

Comparison of an Australian food-frequency questionnaire with diet records: implications for nutrition surveillance

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Abstract

Objectives: To compare a widely used Australian food-frequency questionnaire (FFQ) with diet records and consider the results in relation to its use in nutrition surveillance.

Design: Inter-method reliability study.

Setting: A randomised trial in subjects with past asbestos exposure.

Subjects: Seventy-two adults living in Western Australia.

Methods: A semi-quantitative FFQ developed by the Commonwealth Scientific Industrial Research Organisation in South Australia was administered after the completion of four 7-day diet records (DRs).

Results: Mean agreement between methods was not significantly different from 100% for many nutrients, but the limits of agreement indicated that, at the individual level, the FFQ over- or underestimated the DR by at least 50%. Mean agreement between methods decreased significantly with increasing intakes for the majority of nutrients. Pearson's correlation coefficients were less informative indicators of agreement compared with the limits of agreement.

Conclusions: These results indicate poor agreement between the FFQ and DR when estimating absolute intakes. Therefore, comparing intakes collected using this FFQ with specific cut-off points such as Recommended Dietary Intakes for nutrition surveillance may lead to seriously flawed conclusions about population intakes.

Keywords
Food-frequency questionnaire
Reliability
Validity
Diet records
Nutrition surveys

Food-frequency questionnaires (FFQs) were designed for epidemiological studies to estimate usual intake for ranking individuals when calculating diet–disease risks. However, an FFQ capable of ranking intake does not necessarily provide good absolute measures of intake¹. Good estimates of absolute levels of intake, rather than correct ranks, are required for formulating public health recommendations². For population monitoring, a tool that can detect changes in population intake may often be sufficient. However, more quantitative results, such as the proportion with low intakes of certain nutrients, may also be desired.

Most studies examining the properties of FFQs have assessed their ability to rank subjects with the intent to adjust observed risk ratios for error. Few studies have examined their ability to measure absolute nutrient or food intakes. Despite this, FFQs are becoming quite widely used in national surveys and other surveillance methods. In this paper, we compare the absolute nutrient intakes from a widely used Australian FFQ with multiple 7-day diet records (DRs), and consider some of the implications of using FFQs for quantitative nutrition surveillance.

Background

In the early 1980s, the Commonwealth Scientific Industrial Research Organisation (CSIRO) in South Australia developed a semi-quantitative FFQ^{3,4}. This FFQ collects open-ended frequency and portion size information on nearly 200 items, including single foods, mixed dishes, beverages and alcohol^{3,4}. Most of the food items remain constant but a small number are changed to match the focus of the study it is used in. An example of a medium portion size for each item is given in household units based on weighed diet records collected in previous work⁵ and subjects record whether their own servings are small, medium or large in relation to the nominated amount. Other information including type of fat used and the use of added salt is also collected.

Slightly modified versions of this questionnaire have been used to examine the influence of diet on the risk of stroke and coronary heart disease⁶, asthma in children⁷, pancreatic cancer⁸, colorectal cancer^{9–11} and breast cancer¹². Modified versions have also been used to assess the achievement of Recommended Dietary Intakes (RDIs) in children¹³, adults^{13–15} and the elderly^{16–18}, the

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contribution of nutrients and energy in the diets of children¹⁹, adults^{20,21} and diabetics^{22,23}, and to monitor dietary changes as indicators of the effectiveness of health promotion programmes^{24,25}. We examined the 'Questan' version with 172 items, which was administered in a state-wide survey of the state of Victoria in 1985²¹ and has been used in a national postal survey every 5 years since 1988 to assess usual food and nutrient intakes²⁶.

The repeatability of this FFQ has been reported^{13,27} but little information about its validity relative to other dietary methods has been published, despite its extensive use. The limited reports that exist have examined only a few nutrients^{3,23,28,29}, were conducted with female student dietitians²⁹ or compared total fruit and vegetable intakes only³⁰. In this paper we compare all nutrient intakes from the 'Questan' version with multiple 7-day DRs, in a more general sample of the adult population. Although this type of study is commonly referred to as a validation study, it is more correctly described as an inter-method reliability study³¹. Our primary analysis uses the limits of agreement method³², but we also report the widely used correlation coefficient for comparison with previous work.

