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What do babies eat? Evaluation of a food frequency questionnaire to assess the diets of infants aged 6 months

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Abstract

Objective: To evaluate the relative validity of a food frequency questionnaire (FFQ) for assessing nutrient intakes in 6-month-old infants.
Design and setting: The FFQ was developed to assess the diets of infants born to women in the Southampton Women's Survey (SWS), a population-based survey of young women and their offspring. The energy and nutrient intakes obtained from an interviewer-administered FFQ were compared with those obtained from a 4-day weighed diary.
Subjects and methods: A sub-sample of 50 infants aged 6 months from the SWS had their diets assessed by both methods. The FFQ recorded the frequencies and amounts of milks, baby foods, regular foods and drinks consumed by the infants over the previous seven days. The diaries recorded the weights of all foods and drinks consumed by the infants on four separate days within 15 days following FFQ completion.
Results: Spearman rank correlation coefficients for intakes of energy, macronutrients and 18 micronutrients, determined by the two methods, ranged from $r = 0{\cdot}39$ to $0{\cdot}86$; adjustment for energy intake tended to increase the correlation coefficients, range $r_a = 0{\cdot}55$ to $0{\cdot}89$. Bland–Altman statistics showed that mean differences between methods were in the range of $-12{\cdot}5\%$ to $+12{\cdot}5\%$ except for vitamin B_{12} ($-18{\cdot}9\%$).
Conclusion: Although there were differences in absolute energy and nutrient intakes between methods, Spearman rank correlation coefficients indicated reasonable agreement in the ranking of intakes. The interviewer-administered FFQ is a useful tool for assessing energy and nutrient intakes of healthy infants aged about 6 months.

Keywords
Infants
Food frequency questionnaire
Weighed diary
Dietary intake
Validation

Evidence for the long-term effects of infant nutrition on later health[(1)] has given impetus to the need to develop methods for assessing the diets of populations of infants. Previous studies in Europe and the USA have mainly used estimated or weighed records to assess diet at around 6 months[(2–8)]. While such methods have been shown to produce ranges of energy intakes that are comparable with levels determined by doubly labelled water (DLW) studies[(2)], they are expensive to process, often restricted to small groups of subjects and are unlikely to include all sectors of a population, with the consequent possibility of bias. Food frequency questionnaires (FFQs) have been used in older age groups to assess diet in large groups but few researchers have adapted this approach for infants. Two recently published studies using semi-quantitative FFQs, from Norway[(9)] and Finland[(10)], have reported food and milk patterns. We are unaware of any studies that report on the validity of energy and nutrient intakes from total milk and food intakes assessed by FFQ in 6-month-old infants.

In a sample of infants aged 6 months we aimed to compare the energy and nutrient intakes assessed by a newly developed, interviewer-administered, infant FFQ with intakes determined from a 4-day weighed diary (WD).

Subjects and methods

Subjects

The study was set within the Southampton Women's Survey (SWS)[(11)], in which women were recruited and

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characterised when not pregnant, then followed through their subsequent pregnancy and the offspring followed-up. The SWS study population of infants born between 1998 and 2003 comprised 1973 infants. Of these, 1645 (83 %) were visited within two weeks of their 6-month birthday. After stratification by current breast-feeding status and infant sex, SWS families were randomly selected to participate in a weighed intake study between September 2001 and March 2003. The dietary intakes of 50 infants assessed both by FFQ and WD are described below. Infants were weighed at both FFQ and diary collection.

The FFQ

The FFQ was developed to assess the diets of infants aged 6 months[12]. It includes meat, fish, vegetables, fruits, cereals and snack foods sub-divided into 16 food groups; 12 categories of commercial baby foods, sub-divided by brand; and six types of non-milk drinks. Human milk, baby formulas and other milk intakes, and age of introduction of solids, were recorded in separate sections.

The questionnaire was completed by a nurse using information supplied by the infant's main carer, during a structured interview lasting about 30 minutes. The daily non-human milk intake in the previous week was estimated from the average total volume of bottle-feeds consumed per day; for human milk, the usual feed length and number of feeds per day were recorded. The frequency of consumption and the amount of each food in the 34-item FFQ consumed over the last week were recorded. Prompt cards were used to show the foods included in each FFQ group to ensure consistent responses; portion size was described using household measures and with the aid of food models. Foods not listed in the FFQ, but consumed in the previous week, were recorded in an open section.

