British Journal of Nutrition (2009), 102, S118–S149
doi:10.1017/S0007114509993175

Dietary assessment methods for micronutrient intake in elderly people: a systematic review

Adriana Ortiz-Andrellucchi[1]*, Almudena Sánchez-Villegas[1], Jorge Doreste-Alonso[1], Jeanne de Vries[2], Lisette de Groot[2] and Lluís Serra-Majem[1]

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

[2]*Division of Human Nutrition, Wageningen University and Research Centre, PO Box 8129, 6700EV Wagenigen, The Netherlands*

(Received 5 April 2009 – Revised 28 September 2009 – Accepted 15 October 2009)

The European micronutrient recommendations aligned (EURRECA) Network of Excellence seeks to establish clear guidelines for assessing the validity of reported micronutrient intakes among vulnerable population groups. A systematic literature review identified studies validating the methodology used in elderly people for measuring usual dietary micronutrient intake. The quality of each validation study selected was assessed using a EURRECA-developed scoring system. The validation studies were categorised according to whether the reference method applied reflected short-term intake (<7 d), long-term intake (≥7 d) or used biomarkers (BM). A correlation coefficient for each micronutrient was calculated from the mean of the correlation coefficients from each study weighted by the quality of the study. Thirty-three papers were selected, which included the validation of twenty-five different FFQ, six diet histories (DH), one 24-h recall (24HR) and a videotaped dietary assessment method. A total of five publications analysed BM, which were used to validate four FFQ, and one 24HR, presenting very good correlations only for vitamin E. The analysis of weighted correlation coefficients classified by FFQ or DH showed that most of the micronutrients had higher correlations when the DH was used as the dietary method. Comparing only FFQ results showed very good correlations for measuring short-term intakes of riboflavin and thiamin and long-term intakes of P and Mg. When frequency methods are used for assessing micronutrient intake, the inclusion of dietary supplements improves their reliability for most micronutrients.

Elderly people: Dietary assessment methods: Systematic review: Validation: Micronutrients

The elderly population continues to increase in most countries and inadequate nutrition is a common problem affecting their functional and physical status. A variety of physiological, psychological, economic and social changes that may compromise nutritional status accompany aging. Inadequate nutrition is a major problem for elderly people(1). Most of the tools used to assess nutritional intake in large epidemiological studies were originally developed to be used in young and middle-aged subjects and, therefore, their validity and reliability when employed in older subjects remain uncertain(2). Klein *et al.* (3) concluded in their review of the literature that no gold standard exists for determining nutritional status.

Few studies have assessed the use and validity of dietary assessment methods in elderly people, particularly those classified in the oldest age group (75 years plus)(4). For the assessment of average long-term dietary intake in large numbers of individuals, FFQ have emerged as particularly useful tools since they give a better approximation of usual long-term dietary intake than short-term records, can be self-administered and are relatively inexpensive to use. Short-term recalls and diet records are expensive and unrepresentative of usual intake if only a few days are assessed and inappropriate for assessment of past diet(4).

In studying health and disease in elderly subjects, information may be needed concerning current or past dietary intake. Regardless of which time period was assessed, the validity of self-reported dietary information probably diminishes with increasing respondent age. In studying diet in elderly subjects, obtaining information from surrogate sources may improve information quality and provide data otherwise unavailable for deceased or incompetent subjects, such as those with memory loss or visual impairment(5).

Research conducted as part of the European Commission's EURopean micronutrient RECommendations Aligned (EURRECA) Network of Excellence 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,

Abbreviations: BM, biomarkers; DH, diet history; EDR, estimated dietary records; 24HR, 24-h recall; WDR, weighed dietary records.

On behalf of EURRECA's RA 1.1 'Intake Methods' members: Serra-Majem L (Coordinator), Cavelaars A, De Groot L, De Vries J, Dhonukshe-Rutten R, Doreste JL, Frost-Andersen L, García-Álvarez A, Glibetic M, 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, Tabacchi G, Tepsic J, Trichopoulou A, van't Veer P, Vucic V, Wijnhoven TMA.

* **Corresponding author:** Adriana Ortiz-Andrellucchi, fax +34 928 453475, email aortiza@acciones.ulpgc.es

children, adolescents and elderly people[6]. In the present review, studies validating dietary methods for assessing micronutrient intake in elderly people are presented.

Materials and methods

A systematic literature search was performed in April 2008. The research question applied to the systematic review was, 'Which dietary methods are reliable for the assessment of micronutrient intake in elderly people?'. 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. 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; correlational study in the title and abstract. A second specific search included the following words: elderly; elder; 'aged 65 and over'; 'older people'; 'dietary assessment'; 'dietary intake'; 'nutrition assessment'; 'diet quality'; reliability; reproducibility; validit*; 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 title and abstract 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).

Moreover, the different studies included in this review were scored according to a quality score system developed by EURRECA, which has been described in another article in this supplement[7]. 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 mean weighted correlation was $<0{\cdot}30$. Methods whose mean weighted correlations were between 0·30 and 0·50 were regarded as acceptable for assessing nutrient intake. Good methods were those whose weighted correlation average were between 0·51 and 0·70, and finally, when the mean weighted correlation was $>0{\cdot}70$, the method was considered very good.

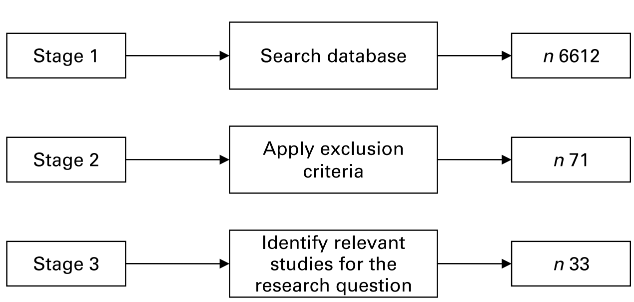

Fig. 1. Main stages of the systematic review process.

Table 1. Inclusion and exclusion criteria

Inclusion criteria
(1) Studies on micronutrient intake in elderly people, including supplements
(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-three publications[4,8–39] were selected for inclusion, with information on each validation study summarised in Table 2. Sixteen of the publications showed results from European countries (Norway, Denmark, United Kingdom, The Netherlands, Spain, Greece, Switzerland, Sweden, Italy and the Europe wide SENECA study), fourteen from the United States, two from Australia and one study was from New Zealand. The number of participants in the selected studies varied from 37 to 1286.

In seven of the studies presented[9,11,16,20,36–38], 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 in total twenty-one micronutrients were analysed. In eleven of the studies presented[10,12–16,20,21,28,30,31], dietary supplements were also analysed. Tables 3 and 4 show information on the correlation between methods and other statistics regarding validation studies in elderly people for twelve vitamins and nine minerals, respectively. Table 5 presents the classification of the dietary methods applied to the elderly according to the mean of the correlation coefficients weighted by the quality of different validation studies for each micronutrient included in this review. Nine studies[8,11,12,14,15,17,23,24,31] validated FFQ against 24HR, and a total of twenty micronutrients were evaluated in these correlation studies. These assessment methods showed acceptable correlation for eight micronutrients, good correlation for another eight micronutrients, while four micronutrients (Mg, Se, thiamin and riboflavin) showed a very good correlation. Six different FFQ were validated against EDR[16,21,27,29,33,38]. In these studies, fifteen micronutrients were analysed, in which acceptable

British Journal of Nutrition

British Journal of Nutrition

Table 2. Characteristics of included studies

Author/year of publication and country	Participants	Dietary method	Reference method	Micronutrient	Conclusions
Quandt *et al.* (2007)[8] USA	122 multi-ethnic population of low socio-economic status aged ≥65 years	Block FFQ, Past 24-h intake. Ninety-four food items Nine frequency categories Portion size (small, medium or large) PSFFQ Same food items as the FFQ and a colour photograph of each food was presented in card. Interviewer-administered	Six 24HR over 6 months at intervals of 1 month. Interviewer-administered	Vitamins A, E, C, B_6, niacin, folate, Ca, Fe, P, Zn, K, Na	Dietary assessment using 24HR and FFQ was similar to results reported elsewhere, although correlations between 24HR and FFQ were somewhat lower.
van de Rest *et al.* (2007)[9] The Netherlands	1286 individuals aged 50–75 years	FFQ specifically measure folate intake Past 3 months intake. Eighty-nine food items Ten frequency categories Portion size in natural units, household units or grams. Interviewer-administered	BM Concentration of serum and erythrocyte folate	Folate	The FFQ showed a weak correlation between folate intake and blood folate concentrations.
Vioque *et al.* (2007)[10] Spain	252 men and 293 woman 65 years and older	135-item FFQ Interviewer-administered Past 12 months intake Nine frequency categories Included dietary supplements	BM Plasma concentrations of β-carotene and vitamin C	β-Carotene, Vitamin C	The present study suggest that plasma carotenoids and vitamin C may be good markers of dietary intake in elderly subjects.
Magkos *et al.* (2006)[11] Greece	390 elderly individuals Mean age 68·6 years	30-item FFQ Past 12 months intake Self-administered	Multipass 24HR Interviewer-administered Standard household measures (cups, tablespoons, etc) Picture food models	Ca	The FFQ under-estimated mean Ca intake compared with the 24HR in all study groups, the magnitude of under-estimation was less in children than in adults or in the elderly, with no differences between the sexes.
Dumartheray*et al.* (2006)[4] Switzerland	401 elderly ambulatory women Mean age 80·4 years	FFQ 110 food items Past 12 months intake Nine frequency categories	4-d WDR (three consecutive weekdays and one weekend day) Self-administered Common household measures (cups, tablespoons, etc)	Ca, Fe, P, K, Mg, vitamins C, D, B_{12}	Provide evidence that FFQ adequately estimate nutrient intakes and can be used to rank individuals within distributions of intake in specific populations.
Messerer *et al.* (2004)[12] Sweden	248 middle-aged and elderly men (40–74 year old)	FFQ Eighty-eight food items Past year intake. Self-administered Nine frequency categories Portion size (small, medium or large) Included dietary supplements	Fourteen 24HR Interviewer-administered Participants were telephoned about once a month for 1 year, covering every day of the week.	Carotene, retinol, vitamins D, E, C, B_6, folate, Fe, Ca, Mg, Se, Zn	Adding information about dietary supplement use increased by 13 % overall the validity of micronutrient estimates based on a self-administered FFQ.
Flood *et al.* (2004)[13] Australia	Seventy-eight people mean age 70 years	FFQ 145 food items Past 12 months intake Included dietary supplements	Three 4-d WDR	Folate, vitamin B_{12}	FFQ were reasonable for ranking individuals according to their vitamin B_{12} intake. FFQ have a tendency to over-estimate folate intake.

Table 2. *Continued*

Author/year of publication and country	Participants	Dietary method	Reference method	Micronutrient	Conclusions
Morris *et al.* (2003)[14] USA	118 black and 114 white participants aged 68–99 years	Modified Harvard self-administered FFQ 139 food items Past 12 months intake Included dietary supplements	Multiple 24HR over \a year's time Interviewer-administered	Vitamins E, C, B_6, B_{12}, folate, Ca	The modified Harvard SFFQ is a reasonable method of dietary assessment even in the elderly.
Tangney *et al.* (2004)[15] USA	Fifty-nine subjects ≥ 65 years	Modified Harvard FFQ 156 food items. Self-administered Included dietary supplements	Six 24HR over a year's time Interviewer-\administered BM (blood concentrations)	Vitamins E, C, β-carotene	The modified Harvard FFQ provide reasonable estimates of serum levels of vitamins E, C and β-carotene among elderly participants
Montomoli *et al.* (2002)[16] Italy	206 Caucasian women aged 25–75 years	FFQ Fifteen food items Portion size (small, medium or large) Interviewer-administered Included Ca supplements	14-d EDR (after completing the FFQ)	Ca	The FFQ could be used in epidemiological studies to assess Ca intake in young to elderly women.
Wengreen *et al.* (2001)[17] USA	208 men and women aged 55–84 years	Picture-sort FFQ 138 food items Interviewer-administered Standard household measures (cups, tablespoons, etc). Five frequency categories Past 12 months intake	Three seasonal 24HR were administered 3 months apart during the year between the two FFQ. Telephone interviews. Included days of the week and included at least one weekend day.	Vitamins A, D, C, Ca	Correlations between methods comparable to those reported in the literature for traditional paper-and-pencil FFQ and one other picture-sort method of FFQ
Pedersen *et al.* (2001)[18] Denmark	240 men and women aged 80 years	Diet history Interviewer-administered	3-d EDR (three consecutive weekdays and one week-end day) Common household measures	Vitamins A, C, B_6, B_{12}, E, D, retinol, carotene, thiamin, riboflavin, folate, Na, K, Ca, Mg, P, Fe, Zn, iodine, Se	The modified DH method can be used to estimate dietary intake in 80-year-old subjects, but some degree of misreporting, especially under-reporting, appears to be present.
Espeland *et al.* (2001)[19] USA	341 participants from the Trial of Nonpharmacological Intervention in the Elderly (TONE)	Repeated 24-h dietary recalls administered over 3 years of follow-up Interviewer-administered	Biomarkers 24-h urine collections	Na, K	Dietary recalls yielded estimates of Na intake that averaged 22 % less than those from urine assays and estimates of K intake that average 16 % greater than those from urine assays.
Tucker *et al.* (1999)[20] USA	346 woman and 201 men, aged 67–93 years, in the Framingham Heart Study	Willett 126-item FFQ Self-administered Included dietary supplements	BM Biochemical plasma measures	β-Carotene	FFQ provide reasonable rankings of carotenoid status among elderly subjects
Klipstein-Grobusch *et al.* (1998)[21] The Netherlands	Eighty men and women Aged 55–75 years	170-item FFQ Included dietary supplements Interviewer-administered Portion size in natural units, household units or grams. Past 12 months intake	15-d EDR	Vit B_6, C, thiamin, riboflavin, Na, K, Fe, Ca, P, Mg, Zn	Adaptation of a SFFQ for use in the elderly resulted in a valid and time-efficient dietary assessment instrument.

Table 2. *Continued*

Author/year of publication and country	Participants	Dietary method	Reference method	Micronutrient	Conclusions
Smith *et al.* (1998)[22] Australia	Seventy-nine participants Aged 63–80 years	145-item FFQ Self-administered. Nine frequency categories Past 12 months intake. Portion size in natural units or household units.	Three 4-d WDR (four consecutive days,starting on a specified day of the week) 4 months interval	β-Carotene, retinol, vitamin C, Zn, Fe, Ca, thiamin, riboflavin	The results verify that it is possible to use relatively simple FFQ to study nutrient intake in the elderly.
Kumanyika *et al.* (1997)[23] USA	Ninety-six men and women Aged 66–100 years	Ninety-nine-item PSFFQ Five frequency categories Interviewer-administered	Six 24-h dietary recalls Interviewer-administered	Retinol, β-carotene, vitamins C, E, Ca, Fe	Sorting or picture-sort procedures deserve systematic attention in research on dietary assessment methods.
Kumanyika *et al.* (1996)[24] USA	Forty-seven female and forty-nine male volunteers aged 66–100 years	Ninety-nine-item pictured sort FFQ Five frequency categories Interviewer-administered	Six 24-h dietary recalls Interviewer-administered	Retinol, β-carotene, vitamins C, E, Ca, Fe	Estimates of picture-sort and estimates based on 24HR, correlations with reference data were similar to those reported in the literature for conventionally administered FFQ
van Staveren *et al.* (1996)[25] SENECA study	387 men and 420 women aged 74–79 years from seven European towns	Diet history Checklist of foods based on the meal pattern of the country Past 1 month intake. Portion size in household units.	3-d EDR Portion size based on standard portion Included weekdays and weekend day	Vitamins C, B_6, Ca, Fe, retinol, thiamin, riboflavin	Overall, correlation coefficients indicate acceptable agreement between the dietary history and record method in ranking individuals according to their intakes.
Groothenhuis *et al.* (1995)[26] The Netherlands	Seventy-four men and women aged 50–75 years	Seventy-five food items FFQ Self-administered Eleven frequency categories Portion size in household units.	Diet history Interviewer-administered	Vitamins A, C, B_6, thiamin, riboflavin, niacin, Na, K, Fe, Ca, P	These results demonstrate an acceptable relative validity for this questionnaire, as compared with the DH method.
Rothenberg E. (1994)[27] Sweden	Seventy-six participants 70 years old	FFQ 224 food items Photographs modelling various portion sizes.	4-d EDR (four consecutive weekdays and one weekend day)	Vitamins D, C, thiamin, Ca, Fe	The FFQ method well reflects habitual intake of elderly Swedes.
Mares-Perlman *et al.* (1993)[28] USA	115 participants aged 65–86 years	Diet history Ninety-nine food items Portion size (small, medium or large) Included dietary supplements Interviewer-administered Past 12 months intake	Four 2-d EDR over a year's time. Three months interval Interviewer-administered	Vitamins A, C, thiamin, niacin, riboflavin, folate, Ca, Fe, Zn	Diet history questionnaire produces nutrient estimates that rank individuals on the basis of intake of most nutrients similar to estimates from multiple food records.
Horwath (1993)[29] New Zeland	Fifty-three participants mean age 70 years	FFQ 120 food items Self-administered. Past 12 months intake	10-d EDR Portion size in household units.	Vitamins B_6, C, folate, Ca, Zn, Se	These data indicate that in elderly subjects a simple self-administered FFQ can provide similar information to that obtained from 10-d EDR.
Nes *et al.* (1992)[30] Norway	Thirty-eight elderly women	FFQ 180 food items Self-administered Included dietary supplements Portion size in household units Nine frequency categories	14-d WDR (ten consecutive weekdays and four weekend days)	Vitamins A, D, C, thiamin, riboflavin, Fe, Mg	The present study indicates that the self-administered FFQ are useful for measuring individual or group intakes for a variety of nutrients.