Methods

Subjects

This study was conducted within a randomised trial examining the efficacy of β -carotene and retinol supplements in reducing the risk of malignant mesothelioma and other cancers. Trial participants were 3240 people aged 8 to 87 years (80% men) recruited from two large cohorts of ex-workers and ex-residents of a blue asbestos mining town in Western Australia³³. All of the 570 people enrolling during the sixth month of the trial were asked if they would provide four 7-day DRs over the following year, except where language or literacy difficulties were apparent at the time of interview. All subjects gave informed consent and the study was approved by the Human Research Ethics Committee of the University of Western Australia and the Clinical Drug Trials Committee of the Sir Charles Gairdner Hospital, Nedlands, Western Australia.

Dietary methods

Subjects agreeing to participate in the reliability study were shown how to record everything consumed for seven consecutive days using household units (not weights) and were provided with measuring instruments and record sheets at their enrolment interview. One 7-day DR was completed in early December 1990 and the others in April, July and October of 1991. Participants were followed up by telephone two weeks after each commencement date to check their progress and to set a date for person-to-person checking of their DR.

After the completion of their fourth 7-day DR, the FFQ was posted to subjects to complete at home. Completed

questionnaires were returned by post and any missing information in the FFQ was followed up with the subject by telephone.

All DRs were entered into a database by the same nutritionist (G.L.A.) using Xyris Diet/1 software³⁴ and daily nutrient intakes were calculated using Australian Food Composition Tables (NUTTAB91–92)³⁵. Mean daily nutrient intakes from the four DRs combined were used for agreement analyses. Mean daily nutrient intakes from the FFQ were calculated by CSIRO Health Sciences and Nutrition (South Australia), utilising their automated system for linking the questionnaire with the same edition of the Australian Food Composition Tables⁴. The percentages of energy derived from fat and carbohydrate were calculated, as these are common surveillance indicators. Nutrient intakes from supplements were excluded. Sodium was excluded because discretionary salt use was not ascertained in the DR. All nutrient intake data were transformed before analyses using natural logarithms to overcome skewed distributions.

Internal validity

The ratio of energy intake to basal metabolic rate (EI/BMR) was used to assess underreporting of total intakes. BMR was calculated using Food and Agriculture Organization/World Health Organization/United Nations University equations adjusting for sex, age and weight³⁶. Estimates of energy intake from each dietary method were checked for extremes. Energy intakes less than 3360 kJ or above 21 000 kJ were considered implausible³⁷.

The characteristics of reliability study participants were compared with those of other trial participants who were invited but declined to participate in the reliability study, using Fisher's exact tests to compare proportions and *t*-tests to compare continuous variables as appropriate.

Agreement

The correlation coefficient describes association but not agreement; therefore the limits of agreement (LOA) were calculated to compare the two dietary methods^{38,39}. For each subject, the difference between the FFQ and DR (FFQ – DR) and the average of the FFQ and DR ((FFQ + DR)/2) was calculated. Plotting these two results allows visual assessment as to whether agreement between methods varies across the range of intakes and, if so, in which direction. This was formally tested by fitting the regression line of differences ($H_0: \beta = 0, \alpha = 0.05$). The LOA define the boundaries within which 95% of all the differences between methods are expected to fall and were calculated as: mean agreement (or mean of all differences) $\pm t_{(n-1, 0.025)}$ standard deviation of the differences³⁸. Acceptable LOA are arbitrary, but should depend upon the required sensitivity of a measure or method³⁸.

Because dietary intakes were log-transformed for the agreement analysis, anti-logging rendered mean

agreement, the LOA and their 95% confidence limits as a ratio, i.e. a multiple of the FFQ relative to the DR. All were expressed as a percentage, with 100% indicating exact agreement³⁸. For example, mean agreement of 120% indicated that, on average, FFQ estimates were 1.2 times greater than the DR estimate. LOA of 50–200% would indicate that 95% of all subjects' FFQ estimates were between one-half and two times their DR estimate. We summarised agreement between methods according to the LOA and any dependency between mean agreement and the magnitude of intake (i.e. regression slope of differences \neq 0). This was done separately for men and women.