The WD

A 4-day WD was used as the method of establishing the relative validity of the FFQ. Calculations of inter-individual and intra-individual variation from energy intake data[13], for infants aged 6 months, demonstrated that four days of recording is sufficient to classify more than 75 % of infants into the correct quintile of intake at this age; and is consistent with the diary lengths chosen for recent dietary intake studies in young children[2,14–16]. Each family was provided with a diary and Soehnle scales accurate to 1 g. At a home visit, the infant's main carer was instructed in diary completion. Carers were contacted during diary completion to address any problems and the WD was checked at collection to resolve queries. All non-human milks, foods and drinks consumed by the infant on each of any four days in the next week were recorded by weight and cooking method. For breast-fed infants, the length of each feed was recorded. In a few instances, the carer estimated the amount of some foods. Additionally, the carer rated each day's intake on how 'typical' it was.

Dietary analysis

For the FFQ and WD, human milk intake was estimated using an algorithm based on length of suckling derived from published intake data[6,17]. Nutritional composition information for infant formulas and commercial baby foods was obtained from manufacturers and/or by calculation from ingredients; and for non-baby products was taken from *McCance & Widdowson's The Composition of Foods*, 5th edition and supplements[18]. Nutrient data for all foods, milks and other drinks in the FFQ and WD were completed for energy, macronutrients and 18 micronutrients. Nutrient intakes from dietary supplements were excluded.

Statistical methods

Spearman's rank correlation coefficients were used to summarise the association between the two assessments of each dietary variable. All nutrients were then adjusted for energy intake using the method of Willett[19] and the correlation coefficients recalculated. Bland–Altman plots[20] were produced to assess the levels of agreement between the methods. As the distributions of all nutrients were skewed, logarithmic transformations were used prior to the Bland–Altman analysis and the results are presented on a log scale. The Bland–Altman limits of agreement are expressed as symmetric percentages, which summarise the percentage differences between the two methods[21]. Regression analysis was used to explore whether there were specific factors that influenced the difference between energy intakes assessed by FFQ and WD.

Results

No statistically significant differences were found between the characteristics of the 50 mother–infant pairs involved in diary completion and those in the SWS cohort who provided FFQ information only (Table 1). The median interval between FFQ completion and the beginning of the WD was 7 d; 84 % of diaries were completed on four consecutive days, the remainder were finished within 8 d; one diary detailed consumption for 3 d only.

Comparison of FFQ with WD

There was close similarity between intakes measured by FFQ and WD, with reasonable to good correlation coefficients ranging from $r = 0{\cdot}39$ to $0{\cdot}86$ (Table 2). The FFQ typically gave higher median intake values than the WD, except for sodium. The correlation coefficients

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Table 1 Characteristics of mother–infant pairs who completed a 4-day weighed diary (WD) and the remainder of the cohort who completed a food frequency questionnaire (FFQ)

Characteristic	FFQ ($n=1595$)*	WD ($n=50$)	*P*
Maternal			
Age at child's birth (years), median (IQR)	30 (27, 33)	30 (28, 33)	0·36
Body mass index (kg/m^2), median (IQR)	24·3 (22·0, 27·7)	24·1 (22·4, 26·0)	0·71
Education, % (*n*)			
Up to CSE	12·9 (206)	8·0 (4)	0·75
O and/or A levels	57·9 (921)	60·0 (30)	
HND or degree	29·4 (464)	32·0 (16)	
Smokers, % (*n*)	27·2 (433)	26·0 (13)	0·86
Infant			
Birth weight (kg), median (IQR)	3·46 (3·15, 3·80)	3·50 (3·20, 3·76)	0·90
Weight at FFQ (kg), median (IQR)	7·93 (7·30, 8·54)	7·96 (7·42, 8·58)	0·79
Sex ratio (girls), % (*n*)	46·0 (732)	50·0 (25)	0·57
Still breast-fed, % (*n*)	29·7 (474)	28·0 (14)	0·79
Age at solid food introduction (weeks), median (IQR)	17·4 (15·0, 18·4)	17·4 (16·0, 18·4)	0·46
Birth order, % (*n*)			
1st	46·2 (736)	44·0 (22)	0·83
2nd/3rd	49·4 (788)	50·0 (25)	
4th or above	4·4 (70)	6·0 (3)	

IQR, interquartile range.
*Total number does not always sum to 1595 due to missing data.

