br>YAQ 13 (11) |

**Table 3.** *Continued*

| Author/year publication/country/ (quality index) | *n*/age group | Methods/ no FFQ items, portion sizes | Correlation between methods/other statistics | |
|---|---|---|---|---|
| Thiamin | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* 50<br>6 months<br>Infants | FFQ *v.* 4 d WDR<br>thirty-four items. HH measures | Energy adjusted<br>CC 0·89 | Median (mg)<br>FFQ 0·65<br>WDR 0·60 |
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50<br>12 months<br>Infants | FFQ *v.* 4 d WDR<br>seventy-eight items. HH measures | Energy adjusted<br>CC 0·53 | Median (μg)<br>FFQ 0·96<br>WDR 0·75 |
| Andersen *et al.* (2003)[2] Norway (4·5) | *n* 64<br>12 months<br>Infants | FFQ *v.* 7 d WDR<br>140 items. HH measures or food photographs | Absolute intake<br>CC 0·41 | Median ($P_{25}$–$P_{75}$) (mg)<br>FFQ 0·7 (0·59–0·88)<br>WDR 0·56 (0·44–0·61)*** |
| Blum *et al.* (1999)[24] USA (2·5) | *n* 233<br>1–5 years<br>Infants<br>Preschool children | FFQ *v.* three 24 HR<br>eighty-four items. | CC 0·57 | Mean (SD) (mg)<br>24 HR 2 (1)<br>FFQ 2 (1) |
| Andersen *et al.* (2004)[18,19] Norway (5) | *n* 187<br>2 years old<br>Preschool children | FFQ *v.* 7 d WDR<br>125 items. HH measures or food photographs | Absolute intake<br>CC 0·52*** | Median ($P_{25}$–$P_{75}$) (mg)<br>FFQ 1·12 (0·86–1·64)<br>WDR 0·66 (0·55–0·91)*** |
| Holmes *et al.* (2008)[10] UK (3) | *n* 124<br>2–17 years<br>Preschool children<br>Children<br>Adolescents | 24 HR *v.* 4 d WDR | Males-Mean difference<br>2–10 years − 0·1 ($P$ = 0·480)<br>11–17 years 0·4 ($P$ = 0·142) | Females-Mean difference<br>2–10 years 0·2 ($P$ = 0·024)<br>11–17 years 0·1 ($P$ = 0·041) |
| | | FC *v.* 4 d WDR | Males-Mean difference<br>2–10 years − 0·2 ($P$ = 0·574)<br>11–17 years 0·2 ($P$ = 0·433) | Females-Mean difference<br>2–10 years 0·3 ($P$ = 0·000)<br>11–17 years 0·2 ($P$ = 0·063) |
| | | SW *v.* 4 d WDR | Males-Mean difference<br>2–10 years − 0·8 ($P$ = 0·243)<br>11–17 years − 0·1 ($P$ = 0·393) | Females-Mean difference<br>2–10 years 0·0 ($P$ = 0·575)<br>11–17 years 0·1 ($P$ = 0·658) |
| Räsänen L. (1979)[39] Finland (5) | *n* 741<br>5 − 13 years<br>Preschool children<br>Children<br>Adolescents | 24 HR *v.* DH | CC 0·46 | Mean DH: 1·9; 24 HR: 1·3 |
| Arnold *et al.* (1995)[31] Canada (3·5) | *n* 707<br>7–12 years<br>Children | FFQ *v.* 14 d EDR<br>160 items. Standard reference portions | Pearson CC 0·35† | |
| Lillegaard *et al.* (2007)[12] Norway (3·5) | *n* 100<br>9 years old<br>Children | PFD *v.* 4 d WDR<br>277 items. HH measures or colour photographs | Boys- Median ($P_{25-}$ $P_{75}$) (mg)<br>PFD 1·1 (0·9, 1·4)<br>WDR 1·1 (0·9, 1·4)<br>CC 0·53*** | Girls-Median ($P_{25-}P_{75}$) (mg)<br>PFD 1·1 (0·9, 1·5)<br>WDR 1·0 (0·8, 1·2)<br>CC 0·40** |
| Bellù *et al.* (1995)[32] Italy (3·5) | *n* 88<br>9–12 years<br>Children | FFQ *v.* 7 d EDR<br>116 items. Reference portion sizes | Raw nutrient 0·24<br>Nutrient density 0·27 | Mean (SD)<br>EDR 0·61 (0·78)<br>FFQ 1·41 (0·78) |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261<br>9–18 years<br>Children<br>Adolescents | YAQ *v.* three 24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·49<br>14–18 years CC 0·54 | Mean (SD) (mg)<br>24 HR 2·3 (1·8)<br>YAQ 2·0 (0·8) |

**Table 3.** *Continued*

| Author/year publication/country/ (quality index) | *n*/age group | Methods/ no FFQ items, portion sizes | Correlation between methods/other statistics | |
|---|---|---|---|---|
| Andersen *et al.* (1995)[33] Norway (3) | *n* 49 Adolescents | FFQ *v.* 7 d WDR 190 items. HH measures | Unadjusted 0·53 Energy adjusted 0·53 | Median FFQ: 1·58 (mg) Median WDR: 1·14 (mg) |
| Riboflavin | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* 50 6 months Infants | FFQ *v.* 4 d WDR thirty-four items. HH measures | Energy adjusted CC 0·87 | Median (mg) FFQ 1·2 WDR 1·2 |
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50 12 months Infants | FFQ *v.* 4 d WDR seventy-eight items. HH measures | Energy adjusted CC 0·51 | Median (μg) FFQ 1·70 WDR 1·43 |
| Andersen *et al.* (2003)[2] Norway (4·5) | *n* 64 12 months Infants | FFQ *v.* 7 d WDR 140 items. HH measures or food photographs | Absolute intake CC 0·58 | Median ($P_{25}$–$P_{75}$) (mg) FFQ 1·02 (0·72–1·34) WDR 0·78 (0·58–1·02)*** |
| Blum *et al.* (1999)[24] USA (2·5) | *n* 233 1–5 years Infants Preschool children | FFQ *v.* three 24 HR eighty-four items. | CC 0·56 | Mean (SD) (mg) 24 HR 2 (1) FFQ 3 (1) |
| Andersen *et al.* (2004)[18,19] Norway (5) | *n* 187 2 years old Preschool children | FFQ *v.* 7 d WDR 125 items. HH measures or food photographs | Absolute intake CC 0·51*** | Median ($P_{25}$–$P_{75}$) (mg) FFQ 1·63 (1·24–2·24) WDR 1·06 (0·84–1·33)*** |
| Räsänen L. (1979)[39] Finland (5) | *n* 741 5–13 years Preschool children Children Adolescents | 24 HR *v.* DH | CC 0·42 | Mean DH: 3·3; 24 HR: 2·3 |
| Arnold *et al.* (1995)[31] Canada (3·5) | *n* 707 7–12 years Children | FFQ *v.* 14 d EDR 160 items. Standard reference portions | Pearson CC 0·36† | |
| Lillegaard *et al.* (2007)[12] Norway (3·5) | *n* 100 9 years old Children | PFD *v.* 4 d WDR 277 items. HH measures or colour photographs | Boys- Median ($P_{25}$– $P_{75}$) (mg) PFD 1·5 (1·1, 2·0) WDR 1·3 (1·1, 1·8) CC 0·56*** | Girls-Median ($P_{25}$– $P_{75}$) (mg) PFD 1·4 (1·1, 1·9) WDR 1·2 (0·9, 1·6) CC 0·56*** |
| Bellù *et al.* (1995)[32] Italy (3·5) | *n* 88 9–12 years Children | FFQ *v.* 7 d EDR 116 items. Reference portion sizes | Raw nutrient 0·26 Nutrient density 0·22 | Mean (SD) EDR 0·64 (0·16) FFQ 0·64 (0·11) |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261 9–18 years Children Adolescents | YAQ *v.* three 24 HR 131 items. Standard reference portions | 9–13 years CC 0·50 14–18 years CC 0·62 | Mean (SD) (mg) 24 HR 2·7 (1·5) YAQ 2·7 (1·0) |
| Andersen *et al.* (1995)[33] Norway (3) | *n* 49 Adolescents | FFQ *v.* 7 d WDR 190 items. HH measures | Unadjusted 0·57 Energy adjusted 0·65 | Median FFQ: 2·01 (mg) Median WDR: 1·47 (mg) |
| Niacin | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* 50 6 months Infants | FFQ *v.* 4 d WDR thirty-four items. HH measures | Energy adjusted CC 0·88 | Median (mg) FFQ 8·1 WDR 8·0 |

**Table 3.** *Continued*

| Author/year publication/country/ (quality index) | *n*/age group | Methods/ no FFQ items, portion sizes | Correlation between methods/other statistics | |
|---|---|---|---|---|
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50<br>12 months<br>Infants | FFQ *v.* 4 d WDR<br>seventy-eight items.<br>HH measures | Energy adjusted<br>CC 0·60 | Median (μg)<br>FFQ 10·52<br>WDR 7·48 |
| Blum *et al.* (1999)[24] USA (2·5) | *n* 233<br>1–5 years<br>Infants<br>Preschool children | FFQ *v.* three 24 HR<br>84 items. | CC 0·55 | Mean (SD) (mg)<br>24 HR 19 (8)<br>FFQ 21 (8) |
| Räsänen L. (1979)[39] Finland (5) | *n* 741<br>5–13 years<br>Preschool children<br>Children<br>Adolescents | 24 HR *v.* DH | CC 0·36 | Mean DH: 16·2; 24 HR: 11·2 |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261<br>9–18 years<br>Children<br>Adolescents | YAQ *v.* three 24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·45<br>14–18 years CC 0·50 | Mean (SD) (mg)<br>24 HR 26 (15)<br>YAQ 25 (10) |
| Vitamin $B_6$ | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* 50<br>6 months<br>Infants | FFQ *v.* 4 d WDR<br>thirty-four items. HH measures | Energy adjusted<br>CC 0·84 | Median (mg)<br>FFQ 0·60<br>WDR 0·60 |
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50<br>12 months<br>Infants | FFQ *v.* 4 d WDR<br>seventy-eight items.<br>HH measures | Energy adjusted<br>CC 0·54 | Median (μg)<br>FFQ 1·09<br>WDR 0·81 |
| Blum *et al.* (1999)[24] USA (2·5) | *n* 233<br>1–5 years<br>Infants<br>Preschool children | FFQ *v.* three 24 HR<br>eighty-four items. | CC 0·58 | Mean (SD) (mg)<br>24 HR 2 (1)<br>FFQ 2 (1) |
| Bellù *et al.* (1995)[32] Italy (3·5) | *n* 88<br>9–12 years<br>Children | FFQ *v.* 7 d EDR<br>116 items. Reference portion sizes | Raw nutrient 0·17<br>Nutrient density 0·26 | Mean (SD)<br>EDR 0·28 (0·09)<br>FFQ 0·25 (0·1) |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261<br>9–18 years<br>Children Adolescents | YAQ *v.* 3–24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·51<br>14–18 years CC 0·55 | Mean (SD) (mg)<br>24 HR 2·2 (1·5)<br>YAQ 2·2 (1·0) |
| Vitamin $B_{12}$ | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* 50<br>6 months<br>Infants | FFQ *v.* 4 d WDR<br>thirty-four items. HH measures | Energy adjusted<br>CC 0·74 | Median (μg)<br>FFQ 1·8<br>WDR 1·8 |
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50<br>12 months<br>Infants | FFQ *v.* 4 d WDR<br>seventy-eight items.<br>HH measures | Energy adjusted<br>CC 0·24 | Median (μg)<br>FFQ 3·08<br>WDR 2·8 |
| Blum *et al.* (1999)[24] USA (2·5) | *n* 233<br>1–5 years<br>Infants<br>Preschool children | FFQ *v.* 3–24 HR<br>eighty-four items. | CC 0·47 | Mean (SD) (mg)<br>24 HR 5 (3)<br>FFQ 6 (2) |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261<br>9–18 years<br>Children<br>Adolescents | YAQ *v.* three 24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·40<br>14–18 years CC 0·38 | Mean (SD) (μg)<br>24 HR 5·7 (4·7)<br>YAQ 7·6 (3·8) |
| Green *et al.* | *n* 105 | FFQ *v.* 3 d WDR | Food only | Food + supplements |