Given the individual variation in usual diet, it is unlikely that agreement between two different dietary methods will be 100%. However, even when mean agreement is close to 100%, very wide LOA indicate that individual differences between dietary methods may be unacceptably large. A dependency between agreement and magnitude of intake indicates that the error in FFQ estimates varies across the range of intakes. This can lead to differential misclassification of intake, which introduces error around any cut-off points applied to absolute intakes, such as those used to make comparisons with RDIs. It also reduces the ranking ability of the FFQ, and the precision of diet–disease risk estimates. Furthermore, when FFQ errors vary across intakes it is inappropriate to apply a single calibration factor across the range of intakes.

To compare our results with other studies on the same FFQ, we also calculated Pearson's correlation coefficients between the natural log-transformed intakes from each method using PROC CORR in SAS⁴⁰.

Results

Of 118 volunteers, 83 people (57 men and 26 women) successfully completed four 7-day DRs and 72 of these (48 men and 24 women) completed the FFQ after their last

7-day DR. Over half of those withdrawing from the reliability study did so before completing their first 7-day DR. The most common reasons for not completing all four diet records or subsequent questionnaires were the commitment required ($n = 31$) and withdrawal from the trial due to side-effects or non-compliance ($n = 11$). The 11 subjects (nine men and two women) not completing the FFQ after their DRs did so mostly due to reluctance to complete more questionnaires. However, they were more likely to be users of dietary supplements before entering the trial and never to have smoked, compared with other reliability subjects and trial subjects (comparisons not shown). There were no significant differences in mean age or body mass index (BMI), the proportions of men and women, current smokers, subjects with BMI $> 25 \text{ kg m}^{-2}$ or supplement users, between reliability study participants and those who declined to participate (Table 1).

Typical EI/BMR in a Western population is 1.55 for men and 1.56 for women⁴². For those completing the DRs and the FFQ, EI/BMR was 1.3 for both men and women using FFQ intakes, and 1.4 and 1.2, respectively, using DR intakes. One subject had to be excluded from the reliability analysis, because his FFQ energy estimate was above 25 000 kJ and could not be explained by his activity level or BMI.

For men the FFQ estimate ranged from 70% (β -carotene) to 127% (sugars) of the DR estimate (Table 2). As indicated by the confidence intervals for mean agreement, many of these discrepancies were statistically significant. The LOA indicate that the FFQ could either underestimate or overestimate many nutrient intakes by at least 50% of the DR estimate. For example, a man with a DR energy intake of 5000 kJ could have an FFQ energy estimate anywhere between 2850 kJ (57%) and 7000 kJ (140%). Particularly wide LOA were observed for alcohol, β -carotene, polyunsaturated fat, retinol, retinol equivalents, sugars and vitamin C.

For women (Table 3), mean agreement ranged from 90% (saturated fat) to 163% (vitamin C). Although the 95%

Table 1 Baseline characteristics of subjects in the reliability study and those who declined to participate

	Men		Women	
	Declined*	Participants	Declined*	Participants
<i>n</i>	389	48	109	24
%	78	67	22	33
Age (years), mean \pm SD	54 \pm 11	55 \pm 10	50 \pm 13	49 \pm 11
BMI (kg m^{-2}), mean \pm SD	28 \pm 4	27 \pm 3	27 \pm 4	28 \pm 5
BMI $> 25 \text{ kg m}^{-2}$ (%)	77	78	63	75
Never smoked (%)	23	30	50	68
Ex-smoker (%)	51	50	30	16
Current smoker (%)	26	20	20	16
Cigarettes smoked per day by current smokers, mean \pm SD (<i>n</i>)	15 \pm 13 (100)	9 \pm 15 (9)	16 \pm 10 (21)	26 \pm 16 (4)
Taking a supplement prior to study† (%)	9	4	14	8

SD – standard deviation; BMI – body mass index.

* Participants who were invited but chose not to participate in the reliability study, including those who agreed and later dropped out.

† Supplement use was assessed using a different FFQ developed for the trial⁴¹.