Table 2. *Continued*

Author/year of publication and country	Participants	Dietary method	Reference method	Micronutrient	Conclusions
Munger *et al.* (1992)[31] USA	Forty-four women aged 55–69 years	FFQ 126 food items Self-administered Included dietary supplements Past 12 month intake	Five 24-h dietary recalls Telephone interviews 2-D Food Portion Visual Includes dietary supplements	Ca, Fe, P, K, vitamins A, D, E, C, B_6, B_{12}, retinol, thiamin, riboflavin, folate	This FFQ appear to be reasonably reproducible and accurate, so that its use may be extended to epidemiologic studies of older women with a broad range of socio-economic backgrounds.
Nes *et al.* (1991)[32] SENECA study	Eighty-two elderly participants	Diet history Interviewer-administered Past 1 month intake Portion size in household units	3-d WDR Interviewer-administered	Ca, Fe, vitamins A, C, B_6, β-carotene, thiamin, riboflavin	The DH method applied in the present study measured a higher food consumption among the elderly than the precise weighed record.
Potosky *et al.* (1990)[33] USA	Ninety-seven women 45–70 years old	FFQ Ninety-four food items Self-administered Past 6 months intake Portion size (small, medium or large)	Three 4-d EDR over 1-year period	Vitamins A, C, Ca, Fe, thiamin, riboflavin, P, K, Na	The apparent validity of a questionnaire increases when it is compared with a greater number of 4-d EDR
Osler & Schroll (1990)[34] Denmark	194 elderly participants aged 70–75 years	Diet history Interviewer-administered Portion size in household units	3-d WDR Interviewer-administered Portion size in household units	Vitamins A, C, Ca	The DH method may be inadequate for determining the exact level of mean and distribution of dietary intake in a group or the precise intake of an individual.
Brown *et al.* (1990)[35] USA	Thirty-seven elderly participants mean age 81·8	Videotape dietary assessment method	24-h dietary recalls Interviewer-administered	Ca, Na, Zn, Fe, vitamins A, C, thiamin, riboflavin, niacin	The videotape method comes very close to representig actual intake and is reproducible among the elderly people.
Jackson *et al.* (1989)[36] UK	Eighty elderly participants men aged 65–74 years women aged 59–65 years	FFQ Short self questionnaire Self-administered	Diet history Interviewer-administered	Ca	The two methods provide estimates of intakes similar to those found in other studies in the UK.
Nelson *et al.* (1988)[37] UK	Thirty elderly women age range72–90 years	FFQ Ca intake questionnaire Interviewer-administered	7-d WDR	Ca	The present study shows that Ca intake in the elderly calculated from a frequency questionnaire correlates well with Ca intake measured by 7-d WDR.
Cummings *et al.* (1987)[38] USA	Thirty-seven elderly women	FFQ Thirty-four food items Portion size (small, medium or large) Interviewer-administered	7-d EDR	Ca	The brief FFQ which rate portion sizes on a simple qualitative scale may be suitable for many clinical uses and adequate for some types of epidemiologic studies of Ca intake in elderly women.
Mahalko *et al.* (1985)[39] USA	Fifty-four healthy older adults	Diet history Interviewer-administered Portion size in household units.	7-d EDR	Vitamins A, C, niacin, riboflavin, thiamin, Ca, P, Fe, Zn, K	Though neither dietary histories nor food records give precise intake data for individuals, either method may be useful for epidemiologic studies with appropriate sample sizes.

PSFFQ, picture-sort FFQ; 24HR, 24-h diet recalls; SFFQ, self-administered FFQ; BM, biomarkers; WDR, weighed dietary record; EDR, estimated dietary record; DH, diet history.

Table 3. Validation studies in elderly people (vitamins)

Author/year publication/ country/(quality index)	Methods	Correlation between methods		Other statistics	
Vitamin A					
Quandt *et al.* (2007)[8] USA (4·5)	FFQ *v.* 24HR	Females CC Crude 0·09 CC Adjusted 0·02	Males CC Crude 0·53* CC Adjusted 0·35*	Females Median (RE) Recalls: 664·1 FFQ: 461·7* PSFFQ: 677·3	Males Median (RE) Recalls: 814·0 FFQ: 451·8** PSFFQ: 771·2
	PSFFQ *v.* 24HR	Crude 0·26* Adjusted 0·23	Crude 0·39* Adjusted 0·39*		
Wengreen *et al.* (2001)[17] USA (4·5)	FFQ *v.* 24HR	Females Crude 0·35 Adjusted 0·27	Males Crude 0·20 Adjusted 0·15	Females Mean (SD) (IU) FFQ: 10 096 (4297) 24HR: 8668 (6128)	Males Mean (SD) (IU) FFQ: 9935 (5411) 24HR: 8355 (8344)
Munger *et al.* (1992)[31] USA (3)	FFQ *v.* 24HR	Food + supplements Crude 0·60; Energy adjusted 0·56 Food only Crude 0·37; Energy adjusted 0·14		Mean (SD) (IU) FFQ: 12 669 (6294) 24HR: 9379 (6017)	
Nes *et al.* (1992)[30] Norway (4)	FFQ *v.* 14-d WDR	Crude 0·52 Energy adjusted 0·58		Mean (μg) 14-d WDR: 1424 4FFQ: 1620	
Potosky *et al.* (1990)[33] USA (1)	FFQ *v.* 12-d EDR	Pearson CC Crude 0·46		Not specified	
Groothenhuis *et al.* (1995)[26] The Netherlands (2·5)	FFQ *v.* DH	Pearson CC Crude 0·36		Mean (SD) (mg) FFQ: 0·84 (0·28) DH: 0·87 (0·37)	
Nes *et al.* (1991)[32] SENECA (3·5)	DH *v.* 3-d WDR	Pearson CC Deattenuated 0·18		Mean (SD) (μg) DH: 1213 3-d WDR: 969	
Osler & Schroll (1990)[34] Denmark (4)	DH *v.* 3-d WDR	Pearson CC Crude 0·24***		Mean (SD) (μg) DH: 1752 (907) 3-d WDR: 1656 (1402)	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·45**	Males Crude 0·22	Females Mean (SD) (RE) DH: 1·48 (1·08) 3-d EDR: 1·41 (1·47)	Males Mean (SD) (RE) DH: 1·55 (1·00) 3-d EDR: 1·25 (1·11)
Mahalko *et al.* (1985)[39] USA (4)	DH *v.* 7-d EDR	Pearson CC Crude 0·22		Mean (SD) (IU) DH: 6147 (3304) 7-d WDR: 6908 (3717)	
Mares-Perlman *et al.* (1993)[28] USA (6·5)	DH *v.* 8-d EDR	Females food only Crude 0·27 Energy adjusted 0·22 Food + supplements Crude 0·49 Energy adjusted 0·51	Males food only Crude 0·18 Energy adjusted 0·26 Food + supplements Crude 0·36 Energy adjusted 0·50	Females Mean (SD) Food only (IU) DH: 5345 (1868) 8-d EDR: 8364 (5061) Food + supplements DH: 7153 (3621) 8-d EDR: 10 967 (7779)	Males Mean (SD) Food only (IU) DH: 8381 (4629) 8-d EDR: 7959 (4642) Food + supplements DH: 8948 (4854) 8-d EDR: 8576 (4949)
Brown *et al.* (1990)[35] USA (2·5)	VDAM *v.* 24HR	Pearson CC Crude 0·57		Mean (SD) (IU) VDAM: 4279 (3927) 24HR: 3804 (3735)	

Table 3. *Continued*

Author/year publication/ country/(quality index)	Methods	Correlation between methods		Other statistics	
Retinol					
Messerer *et al.* (2004)[12] Sweden (5·5)	FFQ *v.* 24HR	Spearman CC Food + supplements: 0·62 Food: 0·37		Mean (SD) (mg) 24HR: Food: 0·9 (0·6) Food + supplements: 1·0 (0·7) FFQ: Food: 1·1 (0·5) Food + supplements: 1·2 (0·6)	
Kumanyika *et al.* (1997)[23] USA (4·5)	FFQ *v.* 24HR	Pearson CC Deattenuated 0·44		Mean (SD) (μg) Recalls: 823 (636) Picture sort: 994 (531)	
Kumanyika *et al.* (1996)[24] USA (4·5)	FFQ *v.* 24HR	Pearson CC Deattenuated 0·45		Mean (SD) (μg) Recalls: 823 (636) Picture sort: 994 (531)	
Munger *et al.* (1992)[31] USA (3)	FFQ *v.* 24HR	Food + supplements Crude 0·70; Energy adjusted 0·68 Food only Crude 0·50; Energy adjusted 0·38		Mean (IU) (mg) FFQ: 2381 (1667) 24HR: 1930 (1293)	
Smith *et al.* (1998)[22] Australia (3)	FFQ *v.* 12-d WDR	Pearson CC Crude 0·30 Adjusted 0·19		Mean (SD) (IU) 4-d WDR: 522 (940) FFQ: 832 (2577)	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·55**	Males Crude 0·35**	Females Mean (SD) (μg) DH: 947 (975) 3-d EDR: 874 (1417)	Males Mean (SD) (μg) DH: 1038 (794) 3-d EDR: 755 (953)
van Staveren *et al.* (1996)[25] SENECA (4·5)	DH *v.* 3-d EDR	Females Crude: 0·32 Unattenuated: 0·46	Males Crude: 0·50 Unattenuated: 0·75	Mean (μg) DH: 883 3-d EDR: 628	
β-Carotene					
Messerer *et al.* (2004)[12] Sweden (5·5)	FFQ *v.* 24HR	Spearman CC Food + supplements: 0·51 Food: 0·49		Mean (SD) (mg) 24HR: Food: 2·3 (1·5) Food + supplements: 2·4 (1·8) FFQ: Food: 2·4 (2·1) Food + supplements: 2·5 (2·1)	
Kumanyika *et al.* (1997)[23] USA (4·5)	FFQ *v.* 24HR	Pearson CC Deattenuated 0·24		Mean (SD) (μg) Recalls: 3899 (2202) Picture sort: 3839 (2858)	
Kumanyika *et al.* (1996)[24] USA (4·5)	FFQ *v.* 24HR	Pearson CC Deattenuated 0·26		Mean (SD) (μg) Recalls: 3899 (2202) Picture sort: 3839 (2858)	
Tangney *et al.* (2004)[15] USA (4·5)	FFQ *v.* 24HR	Not specified		Mean (SD) (μg) FFQ: Females: 4·0 (2·2); Males: 4·7 (3·3) 24HR: Females: 4·9 (2·9); Males: 4·3 (2·9)	
	FFQ *v.* BM	Females	Males	Mean (SD)	

Table 3. *Continued*

Author/year publication/ country/(quality index)	Methods	Correlation between methods		Other statistics	
		Multivariate-adjusted Pearson CC 0·88*	Multivariate-adjusted Pearson CC 0·09	FFQ: Females: 4·0 (2·2); Males: 4·7 (3·3) (μg) BM: Females:0·40 (0·21); Males: 0·51 (0·38) (μmol/l)	
	24HR *v.* BM	Females Multivariate-adjusted Pearson CC 0·04	Males Multivariate-adjusted Pearson CC 0·23	Mean (SD) 24HR: Females: 4·9 (2·9); Males: 4·3 (2·9) (μg) BM: Females: 0·40 (0·21); Males: 0·51(0·38) (μmol/l)	
Vioque *et al.* (2007)[10] Spain (6)	FFQ *v.* BM	Pearson CC Energy adjusted 0·19***		Females Mean (SD) Dietary intake: 4358·2 μg/d (2134·3) Plasma: 0·304*** μmol/l (0·34)	Males Mean (SD) Dietary intake: 4000·1 μg/d (2076·4) Plasma: 0·196*** μmol/l (0·23)
Tucker *et al.* (1999)[20] USA (4·5)	FFQ *v.* BM	Crude 0·25 Adjusted 0·31		Females Mean (SD) Dietary intake: 4508 μg/d (2925) Plasma: 0·51 μmol/l (0·34)	Males Mean (SD) Dietary intake: 3793 μg/d (2608) Plasma: 0·33 μmol/l (0·23)
Nes *et al.* (1991)[32] SENECA (3·5)	DH *v.* 3-d WDR	Pearson CC Deattenuated 0·52		Mean (SD) (μg) DH: 2484 3-d WDR: 2191	
Smith *et al.* (1998)[22] Australia (3)	FFQ *v.* 12-d WDR	Pearson CC Crude 0·49 Adjusted 0·49		Mean (SD) (IU) 4-d WDR: 3392 (1841) FFQ: 7434 (4260)	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·45**	Males Crude 0·39**	Females Mean (SD) (μg) DH: 2835 (2409) 3-d EDR: 2858 (2368)	Males Mean (SD) (μg) DH: 2771 (4145) 3-d EDR: 2646 (3362)
Vitamin D					
Messerer *et al.* (2004)[12] Sweden (5·5)	FFQ *v.* 24HR	Spearman CC Food + supplements: 0·59 Food: 0·48		Mean (SD) (μg) 24HR: Food: 5·7 (2·0) Food + supplements: 6·3 (2·4) FFQ: Food: 5·8 (2·2) Food + supplements: 6·6 (2·8)	
Wengreen *et al.* (2001)[17] USA (4·5)	FFQ *v.* 24HR	Females Crude 0·48 Adjusted 0·51	Males Crude 0·60 Adjusted 0·51	Females Mean (SD) (IU) FFQ: 257 (121) 24HR: 170 (91)	Males Mean (SD) (IU) FFQ: 272 (175) 24HR: 160 (102)
Morris *et al.* (2003)[14] USA (4)	FFQ *v.* 24HR	Pearson CC Food + supplements: 0·51		Not specified	
Munger *et al.* (1992)[31] USA (3)	FFQ *v.* 24HR	Food + supplements Crude 0·51; Energy adjusted 0·51 Food only Crude 0·59; Energy adjusted 0·61		Mean (SD) (IU) FFQ: 233 (125) 24HR: 260 (129)	
Dumartherayet *al.* (2006)[4] Switzerland (3·5)	FFQ *v.* 4-d WDR	Pearson CC Crude 0·20 Energy adjusted 0·01		Mean (SD) (μg) 4-d WDR: 2·6 (2·6) FFQ: 3 (1·9)	
Rothenberg (1994)[27]	FFQ *v.* 4-d EDR	Pearson CC		Mean (95 % CI) (μg)	