**Table 3.** *Continued*

| Author/year publication/country/ (quality index) | *n*/age group | Methods/ no FFQ items, portion sizes | Correlation between methods/other statistics | |
|---|---|---|---|---|
| (1998)[28] Canada (4·5) | 16–19 years<br>Adolescents | 116 items. HH measures | Median (1st – 3rd quartile)(μg)<br>FFQ 4·4 (3·4, 7·0)<br>WDR 1·7 (0·7, 2·4) | Median (1st – 3rd quartile) (μ)<br>FFQ 4·9 (3·6, 10)<br>WDR 1·9 (1·0, 3·7) |
| | | FFQ *v.* BM<br>3 d WDR *v.* BM | CC 0·19<br>CC 0·38 | CC 0·25<br>CC 0·32 |
| Folate | | | | |
| Blum *et al.* (1999)[24] USA (2·5) | *n* 233<br>1–5 years<br>Infants<br>Preschool children | FFQ *v.* three 24 HR eighty-four items. | CC 0·55 | Mean (SD) (μg)<br>24 HR 274 (133)<br>FFQ 307 (147) |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261<br>9–18 years<br>Children<br>Adolescents | YAQ *v.* three 24 HR 131 items. Standard reference portions | 9–13 years CC 0·53<br>14–18 years CC 0·63 | Mean (SD) (μg)<br>24 HR 373 (216)<br>YAQ 382 (187) |
| Green *et al.* (1998)[28] Canada (4·5) | *n* 105<br>16–19 years<br>Adolescents | FFQ *v.* 3 d WDR 116 items. HH measures | Food only<br>Median (1st–3rd quartile)(μg)<br>FFQ 289 (218, 400)<br>WDR 187 (0·7, 2·4) | Food + supplements<br>Median (1st–3rd quartile) (μg)<br>FFQ 346 (229, 494)<br>WDR 212 (155, 301) |
| | | FFQ *v.* BM<br>3 d WDR *v.* BM | CC 0·38<br>CC 0·46 | CC 0·48<br>CC 0·65 |
| Vitamin C | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* 50<br>6 months<br>Infants | FFQ *v.* 4 d WDR thirty-four items. HH measures | Energy adjusted<br>CC 0·67 | Median (mg)<br>FFQ 86<br>WDR 78 |
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50<br>12 months<br>Infants | FFQ *v.* 4 d WDR seventy-eight items. HH measures | Energy adjusted<br>CC 0·47 | Median (μg)<br>FFQ 79·6<br>WDR 42·3 |
| Williams & Innis (2005)[17] Canada (5) | *n* 148<br>8–26 months<br>Infants | FFQ *v.* 3 d EDR 191 items | CC 0·64 | Median (mg)<br>FFQ 74<br>EDR 77·5 |
| Andersen *et al.* (2003)[2] Norway (4·5) | *n* 64<br>12 months<br>Infants | FFQ *v.* 7 d WDR 140 items. HH measures or food photographs | Absolute intake<br>CC 0·41 | Median ($P_{25}$–$P_{75}$) (mg)<br>FFQ 88 (55–118)<br>WDR 51 (33–77)*** |
| Blum *et al.* (1999)[24] USA (2·5) | *n* 233<br>1–5 years<br>Infants<br>Preschool children | FFQ *v.* three 24 HR eighty-four items. | CC 0·58 | Mean (SD) (mg)<br>24 HR 117 (66)<br>FFQ 114 (49) |
| Parrish *et al.* (2003)[22] USA (3·5) | *n* 38<br>1–3 years<br>Infants<br>Preschool children | FFQ *v.* BM<br>111 items. Standard reference portions | CC 0·51 | |
| | | 24 HR *v.* BM | CC 0·16 | |
| Andersen *et al.* (2004)[18,19] Norway (5) | *n* 187<br>2 years old<br>Preschool children | FFQ *v.* 7 d WDR 125 items. HH measures or food photographs | Absolute intake<br>CC 0·43*** | Median ($P_{25}$–$P_{75}$) (mg)<br>FFQ 88 (62–119)<br>WDR 60 (42–79)*** |
| Holmes *et al.* (2008)[10] UK (3) | *n* 124<br>2–17 years | 24 HR *v.* 4 d WDR | Males-Mean difference<br>2–10 years 16 ($P$ = 0·042) | Females-Mean difference<br>2–10 years 28 ($P$ = 0·009) |

**Table 3.** *Continued*

| Author/year publication/country/ (quality index) | *n*/age group | Methods/ no FFQ items, portion sizes | Correlation between methods/other statistics | |
|---|---|---|---|---|
| | Preschool children<br>Children<br>Adolescents | | 11–17 years 4 ($P = 0{\cdot}656$) | 11–17 years 15 ($P = 0{\cdot}207$) |
| | | FC *v.* 4 d WDR | Males-Mean difference<br>2–10 years 33 ($P = 0{\cdot}002$)<br>11–17 years 18 ($P = 0{\cdot}231$) | Females-Mean difference<br>2–10 years 43 ($P = 0{\cdot}001$)<br>11–17 years 24 ($P = 0{\cdot}325$) |
| | | SW *v.* 4 d WDR | Males-Mean difference<br>2–10 years 6 ($P = 0{\cdot}472$)<br>11–17 years − 7 ($P = 0{\cdot}676$) | Females-Mean difference<br>2–10 years 7 ($P = 0{\cdot}639$)<br>11–17 years − 31 ($P = 0{\cdot}017$) |
| Räsänen L. (1979)[39] Finland (5) | *n* 741<br>5–13 years<br>Preschool children<br>Children<br>Adolescents | 24 HR *v.* DH | CC 0·21 | Mean DH: 113; 24 HR: 85 |
| Byers *et al.* (1993)[35] USA (2·5) | *n* 97<br>6–10 years<br>Children | FFQ *v.* BM<br>111 items | Crude 0·39<br>Adjusted 0·37 | |
| Arnold *et al.* (1995)[31] Canada (3·5) | *n* 707<br>7–12 years<br>Children | FFQ *v.* 14 d EDR<br>160 items. Standard reference portions | Pearson CC 0·57† | |
| Lillegaard *et al.* (2007)[12] Norway (3·5) | *n* 100<br>9 years old<br>Children | PFD *v.* 4 d WDR<br>277 items. HH measures or colour photographs | Boys-Median ($P_{25}$–$P_{75}$) (mg)<br>PFD 86 (53, 123)<br>WDR 80 (54, 113)<br>CC 0·40** | Girls-Median ($P_{25}$–$P_{75}$) (mg)<br>PFD 87 (66, 104)<br>WDR 63 (38, 96)<br>CC 0·42*** |
| Bellù *et al.* (1995)[32] Italy (3·5) | *n* 88<br>9–12 years<br>Children | FFQ *v.* 7 d EDR<br>116 items. Reference portion sizes | Raw nutrient 0·45<br>Nutrient density 0·53 | Mean (SD)<br>EDR 34·6 (22·2)<br>FFQ 52·6 (26·7) |
| Field *et al.* (1998)[25] USA (4) | *n* 109<br>Students from fourth to seventh grade<br>Children | FFQ *v.* four 24 HR<br>ninety-seven items. Standard reference portions. | Fourth and fifth grades<br>Crude 0·19<br>Deattenuated 0·32 | Sixth and seventh grades<br>Crude 0·50<br>Deattenuated 0·76 |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261<br>9–18 years<br>Children<br>Adolescents | YAQ *v.* three 24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·61<br>14–18 years CC 0·45 | Mean (SD) (mg)<br>24 HR 166 (164)<br>YAQ 161 (80) |
| Slater *et al.* (2003)[20] Brazil (4) | *n* 79<br>14–18 years<br>Adolescents | FFQ *v.* three 24 HR<br>seventy-six items. Reference portion size | Non-adjusted 0·42**<br>Energy adjusted 0·47**<br>Deattenuated 0·91 | Mean (SD) (mg)<br>24 HR 69·8 (86·5)<br>FFQ 79·9 (41·6) |
| Andersen *et al.* (1995)[33] Norway (3) | *n* 49<br>Adolescents | FFQ *v.* 7 d WDR<br>190 items. HH measures | Unadjusted 0·34<br>Energy adjusted 0·37 | Median FFQ: 123 (mg)<br>Median WDR: 72 (mg) |

WDR, weighed dietary record; CC, correlation coefficient; 24 HR, 24 h recall; RE, retinol equivalent; DH, diet history; BM, biomarker; EDR, estimated dietary record; YAQ, Youth/Adolescent Questionnaire; FC, food checklist; SW, semi-weighed method; SAW, Self-administered workbook; PFD, pre-coded food diary; HH measures, household measures.
Mean values were significantly different: *$P<0{\cdot}05$; **$P<0{\cdot}01$; *** $P<0{\cdot}001$.
† Excluding vitamin supplementation.

**Table 4.** Validation studies in infants, children and adolescents: minerals

| Author/year publication/country/ (quality index) | n/age group | Methods/ no FFQ items, portion sizes | Correlation between methods/other statistics | |
|---|---|---|---|---|
| Na | | | | |
| Marriott et al. (2008)[8] UK (3·5) | n 50<br>6 months<br>Infants | FFQ v. 4 d WDR<br>thirty-four items HH measures | Energy adjusted<br>CC 0·56 | Median (mg)<br>FFQ 248<br>WDR 270 |
| Marriott et al. (2008)[9] UK (3·5) | n 50<br>12 months<br>Infants | FFQ v. 4 d WDR<br>seventy-eight items<br>HH measures | Energy adjusted<br>CC 0·75 | Median (μg)<br>FFQ 861<br>WDR 862 |
| Iannotti et al. (1994)[34] USA (3) | n 17<br>2–4 years<br>Preschool children | FFQ v. three 24 HR | CC 0·27 | Mean (SD)<br>FFQ 1307 (639)<br>24 HR 1410 (656) |
| Stein et al. (1992)[37] USA (5·5) | n 224<br>3·8–5 years<br>Preschool children | FFQ v. four 24 HR | Boys<br>Absolute intake 0·22<br>Adjusted for energy 0·04<br>Adjusted for energy and intra-individual variability 0·06<br>Mean (SD)<br>24 HR 1895 (584)<br>FFQ 2187 (592) | Girls<br>Absolute intake 0·30<br>Adjusted for energy − 0·09<br>Adjusted for energy and intra-individual variability − 0·14<br>Mean (SD)<br>24 HR 1860 (675)<br>FFQ 2120 (654) |
| Lytle et al. (1993)[36] USA (3·5) | n 49<br>8 years old<br>Children | 24 HR v. 1 d EDR | CC 0·53 | Mean (SD)<br>EDR 2554 mg (969)<br>24 HR 2524 mg (1089) |
| Rockett et al. (1997)[29] USA (3·5) | n 261<br>9–18 years<br>Children<br>Adolescents | YAQ v. three 24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·13<br>14–18 years CC 0·32 | Mean (SD) (mg)<br>24 HR 2393 (1120)<br>YAQ 2753 (718) |
| Lietz et al. (2002)[23] UK (3·5) | n 50<br>11–13 years<br>Children | FFQ v. 7 d WDR<br>130 items. Standard reference portions | Unadjusted 0·29<br>Energy adjusted 0·26 | Mean (SD) (mg)<br>WDR 2634 (522)<br>FFQ 3768 (1341) |
| K | | | | |
| Marriott et al. (2008)[8] UK (3·5) | n 50<br>6 months<br>Infants | FFQ v. 4 d WDR<br>thirty-four items<br>Quantified,<br>HH measures | Energy adjusted<br>CC 0·70 | Median (mg)<br>FFQ 1035<br>WDR 1014 |
| Marriott et al. (2008)[9] UK (3·5) | n 50<br>12 months<br>Infants | FFQ v. 4 d WDR<br>seventy-eight items<br>HH measures | Energy adjusted<br>CC 0·42 | Median (μg)<br>FFQ 1744<br>WDR 1402 |
| Stein et al. (1992)[37] USA (5·5) | n 224<br>3·8–5 years<br>Preschool children | FFQ v. four 24 HR | Boys<br>Absolute intake 0·33<br>Adjusted for energy 0·57<br>Adjusted for energy and intra-individual variability 0·71<br>Mean (SD)<br>24 HR 2360 (609)<br>FFQ 3860 (953) | Girls<br>Absolute intake 0·60<br>Adjusted for energy 0·62<br>Adjusted for energy and intra-individual variability 0·78<br>Mean (SD)<br>24 HR 2190* (549)<br>FFQ 3722 (973) |
| Jenner et al. (1989)[38] Australia (3·5) | n 225<br>11–12 years<br>Children | FFQ v. fourteen 24HR<br>175 items | FFQ completed by children CC 0·13<br>FFQ completed by parents CC 0·32 | Mean (SD)<br>24 HR 2·6 (0·7)<br>FFQ (children) 3·3 (1·6)<br>FFQ (parents) 2·9 (0·8) |
| Rockett et al. (1997)[29] USA (3·5) | n 261<br>9–18 years | YAQ v. three 24 HR<br>131 items. | 9–13 years CC 0·41<br>14–18 years CC 0·48 | Mean (SD) (mg)<br>24 HR 2608 (956) |

https://doi.org/10.1017/S0007114509993163 Published online by Cambridge University Press