Table 2 Agreement between the food-frequency questionnaire (FFQ) and the 7-day diet record (DR), men (*n* = 47)

Nutrient	DR		FFQ		Mean % agreement† (95% CI)	95% LOA‡	β§	r¶
	Mean ± SD	Minimum–maximum	Mean ± SD	Minimum–maximum				
Alcohol (g)	23 ± 24	0–97	17 ± 16	0–53	86 (69–106)	19–384	-0.13	0.86***
Calcium (g)	757 ± 222	370–1149	888 ± 331	445–2110	115 (107–124)	68–194	0.15	0.69***
Carbohydrate (g)	240 ± 64	107–362	238 ± 78	141–483	98 (91–106)	57–168	0.14	0.58***
β-Carotene (μg)	4181 ± 1843	1105–9700	3040 ± 1553	449–8272	70 (59–84)	21–238	0.32	0.19
Cholesterol (mg)	348 ± 121	97–679	299 ± 137	54–605	81 (74–89)	42–158	0.43***	0.76***
Energy (kJ)	9788 ± 1852	5413–12890	8880 ± 2288	4164–14163	89 (84–96)	57–140	0.31	0.53**
% Energy from carbohydrate	42 ± 8	25–59	45 ± 8	32–70	109 (106–113)	88–137	-0.14	0.80***
% Energy from fat	37 ± 5	22–50	35 ± 6	14–49	95 (90–100)	65–139	0.43*	0.42*
Fat (g)	93 ± 24	38–158	81 ± 25	15–128	85 (78–93)	47–153	0.32*	0.64***
Fibre (g)	26 ± 8	11–41	24 ± 10	11–65	91 (84–99)	52–161	0.16	0.66***
Iron (mg)	14 ± 4	8–29	13 ± 3	7–20	93 (86–100)	56–153	-0.01	0.48**
Magnesium (mg)	340 ± 69	184–491	332 ± 85	205–553	96 (90–103)	62–148	0.23	0.57***
Monounsaturated fat (g)	33 ± 9	14–55	27 ± 9	5–49	82 (75–90)	43–158	0.34*	0.57***
Niacin (mg)	24 ± 5	14–38	22 ± 6	11–35	90 (85–97)	58–142	0.24	0.58***
Niacin equivalents (mg)	42 ± 9	26–66	39 ± 9	21–58	91 (86–97)	62–136	0.16	0.59***
Phosphorus (mg)	1525 ± 296	812–2224	1363 ± 333	714–2235	88 (83–94)	59–133	0.28	0.59***
Polyunsaturated fat (g)	15 ± 6	4–28	16 ± 7	2–29	100 (90–112)	47–216	0.34**	0.72***
Potassium (mg)	3550 ± 615	2181–4673	3747 ± 1120	2480–8750	103 (97–110)	67–159	0.43*	0.53***
Protein (g)	99 ± 19	62–153	85 ± 18	42–118	85 (81–90)	58–126	0.20	0.57***
Retinol (μg)	1046 ± 1779	122–10334	1175 ± 1283	51–5906	124 (94–163)	19–800	0.11	0.48**
Retinol equivalents (μg)	1744 ± 1809	531–11142	1681 ± 1300	500–6248	97 (81–117)	28–338	0.12	0.51**
Riboflavin (mg)	2.0 ± 0.6	0.9–3.4	2.2 ± 0.6	0.9–4.0	109 (101–117)	64–184	-0.06	0.62***
Saturated fat (g)	38 ± 12	15–74	31 ± 11	7–61	80 (73–87)	43–148	0.29*	0.66***
Starch (g)	136 ± 34	66–220	107 ± 34	60–176	77 (71–84)	42–142	0.24	0.44*
Sugars (g)	103 ± 39	41–189	131 ± 56	65–307	127 (115–139)	66–244	-0.03	0.62***
Thiamin (mg)	1.4 ± 0.4	0.6–2.6	1.3 ± 0.4	0.7–2.0	92 (86–100)	55–156	-0.04	0.61***
Vitamin C (mg)	130 ± 43	48–289	154 ± 81	46–393	110 (96–126)	43–281	0.64**	0.44**
Zinc (mg)	13 ± 3	8–22	11 ± 2	5–16	88 (83–94)	55–140	0.07	0.47**

SD – standard deviation; CI – confidence interval; LOA – limits of agreement.
 † Expl[mean(FFQ – DR)] as a multiple of the DR (all nutrient data were log-transformed).
 ‡ Mean difference ± $t_{(n-1, 0.05)}$ (SD differences).
 § Slope of average of methods regressed on difference between methods ($H_0: \beta = 0, \alpha = 0.05$).
 ¶ Pearson's correlation coefficient.
 *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

confidence intervals and LOA were wider for the majority of nutrients reported by women in comparison to men, this may be a result of the smaller number of women rather than real sex differences.