Table 2 Energy and nutrient intakes estimated by the food frequency questionnaire (FFQ) and the 4-day weighed diary (WD), Spearman rank correlation coefficients (r), energy-adjusted correlation coefficients (r_a), and Bland–Altman statistics

	FFQ	WD			Bland–Altman	
Energy/nutrient	Median (IQR)	Median (IQR)	r*	r_a†	Mean difference, FFQ minus WD (%)	Limits of agreement‡ (%)
Energy (kJ)	3329 (2804, 3792)	2968 (2728, 3423)	0·41	n/a	6·2	−40, 52
Energy/kg body weight (kJ)	424 (366, 486)	370 (342, 423)	0·43	n/a	8·9	−37, 55
Protein (g)	20·6 (17·9, 24·3)	19·7 (17·4, 23·6)	0·51	0·71	0·6	−48, 49
Fat (g)	31·3 (28·4, 37·3)	31·3 (27·6, 34·7)	0·39	0·70	3·6	−47, 54
Carbohydrate (g)	106·0 (86·5, 118·5)	93·1 (81·1, 106·9)	0·51	0·66	9·2	−37, 55
Total sugars (g)	77·4 (65·7, 86·3)	69·4 (63·0, 81·1)	0·55	0·69	9·1	−36, 54
Sodium (mg)	248 (199, 305)	270 (193, 354)	0·60	0·56	−12·2	−87, 62
Potassium (mg)	1035 (871, 1205)	1014 (791, 1137)	0·56	0·70	4·5	−39, 48
Calcium (mg)	547 (462, 668)	543 (419, 726)	0·62	0·78	3·4	−58, 65
Magnesium (mg)	86·7 (67·4, 98·1)	78·7 (63·7, 92·7)	0·66	0·68	7·9	−38, 54
Phosphorus (mg)	422 (330, 534)	409 (318, 531)	0·66	0·77	−0·4	−56, 56
Iron (mg)	7·0 (4·9, 9·1)	6·9 (4·9, 8·7)	0·75	0·78	2·0	−59, 63
Zinc (mg)	5·2 (4·2, 5·9)	4·7 (3·8, 5·5)	0·69	0·83	7·4	−44, 59
Copper (mg)	0·46 (0·40, 0·51)	0·41 (0·36, 0·49)	0·47	0·55	5·1	−42, 52
Retinol (μg)	597 (490, 749)	531 (462, 623)	0·44	0·76	10·0	−49, 69
Vitamin D (μg)	9·3 (5·9, 12·3)	8·3 (3·7, 10·0)	0·86	0·83	9·7	−71, 90
Vitamin E (mg)	6·0 (4·6, 8·4)	5·3 (4·5, 6·9)	0·76	0·83	11·3	−44, 67
Thiamin (mg)	0·65 (0·49, 0·89)	0·60 (0·46, 0·86)	0·85	0·89	9·3	−44, 63
Riboflavin (mg)	1·2 (0·6, 1·3)	1·2 (0·7, 1·4)	0·78	0·87	−2·6	−57, 52
Niacin (mg)	8·1 (5·4, 11·3)	8·0 (5·3, 9·3)	0·86	0·88	7·3	−38, 53
Vitamin B_6 (mg)	0·60 (0·45, 0·79)	0·60 (0·48, 0·72)	0·81	0·84	3·2	−43, 50
Folic acid (μg)	112 (88, 122)	100 (78, 121)	0·68	0·65	9·1	−42, 60
Vitamin B_{12} (μg)	1·8 (1·3, 2·1)	1·8 (1·4, 2·2)	0·75	0·74	−18·9	−135, 97
Vitamin C (mg)	86 (70, 109)	78 (68, 90)	0·67	0·67	11·2	−45, 67

n/a, not applicable.
*All significantly different from zero, $P<0·001$, except energy ($P=0·003$), fat ($P=0·005$) and retinol ($P=0·0013$).
†All significantly different from zero, $P<0·001$.
‡Limits are expressed as symmetric percentage differences between FFQ and WD values.

were strengthened by adjustment for energy intake, range $r_a=0·55$ to 0·89. In the exploration of differences in absolute intakes of energy and nutrients between the FFQ and WD by Bland–Altman plots, most mean differences were positive and all within the range of −12·5% to +12·5% except for vitamin B_{12}, −18·9% (Table 2).