**Table 4.** *Continued*

| Author/year publication/country/ (quality index) | *n*/age group | Methods/ no FFQ items, portion sizes | Correlation between methods/other statistics | | | |
|---|---|---|---|---|---|---|
| | Children<br>Adolescents | Standard reference portions | | | YAQ 2772 (859) | |
| Lietz *et al.* (2002)[23] UK (3·5) | *n* 50<br>11–13 years<br>Children | FFQ *v.* 7 d WDR<br>130 items.<br>Standard reference portions | Unadjusted 0·27<br>Energy adjusted 0·60** | | Mean (SD)<br>WDR 2347 (619)<br>FFQ 3660 (1288) | |
| | | 7 d WDR *v.* BM<br>FFQ *v.* BM | CC 0·78***<br>CC 0·04 | | | |
| Ca | | | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* 50<br>6 months<br>Infants | FFQ *v.* 4 d WDR<br>thirty-four items<br>HH measures | Energy adjusted<br>CC 0·78 | | Median (mg)<br>FFQ 547<br>WDR 543 | |
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50<br>12 months<br>Infants | FFQ *v.* 4 d WDR<br>seventy-eight items<br>HH measures | Energy adjusted<br>CC 0·61 | | Median ($\mu$g)<br>FFQ 877<br>WDR 784 | |
| Williams & Innis (2005)[17] Canada (5) | *n* 148<br>8–26 months<br>Infants | FFQ *v.* 3 d EDR<br>191 items | CC 0·75 | | Median (mg)<br>FFQ 861<br>EDR 691 | |
| Andersen *et al.* (2003)[2] Norway (4·5) | *n* 64<br>12 months<br>Infants | FFQ *v.* 7 d WDR<br>140 items. HH measures or food photographs | Absolute intake<br>CC 0·62 | | Median ($P_{25}$–$P_{75}$) (mg)<br>FFQ 584 (377–773)<br>WDR 527 (329–734) | |
| Marshall *et al.* (2003)[21] USA (4) | *n* 240<br>6–12 months<br>3–5 years<br>Infants<br>Preschool children | FFQ *v.* 3 d WDR<br>seven items. Estimated usual serving size | 6 months<br>CC 0·64***<br>Mean (SD) mg<br>FFQ 409 (153)<br>WDR 380(137) | 12 months<br>CC 0·67***<br>Mean (SD) mg<br>FFQ 608 (378)<br>WDR 601(340) | 3 years<br>CC 0·74***<br>Mean (SD) mg<br>FFQ 383 (269)<br>WDR 449(269) | 5 years<br>CC 0·64***<br>Mean (SD) mg<br>FFQ 393 (245)<br>WDR 406 (222) |
| Blum *et al.* (1999)[24] USA (2·5) | *n* 233<br>1–5 years<br>Infants<br>Preschool children | FFQ *v.* three 24 HR<br>eighty-four items | CC 0·60 | | Mean (SD) (mg)<br>24 HR 1016 (328)<br>FFQ 1087 (319) | |
| Andersen *et al.* (2004)[18,19] Norway (5) | *n* 187<br>2 years old<br>Preschool children | FFQ *v.* 7 d WDR<br>125 items. HH measures or food photographs | Absolute intake<br>CC 0·38*** | | Median ($P_{25}$–$P_{75}$) (mg)<br>FFQ 689 (559–872)<br>WDR 520 (106–649)*** | |
| Huybrechts *et al.* (2006)[15] Belgium (3·5) | *n* 509<br>2·5–6·5 years<br>Preschool children | FFQ *v.* 3 d EDR<br>forty-seven items. Portion size alternatives included. | CC 0·52 | | Mean (SD)<br>EDR 838 (305)<br>FFQ 777 (296) | |
| Stein *et al.* (1992)[37] USA (5·5) | *n* 224<br>3·8–5 years<br>Preschool children | FFQ *v.* four 24 HR | Boys<br>Absolute intake 0·50<br>Adjusted for energy 0·54<br>Adjusted for energy and intra-individual variability 0·65<br>Mean (SD)<br>24 HR 880 (283)<br>FFQ 1418 (404) | | Girls<br>Absolute intake 0·50<br>Adjusted for energy 0·47<br>Adjusted for energy and intra-individual variability 0·57<br>Mean (SD)<br>24 HR 816 (248)<br>FFQ 1351 (369) | |
| Holmes *et al.* (2008)[10] UK (3) | *n* 124<br>2–17 years<br>Preschool children<br>Children<br>Adolescents | 24 HR *v.* 4 d WDR | Males-Mean difference<br>2–10 years 15 ($P = 0·751$)<br>11–17 years 142 ($P = 0·012$) | | Females-Mean difference<br>2–10 years 133 ($P = 0·001$)<br>11–17 years 39 ($P = 0·522$) | |
| | | FC *v.* 4 d WDR | Males-Mean difference<br>2–10 years 60 ($P = 0·248$)<br>11–17 years 39 ($P = 0·480$) | | Females-Mean difference<br>2–10 years 89 ($P = 0·007$)<br>11–17 years 77 ($P = 0·205$) | |





https://doi.org/10.1017/S0007114509993163 Published online by Cambridge University Press

**Table 4.** *Continued*

| Author/year publication/country/ (quality index) | *n*/age group | Methods/ no FFQ items, portion sizes | Correlation between methods/other statistics | | |
|---|---|---|---|---|---|
| | | SW *v.* 4 d WDR | Males-Mean difference<br>2–10 years −77 ($P=0{\cdot}245$)<br>11–17 years 48 ($P=0{\cdot}480$) | Females-Mean difference<br>2–10 years 38 ($P=0{\cdot}452$)<br>11–17 years 43 ($P=0{\cdot}613$) | |
| Taylor & Goulding (1998)[26] New Zealand (2·5) | *n* 67<br>3–6 years<br>Preschool children<br>Children | FFQ *v.* 4 d EDR<br>thirty-five items. | CC 0·52 | Mean (SD)<br>EDR 798 mg (271)<br>FFQ 942 mg (419) | |
| Räsänen L. (1979)[39] Finland (5) | *n* 741<br>5–13 years<br>Preschool children<br>Children<br>Adolescents | 24 HR *v.* DH | CC 0·47 | Mean DH: 1369; 24 HR: 1034 | |
| Bellù *et al.* (1996)[30] Italy (3) | *n* 333<br>8–10 years<br>Children | FFQ *v.* 24 HR<br>116 items. | Girls Mean (SD)<br>24 HR 441 (179)<br>FFQ 445 (125) | Boys Mean (SD)<br>24 HR 453 (203)<br>FFQ 435 (140) | |
| Lillegaard *et al.* (2007)[12] Norway (3·5) | *n* 100<br>9 years old<br>Children | PFD *v.* 4 d WDR<br>277 items. HH measures or colour photographs | Boys-Median ($P_{25}$–$P_{75}$) (mg)<br>PFD 715 (581–1036)<br>WDR 712 (578–917)<br>CC 0·49*** | Girls-Median ($P_{25}$–$P_{75}$) (mg)<br>PFD 740 (572–962)<br>WDR 630 (473–877)<br>CC 0·56*** | |
| Bellù *et al.* (1995)[32] Italy (3·5) | *n* 88<br>9–12 years<br>Children | FFQ *v.* 7 d EDR<br>116 items. Reference portion sizes | Raw nutrient 0·32<br>Nutrient density 0·42 | Mean (SD)<br>EDR 377 (106)<br>FFQ 370 (69) | |
| Magkos *et al.* (2006)[13] Greece (3) | *n* 351<br>Mean age 11·9 years<br>Children | FFQ *v.* 24 HR<br>thirty items. Standard reference portions | CC 0·63*** | Mean (SD) mg/d<br>FFQ 728 (361)<br>24 HR 861(415) | |
| Jenner *et al.* (1989)[38] Australia (3·5) | *n* 225<br>11–12 years<br>Children | FFQ *v.* fourteen 24 HR<br>175 items | FFQ completed by children CC 0·20<br>FFQ completed by parents CC 0·31 | Mean (SD)<br>24 HR 0·8 (0·3)<br>FFQ (children) 1·2 (0·6)<br>FFQ (parents) 1·0 (0·4) | |
| Field *et al.* (1998)[25] USA (4) | *n* 109<br>Students from fourth to seventh grade<br>Children | FFQ *v.* four 24 HR<br>ninety-seven items. Standard reference portions used. | Fourth and fifth grades Crude 0·27<br>Deattenuated 0·39 | Sixth and seventh grades Crude 0·32<br>Deattenuated 0·47 | |
| Bertoli *et al.* (2005)[16] Italy (4) | *n* 37<br>6–10 years 16–20 years<br>Children<br>Adolescents | FFQ *v.* 7 d WDR<br>136 items Portion size estimated using colour photographs | Young adults CC 0·5<br>Children CC 0·60 | Young adults<br>Mean (SD)<br>FFQ 1073 (356)<br>WDR 726 (228) | Children<br>Mean (SD)<br>FFQ 1039 (372)<br>WDR 691 (254) |
| Moore *et al.* (2007)[11] Canada (4·5) | *n* 162<br>9–16 years<br>Children<br>Adolescents | FFQ *v.* 24 HR<br>thirty-two items. Visual aids to approximate portion size | 9–12 years ICC 0·46<br>14–16 years ICC 0·43 | 9–12 years Mean<br>FFQ 1576<br>24 HR 1003 | 14–16 years<br>Mean<br>FFQ 1873<br>24 HR 1159 |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261<br>9–18 years<br>Children<br>Adolescents | YAQ *v.* three 24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·52<br>14–18 years CC 0·57 | Mean (SD) (mg)<br>24 HR 1093 (454)<br>YAQ 1159 (417) | |
| Lietz *et al.* (2002)[23] UK (3·5) | *n* 50<br>11–13 years<br>Children | FFQ *v.* 7 d WDR<br>130 items. Standard reference portions | Unadjusted 0·34*<br>Energy adjusted 0·47** | Mean and (SD) (mg)<br>WDR 813 (218)<br>FFQ 1016 (273) | |
| Harnack *et al.* (2006)[14] USA (2·5) | *n* 248<br>11–14 years<br>Children<br>Adolescents | FFQ *v.* three 24 HR<br>ten items. Portion size alternatives included | 11–12 years ICC 0·59<br>13–14 years ICC 0·33 | 11–12 years<br>Mean (DS)<br>FFQ 855<br>24 HR 1008 | 13–14 years<br>Mean (SD)<br>FFQ 856<br>24 HR 984 |

https://doi.org/10.1017/S0007114509993163 Published online by Cambridge University Press

**Table 4.** *Continued*

| Author/year publication/country/(quality index) | *n*/age group | Methods/no FFQ items, portion sizes | Correlation between methods/other statistics | |
|---|---|---|---|---|
| Mølgaard *et al.* (1998)[27] Denmark (2) | *n* 23<br>13–14 years<br>Adolescents | FFQ *v.* 3 d WDR<br>eighty-eight items<br>HH measures | CC 0·62 | Median ($P_{25}$–$P_{75}$) (mg)<br>FFQ 1102 (931–1339)<br>WDR 924 (727–1145) |
| Slater *et al.* (2003)[20] Brazil (4) | *n* 79<br>14–18 years<br>Adolescents | FFQ *v.* three 24 HR<br>seventy-six items.<br>Reference portion size listed. | Non-adjusted 0·61**<br>Energy adjusted 0·51**<br>Deattenuated 0·70 | Mean (SD) (mg)<br>24 HR 584 (384)<br>FFQ 561 (223) |
| Andersen *et al.* (1995)[33] Norway (3) | *n* 49<br>Adolescents | FFQ *v.* 7 d WDR<br>190 items<br>HH measures | Unadjusted 0·54<br>Energy adjusted 0·54 | Median FFQ: 1178 (mg)<br>Median WDR: 936 (mg) |
| Mg | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* 50<br>6 months<br>Infants | FFQ *v.* 4 d WDR<br>thirty-four items<br>HH measures | Energy adjusted<br>CC 0·68 | Median (mg)<br>FFQ 86·7<br>WDR 78·7 |
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50<br>12 months<br>Infants | FFQ *v.* 4 d WDR<br>seventy-eight items<br>HH measures | Energy adjusted<br>CC 0·57 | Median (μg)<br>FFQ 142<br>WDR 129 |
| Blum *et al.* (1999)[24] USA (2·5) | *n* 233<br>1–5 years<br>Infants<br>Preschool children | FFQ *v.* three 24 HR<br>eighty-four items. | CC 0·63 | Mean (SD) (mg)<br>24 HR 225 (69)<br>FFQ 220 (60) |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261<br>9–18 years<br>Children<br>Adolescents | YAQ *v.* three 24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·51<br>14–18 years CC 0·54 | Mean (SD) (mg)<br>24 HR 278 (101)<br>YAQ 285 (88) |
| Andersen *et al.* (1995)[33] Norway (3) | *n* 49<br>Adolescents | FFQ *v.* 7 d WDR<br>190 items HH measures | Unadjusted 0·49<br>Energy adjusted 0·51 | Median FFQ: 405 (mg)<br>Median WDR: 292 (mg) |
| P | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* 50<br>6 months<br>Infants | FFQ *v.* 4 d WDR<br>thirty-four items<br>HH measures | Energy adjusted<br>CC 0·77 | Median (mg)<br>FFQ 422<br>WDR 409 |
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50<br>12 months<br>Infants | FFQ *v.* 4 d WDR<br>seventy-eight items<br>HH measures | Energy adjusted<br>CC 0·58 | Median (μg)<br>FFQ 833<br>WDR 768 |
| Field *et al.* (1998)[25] USA (4) | *n* 109<br>Students from fourth to seventh grade<br>Children | FFQ *v.* four 24 HR<br>ninety-seven items. Standard reference portions used. | Fourth and fifth grades<br>Crude 0·25<br>Deattenuated 0·33 | Sixth and seventh grades<br>Crude 0·29<br>Deattenuated 0·40 |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261<br>9–18 years<br>Children<br>Adolescents | YAQ *v.* three 24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·47<br>14–18 years CC 0·61 | Mean (SD) (mg)<br>24 HR 1381 (473)<br>YAQ 1515 (446) |
| Mølgaard *et al.* (1998)[27] Denmark (2) | *n* 23<br>13–14 years<br>Adolescents | FFQ *v.* 3 d WDR<br>eighty-eight items<br>HH measures | CC 0·56 | Median ($P_{25}$–$P_{75}$) (mg)<br>FFQ 1191 (1027–1538)<br>WDR 1081 (799–1360) |
| Fe | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* 50<br>6 months<br>Infants | FFQ *v.* 4 d WDR<br>thirty-four items<br>HH measures | Energy adjusted<br>CC 0·78 | Median (mg)<br>FFQ 7·0<br>WDR 6·9 |