Table 3. *Continued*

Author/year publication/ country/(quality index)	Methods	Correlation between methods		Other statistics	
Sweden (3)		Crude 0·38		4-d EDR: 6·8 (6·1, 7·5) FFQ: 8·5 (7·8, 9·2)	
Nes *et al.* (1992)[30] Norway (4)	FFQ *v.* 14-d WDR	Crude 0·67 Energy adjusted 0·59		Mean (μg) 14-d WDR: 5·5 FFQ: 5·6	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·60**	Males Crude 0·51**	Females Mean (SD) (μg) DH: 3·86 (5·15) 3-d EDR: 4·2 (6·38)	Males Mean (SD) (μg) DH: 4·62 (4·91) 3-d EDR: 5·48 (6·94)
Vitamin E					
Quandt *et al.* (2007)[8] USA (4·5)	FFQ *v.* 24HR	Females CC Crude −0·01 CC Adjusted 0·22	Males CC Crude 0·54* CC adjusted 0·32	Females Median (mg TE) Recalls: 5·8 FFQ: 5·4 PSFFQ: 7·7	Males Median (mg TE) Recalls: 6·3 FFQ: 4·8** PSFFQ: 6·0
	PSFFQ *v.* 24HR	Crude 0·25 Adjusted 0·46*	Crude 0·40* Adjusted 0·24		
Messerer *et al.* (2004)[12] Sweden (5·5)	FFQ *v.* 24HR	Spearman CC Food + supplements: 0·57 Food: 0·37		Mean (SD) (mg) 24HR: Food: 7·4 (2·2) Food + supplements: 13·1 (22·2) FFQ: Food: 6·6 (2·6) Food + supplements: 14·5 (38·8)	
Morris *et al.* (2003)[14] USA (4)	FFQ *v.* 24HR	Pearson CC Food + supplements: 0·67 Food: 0·39		Not specified	
Kumanyika *et al.* (1997)[23] USA (4·5)	FFQ *v.* 24HR	Pearson CC Deattenuated 0·42		Mean (SD) (mg) Recalls: 9 (8) Picture sort: 9 (8)	
Munger *et al.* (1992)[31] USA (3)	FFQ *v.* 24HR	Food + supplements Crude 0·62; Energy adjusted 0·55 Food only Crude 0·66 Energy adjusted 0·79		Mean (SD) (mg) FFQ: 6·8 (2·3) 24HR: 9·6 (5·1)	
Kumanyika *et al.* (1996)[24] USA (4·5)	FFQ *v.* 24HR	Pearson CC Deattenuated 0·42		Mean (SD) (mg) Recalls: 9 (8) Picture sort: 9 (8)	
Tangney *et al.* (2004)[15] USA (4·5)	FFQ *v.* 24HR	Not specified		Mean (SD) (mg) FFQ: Females: 85·5 (158·7); Males: 147·7 (211·6) 24HR: Females: 42·3 (74·9); Males: 41·4 (67·6)	
	FFQ *v.* BM	Females Multivariate-adjusted Pearson CC 0·69*	Males Multivariate-adjusted Pearson CC 0·93*	Mean (SD) (mg) FFQ: Females: 85·5 (158·7); Males: 147·7 (211·6) BM: Females: 40·5 (12·4); Males: 41·1 (14·9) (μmol/l)	
	24HR *v.* BM	Females Multivariate-adjusted Pearson CC 0·20	Males Multivariate-adjusted Pearson CC 0·61*	Mean (SD) (mg) (μmol/l) 24HR: Females: 42·3 (74·9); Males: 41·4 (67·6)	

Table 3. *Continued*

Author/year publication/ country/(quality index)	Methods	Correlation between methods		Other statistics	
				BM: Females: 40·5 (12·4); Males: 41·1 (14·9) (μmol/l)	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·80**	Males Crude 0·75**	Females Mean (SD) (TE) DH: 5·98 (2·42) 3-d EDR: 6·19 (2·39)	Males Mean (SD) (TE) DH: 7·62 (4·00) 3-d EDR: 7·60 (3·61)
Thiamin					
Munger *et al.* (1992)[31] USA (3)	FFQ *v.* 24HR	Food + supplements Crude 0·95; Energy adjusted 0·95 Food only Crude 0·60; Energy adjusted 0·68		Mean (SD) (mg) FFQ: 1·3 (0·4) 24HR: 1·4 (0·5)	
Smith *et al.* (1998)[22] Australia (3)	FFQ *v.* 12-d WDR	Pearson CC Crude 0·40 Adjusted 0·51		Mean (SD) (mg) 4-d WDR: 1·18 (0·43) FFQ: 1·37 (0·49)	
Nes *et al.* (1992)[30] Norway (4)	FFQ *v.* 14-d WDR	Crude 0·43 Energy adjusted 0·64		Mean (mg) 14-d WDR: 0·99 FFQ: 1·08	
Rothenberg (1994)[27] Sweden (3)	FFQ *v.* 4-d EDR	Pearson CC Crude 0·57		Mean (95 % CI) (mg) 4-d EDR: 1·37 (1·26, 1·48) FFQ: 1·57 (1·47, 1·66)	
Potosky *et al.* (1990)[33] USA (1)	FFQ *v.* 12-d EDR	Pearson CC Crude 0·62		Not specified	
Klipstein-Grobusch *et al.* (1998)[21] The Netherlands (6)	FFQ *v.* 15-d EDR	Pearson CC Crude 0·60; Adjusted 0·42; Deattenuated 0·45		Mean (SD) (mg) SFFQ: 1·33 (0·34) 15-d EDR: 1·06 (0·24)	
Groothenhuis *et al.* (1995)[26] The Netherlands (2·5)	FFQ *v.* DH	Pearson CC Crude 0·52		Mean (SD) (mg) FFQ: 1·07 (0·24) DH: 0·98 (0·19)	
Nes *et al.* (1991)[32] SENECA (3·5)	DH *v.* 3-d WDR	Pearson CC Deattenuated 0·64		Mean (SD) (mg) DH: 97 3-d WDR: 90	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·68**	Males Crude 0·58**	Females Mean (SD) (mg) DH: 0·92 (0·24) 3-d EDR: 0·93 (0·26)	Males Mean (SD) (mg) DH: 1·04 (0·33) 3-d EDR: 1·00 (0·33)
van Staveren *et al.* (1996)[25] SENECA (4·5)	DH *v.* 3-d EDR	Females Crude: 0·59 Unattenuated: 0·73	Males Crude: 0·83 Unattenuated: 0·67	Mean (mg) DH: 0·99 3-d EDR: 0·86	
Mahalko *et al.* (1985)[39] USA (4)	DH *v.* 7-d EDR	Pearson CC Crude 0·47**		Mean (SD) (mg) DH: 1·3 (0·5) 7-d WDR: 1·2 (0·4)	
Mares-Perlman *et al.* (1993)[28] USA (6·5)	DH *v.* 8-d EDR	Females Food only Crude 0·50 Energy adjusted 0·41 Food + supplements Crude 0·70 Energy adjusted 0·62	Males Food only Crude 0·44 Energy adjusted 0·50 Food + supplements Crude 0·80 Energy adjusted 0·83	Females Mean (SD) Food only (mg) DH: 0·9 (0·3) 8-d EDR: 1·4 (0·3) Food + supplements DH: 2·4 (3·3) 8-d EDR: 5·1 (11·6)	Males Mean (SD) Food only (mg) DH: 1·5 (0·7) 8-d EDR: 1·8 (0·8) Food + supplements DH: 7·8 (35·2) 8-d EDR: 7·4 (34·9)
Brown *et al.* (1990)[35]	VDAM *v.* 24HR	Pearson CC Crude 0·62		Mean (SD) (mg)	

Table 3. *Continued*

Author/year publication/ country/(quality index)	Methods	Correlation between methods		Other statistics	
USA (2·5)				VDAM: 0·7 (0·3) 24 HR: 0·7 (0·4)	
Riboflavin					
Munger *et al.* (1992)[31] USA (3)	FFQ *v.* 24HR	Food + supplements Crude 0·92; Energy adjusted 0·93 Food only Crude 0·36; Energy adjusted 0·32		Mean (SD) (mg) FFQ: 2·0 (0·7) 24 HR: 2·4 (1·9)	
Smith *et al.* (1998)[22] Australia (3)	FFQ *v.* 12-d WDR	Pearson CC Crude 0·39 Adjusted 0·53		Mean (SD) (mg) 4-d WDR: 1·76 (0·61) FFQ: 2·13 (0·86)	
Nes *et al.* (1992)[30] Norway (4)	FFQ *v.* 14-d WDR	Crude 0·66 Energy adjusted 0·63		Mean (mg) 14-d WDR: 1·50 FFQ: 1·49	
Potosky *et al.* (1990)[33] USA (1)	FFQ *v.* 12-d EDR	Pearson CC Crude 0·69		Not specified	
Klipstein-Grobusch *et al.* (1998)[21] The Netherlands (6)	FFQ *v.* 15-d EDR	Pearson CC Crude 0·59; Adjusted 0·54; Deattenuated 0·56		Mean (SD) (mg) SFFQ: 2·36 (0·59) 15-d EDR: 1·47 (0·38)	
Groothenhuis *et al.* (1995)[26] The Netherlands (2·5)	FFQ *v.* DH	Pearson CC Crude 0·69		Mean (SD) (mg) FFQ: 1·65 (0·58) DH: 1·63 (0·45)	
Nes *et al.* (1991)[32] SENECA (3·5)	DH *v.* 3-d WDR	Pearson CC Deattenuated 0·66		Mean (SD) (mg) DH: 156 3-d WDR: 141	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·76**	Males Crude 0·65**	Females Mean (SD) (mg) DH: 1·53 (0·48) 3-d EDR: 1·49 (0·58)	Males Mean (SD) (mg) DH: 1·76 (0·60) 3-d EDR: 1·60 (0·54)
van Staveren *et al.* (1996)[25] SENECA (4·5)	DH *v.* 3-d EDR	Females Crude: 0·71 Unattenuated: 0·80	Males Crude: 0·74 Unattenuated: 0·80	Mean (mg) DH: 1·56 3-d EDR: 1·14	
Mahalko *et al.* (1985)[39] USA (4)	DH *v.* 7-d EDR	Pearson CC Crude 0·45**		Mean (SD) (mg) DH: 1·6 (0·7) 7-d WDR: 1·7 (0·6)	
Mares-Perlman *et al.* (1993)[28] USA (6·5)	DH *v.* 8-d EDR	Females food only Crude 0·58 Energy adjusted 0·51 Food + supplements Crude 0·69 Energy adjusted 0·67	Males food only Crude 0·67 Energy adjusted 0·72 Food + supplements Crude 0·86 Energy adjusted 0·86	Females Mean (SD) Food only (mg) DH: 1·3 (0·5) 8-d EDR: 1·5 (0·4) Food + supplements DH: 2·8 (3·5) 8-d EDR: 6·5 (21·0)	Males Mean (SD) Food only (mg) DH: 2·0 (0·8) 8-d EDR: 2·0 (0·6) Food + supplements DH: 3·3 (4·2) 8-d EDR: 3·2 (4·0)
Brown *et al.* (1990)[35] USA (2·5)	VDAM *v.* 24HR	Pearson CC Crude 0·74		Mean (SD) (mg) VDAM: 1·0 (0·4) 24HR: 1·0 (0·6)	
Niacin					
Quandt *et al.* (2007)[8] USA (4·5)	FFQ *v.* 24HR	Females CC Crude 0·13	Males CC Crude 0·42*	Females Median (mg)	Males Median (mg) Recalls: 17·8

Table 3. *Continued*

Author/year publication/ country/(quality index)	Methods	Correlation between methods		Other statistics	
		CC Adjusted 0·13	CC Adjusted 0·41*	Recalls: 15·3 FFQ: 10·2** PSFFQ: 14·8	FFQ: 9·6** PSFFQ: 13·6*
	PSFFQ *v.* 24HR	Crude 0·18 Adjusted 0·28*	Crude 0·42* Adjusted 0·61*		
Groothenhuis *et al.* (1995)[26] The Netherlands (2·5)	FFQ *v.* DH	Pearson CC Crude 0·73		Mean (SD) (mg) FFQ: 11·4 (3·6) DH: 10·2 (3·2)	
Pedersen *et al.* (2001)[18]Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·68**	Males Crude 0·68**	Females Mean (SD) (mg) DH: 21·2 (5·3) 3-d EDR: 21·5 (6·0)	Males Mean (SD) (mg) DH: 25·9 (5·9) 3-d EDR: 24·9 (6·6)
Mahalko *et al.* (1985)[39] USA (4)	DH *v.* 7-d EDR	Pearson CC Crude 0·56**		Mean (SD) (mg) DH: 31 (9) 7-d WDR: 31 (8)	
Mares-Perlman *et al.* (1993)[28] USA (6·5)	DH *v.* 8-d EDR	Females food only Crude 0·33 Energy adjusted 0·39 Food + supplements Crude 0·66 Energy adjusted 0·65	Males food only Crude 0·16 Energy adjusted 0·43 Food + supplements Crude 0·59 Energy adjusted 0·72	Females Mean (SD) Food only (mg) DH: 12·7 (3·7) 8-d EDR: 17·9 (4·3) Food + supplements DH: 26·9 (32·1) 8-d EDR: 33·7 (36·5)	Males Mean (SD) Food only (mg) DH: 19·9 (6·0) 8-d EDR: 23·5 (6·0) Food + supplements DH: 28·6 (21·7) 8-d EDR: 28·7 (12·8)
Brown *et al.* (1990)[35] USA (2·5)	VDAM *v.* 24HR	Pearson CC Crude 0·42		Mean (SD) (mg) VDAM: 8·0 (3·4) 24HR: 8·0 (3·6)	
Vitamin B_6					
Quandt *et al.* (2007)[8] USA (4·5)	FFQ *v.* 24HR	Females CC Crude 0·14 CC Adjusted 0·46*	Males CC Crude 0·62* CC Adjusted 0·57*	Females Median (mg) Recalls: 1·3 FFQ: 1·0* PSFFQ: 1·3	Males Median (mg) Recalls: 1·3 FFQ: 0·9** PSFFQ: 1·3
	PSFFQ *v.* 24HR	CC Crude 0·24 CC Adjusted 0·59*	CC Crude 0·39* CC Adjusted 0·53*		
Messerer *et al.* (2004)[12] Sweden (5·5)	FFQ *v.* 24HR	Spearman CC Food + supplements: 0·65 Food: 0·43		Mean (SD) (mg) 24HR: Food: 1·9 (0·4) Food + supplements: 2·6 (2·9) FFQ: Food: 1·8 (0·5) Food + supplements: 2·5 (3·8)	
Morris *et al.* (2003)[14] USA (4)	FFQ *v.* 24HR	Pearson CC Food + supplements: 0·51		Not specified	
Munger *et al.* (1992)[31] USA (3)	FFQ *v.* 24HR	Food +supplements Crude 0·70; Energy adjusted 0·69 Food only Crude −0·09; Energy adjusted −0·16		Mean (SD) (mg) FFQ: 2·1 (0·9) 24HR: 5·1 (12·4)	
Horwath (1993)[29] New Zeland (3)	FFQ *v.* 10-d EDR	Females Crude 0·54	Males Crude 0·43	Females Mean (SD) (mg) 10-d EDR: 1·41 (0·36) FFQ: 1·36 (0·39)	Males Mean (SD) (mg) 10-d EDR: 1·62 (0·56) FFQ: 1·50 (0·46)