Many nutrients showed a significant dependency between agreement and the magnitude of intake (Fig. 1 shows an example). Men reported fewer nutrients showing this dependency and had smaller regression coefficients (slopes) than women. Most often the dependency was positive, indicating that agreement became worse with increasing intakes. A negative slope, as seen for alcohol, meant that agreement was worse at lower levels of intake; however, none of these was significant. Expressing carbohydrate and fat as percentages of energy intake improved mean agreement and the LOA for fat only.

Criteria for assessing the adequacy of agreement are arbitrary. We selected (1) constant agreement across levels of intake, i.e. no significant slope in the regression line of differences, and (2) LOA not exceeding 50–200%, i.e. the FFQ yielded up to one-half or double the DR value. According to these criteria, agreement was adequate for all nutrients reported by men except for alcohol, β -carotene, cholesterol, total fat and all fat types, percentage of energy from fat, potassium, retinol, retinol equivalents, sugars and vitamin C. In women, only starch and percentage of energy from carbohydrate showed acceptable agreement. In contrast, most of the correlation coefficients between the two methods (for both men and women) were strong enough that they would often be interpreted as indicating 'good agreement'. Generally, the nutrients with the strongest correlations were not the ones identified as having adequate agreement, e.g. alcohol, cholesterol, polyunsaturated fat. Correlations were generally stronger in the men.

Discussion

These analyses show that, in a sample of free-living adults, broad statements cannot be made about whether the FFQ over- or underestimates intakes compared with the DR. Although mean agreement was close to 100% for most nutrients, this indicates that the two methods agree at the mean; it does not indicate 100% agreement across the scale of intakes. More importantly though, for many nutrients, levels of agreement were not constant but decreased significantly with increasing intakes. Like many FFQs, agreement between vitamin A intakes was poorest, and our results indicate large potential discrepancies between intakes of alcohol, β -carotene, cholesterol, all fat types and percentage of energy from fat, potassium, sugars and vitamin C, for both men and women. There were important differences in mean agreement between the sexes that are not necessarily related to the sample size. However, the wider LOA observed among women are

probably due to their smaller numbers creating wider confidence limits.

This was the third FFQ completed by subjects in one year (but the first CSIRO FFQ), as participants completed another brief FFQ at entry to the trial and at the end of their DRs, for another reliability study⁴¹. Any training effect would have had either no effect on agreement (where subjects may have more efficiently recalled the same errors) or improved subjects' recall. Hence, the agreement observed in this study might be better than would be expected if the FFQ were used in the wider population, among participants who had not completed an FFQ or diet record before.

None of the previous studies examining the CSIRO FFQ have used the LOA method. Pearson's correlation coefficients reported in these earlier studies ranged from 0.38 for protein²⁸ to 0.60 for saturated fat and calcium^{23,28}. Spearman's rank correlations ranged from 0.34 for protein to 0.83 for total fat²⁹. The one study that compared all FFQ nutrients with 12 days of weighed DRs for men and women separately reported kappa statistics less than 0.4 for most nutrients, indicating that classification agreement was generally poor between the two methods⁴³. Median differences and interquartile ranges in that study were greatest for carbohydrates, sugars, fibre, calcium, vitamin C, β -carotene and vitamin A, and agreement was reported as slightly better among men.

The correlation coefficients from these previously published studies are similar to our results in men except that our correlation coefficients for protein, carbohydrates, alcohol and calcium were generally higher. Although the magnitude of a correlation coefficient depends on the range studied, these results may indicate that the patterns observed in our study are not unusual. Therefore our LOA results might reflect the existence of poor agreement in other Australian sub-populations that have used this FFQ. Our results also indicate important differences in FFQ performance between men and women. As our numbers were small, this should be confirmed before making a definite conclusion.

Nutrient intakes from another Australian FFQ, that developed by the Anti-Cancer Council of Victoria (ACCV), have been compared with those from a 7-day weighed DR using the LOA method⁴⁴. In marked contrast to our findings, there were no variations in the level of agreement across levels of intake for any of the 27 nutrients assessed. A notable difference between the ACCV and CSIRO questionnaires is the use of questions in the ACCV FFQ to calibrate fruit and vegetable intakes according to the total number of portions consumed per day. This difference may be important, because another study found that the long list of fruits and vegetables in the CSIRO FFQ yields much higher intake frequencies than the shorter list³⁰. Mean agreement and LOA were not presented as percentages in the ACCV study, but the authors noted – as did we – that LOA outside 50–100% were observed.