British Journal of Nutrition



**Table 4.** *Continued*

| Author/year publication/country/ (quality index) | *n*/age group | Methods/ no FFQ items, portion sizes | Correlation between methods/other statistics | |
|---|---|---|---|---|
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50<br>12 months<br>Infants | FFQ *v.* 4 d WDR<br>seventy-eight items<br>HH measures | Energy adjusted<br>CC 0·50 | Median (μg)<br>FFQ 8·48<br>WDR 5·20 |
| Williams & Innis (2005)[17] Canada (5) | *n* 148<br>8–26 months<br>Infants | FFQ *v.* 3 d EDR<br>191 items | CC 0·64 | Median (mg)<br>FFQ 9·6; EDR 7·1 |
| | | FFQ *v.* BM | Serum ferritin and total Fe from FFQ r = 0·33 | |
| | | 3 d EDR *v.* BM | Serum ferritin and total Fe from 3 d EDR r = 0·19 | |
| Andersen *et al.* (2003)[2] Norway (4·5) | *n* 64<br>12 months<br>Infants | FFQ *v.* 7 d WDR<br>140 items. HH measures or food photographs | Absolute intake<br>CC 0·62 | Median ($P_{25}$–$P_{75}$) (mg)<br>FFQ 8·9 (6·7–12·9)<br>WDR 5·6 (3·6–10·2)*** |
| Blum *et al.* (1999)[24] USA (2·5) | *n* 233<br>1–5 years<br>Infants<br>Preschool children | FFQ *v.* three 24 HR<br>eighty-four items. | CC 0·51 | Mean (SD) (mg)<br>24 HR 16 (4)<br>FFQ 12 (6) |
| Andersen *et al.* (2004)[18,19] Norway (5) | *n* 187<br>2 years old<br>Preschool children | FFQ *v.* 7 d WDR<br>125 items. HH measures or food photographs | Absolute intake<br>CC 0·42*** | Median ($P_{25}$–$P_{75}$) (mg)<br>FFQ 46·5 (5·2–8·0)<br>WDR 4·5 (3·6–5·2)*** |
| Räsänen L. (1979)[39] Finland (5) | *n* 741<br>5–13 years<br>Preschool children<br>Children<br>Adolescents | 24 HR *v.* DH | CC 0·46 | Mean DH: 17·6; 24 HR: 11·6 |
| Holmes *et al.* (2008)[10] UK (3) | *n* 124<br>2–17 years<br>Preschool children<br>Children<br>Adolescents | 24 HR *v.* 4 d WDR | Males-Mean difference<br>2–10 years 0·1 ($P$ = 0·864)<br>11–17 years 1·4 ($P$ = 0·055) | Females-Mean difference<br>2–10 years 0·7 ($P$ = 0·157)<br>11–17 years 1·1 ($P$ = 0·072) |
| | | FC *v.* 4 d WDR | Males-Mean difference<br>2–10 years 0·5 ($P$ = 0·356)<br>11–17 years 0·1 ($P$ = 0·847) | Females-Mean difference<br>2–10 years 1·4 ($P$ = 0·000)<br>11–17 years 0·4 ($P$ = 0·348) |
| | | SW *v.* 4 d WDR | Males-Mean difference<br>2–10 years − 1·1 ($P$ = 0·101)<br>11–17 years − 1·2 ($P$ = 0·237) | Females-Mean difference<br>2–10 years − 0·5 ($P$ = 0·358)<br>11–17 years 0·7 ($P$ = 0·398) |
| Bellù *et al.* (1996)[30] Italy (3) | *n* 333<br>8–10 years<br>Children | FFQ *v.* 24 HR<br>116 items. | Girls Mean (SD)<br>24 HR 5·6 (2·6)<br>FFQ 5·3 (0·9) | Boys Mean (SD)<br>24 HR 5·2 (2·0)<br>FFQ 5·0 (0·9) |
| Lillegaard *et al.* (2007)[12] Norway (3·5) | *n* 100<br>9 years old<br>Children | PFD *v.* 4 d WDR<br>277 items HH measures or colour photographs | Boys-Median ($P_{25}$–$P_{75}$) (mg)<br>PFD 8·7 (6·4–10·3)<br>WDR 8·4 (7·1–9·5)<br>CC 0·32* | Girls-Median ($P_{25}$–$P_{75}$) (mg)<br>PFD 8·4 (7·1–10·8)<br>WDR 7·1 (6·4–8·0)<br>CC 0·52*** |
| Field *et al.* (1998)[25] USA (4) | *n* 109<br>Students from fourth to seventh grade<br>Children | FFQ *v.* four 24 HR<br>ninety-seven items. Standard reference portions used. | Fourth and fifth grades<br>Crude 0·20<br>Deattenuated 0·28 | Sixth and seventh grades<br>Crude 0·29<br>Deattenuated 0·40 |
| Bellù *et al.* (1995)[32] Italy (3·5) | *n* 88<br>9–12 years<br>Children | FFQ *v.* 7 d EDR<br>116 items. Reference portion sizes | Raw nutrient 0·31<br>Nutrient density 0·18 | Mean (SD)<br>EDR 5·1 (0·67)<br>FFQ 5·2 (0·64) |

**Table 4.** *Continued*

| Author/year publication/country/ (quality index) | *n*/age group | Methods/ no FFQ items, portion sizes | Correlation between methods/other statistics | |
|---|---|---|---|---|
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261<br>9–18 years<br>Children<br>Adolescents | YAQ *v.* three 24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·47<br>14–18 years CC 0·59 | Mean (SD) (mg)<br>24 HR 18 (9)<br>YAQ 18 (8) |
| Slater *et al.* (2003)[20] Brazil (4) | *n* 79<br>14–18 years<br>Adolescents | FFQ *v.* three 24 HR<br>seventy-six items.<br>Reference portion size listed. | Non-adjusted 0·46**<br>Energy adjusted 0·17<br>Deattenuated 0·22 | Mean (SD) (mg)<br>24 HR 11·7 (5·6)<br>FFQ 8·4 (2·4) |
| Andersen *et al.* (1995)[33] Norway (3) | *n* 49<br>Adolescents | FFQ *v.* 7 d WDR<br>190 items HH measures | Unadjusted 0·52<br>Energy adjusted 0·39 | Median FFQ: 12 (mg)<br>Median WDR: 9 (mg) |
| Zn | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* equals;50<br>6 months<br>Infants | FFQ *v.* 4 d WDR<br>thirty-four items HH measures | Energy adjusted<br>CC 0·83 | Median (mg)<br>FFQ 5·2<br>WDR 4·7 |
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50<br>12 months<br>Infants | FFQ *v.* 4 d WDR<br>seventy-eight items HH measures | Energy adjusted<br>CC 0·48 | Median (μg)<br>FFQ 6·25<br>WDR 4·54 |
| Blum *et al.* (1999)[24] USA (2·5) | *n* 233<br>1–5 years<br>Infants<br>Preschool children | FFQ *v.* three 24 HR<br>eighty-four items. | CC 0·31 | Mean (SD) (mg)<br>24 HR 10 (7)<br>FFQ 11 (5) |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261<br>9–18 years<br>Children<br>Adolescents | YAQ *v.* three 24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·36<br>14–18 years CC 0·59 | Mean (SD) (mg)<br>24 HR 12 (6)<br>YAQ 14 (7) |
| Cu | | | | |
| Marriott *et al.* (2008)[8] UK (3·5) | *n* 50<br>6 months<br>Infants | FFQ *v.* 4 d WDR<br>thirty-four items HH measures | Energy adjusted<br>CC 0·55 | Median (mg)<br>FFQ 0·46<br>WDR 0·41 |
| Marriott *et al.* (2008)[9] UK (3·5) | *n* 50<br>12 months<br>Infants | FFQ *v.* 4 d WDR<br>seventy-eight items HH measures | Energy adjusted<br>CC 0·63 | Median (μg)<br>FFQ 0·64<br>WDR 0·43 |
| Rockett *et al.* (1997)[29] USA (3·5) | *n* 261<br>9–18 years<br>Children<br>Adolescents | YAQ *v.* three 24 HR<br>131 items. Standard reference portions | 9–13 years CC 0·47<br>14–18 years CC 0·61 | Mean (SD) (mg)<br>24 HR 1·4 (0·8)<br>YAQ 1·7 (0·8) |

WDR, weighed dietary record; CC, correlation coefficient; 24 HR, 24 h recall; EDR, estimated dietary record; YAQ, Youth/Adolescent Questionnaire; BM, biomarker; HH measures, household measures; FC, food checklist; SW, semi-weighed method; DH, diet history; PFD, pre-coded food diary; IIC, intra-class correlation coefficients.
Mean values were significantly different: *$P<0·05$; **$P<0·01$; *** $P<0·001$.

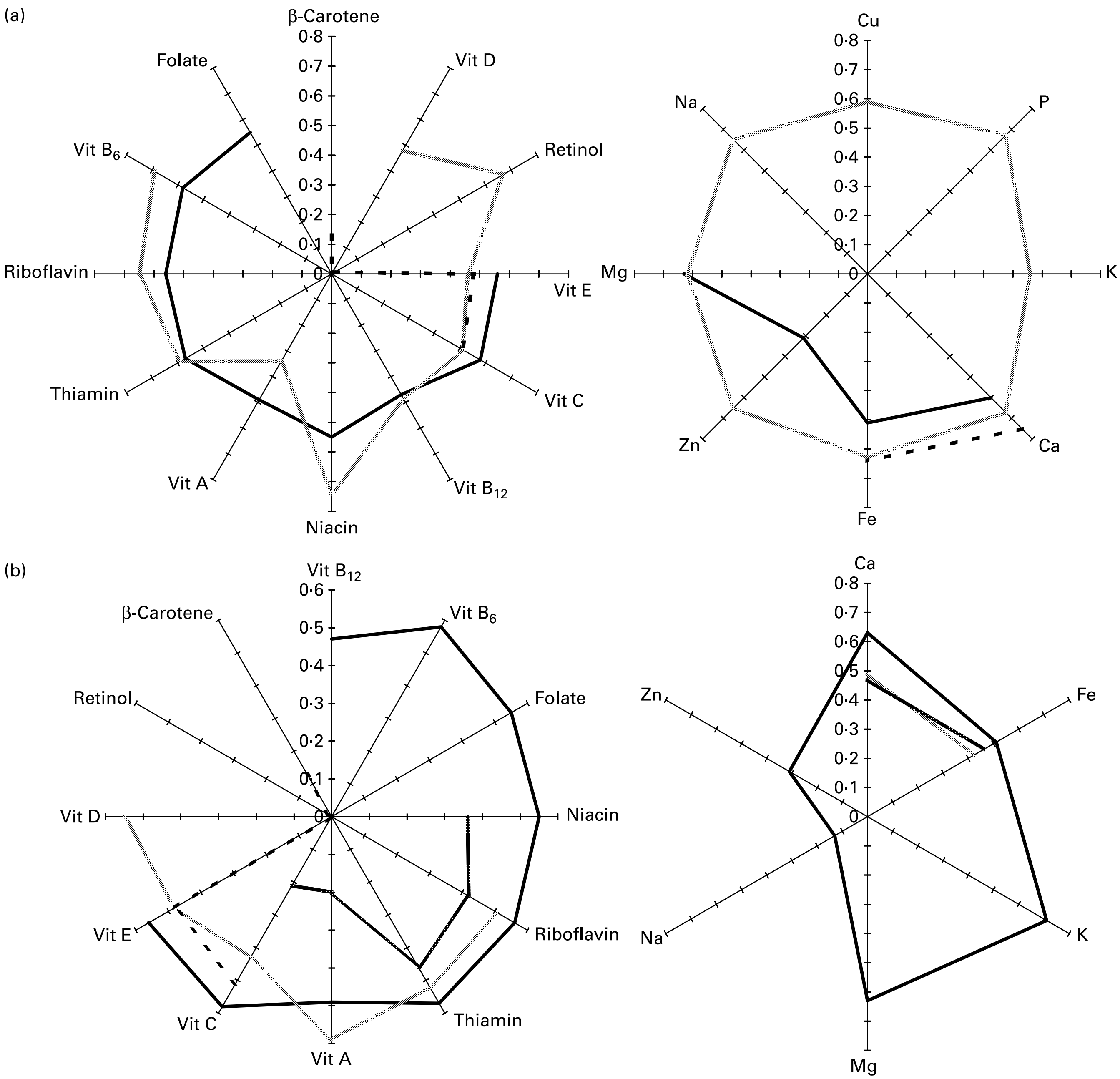


**Fig. 2.** Comparison of different dietary assessment methods in infants (1–23 months) and preschool children (2–5 years) by vitamins and minerals (mean of quality weighted correlation coefficients) 24 HR, 24 h recall; EDR, estimated dietary record; WDR, weighed dietary record; BM, biomarker; DH, diet history. (a) Infants (three or more studies: vitamin D, four studies FFQ *v.* WDR; vitamin E, three studies FFQ *v.* WDR; vitamin C, three studies FFQ *v.* WDR; thiamin, three studies FFQ *v.* WDR; riboflavin, four studies FFQ *v.* WDR; calcium, four studies FFQ *v.* WDR; iron, four studies FFQ *v.* WDR). , FFQ *v.* 24 HR (one study[24]); , FFQ *v.* WDR (four studies[2,8,9,21]); , FFQ *v.* EDR (one study[17]); , FFQ *v.* BM (one study[22]). (b) Preschool children (three or more studies: not for any micronutrient). , FFQ *v.* 24 HR (three studies[24,34,37]); , FFQ *v.* WDR (two studies[18,19,21]); , FFQ *v.* BM (one study[22]); , 24 HR *v.* DH (one study[39]).

the number of food items were observed (7–191 items). In addition, five studies were classified into group 1 with a reference method that reflected short-term intake, in which one applied 24 h recalls[24], three used WDR[8,9,21] and one applied EDR[17]. Likewise, another study was classified into group 2, where the reference method reflected long-term intake; this study used WDR as the reference method[2]. Finally, two studies utilised BM as the reference method[17,22], of which one[17] presented validation of more than one instrument. The number of repeated 24 h recalls ranged from 3 to 4 d of administration. Dietary records varying in the number of recording days (from 3 to 7 d) were used as the reference method in a total of five studies.