Table 3. *Continued*

Author/year publication/ country/(quality index)	Methods	Correlation between methods		Other statistics	
Klipstein-Grobusch *et al.* (1998)[21] The Netherlands (6)	FFQ *v.* 15-d EDR	Pearson CC Crude 0·62; Adjusted 0·46; Deattenuated 0·49		Mean (SD) (mg) SFFQ: 1·82 (0·43) 15-d EDR: 1·55 (0·33)	
Groothenhuis *et al.* (1995)[26] The Netherlands (2·5)	FFQ *v.* DH	Pearson CC Crude 0·61		Mean (SD) (mg) FFQ: 1·32 (0·32) DH: 1·22 (0·29)	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·72**	Males Crude 0·68**	Females Mean (SD) (mg) DH: 1·07 (0·28) 3-d EDR: 1·08 (0·33)	Males Mean (SD) (mg) DH: 1·24 (0·34) 3-d EDR: 1·20 (0·39)
van Staveren *et al.* (1996)[25] SENECA (4·5)	DH *v.* 3-d EDR	Females Crude: 0·58 Unattenuated: 0·72	Males Crude: 0·65 Unattenuated: 0·74	Mean (mg) DH: 1·36 3-d EDR: 1·20	
Nes *et al.* (1991)[32] SENECA (3·5)	DH *v.* 3-d WDR	Pearson CC Deattenuated 0·75		Mean (SD) (mg) DH: 124 3-d WDR: 107	
Vitamin B_{12}					
Morris *et al.* (2003)[14] USA (4)	FFQ *v.* 24HR	Pearson CC Food + supplements: 0·38		Not specified	
Munger *et al.* (1992)[31] USA (3)	FFQ *v.* 24HR	Food + supplements Crude 0·58; Energy adjusted 0·76 Food only Crude 0·38; Energy adjusted 0·47		Mean (SD) (μg) FFQ: 9·1 (5·0) 24HR: 6·1 (3·7)	
Dumartherayet *al.* (2006)[4] Switzerland (3·5)	FFQ *v.* 4-d WDR	Pearson CC Crude 0·49** Energy adjusted 0·22		Mean (SD) (μg) 4-d WDR: 4·1 (3·4) FFQ: 4·9 (2·3)	
Flood *et al.* (2004)[13] Australia (5)	FFQ *v.* 12-d WDR	Spearman CC Energy adjusted 0·38		Mean (SD) (μg) 4-d WDR: 3·2 (2·2) FFQ: 4·4 (2·7)	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·31**	Males Crude 0·50**	Females Mean (SD) (mg) DH: 5·93 (4·17) 3-d EDR: 5·74 (6·04)	Males Mean (SD) (mg) DH: 6·78 (3·52) 3-d EDR: 5·67 (3·70)
Folate					
Quandt *et al.* (2007)[8] USA (4·5)	FFQ *v.* 24HR	Females CC Crude 0·12 CC Adjusted 0·24	Males CC Crude 0·43* CC Adjusted 0·01	Females Median (μg) Recalls: 267·0 FFQ: 240·5* PSFFQ: 280·5	Males Median (μg) Recalls: 300·8 FFQ: 178·7** PSFFQ: 277·1
	PSFFQ *v.* 24HR	Crude 0·28* Adjusted 0·47*	Crude 0·41* Adjusted 0·37*		
Messerer *et al.* (2004)[12] Sweden (5·5)	FFQ *v.* 24HR	Spearman CC Food + supplements: 0·50 Food: 0·29		Mean (SD) (μg) 24HR: Food: 212·9 (51·8) Food + supplements: 239·6 (93·0) FFQ: Food: 220·0 (66·3) Food + supplements: 263·7 (135·1)	
Morris *et al.* (2003)[14] USA (4)	FFQ *v.* 24HR	Pearson CC Food + supplements: 0·50		Not specified	

Table 3. *Continued*

Author/year publication/ country/(quality index)	Methods	Correlation between methods		Other statistics	
Munger *et al.* (1992)[31] USA (3)	FFQ *v.* 24HR	Food + supplements Crude 0·43; Energy adjusted 0·43 Food only Crude 0·35; Energy adjusted 0·26		Mean (SD) (μg) FFQ: 281 (120) 24HR: 289 (188)	
Flood *et al.* (2004)[13] Australia (5)	FFQ *v.* 12-d WDR	Spearman CC Energy-adjusted 0·66		Mean (SD) (μg) 4-d WDR: 238 (67) FFQ: 329 (114)	
Horwath (1993)[29] New Zeland (3)	FFQ *v.* 10-d EDR	Females Crude 0·49	Males Crude 0·58	Females Mean (SD) (μg) 10-d EDR: 220 (53) FFQ: 236 (62)	Males Mean (SD) (μg) 10-d EDR: 233 (74) FFQ: 243 (70)
van de Rest *et al.* (2007)[9] The Netherlands (3·5)	FFQ *v.* BM	Spearman CC Serum folate 0·14 Erythrocyte folate 0·05		Mean (SD) Serum folate: 12·8 nmol/l (4·4) Erythrocyte folate: 661·3 nmol/l (263·9) Folate intake: 196 μg/d (69)	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·31**	Males Crude 0·42**	Females Mean (SD) (mg) DH: 322 (178) 3-d EDR: 319 (283)	Males Mean (SD) (mg) DH: 340 (152) 3-d EDR: 288 (143)
Mares-Perlman *et al.* (1993)[28] USA (6·5)	DH *v.* 8-d EDR	Females food only Crude 0·60 Energy adjusted 0·52 Food + supplements Crude 0·67 Energy adjusted 0·57	Males food only Crude 0·59 Energy adjusted 0·64 Food + supplements Crude 0·83 Energy adjusted 0·84	Females Mean (SD) Food only (μg) DH: 211 (88) 8-d EDR: 255 (82) Food + supplements DH: 343 (225) 8-d EDR: 366 (187)	Males Mean (SD) Food only (μg) DH: 295 (97) 8-d EDR: 268 (96) Food + supplements DH: 387 (216) 8-d EDR: 345 (198)
Vitamin C					
Quandt *et al.* (2007)[8] USA (4·5)	FFQ *v.* 24HR	Females CC Crude 0·19 CC Adjusted 0·40*	Males CC Crude 0·57* CC Adjusted 0·61*	Females Median (mg) Recalls: 63·1 FFQ: 80·0** PSFFQ: 99·7**	Males Median (mg) Recalls: 53·4 FFQ: 54·2 PSFFQ: 61·9**
	PSFFQ *v.* 24HR	Crude 0·36* Adjusted 0·54*	Crude 0·52* Adjusted 0·48*		
Messerer *et al.* (2004)[12] Sweden (5·5)	FFQ *v.* 24HR	Spearman CC Food + supplements: 0·81 Food: 0·44		Mean (SD) (mg) 24HR: Food: 75·9 (36·2) Food + supplements: 220·5 (12·7) FFQ: Food: 63·8 (32·7) Food + supplements: 146·9 (240·1)	
Wengreen *et al.* (2001)[17] USA (4·5)	FFQ *v.* 24HR	Females Crude 0·42 Adjusted 0·49	Males Crude 0·40 Adjusted 0·43	Females Mean (SD) (mg) FFQ: 146 (78) 24HR: 109 (46)	Males Mean (SD) (mg) FFQ: 138 (57) 24HR: 115 (66)
Morris *et al.* (2003)[14] USA (4)	FFQ *v.* 24HR	Pearson CC Food + supplements: 0·60 Food: 0·46		Not specified	

Table 3. *Continued*

Author/year publication/ country/(quality index)	Methods	Correlation between methods		Other statistics	
Kumanyika *et al.* (1997)[23] USA (4·5)	FFQ *v.* 24HR	Pearson CC Deattenuated 0·51		Mean (SD) (mg) Recalls: 123 (48) Picture sort: 170 (83)	
Kumanyika *et al.* (1996)[24] USA (4·5)	FFQ *v.* 24HR	Pearson CC Deattenuated 0·51		Mean (SD) (mg) RECALLS: 123 (48) Picture sort: 170 (83)	
Munger *et al.* (1992)[31] USA (3)	FFQ *v.* 24HR	Food + supplements Crude 0·82; Energy adjusted 0·76 Food only Crude 0·55; Energy adjusted 0·53		Mean (SD) (mg) FFQ: 148 (82) 24HR: 130 (61)	
Tangney *et al.* (2004)[15] USA (4·5)	FFQ *v.* 24HR	Not specified		Mean (SD) (mg) FFQ: Females: 231·9 (293·1); Males: 311·4 (280·1) 24HR: Females: 183·2 (237·1); Males: 199·5 (200·8)	
	FFQ *v.* BM	Females Multivariate-adjusted Pearson CC 0·12	Males Multivariate-adjusted Pearson CC 0·82	Mean (SD) (mg) FFQ: Females: 231·9 (293·1); Males: 311·4 (280·1) BM: Females: 31·5 (12·8); Males: 28·7 (12·0) µmol/l	
	24HR *v.* BM	Females Multivariate-adjusted Pearson CC 0·37	Males Multivariate-adjusted Pearson CC 0·01	Mean (SD) (mg) 24HR: Females: 183·2 (237·1); Males:199·5 (200·8) BM: Females: 31·5 (12·8); Males: 28·7 (12·0) (µmol/l)	
Vioque *et al.* (2007)[10] Spain (6)	FFQ *v.* BM	Pearson CC Energy-adjusted 0·36***		Females Mean (SD) Dietary intake: 136·2 mg/d (69·8) Plasma: 51·0*** µmol/l (18·4)	Males Mean (SD) Dietary intake: 125·4 mg/d (64·1) Plasma: 38·3 µmol/l (19·5)
Dumartheray *et al.* (2006)[4] Switzerland (3·5)	FFQ *v.* 4-d WDR	Pearson CC Crude 0·55** Energy adjusted 0·50**		Mean (SD) (mg) 4-d WDR: 105·4 (54·9) FFQ: 94·1 (43·3)	
Smith *et al.* (1998)[22] Australia (3)	FFQ *v.* 12-d WDR	Pearson CC Crude 0·68 Adjusted 0·70		Mean (SD) (mg) 4-d WDR: 118 (58) FFQ: 188 (105)	
Nes *et al.* (1992)[30] Norway (4)	FFQ *v.* 14-d WDR	Crude 0·31 Energy adjusted 0·48		Mean (mg) 14-d WDR: 114 FFQ: 118	
Rothenberg (1994)[27] Sweden (3)	FFQ *v.* 4-d EDR	Pearson CC Crude 0·53		Mean (95 % CI) (µg) 4-d EDR: 73 (63, 83) FFQ: 130 (116,144)	
Horwath (1993)[29] New Zeland (3)	FFQ *v.* 10-d EDR	Females Crude 0·39	Males Crude 0·58	Females Mean (SD) (mg) 10-d EDR: 111 (42) FFQ: 146 (75)	Males Mean (SD) (mg) 10-d EDR: 96 (57) FFQ: 105 (53)
Potosky *et al.* (1990)[33] USA (1)	FFQ *v.* 12-d EDR	Pearson CC Crude 0·60		Not specified	

Table 3. *Continued*

Author/year publication/ country/(quality index)	Methods	Correlation between methods		Other statistics	
Klipstein-Grobusch *et al.* (1998)[21] The Netherlands (6)	FFQ *v.* 15-d EDR	Pearson CC Crude 0·68; Adjusted 0·64; Deattenuated 0·70		Mean (SD) (mg) SFFQ: 105·2 (45·8) 15-d EDR: 91·5 (39·6)	
Groothenhuis *et al.* (1995)[26] The Netherlands (2·5)	FFQ *v.* DH	Pearson CC Crude 0·70		Mean (SD) (mg) FFQ: 102·2 (48·6) DH: 85·9 (43·6)	
Nes *et al.* (1991)[32] SENECA (3·5)	DH *v.* 3-d WDR	Pearson CC Deattenuated 0·55		Mean (SD) (mg) DH: 118 3-d WDR: 96	
Osler & Schroll (1990)[34] Denmark (4)	DH *v.* 3-d WDR	Pearson CC Crude 0·64***		Mean (SD) (mg) DH: 73 (45) 3-d WDR: 70 (49)	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·59**	Males Crude 0·60**	Females Mean (SD) (mg) DH: 59 (43) 3-d EDR: 58 (47)	Males Mean (SD) (mg) DH: 51 (44) 3-d EDR: 53 (479)
van Staveren *et al.* (1996)[25]SENECA (4·5)	DH *v.* 3-d EDR	Females Crude: 0·47 Unattenuated: 0·56	Males Crude: 0·32 Unattenuated: 0·38	Mean (mg) DH: 95 3-d EDR: 76	
Mahalko *et al.* (1985)[39] USA (4)	DH *v.* 7-d EDR	Pearson CC Crude 0·45**		Mean (SD) (mg) DH: 106 (50) 7-d WDR: 90 (37)	
Mares-Perlman *et al.* (1993)[28] USA (6·5)	DH *v.* 8-d EDR	Females food only Crude 0·53 Energy adjusted 0·50 Food + supplements Crude 0·70 Energy adjusted 0·60	Males Food only Crude 0·47 Energy adjusted 0·57 Food + supplements Crude 0·70 Energy adjusted 0·73	Females Mean (SD) Food only (mg) DH: 130 (70) 8-d EDR: 127 (47) Food + supplements DH: 240 (244) 8-d EDR: 236 (252)	Males Mean (SD) Food only (mg) DH: 117 (52) 8-d EDR: 102 (45) Food + supplements DH: 141 (110) 8-d EDR: 126 (110)
Brown *et al.* (1990)[35] USA (2·5)	VDAM *v.* 24HR	Pearson CC Crude 0·43		Mean (SD) (mg) VDAM: 53 (32) 24HR: 58 (34)	

CC, correlation coefficient; SFFQ, self-administered FFQ; PSFFQ, picture-sort FFQ; RE, retinol equivalent; 24HR, 24-h recall; WDR, weighed dietary record; EDR, estimated dietary record; VDAM, videotape dietary assessment method; DH, diet history; BM, biomarker; TE, tocopherol equivalents.
Mean values were significantly different: $^{*}P<0.05$; $^{**}P<0.01$; $^{***}P<0.001$.

Table 4. Validation studies in elderly people (minerals)

Author/year publication/country/ (quality index)	Methods	Correlation between methods		Other statistics	
Na					
Quandt *et al.* (2007)[8] USA (4·5)	FFQ *v.* 24HR	Females CC Crude 0·31* CC Adjusted 0·34*	Males CC Crude 0·47* CC Adjusted 0·35*	Females Median (mg) Recalls: 2463·9 FFQ: 1174·5** PSFFQ: 1702·6**	Males Median (mg) Recalls: 2841·9 FFQ: 1289·0** PSFFQ: 1682·4**
	PSFFQ *v.* 24HR	Crude 0·32* Adjusted 0·23	Crude 0·32* Adjusted 0·39*		
Potosky *et al.* (1990)[33] USA (1)	FFQ *v.* 12-d EDR	Pearson CC Crude 0·47		Not specified	
Klipstein-Grobusch *et al.* (1998)[21] The Netherlands (6)	FFQ *v.* 15-d EDR	Pearson CC Crude 0·73; Adjusted 0·55; Deattenuated 0·58		Mean (SD) (mg) SFFQ: 2360 (756) 15-d EDR: 2522 (739)	
Groothenhuis *et al.* (1995)[26] The Netherlands (2·5)	FFQ *v.* DH	Pearson CC Crude 0·69		Mean (SD) (g) FFQ: 2·25 (1·09) DH: 2·29 (0·85)	
Espeland *et al.* (2001)[19]USA (3)	24HR *v.* BM	Pearson CC Crude 0·30		Not specified	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·47**	Males Crude 0·62**	Females Mean (SD) (mg) DH: 2206 (581) 3-d EDR: 2184 (661)	Males Mean (SD) (mg) DH: 2822 (858) 3-d EDR: 2770 (970)
Brown *et al.* (1990)[35] USA (2·5)	VDAM *v.* 24HR	Pearson CC Crude 0·46		Mean (SD) (mg) VDAM: 1931 (505) 24HR: 1829 (686)	
K					
Quandt *et al.* (2007)[8] USA (4·5)	FFQ *v.* 24HR	Females CC Crude 0·06 CC Adjusted 0·35*	Males CC Crude 0·62* CC Adjusted 0·55*	Females Median (mg) Recalls: 1730·5 FFQ: 2022·4 PSFFQ: 2439·7**	Males Median (mg) Recalls: 2009·2 FFQ: 1752·9 PSFFQ:2219·3**
	PSFFQ *v.* 24HR	Crude 0·11 Adjusted 0·40*	Crude 0·42* Adjusted 0·45*		
Munger *et al.* (1992)[31] USA (3)	FFQ *v.* 24HR	Crude 0·52 Energy adjusted 0·65		Mean (SD) (mg) FFQ: 3364 (1075) 24HR: 3285 (961)	
Dumartherayet *al.* (2006)[4] Switzerland (3·5)	FFQ *v.* 4-d WDR	Pearson CC Crude 0·42** Energy adjusted 0·37*		Mean (SD) (mg) 4-d WDR: 2681 (742) FFQ: 2960·5 (973)	
Potosky *et al.* (1990)[33] USA (1)	FFQ *v.* 12-d EDR	Pearson CC Crude 0·56		Not specified	
Klipstein-Grobusch *et al.* (1998)[21] The Netherlands (6)	FFQ *v.* 15-d EDR	Pearson CC Crude 0·63; Adjusted 0·50; Deattenuated 0·52		Mean (SD) (mg) SFFQ: 4725 (1010) 15-d EDR: 3550 (701)	
Groothenhuis *et al.* (1995)[26] The Netherlands (2·5)	FFQ *v.* DH	Pearson CC Crude 0·62		Mean (SD) (g) FFQ: 3·6 (0·81) DH: 3·6 (0·67)	