Table 3 Agreement between the food-frequency questionnaire (FFQ) and the 7-day diet record (DR), women ($n = 24$)

Nutrient	DR		FFQ		Mean % agreement† (95% CI)	95% LOA‡	β§	r¶
	Mean ± SD	Minimum–maximum	Mean ± SD	Minimum–maximum				
Alcohol (g)	9 ± 10	0.28–38	8 ± 8	0.4–27	95 (64–142)	13–686	-0.12	0.72***
Calcium (g)	721 ± 192	418–1034	965 ± 446	262–1856	124 (107–143)	61–251	0.66***	0.74***
Carbohydrate (g)	174 ± 38	115–246	201 ± 65	75–361	112 (99–127)	60–206	0.60*	0.51*
β-Carotene (μg)	3688 ± 1976	1145–10865	3417 ± 1608	1663–8060	95 (78–117)	35–258	0.25	0.40
Cholesterol (mg)	226 ± 53	126–362	232 ± 106	56–495	94 (75–117)	31–279	1.2***	0.21
Energy (kJ)	6712 ± 1196	4433–8718	7270 ± 2230	2185–11094	104 (91–119)	54–201	0.86**	0.43*
% Energy from carbohydrate	44 ± 6	28–54	48 ± 9	32–68	107 (101–114)	81–142	0.33	0.52*
% Energy from fat	37 ± 5	29–48	34 ± 8	18–46	91 (83–99)	60–138	0.81**	0.65***
Fat (g)	64 ± 16	43–95	66 ± 27	11–117	94 (78–115)	37–244	0.96***	0.51*
Fibre (g)	20 ± 5	11–33	24 ± 8	10–38	119 (104–136)	61–232	0.33	0.48*
Iron (mg)	10 ± 2	6–14	12 ± 3	4–18	119 (102–139)	55–257	0.83*	0.08
Magnesium (mg)	271 ± 55	174–380	312 ± 85	121–462	112 (99–127)	61–206	0.60*	0.40
Monounsaturated fat (g)	21 ± 5	13–31	22 ± 9	4–38	93 (77–113)	37–237	0.91***	0.54**
Niacin (mg)	17 ± 2	13–21	20 ± 6	9–29	113 (98–131)	56–231	1.39***	0.04
Niacin equivalents (mg)	31 ± 3	22–38	35 ± 10	15–52	110 (95–127)	54–224	1.65***	-0.08
Phosphorus (mg)	1202 ± 198	826–1493	1326 ± 447	559–2195	105 (92–120)	54–204	0.97***	0.47*
Polyunsaturated fat (g)	11 ± 4	6–19	12 ± 6	2–22	103 (78–135)	27–389	0.96**	0.08
Potassium (mg)	2866 ± 473	1920–3810	3717 ± 901	1407–5225	127 (115–140)	78–205	0.69**	0.60**
Protein (g)	72 ± 9	53–93	77 ± 23	30–116	102 (89–117)	53–199	1.3***	0.26
Retinol (μg)	430 ± 306	198–1407	1170 ± 1968	41–8266	128 (80–205)	13–1285	1.0***	0.46*
Retinol equivalents (μg)	1045 ± 447	424–2132	1740 ± 1984	352–8764	123 (92–166)	29–528	0.84**	0.45*
Riboflavin (mg)	1.6 ± 0.5	0.8–2.7	2.1 ± 1.0	0.7–4.9	126 (106–150)	54–296	0.66*	0.47*
Saturated fat (g)	26 ± 8	16–47	26 ± 13	3–53	90 (73–110)	34–241	0.88***	0.63**
Starch (g)	88 ± 18	56–124	83 ± 24	32–137	92 (80–106)	46–184	0.64	0.24
Sugars (g)	85 ± 30	31–172	118 ± 52	17–260	131 (113–151)	64–268	0.48**	0.76***
Thiamin (mg)	1.1 ± 0.3	0.6–1.7	1.2 ± 0.4	0.5–2.1	110 (94–129)	51–238	0.40	0.34
Vitamin C (mg)	96 ± 28	52–144	171 ± 93	37–483	163 (131–203)	55–477	0.86**	0.26
Zinc (mg)	9 ± 1	6–12	10 ± 3	3–16	106 (90–125)	47–240	1.26***	0.13

SD – standard deviation; CI – confidence interval; LOA – limits of agreement.