Comparison of different dietary assessment methods in infants by vitamins and minerals is presented in Fig. 2. This figure shows that WDR used as the reference method for evaluating FFQ presented better correlations for several micronutrients than the other methods in this population

**Table 5.** Classification of the dietary assessment methods for infants, children and adolescents according to the weighted mean of the correlations of each micronutrient (including three or more studies)

| | Correlation* | | | |
|---|---|---|---|---|
| Micronutrient/age group | FFQ *v.* WDR | FFQ *v.* (WDR + EDR) | FFQ *v.* 24 HR | (FFQ + YAQ) *v.* 24 HR |
| Vitamin D infants | A = 0·48 (four studies) | | | |
| Vitamin C infants | G = 0·51 (three studies) | | | |
| Vitamin E infants | A = 0·46 (three studies) | | | |
| Thiamin infants | G = 0·59 (three studies) | | | |
| Riboflavin infants | G = 0·65 (three studies) | | | |
| Ca | | | | |
| Infants | G = 0·67 (four studies) | G = 0·69 (five studies) | | |
| Preschool children | | A = 0·50 (four studies) | | |
| Children | | A = 0·50 (four studies) | A = 0·48 (five studies) | A = 0·49 (six studies) |
| Adolescents | G = 0·58 (three studies) | | A = 0·50 (three studies) | G = 0·52 (four studies) |
| Fe | G = 0·63 (three studies) | G = 0·63 (four studies) | | |
| Infants | | | | |

WDR, weighed dietary record; EDR, estimated dietary record; 24 HR, 24 h recall; YAQ, Youth/Adolescent Questionnaire.
* Correlation V: very good (>0·7); G: good (0·51–0·70); A: acceptable (0·30–0·50); P: poor (<0·30)

group. However, we must emphasise that this result is probably due to the fact that 57 % of the studies analysed in this group used WDR as the reference method.

Table 5 presents the classification of the dietary methods utilised for studies in infants according to the mean of the correlation coefficients for each micronutrient weighted by the quality of different validation studies included in this review. Methods analysed met the criteria of having at least three studies, thus providing sufficient data to conduct quantitative estimates for each micronutrient[40]. Vitamin D and vitamin E intake analysed using FFQ *v.* WDR showed acceptable correlations. Comparing these methods, we observed that vitamin C, thiamin, riboflavin, Ca and Fe presented a good correlation. Additionally, when FFQ were validated considering WDR and EDR as the reference methods, only Ca's correlation increased slightly. The correlation for Fe was not modified, and for the rest of the micronutrients, there was insufficient data to conduct an analysis. (Table 5)

### *Preschool children*

For this review, the preschool children group included children aged 2–5 years. Of the thirty-two articles included in the present review, ten showed data on the validation of methods used to assess micronutrient intake in preschool children[10,15,18,21,22,24,26,34,37,39]. Eight different FFQ had been validated[15,18,21,22,24,26,34,37], and a 24 h recall had been validated in two studies[10,39]. Some articles presented validation of more than one instrument, of which one study also validated 24 h recalls[22], and another study validated a food checklist and a semi-weighed method[10]. After evaluating the quality of these validation studies, the quality scores obtained ranged from 2·5 to 5. Different FFQ were validated for which wide variations in the number of food items were observed (7–125 items). Eight studies were classified into group 1 with a reference method that reflected short-term intake, in which two used WDR[10,21], another two applied EDR[15,26], three used 24 h recalls[24,34,38] and one applied a DH[39]. Likewise, one study was classified into group 2, where the reference method reflected long-term intake, in which WDR were applied[18]. Finally, one study utilised BM as the reference method, which presented validation of more than one instrument[22]. The number of repeated 24 h recalls ranged from 3 to 4 d of administration. Dietary records varying in the number of recording days (from 3 to 7 d) were used as the reference method in a total of four studies.

Comparison of different dietary assessment methods for vitamin and mineral intake in preschool children is presented in Fig. 2. This figure shows that there were not enough studies to conduct a comparison per micronutrient, as the minimum criterion of three studies per intake assessment method was not met. Moreover, when FFQ were validated applying WDR and EDR as the reference methods, only the correlation for Ca presented acceptable values (*r* 0·50; Table 5 and Fig. 3 ).

Fig. 4 only shows FFQ validation studies that assessed micronutrient intake in infants and preschool children, using a short-term[8,9,15,17,21,24,26,34,37] or a long-term[2,18] dietary assessment instrument or BM as a reference method[17,22]. In regards to the reference method that reflected short-term intake, good correlations were observed for niacin, thiamin, vitamins $B_6$, D, C, E, riboflavin, Ca, K, Mg, Fe, and Zn. However, when the reference method used reflected long-term intake, good correlations were observed only for riboflavin and Fe. Additionally, when BM were used as the reference method, a good correlation was observed only for vitamin C. None of the micronutrients analysed showed correlations higher than 0·7 using a short-term or a long-term dietary assessment instrument or BM as the reference method. However, results presented in FFQ validation studies using short-term or long-term dietary instruments or BM as the reference methods based on correlations from only one or two studies should be viewed with caution (Fig. 4). To conduct micronutrient comparisons, there should be at least three or more studies to ensure the robustness of the results obtained.

### *Children*

This group included children aged 6–12 years. Of the thirty-two articles included in the present review, seventeen showed data on validation of methods used to assess

British Journal of Nutrition

micronutrient intake in children[10–14,16,23,25,26,29–32,35,36,38,39]. After evaluating the quality of these studies, the quality scores obtained ranged from 2·5 to 5. Eleven different FFQ[11,13,14,16,23,25,26,30–32,35,38] had been validated, and 24 h recalls had been validated in three studies[10,36,39]. Different FFQ were validated for which wide variations in the number of food items were observed (10–175 items). Of these, it is worth pointing out the Youth/Adolescent Questionnaire (YAQ)[29] that is a self-administered FFQ specifically designed for children aged 9–18 years. Another validated dietary method analysed included 4 d pre-coded food diaries[12]. The pre-coded food diary is scanable and is developed to simplify the work of the respondents as well as of the researcher. Some articles presented validation of more than one instrument, of which one study also validated a food checklist and a semi-weighed method[10], and another study correlated data from WDR[23]. Eleven studies were classified into group 1 with a reference method that reflected short-term intake, in which six studies used 24HR[11,13,14,25,29,30], two applied WDR[10,12], only one study used EDR[26], one applied a DH[39] and another study observed intakes[36]. Likewise, five other studies were classified into group 3, where the reference method reflected long-term intake, two studies used WDR[16,23], two applied EDR[31,32] and only one study utilised 24 h recalls[38] as the reference method. Finally, one study was validated using

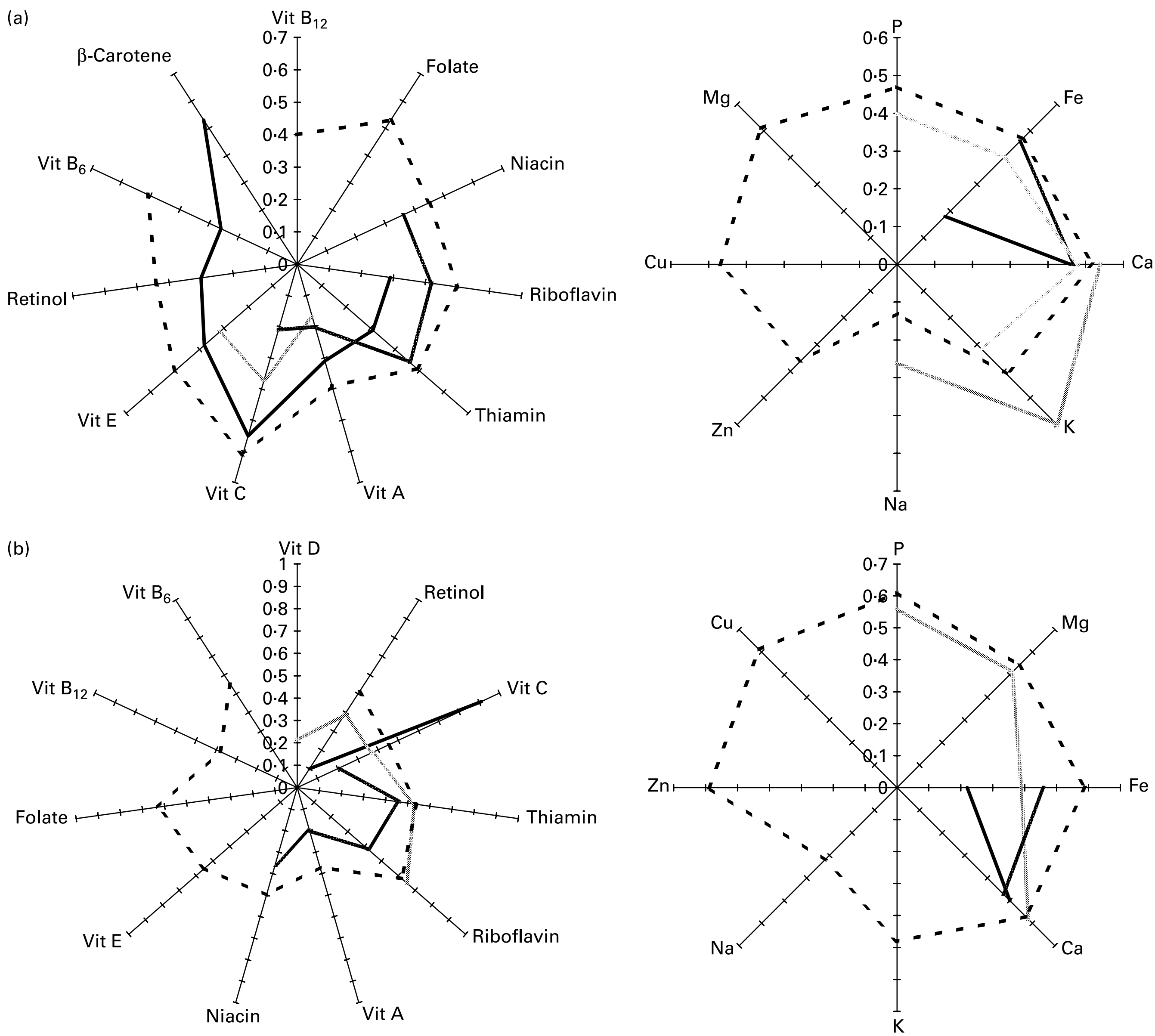


**Fig. 3.** Comparison of different dietary assessment methods in children (6–12 years) and adolescents (13–10 years) by vitamins and minerals (mean of quality weighted correlation coefficients) 24 HR, 24 h recall; EDR, estimated dietary record; WDR, weighed dietary record; DH, dietary history; YAQ, Youth/Adolescent Questionnaire. (a) Children (three or more studies: calcium, five studies FFQ *v.* 24 HR). , FFQ *v.* EDR (three studies[26,31,36]); , FFQ *v.* WDR (two studies[16,23]); , FFQ *v.* BM (one study[35]); , 24 HR *v.* DH (one study[39]); , YAQ *v.* 24 HR (one study[29]); , FFQ *v.* 24 HR (five studies[11,13,16,25,38]). (b) Adolescents (three or more studies: calcium: three studies FFQ *v.* 24 HR; three studies FFQ *v.* WDR). , FFQ *v.* 24 HR (three studies[11,14,20]); , FFQ *v.* WDR (three studies[16,27,33]); , 24 HR *v.* DH (one study[39]); , YAQ *v.* 24 HR (one study[29]).

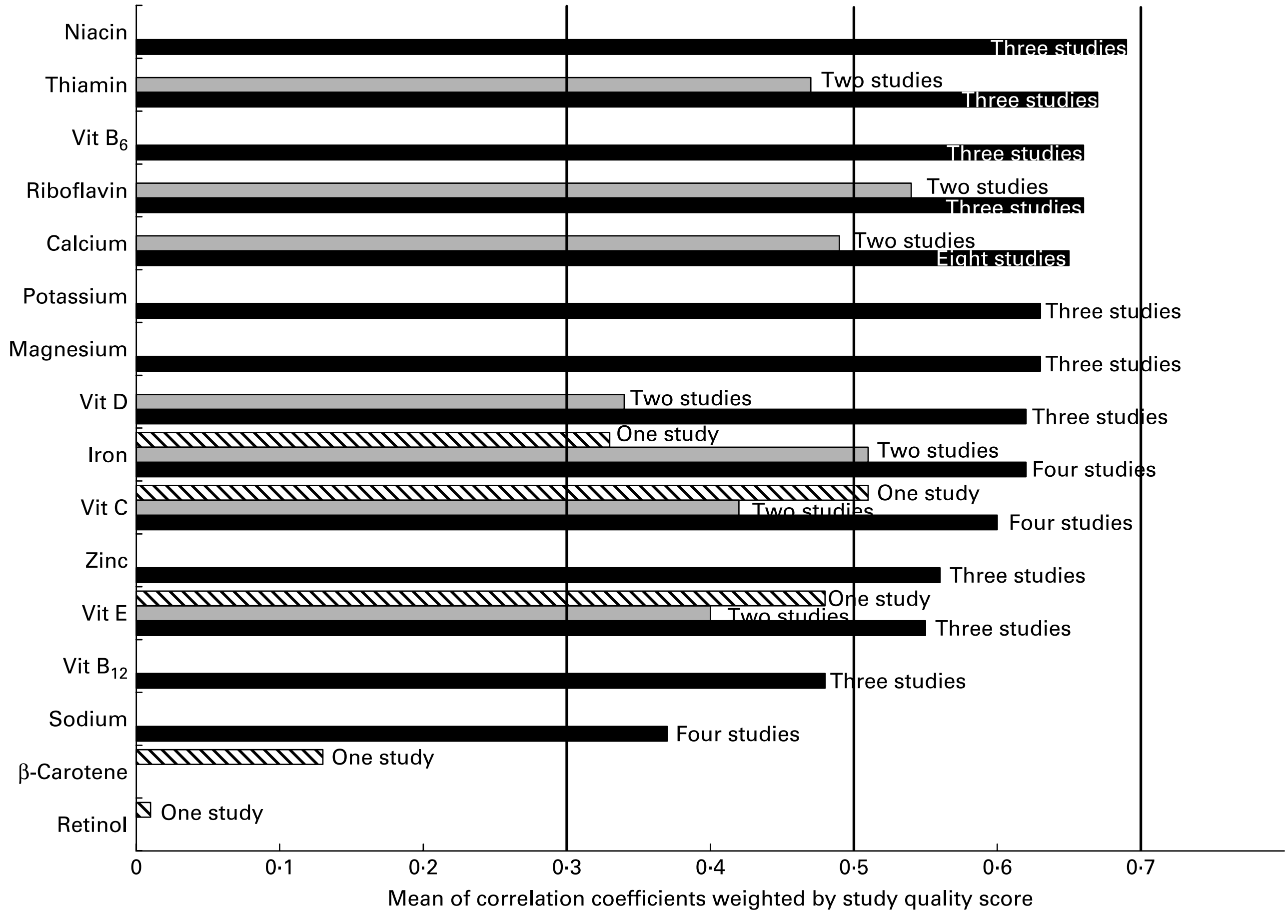


**Fig. 4.** Validation of FFQ studies that assess micronutrient intake in infants (1–23 months) and preschool children (2–5 years) using as the reference method: short-term or long-term dietary instruments or biomarkers. Correlations: poor (<0·30), acceptable (0·30–0·50), good (0·51–0·70) and very good (>0·70). Three or more studies: sodium, vitamins $B_{12}$, E, C, D, $B_6$, zinc, iron, magnesium, potassium, calcium, riboflavin, thiamin, niacin. ■, Short-term intake (<7 d); ▨, long-term intake (≥7 d); ▧, biomarkers.