Table 4. *Continued*

Author/year publication/country/(quality index)	Methods	Correlation between methods		Other statistics	
Espeland *et al.* (2001)[19] USA (3)	24HR *v.* BM	Pearson CC Crude 0·43		Not specified	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·81**	Males Crude 0·79**	Females Mean (SD) (mg) DH: 2407 (658) 3-d EDR: 2398 (681)	Males Mean (SD) (mg) DH: 2781 (845) 3-d EDR: 2649 (812)
Mahalko *et al.* (1985)[39] USA (4)	DH *v.* 7-d EDR	Pearson CC Crude 0·51**		Mean (SD) (g) DH: 2·8 (0·7) 7-d WDR: 2·6 (0·7)	
Ca					
Quandt *et al.* (2007)[8] USA (4·5)	FFQ *v.* 24HR	Females CC Crude 0·15 CC Adjusted 0·22	Males CC Crude 0·67* CC Adjusted 0·62*	Females Median (mg) Recalls: 488·0 FFQ: 406·3 PSFFQ: 519·6	Males Median (mg) Recalls: 488·3 FFQ: 366·3** PSFFQ: 503·8*
	PSFFQ *v.* 24HR	Crude 0·18 Adjusted 0·27*	Crude 0·53* Adjusted 0·55*		
Magkos *et al.* (2006)[11] Greece (3)	FFQ *v.* 24HR	Females Pearson CC 0·57***	Males Pearson CC 0·62***	Females mg/d (SD) FFQ: 594 (314) 24HR: 720 (339)	Males mg/d (SD) FFQ: 615 (355) 24HR: 720 (339)
Messerer *et al.* (2004)[12] Sweden (5·5)	FFQ *v.* 24HR	Spearman CC Food + supplements: 0·77 Food: 0·77		Mean (SD) (mg) 24HR: Food: 965·9 (297·1) Food + supplements: 969·3 (299·6) FFQ: Food: 1239·7 (539·2) Food + supplements: 1246·0 (542·0)	
Wengreen *et al.* (2001)[17]USA (4·5)	FFQ *v.* 24HR	Females Crude 0·32 Adjusted 0·33	Males Crude 0·62 Adjusted 0·59	Females Mean (SD) (mg) FFQ: 981 (370) 24HR: 752 (278)	Males Mean (SD) (mg) FFQ: 1013 (485) 24HR: 814 (378)
Morris *et al.* (2003)[14] USA (4)	FFQ *v.* 24HR	Pearson CC Food + supplements: 0·56		Not specified	
Kumanyika *et al.* (1997)[23] USA (4·5)	FFQ *v.* 24HR	Pearson CC Deattenuated 0·62		Mean (SD) (mg) Recalls: 732 (252) Picture sort: 923 (439)	
Kumanyika *et al.* (1996)[24] USA (4·5)	FFQ *v.* 24HR	Pearson C Deattenuated 0·62		Mean (SD) (mg) Recalls: 732 (252) Picture sort: 923 (439)	
Munger *et al.* (1992)[31] USA (3)	FFQ *v.* 24HR	Food + supplements Crude 0·67; Energy adjusted 0·64 Food only Crude 0·54; Energy adjusted 0·49		Mean (SD) (mg) FFQ: 848 (358) 24HR: 912 (346)	
Dumartherayet *al.* (2006)[4] Switzerland (3·5)	FFQ *v.* 4-d WDR	Pearson CC Crude 0·37* Energy adjusted 0·44**		Mean (SD) (mg) 4-d WDR: 893·5 (397·4) FFQ: 1008·4 (444)	

Table 4. *Continued*

Author/year publication/country/ (quality index)	Methods	Correlation between methods		Other statistics	
Nelson *et al.* (1988)[37] UK (2)	FFQ *v.* 7-d WDR	Pearson CC Crude 0·69		Mean (SD) (mg) 7-d WDR: 794 (288) FFQ: 669 (260)	
Smith *et al.* (1998)[22] Australia (3)	FFQ *v.* 12-d WDR	Pearson CC Crude 0·55 Adjusted 0·61		Mean (SD) (mg) 4-d WDR: 721 (265) FFQ: 911 (429)	
Nes *et al.* (1992)[30] Norway (4)	FFQ *v.* 14-d WDR	Crude 0·63 Energy adjusted 0·34		Mean (mg) 14-d WDR: 925 FFQ: 886	
Rothenberg (1994)[27] Sweden (3)	FFQ *v.* 4-d EDR	Pearson CC Crude 0·50		Mean (95 % CI) (μg) 4-d EDR: 854 (788, 920) FFQ: 1099(987, 1211)	
Cummings *et al.* (1987)[38] USA (2)	FFQ *v.* 7-d EDR	Pearson CC Crude 0·76		Mean (SD) (mg) 7-d EDR: 612 (212) FFQ: 637 (274)	
Horwath (1993)[29] New Zeland (3)	FFQ *v.* 10-d EDR	Females Crude 0·62	Males Crude 0·75	Females Mean (SD) (mg) 10-d EDR: 724 (242) FFQ: 845 (258)	Males Mean (SD) (mg) 10-d EDR: 810 (333) FFQ: 924 (315)
Potosky *et al.* (1990)[33] USA (1)	FFQ *v.* 12-d EDR	Pearson CC Crude 0·60		Not specified	
Montomoli *et al.* (2002)[16] Italy (3·5)	FFQ *v.* 14-d EDR	Crude (95 % CI) 0·90 (0·87, 0·92)		Mean (SD) 14-d EDR: 818·1 (260·5) FFQ: 829·4 (255·1)	
Klipstein-Grobusch *et al.* (1998)[21] The Netherlands (6)	FFQ *v.* 15-d EDR	Pearson CC Crude 0·73; Adjusted 0·70; Deattenuated 0·72		Mean (SD) (mg) SFFQ: 1174 (398) 15-d EDR: 1022 (364)	
Jackson *et al.* (1989)[36] UK (1·5)	FFQ *v.* DH	Pearson CC (95 % CI) Crude 0·42		Range of estimated weekly intakes (mg) FFQ: 1254–8822 DH: 1725–7371	
Groothenhuis *et al.* (1995)[26] The Netherlands (2·5)	FFQ *v.* DH	Pearson CC Crude 0·75		Mean (SD) (g) FFQ: 1·11 (0·46) DH: 1·15 (0·33)	
Nes *et al.* (1991)[32] SENECA (3·5)	DH *v.* 3-d WDR	Pearson CC Deattenuated 0·67		Mean (SD) (mg) DH: 1030 3-d WDR: 894	
Osler & Schroll (1990)[34] Denmark (4)	DH *v.* 3-d WDR	Pearson CC Crude 0·75***		Mean (SD) (mg) DH: 1209 (414) 3-d WDR: 1135 (436)	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·79**	Males Crude 0·81**	Females Mean (SD) (mg) DH: 930 (329) 3-d EDR: 895 (329)	Males Mean (SD) (mg) DH: 952 (388) 3-d EDR: 902 (374)
van Staveren *et al.* (1996)[25] SENECA (4·5)	DH *v.* 3-d EDR	Females Crude: 0·59 Unattenuated: 0·69	Males Crude: 0·72 Unattenuated:0·82	Mean (mg) DH: 823 3-d EDR: 703	
Mahalko *et al.* (1985)[39] USA (4)	DH *v.* 7-d EDR	Pearson CC Crude 0·69**		Mean (SD) (mg) DH: 754 (397) 7-d WDR: 725 (337)	

NS British Journal of Nutrition

Table 4. *Continued*

Author/year publication/country/ (quality index)	Methods	Correlation between methods		Other statistics	
Mares-Perlman *et al.* (1993)[28] USA (6·5)	DH *v.* 8-d EDR	Females food only Crude 0·60 Energy adjusted 0·62 Food + supplements Crude 0·67 Energy adjusted 0·63	Males food only Crude 0·69 Energy adjusted 0·77 Food + supplements Crude 0·75 Energy adjusted 0·75	Females Mean (SD) Food only (mg) DH: 584 (290) 8-d EDR: 598 (175) Food + supplements DH: 719 (398) 8-d EDR: 733 (336)	Males Mean (SD) Food only (mg) DH: 902 (473) 8-d EDR: 821 (320) Food + supplements DH: 958 (485) 8-d EDR: 877 (356)
Brown *et al.* (1990)[35] USA (2·5)	VDAM *v.* 24HR	Pearson CC Crude 0·82		Mean (SD) (mg) VDAM: 530 (291) 24HR: 520 (382)	
Mg					
Messerer *et al.* (2004)[12] Sweden (5·5)	FFQ *v.* 24HR	Spearman CC Food + supplements: 0·73 Food: 0·73		Mean (SD) (mg) 24HR: Food: 326·6 (66·7) Food + supplements: 328·5 (68·8) FFQ: Food: 316·3 (85·3) Foods + supplements: 320·5 (94·9)	
Dumartherayet *al.* (2006)[4] Switzerland (3·5)	FFQ *v.* 4-d WDR	Pearson CC Crude 0·48** Energy adjusted 0·63**		Mean (SD) (mg) 4-d WDR: 281·1 (100·6) FFQ: 310 (104·2)	
Nes *et al.* (1992)[30] Norway (4)	FFQ *v.* 14-d WDR	Crude 0·57 Energy adjusted 0·71		Mean (mg) 14-d WDR: 330 FFQ: 320	
Klipstein-Grobusch *et al.* (1998)[21] The Netherlands (6)	FFQ *v.* 15-d EDR	Pearson CC Crude 0·75; Adjusted 0·69; Deattenuated 0·71		Mean (SD) (mg) SFFQ: 318 (77·8) 15-d EDR: 308·1 (65·4)	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·80**	Males Crude 0·84**	Females Mean (SD) (mg) DH: 244 (62) 3-d EDR: 242 (65)	Males Mean (SD) (mg) DH: 290 (84) 3-d EDR: 276 (83)
P					
Quandt *et al.* (2007)[8] USA (4·5)	FFQ *v.* 24HR	Females CC Crude 0·16 CC Adjusted 0·31*	Males CC Crude 0·60* CC Adjusted 0·57*	Females Median (mg) Recalls: 830·3 FFQ: 639·7 PSFFQ: 845·1	Males Median (mg) Recalls: 944·8 FFQ: 601·5** PSFFQ: 930·7
	PSFFQ *v.* 24HR	CC Crude 0·12 CC Adjusted 0·18	CC Crude 0·40* CC Adjusted 0·40*		
Munger *et al.* (1992)[31] USA (3)	FFQ *v.* 24HR	Crude 0·46 Energy adjusted 0·52		Mean (SD) (mg) FFQ: 1318 (375) 24HR: 1339 (414)	
Dumartherayet *al.* (2006)[4] Switzerland (3·5)	FFQ *v.* 4-d WDR	Pearson CC Crude 0·55** Energy adjusted 0·57**		Mean (SD) (mg) 4-d WDR: 1175 (381·8) FFQ: 1260·2 (451·5)	
Potosky *et al.* (1990)[33] USA (1)	FFQ *v.* 12-d EDR	Pearson CC Crude 0·61		Not specified	
Klipstein-Grobusch *et al.* (1998)[21] The Netherlands (6)	FFQ *v.* 15-d EDR	Pearson CC Crude 0·76; Adjusted 0·72; Deattenuated 0·74		Mean (SD) (mg) SFFQ: 2108 (810) 15-d EDR: 1677 (560)	

Table 4. *Continued*

Author/year publication/country/ (quality index)	Methods	Correlation between methods		Other statistics	
Groothenhuis *et al.* (1995)[26] The Netherlands (2·5)	FFQ *v.* DH	Pearson CC Crude 0·72		Mean (SD) (g) FFQ: 1·45 (0·42) DH: 1·47 (0·31)	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·78**	Males Crude 0·77**	Females Mean (SD) (mg) DH: 1084 (300) 3-d EDR: 1074 (310)	Males Mean (SD) (mg) DH: 1221 (359) 3-d EDR: 1190 (349)
Mahalko *et al.* (1985)[39] USA (4)	DH *v.* 7-d EDR	Pearson CC Crude 0·68**		Mean (SD) (mg) DH: 1221 (402) 7-d WDR: 1206 (367)	
Fe					
Quandt *et al.* (2007)[8] USA (4·5)	FFQ *v.* 24HR	Females CC Crude 0·03 CC Adjusted 0·08	Males CC Crude 0·41* CC Adjusted 0·36*	Females Median (mg) Recalls: 10·1 FFQ: 6·8** PSFFQ: 9·1	Males Median (mg) Recalls: 11·2 FFQ: 5·9** PSFFQ: 8·3**
	PSFFQ *v.* 24HR	CC Crude 0·26* CC Adjusted 0·50*	CC Crude 0·49* CC Adjusted 0. 58*		
Messerer *et al.* (2004)[12] Sweden (5·5)	FFQ *v.* 24HR	Spearman CC Food + supplements: 0·38 Food: 0·25		Mean (SD) (mg) 24HR: Food: 15·4 (3·6) Food + supplements: 16·7 (8·4) FFQ: Food: 14·4 (3·9) Food + supplements: 16·0 (6·7)	
Kumanyika *et al.* (1997)[23] USA (4·5)	FFQ *v.* 24HR	Pearson CC Deattenuated 0·57		Mean (SD) (mg) Recalls: 16 (7) Picture sort: 13 (5)	
Kumanyika *et al.* (1996)[24] USA (4·5)	FFQ *v.* 24HR	Pearson CC Deattenuated 0·59		Mean (SD) (mg) Recalls: 16 (7) Picture sort: 13 (5)	
Munger *et al.* (1992)[31] USA (3)	FFQ *v.* 24HR	Food + supplements Crude 0·00; Energy adjusted −0·01 Food only Crude 0·07; Energy adjusted −0·09		Mean (SD) (mg) FFQ: 13·0 (3·9) 24HR: 25·2 (60·6)	
Dumartherayet *al.* (2006)[4] Switzerland (3·5)	FFQ *v.* 4-d WDR	Pearson CC Crude 0·49** Energy adjusted 0·51**		Mean (SD) (mg) 4-d WDR: 11·77 (4·28) FFQ: 12·25 (4·15)	
Smith *et al.* (1998)[22] Australia (3)	FFQ *v.* 12-d WDR	Pearson CC Crude 0·25 Adjusted 0·41		Mean (SD) (mg) 4-d WDR: 12·4 (3·1) FFQ: 12·7 (4·2)	
Nes *et al.* (1992)[30] Norway (4)	FFQ *v.* 14-d WDR	Crude 0·73 Energy adjusted 0·76		Mean (mg) 14-d WDR: 12 FFQ: 13	
Rothenberg E. (1994)[27] Sweden (3)	FFQ *v.* 4-d EDR	Pearson CC Crude 0·50		Mean (95 % CI) (μg) 4-d EDR: 15 (14, 16) FFQ: 17 (16, 18)	
Potosky *et al.* (1990)[33] USA (1)	FFQ *v.* 12-d EDR	Pearson CC Crude 0·48		Not specified	