† Expl[mean(FFQ – DR)] as a multiple of the DR (all nutrient data were log-transformed).

‡ Mean difference ± $t_{(n-1, 0.05)}$ (SD differences).§ Slope of average of methods regressed on difference between methods ($H_0: \beta = 0, \alpha = 0.05$).

¶ Pearson's correlation coefficient.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

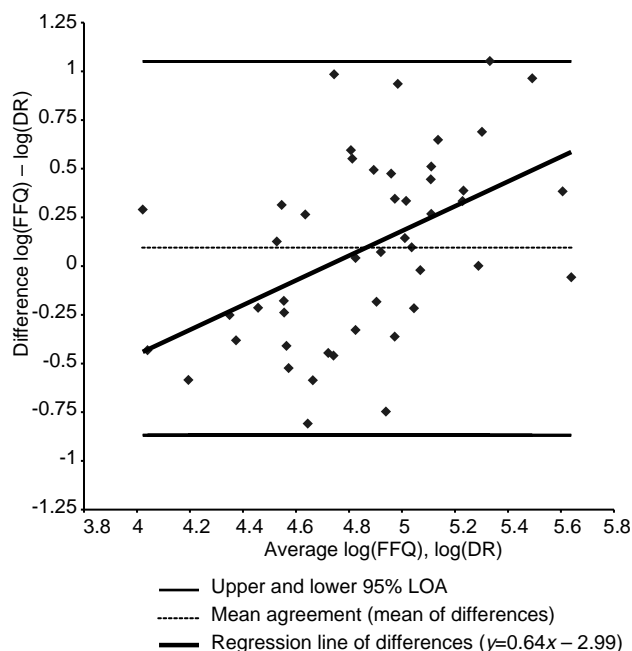


Fig. 1 Limits of agreement (LOA) for vitamin C intake, men ($n = 47$). FFQ – food-frequency questionnaire; DR – 7-day diet record

The ACCV findings were also similar to ours in that agreement was poor for vitamin A, β -carotene, vitamin C, all types of fat, cholesterol and calcium. Although the ACCV study included women only, it confirms that wide LOA observed between an FFQ and DR are not unusual.

It can be argued that dietary intakes used to assess the achievement of RDIs should be obtained in the same way that RDIs have been established, i.e. using duplicate weighed diet records. The large discrepancies observed between the FFQ and DR in this study indicate that FFQ intakes do not permit confident assessments of absolute intake against specific cut-off points such as RDIs or dietary goals. However, this FFQ is used regularly for such monitoring. One important drawback for monitoring purposes is that intakes are generally underestimated by both methods (indicated by the low EI/BMR) and this will lead to general overestimation of the proportion of the population with low intakes. As the underestimation was similar in both methods, it is reasonable to compare the extent of the disparity. For example, the proportion of women with intakes below the RDI for calcium was 58% and 92% for the FFQ and DR, respectively. Similarly, the proportion consuming more than 30% of energy as fat according to FFQ estimates was 90% for men and 71% for women, and according to the DR it was 92% for men and 96% for women. These problems also indicate that quantitative targets for population intakes to prevent chronic disease cannot be derived from epidemiological studies that have used FFQs unless the errors have been corrected.

FFQs represent a useful, economical and rapid method for large nutrition surveys compared with more

labour-intensive methods like the diet record. However, FFQs require further evaluation if they are to be used quantitatively, and their estimates can be calibrated using well-conducted reliability studies and simple regression techniques³². The limits of agreement method used here shows significant discrepancies between FFQ intakes and a diet record, and that agreement between methods can vary significantly across levels of intake in the population being studied. Although this study is small, it also raises the possibility that this FFQ performs differently in men and women, and that therefore intakes from this, and perhaps other FFQs, are not automatically comparable between the sexes. The degree of agreement, or lack of it, between the FFQ and DR examined here highlights the potential problems with using food-frequency questionnaires to assess absolute dietary intakes and other specific properties of dietary intake for quantitative surveillance purposes.

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