BM[35]. Some articles applied more than one instrument as the reference methods, also employing the use of BM[23]. The number of repeated 24 h recalls ranged from 1 to 14 administration days. Dietary records varying in the number of recording days (from 1 to 14 d) were used as the reference method in a total of seven studies.

Fig. 3 presents the comparison of different dietary assessment methods in children by vitamins and minerals. In this figure, when the 24HR was used as the reference method, it seemed to obtain better correlations for several micronutrients. However, only five studies were included for measuring Ca intake, for which FFQ were validated against 24HR, presenting an acceptable correlation.

Additionally, when FFQ were validated utilising WDR and EDR as the reference methods, only the correlation for Ca presented an acceptable value ($r$ 0·50). Similar correlations were observed when the validity of Ca intake methods using FFQ (FFQ and YAQ) was assessed by comparing them with Ca intake estimated by 24 HR ($r$ 0·48 and $r$ 0·49, respectively). The analysis for Ca was conducted as it met the minimum of having data from at least three studies. However, for the rest of the micronutrients, there were insufficient data to conduct a comparative analysis (Table 5).

*Adolescents*

For the present paper, the adolescent age group included children aged 13–18 years. Of the thirty-two articles included in the present review, ten showed data on validation of methods used to assess micronutrient intake in adolescents[10,11,14,16,20,27–29,33,39]. Eight different FFQ[11,14,16,20,27–29,33,39] had been validated (of which one was the YAQ)[29], and 24 h recalls had been validated in two studies[10,39]. Some articles presented validation of more than one instrument, of which one study also validated a food checklist and a semi-weighed method[10]. After evaluating the quality of these studies, the quality scores obtained ranged from 2·5 to 5. Seven studies were classified into group 1 with a reference method that reflected short-term intake, in which four studies used 24HR[11,14,20,29], two studies applied WDR[10,27] and another study administered a DH[39]. In addition, two studies were classified into group 2 with a reference method that reflected long-term intake, in which WDR were used as the reference method[16,33] and finally, one study used BM[28]. The number of repeated 24 h recalls ranged from 1 to 3. Different FFQ were validated for which wide variations in the number of food items were observed (10–190 items). Dietary records varying in the number of

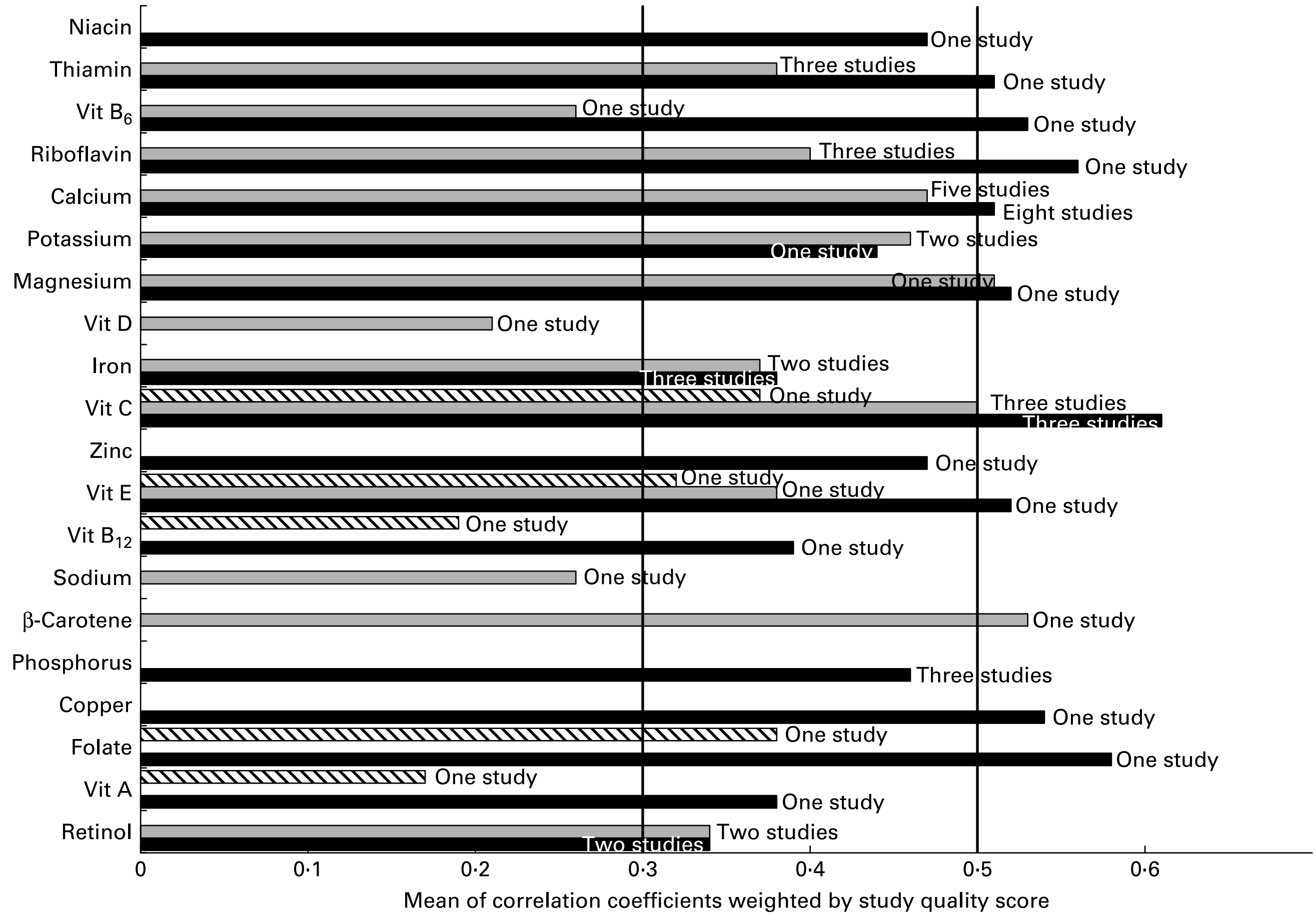


**Fig. 5.** Validation of FFQ studies that assess micronutrient intake in children (6–12 years) and adolescents (13–10 years) using short-term or long-term dietary instruments or biomarkers as the reference methods. Correlations: poor (<0·30), acceptable (0·30–0·50), good (0·51–0·70) and very good (>0·70). ■, Short-term intake (<7 d; three or more studies: vitamin C, iron, calcium, phosphorus); ▨, long-term intake (≥7 d; three or more studies: vitamin C, calcium, riboflavin, thiamin); ▧, biomarkers.

recording days (from 1 to 7 d) were used as the reference method in a total of four studies.

Comparison of different dietary assessment methods was limited in the adolescent group, due to the fact that there was an insufficient number of studies for each micronutrient that could provide conclusive results (Fig. 3). A good correlation ($r$ 0·58) was observed, when FFQ were validated applying WDR as the reference method only for Ca. Additionally, when FFQ were validated considering 24HR as the reference method, the correlation for Ca presented an acceptable correlation ($r$ 0·50). Similar correlations were observed when the validity of Ca intake using the FFQ (including the YAQ) was assessed by comparing them with Ca intake using the 24HR ($r$ 0·52). There were not enough data to conduct an analysis for the rest of the micronutrients in this population group (Table 5).

Fig. 5 shows only FFQ validation studies that assessed micronutrient intake in children and adolescents, using a short-term[11,13,14,20,25–27,29] or a long-term[16,23,31–33,38] dietary assessment instrument or BM as the reference method[23,28,35]. In regards to the reference method that reflected short-term intake, good correlations were observed for thiamin, vitamins $B_6$, C, E, riboflavin, Ca, Mg, Cu and folate. However, when the reference method used reflected long-term intake, good correlations were observed only for Mg and β-carotene. Additionally, when BM were used as the reference method, correlations having a very good classification were not observed. None of the micronutrients analysed showed correlations higher than 0·7 using short or long-term dietary assessment instruments or BM as the reference method. Nevertheless, the results presented in FFQ validation studies using short-term or long-term dietary instruments or BM as the reference methods based on correlations from less than three studies should be viewed with caution (Fig. 5).

### *Biomarkers*

A total of five publications analysed BM[17,22,23,28,35], which were used to validate five FFQ. Some articles presented validation of more than one instrument, of which one study also validated estimated dietary records[17] and two studies validated WDR using BM as the reference method[23,28]. The BM analysed were: serum markers of Fe status (ferritin, Hb)[17], plasma levels of vitamins C, D, retinol, β-carotene and α-tocopherol (vitamin E)[22], 24 h urine K[23], serum folate and serum vitamin $B_{12}$[28] and serum levels of vitamins C, A and E[35].

https://doi.org/10.1017/S0007114509993163 Published online by Cambridge University Press

## Discussion

In the present review, thirty-two studies[2,8–39] are described. The aim of this analysis was to determine the reliability of methods used to measure the usual intake of vitamins and minerals in infants, children and adolescents and how these were validated. The different studies included in this review were classified according to which reference method was used, those reflecting short-term intake, long-term intake or BM. To rate the different studies, a quality score system was developed by the European micronutrient Recommendations Aligned network. A total score was calculated according to the weighted mean of the correlations that had been adjusted by the quality of the different validation studies, and all the methods were scored into the categories: poor, acceptable, good or very good. Measuring dietary intake in very young children is difficult because of the rapid changes in the food habits of toddlers, the need to rely on parental reporting and the questionable ability of parents to accurately report their child's diet when other caregivers are also involved in feeding the child[22]. Adolescents' eating habits are highly influenced by family patterns and habits, their peer group, as well as by their increasing concern with body image. Habits such as meal skipping (particularly breakfast), consuming high-energy foods that are poor in nutrients and the tendency, particularly among girls, to restrict their diet and to go on diets are part of the repertoire of adolescent eating behaviour[20].

### *Infants*

This group included infants aged 1–23 months. Evidence for the long-term effects of infant nutrition on later health has given impetus to the need for developing methods to assess the diets of infant populations[41]. In general, for this group, the daily non-human milk intake in the previous day or week was estimated from the average total volume of bottle-feeds consumed per day; for breast-fed infants, the usual feeding length and number of feeds per day were recorded. In Andersen's study[2], the relative validity of a semi-quantitative FFQ (140-item semi-quantitative FFQ) used in 12-month-old infants was examined (with correlations ranging from 0·18 for vitamin D to 0·62 for Ca and Fe). This validation study indicated that the semi-quantitative FFQ used in infants overestimated the median intake of nutrients except for Ca intake. In a sample of fifty infants aged 6 months, Marriott *et al.* [8] compared the energy and nutrient intakes assessed by a newly developed, interviewer-administered, 34-item infant FFQ with intakes determined from 4 d WDR. Differences in intakes between methods were observed, and the agreement tended to be lower for breast-fed than for formula-fed infants. The correlation coefficients of this study compared favourably with other FFQ validation studies for young children. Reported correlation coefficients for energy and nutrients were 0·18–0·72 at 1 year in Andersen's study[2], and 0·26–0·63 for 1- to 5-year-olds in Blum's study[24]. In the latter study, an 84-item FFQ was used, with correlations ranging from 0·31 for Zn to 0·63 for Mg. Marriott *et al.* [9] also evaluated the relative validity of a 76-item FFQ for assessing micronutrient intakes in 12-month-old infants. They reported smaller correlations in infants aged 12 months (with correlations ranging from 0·24 for vitamin $B_{12}$ to 0·75 for Na) than in the infants aged 6 months (with correlations ranging from 0·55 for Cu to 0·89 for thiamin). Marshall *et al.* [21] compared nutrient intakes from beverages in a sample of 6-month-old infants using a 7-item FFQ and obtained coefficients for Ca and vitamin D intakes of 0·64 and 0·80, respectively. Similar results were shown for Marriott *et al.* [8] for these nutrients (Ca, $r$ 0·78 and vitamin D, $r = 0·83$). The ability of the FFQ to accurately rank intakes of energy and all the nutrients in infants is enhanced by the quality and detail of the information collected, which includes information about brands and types of baby foods and milks used[8]. In Williams & Innis[17], parents of 148 infants aged 8–26 months completed a 191-item FFQ and 3 d EDR for assessing Fe nutrition in infants (with correlations ranging from 0·64 for vitamin C and Fe to 0·75 for Ca). These results showed relative validity of a FFQ in comparison with 3 d EDR for estimating Fe intakes in a group of infants and suggested that while dietary assessments can serve as useful research tools to assess nutrient intakes in 8- to 26-month-old infants, they have limited value as tools to identify infants at risk of Fe deficiency.