Table 4. *Continued*

Author/year publication/country/ (quality index)	Methods	Correlation between methods		Other statistics	
Klipstein-Grobusch *et al.* (1998)[21] The Netherlands (6)	FFQ *v.* 15-d EDR	Pearson CC Crude 0·67; Adjusted 0·42; Deattenuated 0·44		Mean (SD) (mg) SFFQ: 15·1 (3·4) 15-d EDR: 12·0 (2·8)	
Groothenhuis *et al.* (1995)[26] The Netherlands (2·5)	FFQ *v.* DH	Pearson CC Crude 0·74		Mean (SD) (g) FFQ: 12·0 (2·9) DH: 11·7 (2·9)	
Nes *et al.* (1991)[32] SENECA (3·5)	DH *v.* 3-d WDR	Pearson CC Deattenuated 0·58		Mean (SD) (mg) DH: 113 3-d WDR: 101	
Pedersen *et al.* (2001)[18]Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·57**	Males Crude 0·79**	Females Mean (SD) (mg) DH: 7·31 (1·79) 3-d EDR: 7·55 (2·27)	Males Mean (SD) (mg) DH: 9·14 (2·87) 3-d EDR: 8·85 (2·85)
van Staveren *et al.* (1996)[25] SENECA (4·5)	DH *v.* 3-d EDR	Females Crude: 0·48 Unattenuated: 0·63	Males Crude: 0·51 Unattenuated: 0·59	Mean (mg) DH: 11·0 3-d EDR: 9·9	
Mahalko *et al.* (1985)[39] USA (4)	DH *v.* 7-d EDR	Pearson CC Crude 0·43**		Mean (SD) (mg) DH: 13·8 (5·0) 7-d WDR: 13·7 (5·6)	
Mares-Perlman *et al.* (1993)[28] USA (6·5)	DH *v.* 8-d EDR	Females Food only Crude 0·62 Energy adjusted 0·50 Food + supplements Crude 0·54 Energy adjusted 0·46	Males Food only Crude 0·33 Energy adjusted 0·32 Food + supplements Crude 0·51 Energy adjusted 0·58	Females Mean (SD) Food only (mg) DH: 9·0 (3·0) 8-d EDR: 12·4 (3·3) Food + supplements DH: 15·1 (16·2) 8-d EDR: 17·6 (14·7)	Males Mean (SD) Food only (mg) DH: 13·6 (4·5) 8-d EDR: 15·5 (3·2) Food + supplements DH: 16·9 (9·0) 8-d EDR: 19·1 (13·3)
Brown *et al.* (1990)[35] USA (2·5)	VDAM *v.* 24HR	Pearson CC Crude 0·31		Mean (SD) (mg) VDAM: 8·2 (3·6) 24HR: 6·6 (2·2)	
Zn					
Quandt *et al.* (2007)[8] USA (4·5)	FFQ *v.* 24HR	Females CC Crude 0·16 CC Adjusted 0·26*	Males CC Crude 0·50* CC Adjusted 0·44*	Females Median (mg) Recalls: 6·7 FFQ: 4·6** PSFFQ: 6·4	Males Median (mg) Recalls: 7·5 FFQ: 4·0** PSFFQ: 5·8*
	PSFFQ *v.* 24HR	Crude 0·19 Adjusted 0·34*	Crude 0·39* Adjusted 0·37*		
Messerer *et al.* (2004)[12] Sweden (5·5)	FFQ *v.* 24HR	Spearman CC Food + supplements: 0·56 Food: 0·34		Mean (SD) (mg) 24HR: Food: 10·4 (2·2) Food + supplements: 11·6 (3·9) FFQ: Food: 10·9 (3·1) Food + supplements: 13·1 (8·3)	
Smith *et al.* (1998)[22] Australia (3)	FFQ *v.* 12-d WDR	Pearson CC Crude 0·19 Adjusted 0·10		Mean (SD) (mg) 4-d WDR: 10·4 (2·9) FFQ: 11·2 (3·8)	
Horwath (1993)[29] New Zeland (3)	FFQ *v.* 10-d EDR	Females Crude 0·34	Males Crude 0·77	Females Mean (SD) (mg) 10-d EDR: 9·5 (2·1) FFQ: 8·6 (2·1)	Males Mean (SD) (mg) 10-d EDR: 11·0 (3·0) FFQ: 9·9 (2·6)

British Journal of Nutrition

Table 4. *Continued*

Author/year publication/country/ (quality index)	Methods	Correlation between methods		Other statistics	
Klipstein-Grobusch *et al.* (1998)[21] The Netherlands (6)	FFQ *v.* 15-d EDR	Pearson CC Crude 0·70; Adjusted 0·51; Deattenuated 0·54		Mean (SD) (mg) SFFQ: 11·8 (3·0) 15-d EDR: 10·5 (2·9)	
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·70**	Males Crude 0·67**	Females Mean (SD) (mg) DH: 8·63 (1·99) 3-d EDR: 8·59 (2·07)	Males Mean (SD) (mg) DH: 9·99(2·57) 3-d EDR: 9·67 (2·45)
Mahalko *et al.* (1985)[39] USA (4)	DH *v.* 7-d EDR	Pearson CC Crude 0 59**		Mean (SD) (mg) DH: 10·5 (3·5) 7-d WDR: 10·2 (3·3)	
Mares-Perlman *et al.* (1993)[28] USA (6·5)	DH *v.* 8-d EDR	Females food only Crude 0·45 Energy adjusted 0·37 Food + supplements Crude 0·48 Energy adjusted 0·48	Males food only Crude 0·51 Energy adjusted 0·47 Food + supplements Crude 0·67 Energy adjusted 0·61	Females Mean (SD) Food only (mg) DH: 6·2 (2·0) 8-d EDR: 8·6 (2·3) Food + supplements DH: 9·6 (7·9) 8-d EDR: 11·7 (7·4)	Males Mean (SD) Food only (mg) DH: 9·7 (3·1) 8-d EDR: 11·6 (3·0) Food + supplements DH: 11·8 (6·9) 8-d EDR: 13·9 (7·7)
Brown *et al.* (1990)[35] USA (2·5)	VDAM *v.* 24HR	Pearson CC Crude 0·35		Mean (SD) (mg) VDAM: 4·9 (1·5) 24HR: 4·5 (1·9)	
Se					
Messerer *et al.* (2004)[12] Sweden (5·5)	FFQ *v.* 24 HR	Spearman CC Food + supplements: 0·75 Food: 0·72		Mean (SD) (µg) 24HR: Food: 29·8 (9·0) Food + supplements: 34·8 (15·7) FFQ: Food: 29·2 (9·9) Food + supplements: 37·7(32·6)	
Horwath (1993)[29] New Zeland (3)	FFQ *v.* 10-d EDR	Females Crude 0·40	Males Crude 0·61	Females Mean (SD) (µg) 10-d EDR: 37·2 (15·6) FFQ: 31·8 (11·3)	Males Mean (SD) (µg) 10-d EDR: 39·3 (14·2) FFQ: 37·1 (12·2)
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·52**	Males Crude 0·57**	Females Mean (SD) (mg) DH: 32 (10) 3-d EDR: 33 (14)	Males Mean (SD) (mg) DH: 38 (11) 3-d EDR: 39 (17)
Iodine					
Pedersen *et al.* (2001)[18] Denmark (4)	DH *v.* 3-d EDR	Females Crude 0·64**	Males Crude 0·67**	Females Mean (SD) (mg) DH: 95 (57) 3-d EDR: 88 (51)	Males Mean (SD) (mg) DH: 113 (99) 3-d EDR: 117 (92)

CC, correlation coefficient; 24HR, 24-h recall; PSFFQ, Picture-sort FFQ; EDR, estimated dietary record; SFFQ, Self-administered FFQ; DH, diet history; BM, biomarker; VDAM, videotape dietary assessment method; WDR, weighed dietary record.

Mean values were significantly different: $^{*}P<0{\cdot}05$; $^{**}P<0{\cdot}01$; $^{***}P<0{\cdot}001$.

British Journal of Nutrition

Table 5. Classification of dietary assessment methods applied to the elderly according to the study quality-weighted mean of the correlations for each micronutrient

	FFQ *v.* 24HR	FFQ *v.* EDR	FFQ *v.* WDR	FFQ *v.* DH	FFQ *v.* BM	24HR *v.* BM	DH *v.* EDR	DH *v.* WDR	VDAM *v.* 24HR
Very good (>0·70)	Mg, Se, thiamin, riboflavin	Mg, P, Ca		Niacin, Fe, P	Vitamin E		Vitamins E, B_6, thiamin, riboflavin, Mg, Ca, P	Ca, vitamin B_6	Ca, riboflavin
Good (0·51–0·70)	K, Ca, P, retinol, vitamins D, B_{12}, B_6, C	Riboflavin, folate, Na, K,Se, Zn, vitamin C	Vitamins A, C, thiamin, riboflavin, folate, P, Fe, Ca	Thiamin, riboflavin, Na, K, Ca, vitamins B_6, C.	Vitamin C		Retinol, vitamins D, C niacin, folate, Na, Fe, Se, iodine, Zn, K	Fe, β-carotene, thiamin, riboflavin, vitamin C	Vitamin A, thiamin
Acceptable (0·30–0·50)	Na, Fe, Zn, β-carotene, niacin, folate, vitamins A, E	Vitamins D, A, B_6, thiamin, Fe	β-Carotene, vitamins B_{12}, D, Mg, K	Vitamin A		Na, K, vitamin E	Vitamin A, B_{12}, β-carotene		Na, Zn, Fe, niacin, vitamin C
Poor (<0·30)			Retinol, Zn		Folate, β-carotene	β-Caronete, vitamin C		Vitamin A	

EDR, estimated dietary record; WDR, weighed dietary record; 24HR, 24-h recall; BM, biomarker; DH, diet history; VDAM, videotape dietary assessment.

correlations were observed in five micronutrients, whereas another seven micronutrients presented a good rating and three micronutrients (Mg, P and Ca) showed a very good rating ($r > 0·7$). Micronutrients with correlations $<0·3$ (poor) were not observed in any of the studies in this category. Additionally, five FFQ[4,13,22,30,37] were validated against WDR, and a total of fifteen micronutrients were analysed. These assessment methods showed poor correlations for retinol and Zn, acceptable correlations for five micronutrients, while eight micronutrients showed a good correlation and therefore a good rating. It should be noted that micronutrients with correlations $>0·7$ (very good) were not observed in any study in this category. In addition, two studies presented results of the validation of FFQ against diet history (DH)[26,36] in which a total of eleven micronutrients were studied. These methods presented acceptable correlations only for vitamin A, good correlations for seven micronutrients, and very good correlations were observed in niacin, Fe and P. Four studies validated FFQ with BM[9,10,15,20], in which poor correlations were observed for folate and β-carotene, whereas vitamins C and E presented good and acceptable ratings, respectively. On the other hand, four studies validated DH against EDR[18,25,28,39] and twenty-one micronutrients were analysed, of which vitamins A, B_{12} and β-carotene showed acceptable correlations, eleven presented good correlations and seven micronutrients showed very good ratings. Micronutrients with correlations $<0·3$ (poor) were not observed in any study in this category. Likewise, two other studies validated DH against WDR[32,34] and a total of eight micronutrients were ranked, five showing good correlations, Ca and vitamin B_6 with very good classification and poor correlations being observed for vitamin A. Comparisons of different dietary assessment methods in elderly people by vitamins and minerals are shown in Fig. 2. This figure demonstrates that DH using EDR as the reference method present better correlations for several micronutrients than other combinations of instruments and reference methods in these population groups.

Moreover, these studies were classified according to which reference method was used reflecting short-term intake, long-term intake or BM. Seventeen studies were classified in group 1 with a reference method that reflected short-term intake (<7 d), in which nine studies applied 24HR[8,11,14,15,17,23, 24,31,35], three publications used WDR[4,32,34], another three papers applied EDR[18,25,27] and finally, two studies utilised a DH[26,36]. Likewise, twelve other studies were classified in group 2 where the reference method reflected long-term intake (≥7 d), in which one study used 24HR[12], four applied WDR[13,22,30,37] and another seven used EDR[16,21,28,29,33, 38,39]. Finally, in group 3 where dietary methods were validated against BM, five studies were identified[9,10,15,19,20]. Some articles present validations using more than one instrument[8,15].

The FFQ were the main dietary method applied, which was validated in twenty-five studies[4,8–17,20–24,26,27,29–31,33,36–38]. Accordingly, Fig. 3 shows only FFQ validation studies that assess micronutrient intake in elderly people using as a reference method a short-term or a long-term dietary assessment instrument or BM. Regarding the reference method that reflected short-term intake, very good correlations were observed for thiamin and riboflavin. However, when the reference method used reflected long-term intake, we observed

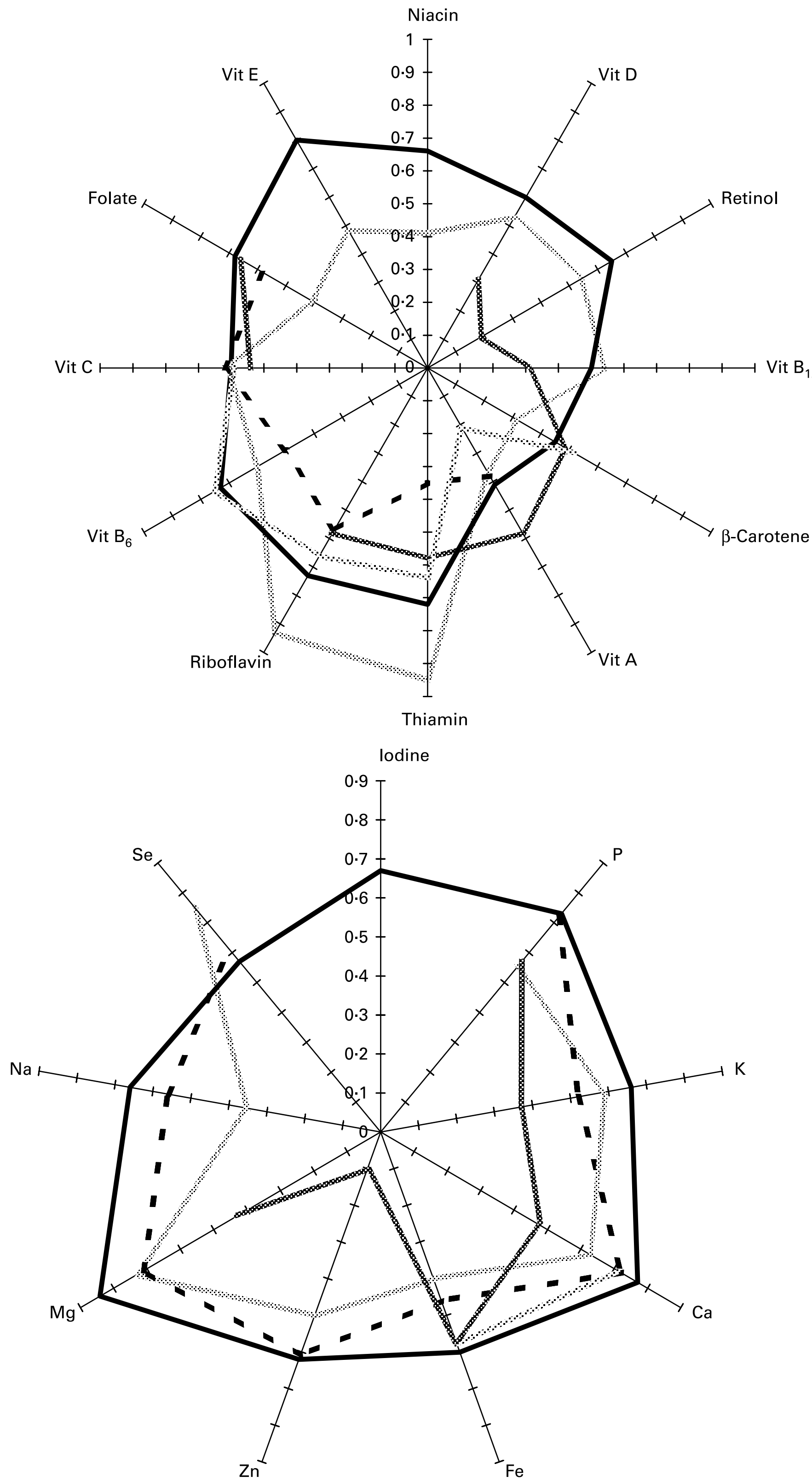

Fig. 2. Comparison of different dietary assessment methods in elderly people by vitamins and minerals. 24HR, 24-h recall; EDR, estimated dietary record; WDR, weighed dietary record; DH, dietary history. ·········, FFQ *v.* 24HR; ▬ ▬, FFQ *v.* EDR; ▬▬▬, FFQ *v.* WDR; ▬▬▬, DH *v.* EDR; ·········, DH *v.* WDR.

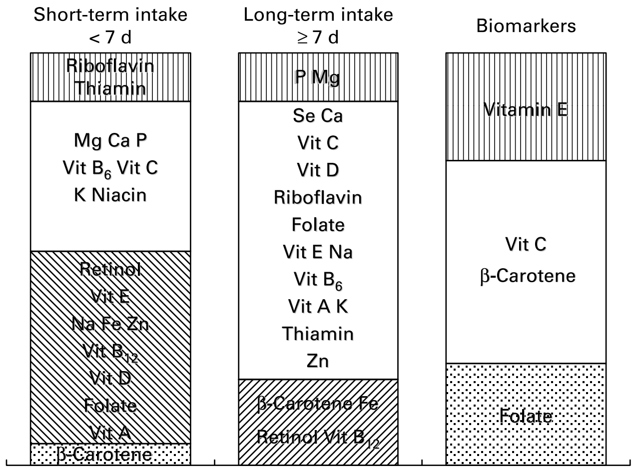

Fig. 3. FFQ validation studies that assess micronutrient intake in elderly people using short-term or long-term dietary instruments or biomarkers as the reference method. Mean of correlation coefficients weighted by study quality score: Four categories: Poor (<0·30); Acceptable (0·30–0·50); Good (<0·51–0·70); Very good (>0·70).

that a greater number of micronutrients presented good correlations. Moreover, micronutrients with correlations <0·3 (poor) were not observed when the reference method used reflected long-term intake. Finally, BM used as reference methods presented very good correlations for vitamin E. FFQ validation studies assessing micronutrient intake in elderly people, which included or did not include dietary supplements, are presented in Fig. 4. For most of the micronutrients, the correlation improved when the FFQ evaluated supplement use.

Validated dietary methods

In the thirty-three articles included in this review, twenty-five different FFQ had been validated[4,8–17,20–24,26,27,29–31,33, 36–38]. A DH was validated in six studies[18,25,28,32,34,39], in another study a 24HR was validated[19] and one study validated a videotape dietary assessment method[35]. All the FFQ were designed to capture usual diet, however, the time period covered ranged from habitual diet in the last 24 h (one study), the last month (one study), the last 3 months (one study), the last 6 months (one study), the last 12 months (twelve studies) or the last 3 years (one study). This information was not specified in fourteen studies. The studies covered a wide range of items (30–224 food items) that were included in the questionnaire. The frequency categories reported ranged from 5 to 11. Twelve studies developed self-administered FFQ to assess dietary intake in elderly people and in another ten studies, the FFQ were completed by an interviewer. Fig. 5 shows mean study quality-weighted correlation coefficients distributed by use of FFQ or DH as the study instrument. For most of the micronutrients, the correlation improved when the DH was the study instrument being validated.

Reference methods used

Seventeen studies were classified in group 1, where the reference method reflected short-term intake, in which nine applied 24HR[8,11,14,15,17,23,24,31,35], three used WDR[4,32,34], three applied EDR[18,25,27] and two studies administered a DH[26,36] as the reference method. Likewise, twelve other

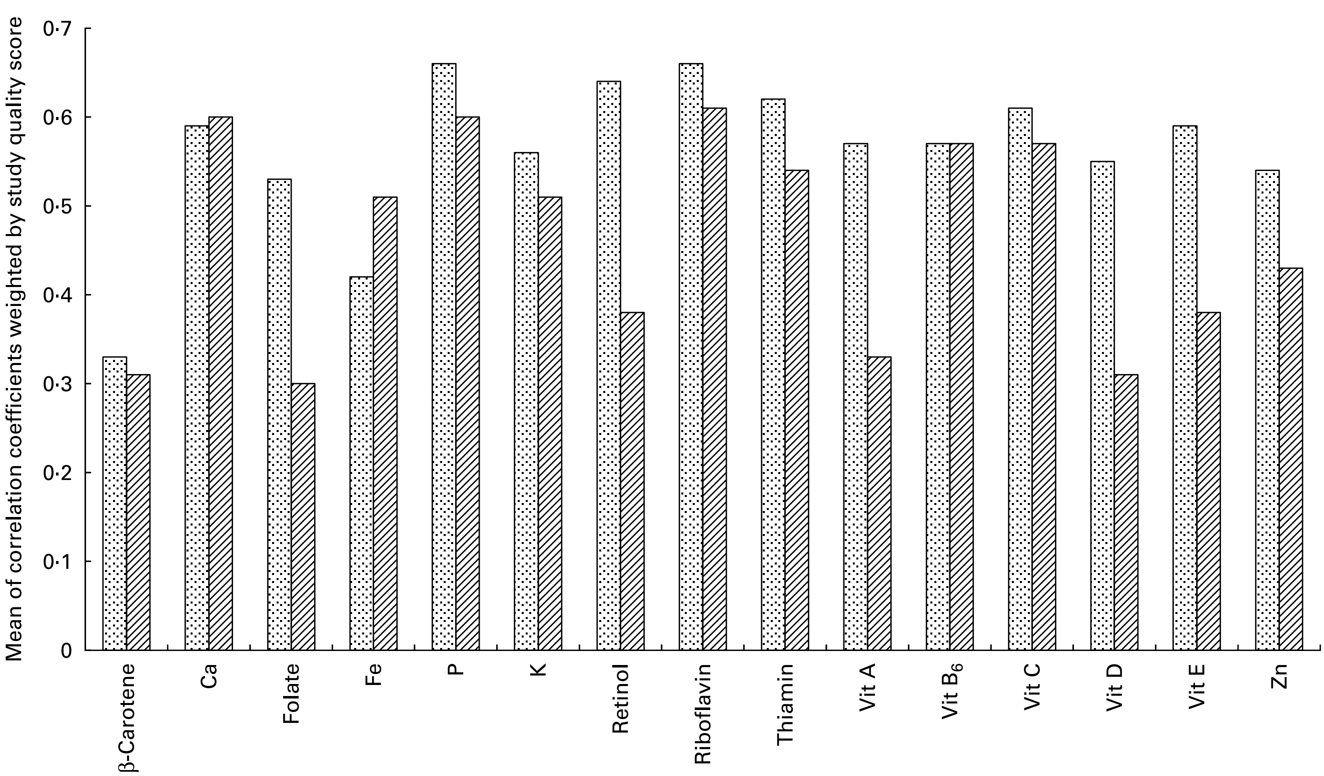

Fig. 4. FFQ validation studies that assess micronutrient intake in elderly people, including or not including dietary supplements. ⚃, Including supplements; ▨ not including supplements.

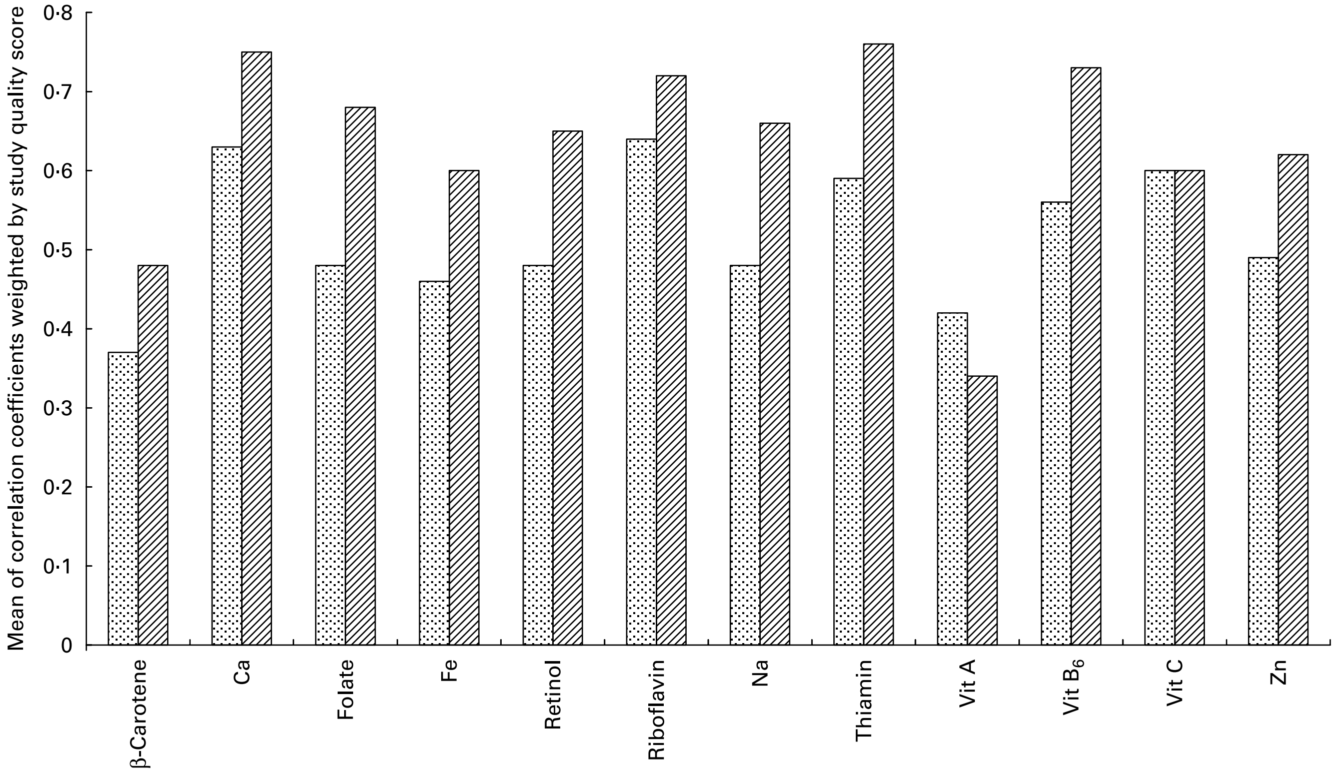

Fig. 5. Mean weighted correlation coefficients distributed by use of FFQ or diet history (DH) as study instrument. ▩, FFQ; ▨ DH.

studies were classified in group 2, where the reference method reflected long-term intake (one 24HR[12], four WDR[13,22,30,37] and seven EDR[16,21,28,29,33,38,39]). Dietary records ranging from 3 to 15 d for data collection were used as the reference method in a total of seventeen studies. The number of repeated 24HR ranged from 5 to 14, which were administered in person or by telephone.

Biomarkers

A total of five publications analysed BM, which were used to validate four FFQ[9,10,15,20], and one 24HR[19]. Some articles presented validation of more than one instrument, of which one study[15] also validated a 24HR using BM as the reference method. The BM analysed were: concentration of serum and erythrocyte folate; plasma concentration of β-carotene; vitamin C; vitamin E and one study analysed Na and K in urine samples.

Discussion

In this review, thirty-three validation studies[4,8–39] 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 elderly people 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 EURRECA Network. For each micronutrient and reference method category, a mean of the correlations adjusted by the quality of the different validation studies was obtained, and all methods were classified as poor, acceptable, good, or very good. Dietary assessment constitutes a difficult task for epidemiological studies in the elderly population. Limited recall due to fading memory or impairments in sight or attention may require more complicated approaches and as such, result in a higher respondent burden and low participation rates[21,40].

Short-term intake

Different FFQ were validated for which wide variations in the number of food items were observed (30–224 items). Grootenhuis *et al.*[26] found that good agreement of mean nutrient intake and high correlation coefficients between the estimates of the self-administered semi-quantitative questionnaire and the DH method, the absence of non-constant bias for most nutrients and the ability of the questionnaire to classify individuals adequately into broad categories, demonstrated an acceptable relative validity. The results of Rothenberg *et al.*[27] indicated that the FFQ considerably over-estimated vitamin C intake compared with 4-d EDR. However, using 4-d WDR as the reference method, Dumartheray *et al.*[4] demonstrated a good level of nutrient intake estimation by FFQ for the majority of the micronutrients assessed. The validation correlations were similar to another validation study conducted in the elderly[22]. Most correlation coefficients for unadjusted nutrients were lower than the correlation coefficients after adjustment for energy. This demonstrates that the variability of the nutrient consumption is related to energy intake. Moreover, the correlation coefficient is higher for unadjusted nutrients compared with

British Journal of Nutrition

energy-adjusted nutrients when variability of the nutrient depends on systematic errors of over- or under-estimation[4].

The correlation coefficients between FFQ and 24HR showed by Quandt *et al.* [8] were slightly below the range observed in other studies of older populations[14]. This might be due to the method of FFQ administration that was conducted by telephone rather than by face-to-face interviews. Wengreen *et al.* [17] utilised three 24HR and two picture-sort FFQ to assess the ability of the FFQ to discriminate among individuals' usual dietary intake. Mean intakes estimated from 138-item picture-sort FFQ used by Wengreen *et al.* [17] were higher than those reported by Kumanyika *et al.* [24], the latter being a similar study comparing multiple 24HR to picture- sort FFQ.

The correlation coefficients for the dietary history against the 3-d EDR obtained by Pedersen *et al.* [18] were generally high except for vitamin A, probably because of large day-to-day variations for this nutrient. The correlations for dietary data are in the same range as those seen for various physiological measures, as intraindividual variability is also present in these types of measures as well[41]. Pearson's correlation coefficients found by Osler & Schroll[34] were of the order of 0·61, with the exception of vitamin A, for which the value was considerably lower (*r* 0·24). When the data were classified into tertiles (low, medium and high intakes), Pearson's correlations observed by Nes *et al.* [32], with most values falling between 0·5 and 0·8, were comparable with those observed in studies of elderly people by Mahalko *et al.* [39], but were slightly higher than those reported by Potosky *et al.* [33] However, comparisons with other studies are not straightforward since the reference methods vary in the number of days recorded, the independence of the days (consecutive or non-consecutive), between-person variation and how portions are measured (weighed or estimated). Potosky *et al.* [33] demonstrated that the apparent validity of a quantitative FFQ increases when it is compared with a greater number of cycles of 4-d dietary records.

Utilisation of the videotape method of dietary assessment described by Brown *et al.* [35] resulted in the calculation of food amounts that were, on average, 6 % below amounts determined by recall methods. They found a difference of ≤10 % between means using the videotape method and measured amounts in recalls. These results provide strong evidence of the utility of the videotape method. The videotape method comes very close to representing actual intake, is reproducible, and may prove to be useful in identifying the effects of dietary composition on the health status of the elderly and other populations having a relatively high prevalence of cognitive or communication impairments. This study suggested that 24HR may be an inappropiate method of dietary assessment for the elderly due to the high percentage of error and misclassification that may occur due to impaired cognition resulting from disease or even medications affecting memory among others.

Long-term intake

Messerer *et al.* [12] assessed the validity of a self-administered FFQ and showed that overall, adding information about dietary supplement use increased the validity of micronutrient estimates by 13 % based on a self-administered FFQ. Furthermore, correct classification of micronutrient estimates into quintiles increased by 14 %. In line with these findings, Mares-Perlman *et al.* [28] showed that the inclusion of dietary supplements increased the overall correlation coefficient from 0·52 to 0·71 among older men. Klipstein-Grobusch *et al.* [21] evaluated the relative validity of micronutrient intake estimated by a FFQ adapted for dietary assessment in the elderly as compared to 15-d EDR. The correlation coefficients observed in the present study ranged from 0·5 to 0·9 for crude and from 0·4 to 0·8 for adjusted data, indicating relatively good validity and being similar to results of validation studies in which either a FFQ or DH were administered to an elderly population[25–31,39]. Cummings *et al.* [38] found that the daily Ca intake of elderly Caucasian women measured by interview-administered FFQ developed by Block and colleagues correlated well (*r* 0·76) with daily Ca intake calculated from 7-d EDR. This is consistent with the observation of Byers *et al.* [42], who found that measurement of the intake of a specific nutrient by brief food frequency interviews was reasonably highly correlated with measurements made by longer and detailed food frequency interviews. Similar findings were found by Nelson *et al.* [37] who showed that the Ca intake FFQ correlated well (*r* 0·69) with Ca intake measured by 7-d WDR.

Biomarkers

Espeland *et al.* [19] found that estimates of Na intake from 24-h dietary recalls were an average of 22 % lower than those from 24-h urine collection. Diet-based estimates of K intake exceeded those from urine assays by 16 % overall. In contrast, Na intake estimated from the urine collections were 7 % lower than intakes estimated from food records. K intakes estimated from urine were 8 % lower than those obtained from food records[43,44].