### *Preschool children*

In this review, the preschool children group included children aged 2–5 years. Many factors contribute to making intake assessment in this age group difficult: preschool children eat small amounts of food at frequent intervals, they are not able to complete questionnaires and their food habits and nutrient intakes may rapidly change[42,43]. In Huybrechts *et al.* [15], the relative validity of a 47-item FFQ for measuring preschool children's usual Ca intake was assessed using parents or guardians as a proxy, and EDR were used as the reference method. Based on the comparison of means, the FFQ underestimated the mean Ca intake measured by the EDR. These findings are in contrast to the findings of another study[26], which reported overestimates of actual Ca intakes in young children (3–6 years) using a 35-item FFQ. Andersen *et al.* [18] presented the relative validity of food and nutrient intakes estimated by the 125-item FFQ against intakes from 7 d WDR applied in the nation-wide survey among 2-year-old children in Norway. The correlations in this study were also lower than those observed by Blum *et al.* [24] However, the correlation coefficients for nutrient density values estimated from the two methods were much higher than those seen for absolute nutrient intakes, and for ten out of sixteen nutrients, the correlations were $>0·50$. The average correlation (median $r$ 0·52) for nutrient density was similar to that observed among 12-month-old Norwegian infants (median $r$ 0·50)[2]. The agreement across quartiles between the two methods was on average (median) 36 %, which is similar to the results observed among 12-month-old infants (38 %)[2]. In Andersen's study[18], agreement across quartiles increased when using nutrient density. Other authors studied 224 preschool children and obtained dietary data by interviewing the child's mother[37]. The present study was performed to determine the utility of the Willett semi-quantitative FFQ for assessing habitual diets of preschool children. Results reported associations between nutrient intakes estimated by the FFQ and 24 h recalls, with correlations (adjusted for within-person variability and non-differential measurement error) in the range of 0·20–0·60[37]. Blum et al.[24] demonstrated that past dietary intake of children aged 1–5 years could be measured reasonably well with an 84-item FFQ completed by child's parent or guardian. Correlation coefficients between the dietary intakes assessed by the two methods ranged from 0·26 for fibre to 0·63 for Mg. All but three nutrients (protein, dietary fibre and Zn) had correlations of 0·47 or higher. After adjusting for energy intake and within-person variation, the average correlation was 0·52.

### *Children*

This group included children aged 6–12 years. The food and nutrient intake of children is important not only for growth and development but also for present and future health, including the prevention of chronic diseases in adulthood[44,45]. To succeed in nutrition monitoring and epidemiologic research among large groups of children, it is necessary to have a dietary assessment method that is both valid and functional with young age groups[12]. Almost all of the reviewed validity and reliability studies in children younger than age 9 included adult assistance in providing information on the child's intake. In general, the reviews concluded that children generally have difficulty in estimating portion sizes[46]. Räsänen[39] compared the 24 h recall method with the diet history method as used in a food consumption survey for children. The correlation coefficients between the values obtained by the 24 h recalls and the diet history method varied from 0·20 (vitamin A) to 0·50 (energy). The history method used in this study gave consistently higher mean values than the 24 h recalls. Lytle et al.[36] found correlations for nutrient intake between 0·45 and 0·79 when comparing observed and recalled food intake in 8- to 10-year-old children. These are within the same range or somewhat higher than results obtained in Lillegaard's study[12], which evaluated intake of energy, macro- and micronutrients assessed from pre-coded food diaries and by using 4 d WDR as the reference method in 9-year-old Norwegians. The pre-coded food diary is scanable and is developed to simplify the work of the respondents as well as of the researcher. In Belgium, a self-administered computer dietary assessment program 'Young Adolescents Nutrition Assessment Computer' was developed, based on the concept of the 24HR. The Young Adolescents Nutrition Assessment Computer is a computer program designed for use with children and adolescents aged 11 years and over[47]. Vereecken et al.[47] assessed the relative validity of the computerised 24 h recall Young Adolescents Nutrition Assessment Computer comparing results with a 1 d EDR and 24 h recall; the Spearman's correlations obtained for the 24 h recall (ranging from 0·44 to 0·86) were comparable to those observed by Lytle et al.[36] between 24 h recalled and observed nutrient intake of third-grade children (ranging between 0·45 and 0·79). In the study of Van Horn et al.[48], the correlations were slightly higher (0·64–0·96) using electronic methods such as telephone recalls and tape-recorded dietary records. Bellù et al.[30] reported on the ability of a 116-item FFQ to estimate the mean nutrient intake at the population level for an Italian paediatric population (mean age = 9·3 years) comparing results with a 24 h recall. Moderate concordance between the two methods was found. Similar results were presented in by Stein et al.[37] In another study, Bellù et al.[32] tested the validity for the assessment of individual nutrient intake by a 116-item FFQ for Northern Italian school children comparing results with 7 d EDR. In this study, the Pearson's correlation coefficients ranged between 0·30 and 0·58, and for some nutrients (vitamins A and $B_6$) the correlation was found to be low.

### *Adolescents*

For the present paper, the adolescent age group included youth aged 13–18 years. Adolescents are a group whose eating habits are characterised by factors such as irregular meals, snacking and meal-skipping. These eating habits are not easily conducive to diet assessment by a prospective methodology[23]. Slater et al.[20] compared the 76-item FFQ developed for adolescents to data obtained from 24 h recalls, and similar values for energy, carbohydrates, total fat and Ca intake were observed, suggesting a high consistency in estimating these nutrients. However, there was a significant difference for seven remaining nutrients (protein, polyunsaturated fat, dietary fibre, cholesterol, retinol, vitamin C and Fe). Higher values (mean $r$ 0·57) were observed with unadjusted correlations compared with results obtained by Rockett et al.[29] (mean $r$ 0·39) and Field et al.[25] (0·27 for Ca, 0·25 for P, 0·20 for Fe, 0·19 for vitamin C). The YAQ is a youth-friendly FFQ that allows 9- to 18-year-old adolescents to report on their own diet[49]. Rockett et al.[29] evaluated the questionnaire's validity by comparing the nutrient scores of the YAQ with those from the average of three 24 h recalls. Similar mean nutrients were found by both the methods. Correlation coefficients between the mean energy-adjusted nutrients computed by the two methods ranged from 0·21 for Na to 0·58 for folate. After correction for within-person error, the average correlation coefficient was 0·54, similar to that found for adults[50]. In the validation study developed by Mølgaard et al.[27], twenty-three children aged 13–14 years filled in an 88-item FFQ designed to assess Ca, protein and P intakes and kept 3 d WDR. Spearman rank correlations between nutrient intake values from the FFQ and WDR were 0·56–0·62 (mean 0·60). Another study showed similar findings for Ca intake ($r$ 0·54)[33] using 7 d WDR as the reference method.

### *Biomarkers*

Williams & Innis[17] showed the validity of nutrient intake estimates using a 191-item FFQ that was assessed by comparing data with biochemical measures of Fe status in infants. These results presented weak correlations for assessment methods (acceptable classification for FFQ v. BM $r$ 0·33 and poor classification for a 3 d EDR v. BM $r$ 0·19). This is the only study presented in this review that analyses biochemical measures of Fe status in infants and possibly, the lower correlation coefficients between Fe intake and serum ferritin observed in this study, as compared to previous studies with older subjects, involve factors inherent to studies in infants but not in older children and adults[51]. Lietz et al.[23] reported on the correlation coefficient between urinary K and dietary intake from a 130-item FFQ ($r$ −0·04) and from a 7 d WDR ($r$ 0·78) in fifty children between 11 and 13 years. The latter correlation was higher than correlations reported in a previous study[52].

Green *et al.* [28] validated a 116-item FFQ and a 3 d WDR by comparing nutrient intake estimates using these methods with serum folate and serum vitamin $B_{12}$ concentrations in 105 females aged 16–19 years. Using serum folate concentration as the sole biochemical criterion, it appeared that the 3 d WDR was superior to the FFQ as a tool to predict folate intakes. The correlations between folate intakes and serum folate as determined by 3 d WDR (adjusted *r* 0·65) showed higher correlations than those determined by FFQ (*r* 0·48; supplement users were included in these analyses). Vitamin $B_{12}$ intake as determined by either of the dietary methods showed only a modest association with serum vitamin $B_{12}$ concentrations, when supplement users were included in the analyses (3 d WDR *r* 0·32; FFQ *r* 0·25). Another author[53] using a FFQ reported a correlation of *r* 0·60 between folate intakes and plasma folate concentrations and a correlation of *r* 0·35 between vitamin $B_{12}$ intakes and serum vitamin $B_{12}$ concentrations in a group of 139 adults aged 40–83 years.

The correlations observed by Parrish *et al.* [22] compared the reported dietary intake in infants and preschool children using a 111-item FFQ with plasma concentrations of the micronutrient. The highest correlation between plasma concentrations and dietary intake as measured by the FFQ was for vitamin C (*r* 0·51), and the correlations were weak or absent for vitamin D, retinol and β-carotene. Byers *et al.* [35] administered a 111-item FFQ to ninety-seven parents of children aged 6–10 years to evaluate their children's usual dietary intake and compared results with children's serum levels of vitamins C, A and E. The correlations observed in this study between circulating levels of vitamin C (*r* 0·37) and vitamin E (*r* 0·32), and the parent's reports of their children's diets were similar to those observed in dietary validation studies conducted in adults[54]. However, it is important to keep in mind that the results presented in FFQ validation studies using BM as the reference method based on correlations from only one or two studies should be interpreted with caution (Figs. 4 and 5).

## *Conclusion*

When comparing different validation methods in infants, the reviewed studies showed that the FFQ was the method used in all the studies to assess micronutrient intake in infants. Different FFQ were validated for which wide variations in the number of food items were observed (7–191 items). The ability of the FFQ to accurately rank intakes of energy and all the nutrients in infants is enhanced by the quality and detail of the information collected, which includes information about brands and types of baby foods and milks used[8]. The WDR used as the reference method for evaluating FFQ present better correlations for several micronutrients than other methods in this population group. However, we must emphasise that this result is probably due to the fact that 57 % of the studies analysed in infants used WDR as the reference method. Vitamin D and vitamin E intake analysed using FFQ *v.* WDR showed acceptable correlations, and good correlations were observed for vitamin C, thiamin, riboflavin, Ca and Fe. For the rest of the micronutrients, there were insufficient data to conduct an analysis (three or more studies were needed for each micronutrient).

In the preschool children cluster, different FFQ were validated for which wide variations in the number of food items were observed (7–125 items).The FFQ was used as the method to assess micronutrient intake in 80 % of the studies in preschool children. Comparison of different dietary assessment methods was difficult in this group, as there were not enough studies to analyse for each micronutrient. Except for the measurement of Ca intake, acceptable correlations (*r* 0·50) were observed when FFQ were validated applying WDR and EDR as the reference methods. This age group typically eat more frequently, and since 50 % of the preschool children consume two meals outside of their homes, parents may not be able to accurately describe what was actually consumed[34].

The results presented in the FFQ validation studies for infants and preschool children, using long-term dietary instruments or BM as the reference methods were based on only one or two correlation studies and as such, there were insufficient data to reach robust conclusions. In regards to the reference method that reflected short-term intake in the infants and preschool children group, good correlations were observed for niacin, thiamin, vitamins $B_6$, D, C, E, riboflavin, Ca, K, Mg, Fe, and Zn (with mean weighted correlations ranging from 0·55 for vitamin E to 0·69 for niacin). For the analysis of these micronutrients, data from three or more studies were included (the study quality scores ranging from 2·5 to 5·5).

For the children group, 65 % of the reviewed studies used FFQ to assess micronutrient intake for which wide variations in the number of food items were observed (10–175 items). When comparing different validation methods in this group, only an acceptable correlation (*r* 0·50) was observed for measuring of Ca intake, when FFQ were validated applying WDR and EDR as the reference methods. Similar correlations were observed when the validity of Ca intake estimates using the FFQ (including YAQ) was assessed by comparing them with the Ca intake estimates using a 24HR (*r* 0·49). For the other micronutrients, there were insufficient data to compare.

Assessing the validation of different dietary assessment methods in adolescents was difficult as there were not enough studies to compare for each micronutrient. A good correlation (*r* 0·58) was observed when FFQ were validated applying WDR as the reference method only for Ca intake. Additionally, when FFQ were validated using a 24 HR as the reference method, correlations for Ca presented acceptable values (*r* 0·50). In the adolescent group, 80 % of the reviewed studies used FFQ to assess micronutrient intake for which wide variations in the number of food items were observed (10–190 items).

There were not enough data to contrast FFQ studies that assessed micronutrient intake in children and adolescents using long-term dietary instruments (except for thiamin, riboflavin, Ca and vitamin C intake that showed acceptable correlations) or BM as the reference methods. (Only one or two studies, thus being insufficient to reach strong conclusions). Regarding the reference method that reflected short-term intake in children and adolescents, good correlations were observed only for vitamin C (*r* 0·61) and Ca (*r* 0·51). In the analysis of these micronutrients, data from three or more studies were included (the study quality scores ranging from 2 to 4·5).

In the studies reviewed, FFQ comprised the dietary method that was most utilised to assess the micronutrient intake in these groups, in which it is of utmost importance to recognise methodological aspects such as food composition databases used for analysis, portion size assessment and the time periods between the two dietary assessment methods[23]. On the other hand, dietary assessment in children and adolescents using electronic methods for deriving self-reports, such as the tape-recorded food record or the computer dietary assessment program, may help improve compliance and frequency of record keeping in these age groups[48].

The micronutrients analysed in this review using BM as the reference method were: vitamins A, C, D, E, and $B_{12}$, retinol, β-carotene, folate and K. In general, the best correlations were observed when the validity of nutrient intake estimates using WDR was assessed by comparing them with micronutrient serum levels. Validation of FFQ studies that assess micronutrient intake in the infant and preschool children group using BM as the reference method presented good correlations only for vitamin C. Poor rankings ($r < 0{\cdot}3$) were observed for retinol, β-carotene and K, and acceptable rankings were observed only for vitamin E and Fe. In the children and adolescent group, the validation of FFQ studies that assess micronutrient intake comparing them with biochemical measures of micronutrient status presented poor correlations for vitamins A and $B_{12}$ and acceptable correlations for folate, vitamins E and C. However, we must emphasise once more that the data presented in FFQ validation studies using BM as the reference method showed correlations from only one or two studies; as such, this information should be viewed with caution. Including supplement users generally improved the correlations between micronutrients intakes estimated by either of the dietary intake methods and their respective biochemical indices. Nutrient BM are appealing as a comparison method because measurement errors are uncorrelated with reporting errors[55]. However, given that blood concentrations may be a result of absorption and metabolism and not only reflecting intake, nutrient BM may not always be an appropriate method of comparison[22].

## Acknowledgements

The studies reported herein have been carried out within the European micronutrient Recommendations Aligned Network of Excellence (www.eurreca.org), financially supported by the Commission of the European Communities, specific Research, Technology and Development (RTD) Programme Quality of Life and Management of Living Resources, within the Sixth Framework Programme, contract no 036196. This report does not necessarily reflect the Commission's views or its future policy in this area. A. O.-A. wrote the first manuscript; A. O.-A., P. H.-S. and A. S.-V. contributed to the planning of the search and analysed the articles included in this review; M. M. analysed the articles included in this review; L. P.-Q. and M. M. revised and discussed previous drafts; L. S.-M. contributed to the planning of the search, decided the analysis and presentation of the results and created the quality assessment tool of the articles, and revised and discussed previous drafts. There are no conflicts of interest to report. The authors of the present paper would like to thank Dr Margaret Ashwell, Dr Janet Lambert, Dr Adriënne Cavelaars, Dr Olga Souverein and Mrs Sandra Crispim for their technical contribution and advice to this publication. The authors also thank the Health Sciences Library of the University of Las Palmas de Gran Canaria, Lourdes Ribas, and Nuria Melián for their contribution in the collection of articles analysed in this review. Special thanks to Joy Ngo, RD from the Nutrition Research Foundation (FIN) for her help in editing the English version of the manuscript.

## References

1. Mascarenhas MR, Zemel B & Stallings VA (1998) Nutritional assessment in paediatrics. *Nutrition* **14**, 105–115.
2. Andersen LF, Lande B, Arsky GH, *et al.* (2003) Validation of a semi-quantitative food-frequency questionnaire used among 12-month-old Norwegian infants. *Eur J Clin Nutr* **57**, 881–888.
3. Baranowski T & Domel SB (1994) A cognitive model of children's reporting of food intake. *Am J Clin Nutr* **59**, S212–S217.
4. Livingstone MB & Robson PJ (2000) Measurement of dietary intake in children. *Proc Nutr Soc* **59**, 279–293.
5. Sobo EJ & Rock CL (2001) 'You ate all that!?': caretaker-child interaction during children's assisted dietary recall interviews. *Med Anthropol Q* **15**, 222–244.
6. Frank GC (1997) Methodological issues regarding eating behavior of high-risk adolescents. *Ann N Y Acad Sci* **817**, 66–82.
7. Ashwell M, Lambert JP, Alles MS, *et al.* (2008) How we will produce the evidence-based EURRECA toolkit to support nutrition and food policy. *Eur J Nutr* **47**, Suppl. 1, 2–16.
8. Marriott LD, Robinson SM, Poole J, *et al.* (2008) What do babies eat? Evaluation of a food frequency questionnaire to assess the diets of infants aged 6 months. *Public Health Nutr* **11**, 751–756.
9. Marriott LD, Inskip HM, Borland SE, *et al.* (2008) What do babies eat? Evaluation of a food frequency questionnaire to assess the diets of infants aged 12 months. *Public Health Nutr* **12**, 967–972.
10. Holmes B, Dick K & Nelson M (2008) A comparison of four dietary assessment methods in materially deprived households in England. *Public Health Nutr* **11**, 444–456.
11. Moore M, Braid S, Falk B, *et al.* (2007) Daily calcium intake in male children and adolescents obtained from the rapid assessment method and the 24-hour recall method. *Nutr J* **6**, 24–28.
12. Lillegaard IT, Løken EB & Andersen LF (2007) Relative validation of a pre-coded food diary among children, under-reporting varies with reporting day and time of the day. *Eur J Clin Nutr* **61**, 61–68.
13. Magkos F, Manios Y, Babaroutsi E, *et al.* (2006) Development and validation of a food frequency questionnaire for assessing dietary calcium intake in the general population. *Osteoporos Int* **17**, 304–312.
14. Harnack LJ, Lytle LA, Story M, *et al.* (2006) Reliability and validity of a brief questionnaire to assess calcium intake of middle-school-aged children. *J Am Diet Assoc* **106**, 1790–1795.
15. Huybrechts I, De Bacquer D, Matthys C, *et al.* (2006) Validity and reproducibility of a semi-quantitative food-frequency questionnaire for estimating calcium intake in Belgian preschool children. *Br J Nutr* **95**, 802–816.
16. Bertoli S, Petroni ML, Pagliato E, *et al.* (2005) Validation of food frequency questionnaire for assessing dietary macronutrients and calcium intake in Italian children and adolescents. *J Pediatr Gastroenterol Nutr* **40**, 555–560.
17. Williams PL & Innis SM (2005) Food frequency questionnaire for assessing infant iron nutrition. *Can J Diet Pract Res* **66**, 176–182.

18. Andersen LF, Lande B, Trygg K, *et al.* (2004) Validation of a semi-quantitative food-frequency questionnaire used among 2-year-old Norwegian children. *Public Health Nutr* **7**, 757–764.
19. Andersen LF, Lande B, Trygg K, *et al.* (2004) Validation of a semi-quantitative food-frequency questionnaire used among 2-year-old Norwegian children – Corrigendum. *Public Health Nutr* **12**, 1026–1027.
20. Slater B, Philippi ST, Fisberg RM, *et al.* (2003) Validation of a semi-quantitative adolescent food frequency questionnaire applied at a public school in São Paulo, Brazil. *Eur J Clin Nutr* **57**, 629–635.
21. Marshall TA, Eichenberger Gilmore JM, Broffitt B, *et al.* (2003) Relative validation of a beverage frequency questionnaire in children ages 6 months through 5 years using 3-day food and beverage diaries. *Am Diet Assoc* **103**, 714–720.
22. Parrish LA, Marshall JA, Krebs NF, *et al.* (2003) Validation of a food frequency questionnaire in preschool children. *Epidemiology* **14**, 213–217.
23. Lietz G, Barton KL, Longbottom PJ, *et al.* (2002) Can the EPIC food-frequency questionnaire be used in adolescent populations? *Public Health Nutr* **5**, 783–789.
24. Blum RE, Wei EK, Rockett HR, *et al.* (1999) Validation of a food frequency questionnaire in Native American and Caucasian children 1 to 5 years of age. *Matern Child Health J* **3**, 167–172.
25. Field AE, Peterson KE, Gortmaker SL, *et al.* (1999) Reproducibility and validity of a food frequency questionnaire among fourth to seventh grade inner-city school children: implications of age and day-to-day variation in dietary intake. *Public Health Nutr* **2**, 293–300.
26. Taylor RW & Goulding A (1998) Validation of a short food frequency questionnaire to assess calcium intake in children aged 3 to 6 years. *Eur J Clin Nutr* **52**, 464–465.
27. Mølgaard C, Sandström B & Michaelsen KF (1998) Evaluation of a food frequency questionnaire for assessing of calcium, protein and phosphorus intakes in children and adolescents. *Scand J Nutr* **42**, 2–5.
28. Green TJ, Allen OB & O'Connor DL (1998) A three-day weighed food record and a semiquantitative food-frequency questionnaire are valid measures for assessing the folate and vitamin B-12 intakes of women aged 16 to 19 years. *J Nutr* **128**, 1665–1671.
29. Rockett HR, Breitenbach M, Frazier AL, *et al.* (1997) Validation of a youth/adolescent food frequency questionnaire. *Prev Med* **26**, 808–816.
30. Bellù R, Riva E, Ortisi MT, *et al.* (1996) Validity of a food frequency questionnaire to estimate mean nutrient intake of Italian school children. *Nutr Res* **16**, 197–200.
31. Arnold JE, Rohan T, Howe G, *et al.* (1995) Reproducibility and validity of a food-frequency questionnaire designed for use in girls age 7 to 12 years. *Ann Epidemiol* **5**, 369–377.
32. Bellù R, Ortisi MT, Riva E, *et al.* (1995) Validity assessment of a food frequency questionnaire for school-age children in Northern Italy. *Nutr Res* **15**, 1121–1128.
33. Andersen LF, Nes M, Lillegaard IT, *et al.* (1995) Evaluation of a quantitative food frequency questionnaire used in a group of Norwegian adolescents. *Eur J Clin Nutr* **49**, 543–554.
34. Iannotti RJ, Zuckerman AE, Blyer EM, *et al.* (1994) Comparison of dietary intake methods with young children. *Psychol Rep* **74**, 883–889.
35. Byers T, Trieber F, Gunter E, *et al.* (1993) The accuracy of parental reports of their children's intake of fruits and vegetables: validation of a food frequency questionnaire with serum levels of carotenoids and vitamins C, A, and E. *Epidemiology* **4**, 350–355.
36. Lytle LA, Nichaman MZ, Obarzanek E, *et al.* (1993) Validation of 24-hour recalls assisted by food records in third-grade children. The CATCH Collaborative Group. *J Am Diet Assoc* **93**, 1431–1436.
37. Stein AD, Shea S, Basch CE, *et al.* (1992) Consistency of the Willett semiquantitative food frequency questionnaire and 24-hour dietary recalls in estimating nutrient intakes of preschool children. *Am J Epidemiol* **15**, 667–677.
38. Jenner DA, Neylon K, Croft S, *et al.* (1989) A comparison of methods of dietary assessment in Australian children aged 11–12 years. *Eur J Clin Nutr* **43**, 663–673.
39. Räsänen L (1979) Nutrition survey of Finnish rural children. VI. Methodological study comparing the 24-hour recall and the dietary history interview. *Am J Clin Nutr* **32**, 2560–2567.
40. Treadwell JR, Tregear SJ, Reston JT, *et al.* (2006) A system for rating the stability and strength of medical evidence. *BMC Med Res Methodol* **6**, 52–70.
41. Owen CG, Martin RM, Whincup PH, *et al.* (2005) Effect of infant feeding on the risk of obesity across the life course: a quantitative review of published evidence. *Pediatrics* **115**, 1367–1377.
42. Hertzler AA, Bowens J & Hull S (1993) Preschoolers' reporting of food habits. *J Am Diet Assoc* **93**, 1159–1161.
43. Stein AD, Shea S, Basch CE, *et al.* (1991) Variability and tracking of nutrient intakes of preschool children based on multiple administrations of the 24-hour dietary recall. *Am J Epidemiol* **134**, 1427–1437.
44. Berenson GS (2002) Childhood risk factors predict adult risk associated with subclinical cardiovascular disease. The Bogalusa Heart Study. *Am J Cardiol* **90**, 3L–7L.
45. McGill HC Jr, McMahan CA, Herderick EE, *et al.* (2000) Origin of atherosclerosis in childhood and adolescence. *Am J Clin Nutr* **72**, Suppl. 5, 1307–1315.
46. Cypel YS, Guenther PM & Petot GJ (1997) Validity of portion-size measurement aids: a review. *J Am Diet Assoc* **97**, 289–292.
47. Vereecken CA, Covents M, Matthys C, *et al.* (2005) Young adolescents' nutrition assessment on computer (YANA-C). *Eur J Clin Nutr* **59**, 658–667.
48. Van Horn LV, Gernhofer N, Moag-Stahlberg A, *et al.* (1990) Dietary assessment in children using electronic methods: telephones and tape recorders. *J Am Diet Assoc* **90**, 412–416.
49. Lamb MM, Ross CA, Brady HL, *et al.* (2007) Comparison of children's diets as reported by the child via the Youth/Adolescent Questionnaire and the parent via the Willett food-frequency questionnaire. *Public Health Nutr* **10**, 663–670.
50. Rimm EB, Giovannucci EL, Stampfer MJ, *et al.* (1992) Reproducibility and validity of an expanded self-administered semi-quantitative food frequency questionnaire among male health professionals. *Am J Epidemiol* **135**, 1114–1126.
51. Fomon SJ, Ziegler EE, Nelson SE, *et al.* (1981) Cow milk feeding in infancy: gastrointestinal blood loss and iron nutritional status. *J Pediatr* **98**, 540–545.
52. McKeown NM, Day NE, Welch AA, *et al.* (2001) Use of biological markers to validate self-reported dietary intake in a random sample of the European Prospective Investigation into Cancer United Kingdom Norfolk cohort. *Am J Clin Nutr* **74**, 188–196.
53. Jacques PF, Sulsky SI, Sadowski JA, *et al.* (1993) Comparison of micronutrient intake measured by a dietary questionnaire and biochemical indicators of micronutrient status. *Am J Clin Nutr* **57**, 182–189.
54. Coates RJ, Eley JW, Block G, *et al.* (1991) An evaluation of a food frequency questionnaire for assessing dietary intake of specific carotenoids and vitamin E among low-income black women. *Am J Epidemiol* **134**, 658–671.
55. Willett WC, Sampson L, Stampfer MJ, *et al.* (1985) Reproducibility and validity of a semiquantitative food frequency questionnaire. *Am J Epidemiol* **122**, 51–65.

British Journal of Nutrition