On the other hand, four FFQ were validated against BM. These assessment methods presented poor correlations for folate and β-carotene, good correlation for vitamin C and very good correlation for vitamin E. The FFQ developed by van de Rest *et al.* [9] to assess folate intake over the past 3 months in Dutch elderly people showed a weak positive correlation between folate intakes estimated with the FFQ and serum folate concentrations (*r* 0·14), but not erythrocyte folate (*r* 0·05). This could be explained by the fact that the serum folate reflects recent intake and the erythrocyte folate reflects long-term intake[45] and in this study, FFQ assessed food intake in the previous 3 months. Dietary intakes of β-carotene estimated by three different FFQ[10,15,20] were validated against plasma concentrations of this micronutrient. Vioque *et al.* [10] demonstrated that the correlations between usual intake of this micronutrient assessed by FFQ and their plasma concentration changed when the participants were grouped by BMI category. This finding was supported by Tucker *et al.* [20], who has shown that the correlations between carotenoid intakes and plasma concentrations improved after adjustment for BMI, plasma cholesterol concentrations and smoking status, particulary for α- and β-carotene, in men but not in women. The study by Tangney *et al.* [15] was designed to assess the performance of the modified Harvard FFQ with elderly people from two ethnic groups, differing cognitive abilities and various educational backgrounds from

British Journal of Nutrition

the Chicago Health and Aging Project. Because short-term memory declines with age, the reliability of multiple 24HR among elderly adults is often questioned[46]. Multiple 24HR interviews may burden respondents, contributing to low participation rates and compromising general applicability. The FFQ require a more generic representation of intake[47]. BM are subjected to error as well[48], but such errors are independent of those inherent in 24HR and FFQ. The Chicago Health and Aging Project correlations for vitamin E were considerably higher than those reported by the Dutch group (*r* 0·29 and 0·14 for men and women, respectively), in which considerably fewer older adults were represented[49]. The Chicago Health and Aging Project correlations for vitamin C were lower than those reported by Jacques *et al.* [50] for men and women from 40 to 83 years of age (*r* 0·44). BM should reflect the amount of nutrient present in the diet, which may vary according to the metabolism of the given nutrient. In the case of vitamin C, serologic response is seen several hours after postprandial spikes occur. For folate, most elderly have low intakes of this nutrient from food sources as well as being on medications, both of which can interfere with the correlation of intake with BM[51].

Conclusion

The aim of the present review was to determine the reliability of methods used to measure the usual intake of vitamins and minerals in elderly people and to evaluate how these were validated. The estimation of micronutrient intake is often a difficult task and can present extra challenges in elderly people. This population often suffers from diminished functionality and cognitive decline, which may hamper diet assessment and requires tailored approaches to assess dietary intake[52]. Declining short-term memory can imply that the 24HR method may be particularly inappropiate, and several investigators have demonstrated that dietary recall ability decreases with age. The very elderly can become easily fatigued and frustrated with long-DH interviews and may take far longer than younger people to complete them, as they are particularly prone to digressions in interview situations[29,40]. When frequency methods are used for assessing micronutrient intake, the inclusion of dietary supplements improves their reliability for most nutrients, with notable differences observed for folate, retinol, vitamins A, D, E and Zn. The FFQ administered to elderly people had a wide range of included food items, varying from 30 to 224. The frequency categories reported were from 5 to 11. Future research to clarify the number of food items and frequency categories that are to be included in the questionnaires needs to be developed for this population group. Comparing FFQ methods used for assessing micronutrient intake with short-term reference methods, very good correlations were observed for thiamin and riboflavin. Nevertheless, a poor correlation was observed for β-carotene. When FFQ using long-term intakes as reference methods are compared, we have observed that a greater number of micronutrients present good correlations. They are also very good for measuring long-term intake of P and Mg. Micronutrients with correlations $<0·3$ (poor) were not observed when the reference method used reflected long-term intake. Micronutrient intake correlates better with long-term rather than short-term daily intake. Additionally, BM used as reference methods present very good correlations for vitamin E and poor correlations for folate.

According to this systematic review, when comparing different validation methods, the DH presents better correlations when EDR are used as the reference method. When we analyse the mean of correlation coefficients weighted by study quality and their distribution by FFQ or DH as validated dietary methods, we observed that most of the micronutrients improved the correlation when the DH was used as the study instrument. Mares-Perlman *et al.* [28] used a modification of the DH questionnaire developed as part of the Health Habits and History Questionnaire by Block *et al.* [53] The questionnaire assessing dietary intake had three parts: a FFQ; additional food intake questions; questions about vitamin and mineral supplement intake. DH questionnaires of this type require less time and cost to administer and analyse than multiple food records or multiple 24HR. As such, this dietary assessment method is more economical in large epidemiological studies and also reduces the potential for response bias that can be introduced due to lower response rates associated with more rigorous methods[28].

Acknowledgements

The studies reported herein have been carried out within the EURRECA 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., A. S.-V. and J. D.-A. contributed to the planning of the search and analysed the articles included in this review; J. V. and L. G. revised and discussed previous drafts; L. S.-M. contributed to the planning of the search, decided the analysis and presentation of results and created the quality assessment tool of the articles and revised and discussed previous drafts. There has been no conflict of interest. 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 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 for her help in editing the English version of the manuscript.

References

1. Kucukerdonmez O, Koksal E, Rakicioglu N, *et al.* (2005) Assessment and evaluation of the nutritional status of the elderly using 2 different instruments. *Saudi Med J* **26**, 1611–1616.
2. Bartali B, Turrini A, Salvini S, *et al.* (2004) Dietary intake estimated using different methods in two Italian older populations. *Arch Gerontol Geriatr* **38**, 51–60.
3. Klein S, Kinney J, Jeejeebhoy K, *et al.* (1997) Nutrition support in clinical practice: review of published data and recommen-

dations for future research directions. National Institutes of Health, American Society for Parenteral and Enteral Nutrition, and American Society for Clinical Nutrition. *J Parenter Enteral Nutr* **21**, 133–156.
4. Dumartheray EW, Krieg MA, Cornuz J, *et al.* (2006) Validation and reproducibility of a semi-quantitative food frequency questionnaire for use in elderly Swiss women. *J Hum Nutr Diet* **19**, 321–330.
5. Samet JM (1989) Surrogate measures of dietary intake. *Am J Clin Nutr* **50**, Suppl. 5, S1139–S1144.
6. 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, S2–S16.
7. Serra-Majem L, Frost Andersen L, Henriquez-Sánchez P, *et al.* (2009) Evaluating the quality of dietary intake validation studies. *Br J Nutr* **102**, Suppl. 1, S3–S9.
8. Quandt SA, Vitolins MZ, Smith SL, *et al.* (2007) Comparative validation of standard, picture-sort and meal-based food-frequency questionnaires adapted for an elderly population of low socio-economic status. *Public Health Nutr* **10**, 524–532.
9. van de Rest O, Durga J, Verhoef P, *et al.* (2007) Validation of a food frequency questionnaire to assess folate intake of Dutch elderly people. *Br J Nutr* **98**, 1014–1020.
10. Vioque J, Weinbrenner T, Asensio L, *et al.* (2007) Plasma concentrations of carotenoids and vitamin C are better correlated with dietary intake in normal weight than overweight and obese elderly subjects. *Br J Nutr* **97**, 977–986.
11. Magkos F, Manios Y, Babaroutsi E, *et al.* (2006) Differences in the quantitative and qualitative performance of a calcium-specific food frequency questionnaire across age and sex. *J Hum Nutr Diet* **19**, 331–342.
12. Messerer M, Johansson SE & Wolk A (2004) The validity of questionnaire-based micronutrient intake estimates is increased by including dietary supplement use in Swedish men. *J Nutr* **134**, 1800–1805.
13. Flood VM, Smith WT, Webb KL, *et al.* (2004) Issues in assessing the validity of nutrient data obtained from a food-frequency questionnaire: folate and vitamin B12 examples. *Public Health Nutr* **7**, 751–756.
14. Morris MC, Tangney CC, Bienias JL, *et al.* (2003) Validity and reproducibility of a food frequency questionnaire by cognition in an older biracial sample. *Am J Epidemiol* **158**, 1213–1217.
15. Tangney CC, Bienias JL, Evans DA, *et al.* (2004) Reasonable estimates of serum vitamin E, vitamin C, and beta-cryptoxanthin are obtained with a food frequency questionnaire in older black and white adults. *J Nutr* **134**, 927–934.
16. Montomoli M, Gonnelli S, Giacchi M, *et al.* (2002) Validation of a food frequency questionnaire for nutritional calcium intake assessment in Italian women. *Eur J Clin Nutr* **56**, 21–30.
17. Wengreen HJ, Munger RG, Wong SS, *et al.* (2001) Comparison of a picture-sort food-frequency questionnaire with 24-hour dietary recalls in an elderly Utah population. *Public Health Nutr* **4**, 961–970.
18. Pedersen AN, Fagt S, Ovesen L, *et al.* (2001) Quality control including validation in dietary surveys of elderly subjects. The validation of a diet history method (the SENECA-method) used in the 1914-population study in Glostrup of Danish men and women aged 80 years. *Nutr Health Aging* **5**, 208–216.
19. Espeland MA, Kumanyika S, Wilson AC, *et al.* (2001) Statistical issues in analyzing 24-hour dietary recall and 24-hour urine collection data for sodium and potassium intakes. *Am J Epidemiol* **153**, 996–1006.
20. Tucker KL, Chen H, Vogel S, *et al.* (1999) Carotenoid intakes, assessed by dietary questionnaire, are associated with plasma carotenoid concentrations in an elderly population. *J Nutr* **129**, 438–445.
21. Klipstein-Grobusch K, den Breeijen JH, Goldbohm RA, *et al.* (1998) Dietary assessment in the elderly: validation of a semiquantitative food frequency questionnaire. *Eur J Clin Nutr* **52**, 588–596.
22. Smith W, Mitchell P, Reay EM, *et al.* (1998) Validity and reproducibility of a self-administered food frequency questionnaire in older people. *Aust N Z J Public Health* **22**, 456–463.
23. Kumanyika SK, Tell GS, Shemanski L, *et al.* (1997) Dietary assessment using a picture-sort approach. *Am J Clin Nutr* **65**, Suppl. 4, S1123–S1129.
24. Kumanyika S, Tell GS, Fried L, *et al.* (1996) Picture-sort method for administering a food frequency questionnaire to older adults. *J Am Diet Assoc* **96**, 137–144.
25. van Staveren WA, Burema J, Livingstone MB, *et al.* (1996) Evaluation of the dietary history method used in the SENECA Study. *Eur J Clin Nutr* **50**, Suppl. 2, S47–S55.
26. Grootenhuis PA, Westenbrink S, Sie CM, *et al.* (1995) A semiquantitative food frequency questionnaire for use in epidemiologic research among the elderly: validation by comparison with dietary history. *J Clin Epidemiol* **48**, 859–868.
27. Rothenberg E (1994) Validation of the food frequency questionnaire with the 4-day record method and analysis of 24-h urinary nitrogen. *Eur J Clin Nutr* **48**, 725–735.
28. Mares-Perlman JA, Klein BE, Klein R, *et al.* (1993) A diet history questionnaire ranks nutrient intakes in middle-aged and older men and women similarly to multiple food records. *J Nutr* **123**, 489–501.
29. Horwath CC (1993) Validity of a short food frequency questionnaire for estimating nutrient intake in elderly people. *Br J Nutr* **70**, 3–14.
30. Nes M, Frost Andersen L, Solvoll K, *et al.* (1992) Accuracy of a quantitative food frequency questionnaire applied in elderly Norwegian women. *Eur J Clin Nutr* **46**, 809–821.
31. Munger RG, Folsom AR, Kushi LH, *et al.* (1992) Dietary assessment of older Iowa women with a food frequency questionnaire: nutrient intake, reproducibility, and comparison with 24-hour dietary recall interviews. *Am J Epidemiol* **136**, 192–200.
32. Nes M, van Staveren WA, Zajkás G, *et al.* (1991) Validity of the dietary history method in elderly subjects. Euronut SENECA investigators. *Eur J Clin Nutr* **45**, Suppl. 3, S97–S104.
33. Potosky AL, Block G & Hartman AM (1990) The apparent validity of diet questionnaires is influenced by number of diet-record days used for comparison. *J Am Diet Assoc* **90**, 810–813.
34. Osler M & Schroll M (1990) A dietary study of the elderly in the City of Roskilde 1988/89. Methodological aspects of the relative validity of the dietary history method. *Dan Med Bull* **37**, 462–466.
35. Brown JE, Tharp TM, Dahlberg-Luby EM, *et al.* (1990) Videotape dietary assessment: validity, reliability, and comparison of results with 24-hour dietary recalls from elderly women in a retirement home. *J Am Diet Assoc* **90**, 1675–1679.
36. Jackson N, Little J & Wilson AD (1990) Comparison of diet history interview and self completed questionnaire in assessment of diet in an elderly population. *J Epidemiol Community Health* **44**, 162–169.
37. Nelson M, Hague G, Cooper C, *et al.* (1988) Calcium intake in the elderly: validation of a dietary questionnaire. *J Hum Nutr Diet* **1**, 115–127.
38. Cummings SR, Block G, McHenry K, *et al.* (1987) Evaluation of two food frequency methods of measuring dietary calcium intake. *Am J Epidemiol* **126**, 796–802.
39. Mahalko JR, Johnson LK, Gallagher SK, *et al.* (1985) Comparison of dietary histories and seven-day food records in

a nutritional assessment of older adults. *Am J Clin Nutr* **42**, 542–553.
40. van Staveren WA, de Groot LC, Blauw YH, *et al.* (1994) Assessing diets of elderly people: problems and approaches. *Am J Clin Nutr* **59**, Suppl. 1, S221–S223.
41. Block G & Hartman AM (1989) Issues in reproducibility and validity of dietary studies. *Am J Clin Nutr* **50**, Suppl. 5, S1133–S1138.
42. Byers T, Marshall J, Fiedler R, *et al.* (1985) Assessing nutrient intake with an abbreviated dietary interview. *Am J Epidemiol* **122**, 41–50.
43. Mickelsen O, Makdani D, Gill JL, *et al.* (1977) Sodium and potassium intakes and excretions of normal men consuming sodium chloride or a 1:1 mixture of sodium and potassium chlorides. *Am J Clin Nutr* **30**, 2033–2040.
44. Schachter J, Harper PH, Radin ME, *et al.* (1980) Comparison of sodium and potassium intake with excretion. *Hypertension* **2**, 695–699.
45. Crews H, Alink G, Andersen R, *et al.* (2001) A critical assessment of some biomarker approaches linked with dietary intake. *Br J Nutr* **86**, Suppl. 1, S5–S35.
46. Dubois S & Boivin JF (1990) Accuracy of telephone dietary recalls in elderly subjects. *J Am Diet Assoc* **90**, 1680–1687.
47. Smith AF (1991) Cognitive processes in long-term dietary recall. *Vital Health Stat* **6**, 4–18.
48. Tangney CC, Shekelle RB, Raynor W, *et al.* (1987) Intra- and interindividual variation in measurements of beta-carotene, retinol, and tocopherols in diet and plasma. *Am J Clin Nutr* **45**, 764–769.
49. Ocké MC, Bueno-de-Mesquita HB, Pols MA, *et al.* (1997) The Dutch EPIC food frequency questionnaire. II. Relative validity and reproducibility for nutrients. *Int J Epidemiol* **26**, Suppl. 1, S49–S58.
50. 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.
51. Potischman N (2003) Biologic and methodologic issues for nutritional biomarkers. *J Nutr* **133**, Suppl. 3, S875–S880.
52. de Vries JH, de Groot LC & van Staveren WA (2009) Dietary assessment in elderly people: experiences gained from studies in the Netherlands. *Eur J Clin Nutr* **63**, Suppl. 1, S69–S74.
53. Block G, Hartman AM, Dresser CM, *et al.* (1986) A data-based approach to diet questionnaire design and testing. *Am J Epidemiol* **124**, 453–469.

British Journal of Nutrition