Exploration of differences in intakes

The between-methods Spearman rank correlation coefficient for energy intake was lower ($r=0·28$) for the 28% of infants who were still breast-fed at FFQ completion than for infants who were not receiving human milk ($r=0·48$), a possible consequence of the imprecision of

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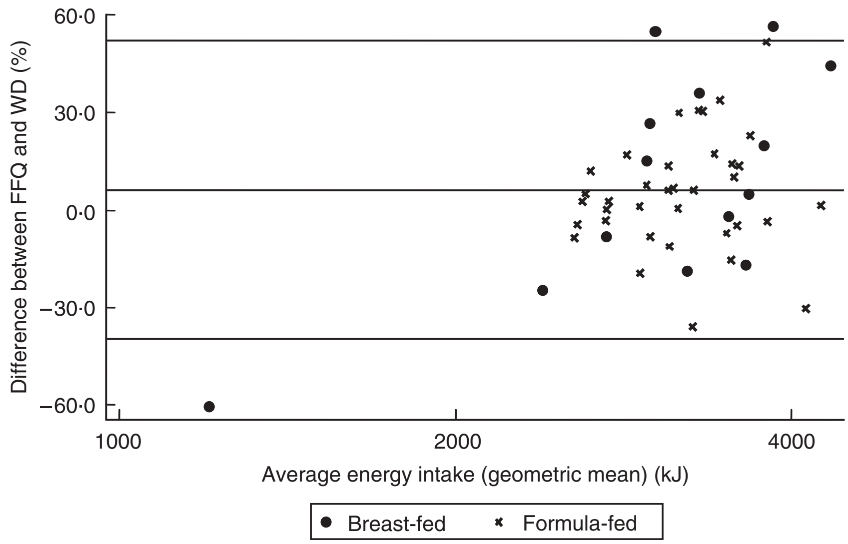

Fig. 1 Bland–Altman plot assessing the agreement for energy intakes obtained with the food frequency questionnaire (FFQ) and the 4-day weighed diary (WD), differentiated by milk feeding. Filled circles represent infants still breast-fed at FFQ completion; crosses represent formula-fed infants

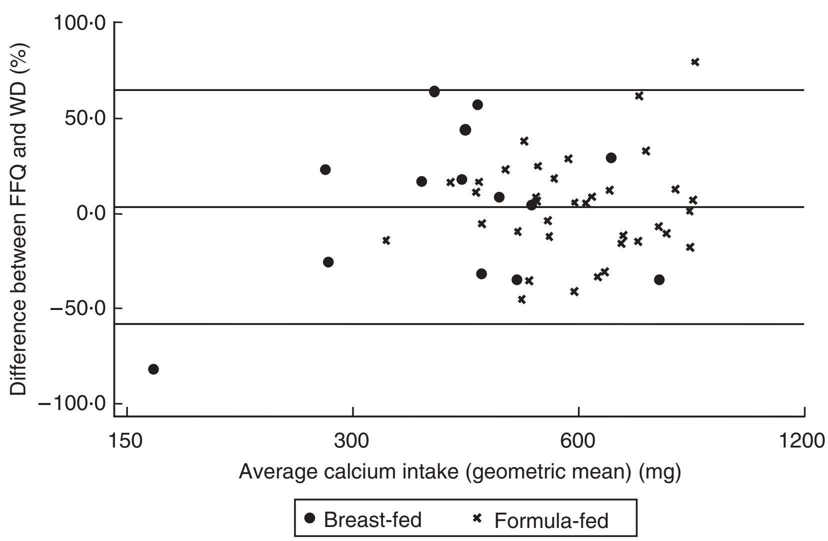

Fig. 2 Bland–Altman plot assessing the agreement for calcium intakes obtained with the food frequency questionnaire (FFQ) and the 4-day weighed diary (WD), differentiated by milk feeding. Filled circles represent infants still breast-fed at FFQ completion; crosses represent formula-fed infants

human milk intake estimation. Additionally, in the Bland–Altman plots (Figs 1 and 2) the distributions of points for the 'breast-fed' infants were more widely spread than those for the 'formula-fed' infants. However, univariate regression analysis of the differences in energy intakes from the two assessments showed no association with whether the infant was still breast-fed at 6 months ($P = 0{\cdot}24$).

Univariate regression analysis was used to investigate factors that might influence the difference in energy intakes determined by the FFQ and WD. We considered characteristics of the mother (age, body mass index and educational level) and the infant (weight, gender, age solid foods were introduced, existence of non-typical days of diary recording, the number of days between FFQ and WD recording). No predictors of energy difference were found.

Discussion

A comparison of intakes from the FFQ and WD showed reasonable agreement. This indicates that the interviewer-administered FFQ is a useful tool for estimating energy

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and nutrient intakes in infants about 6 months old. While there were differences in intakes between methods, and the agreement tended to be less good for breast-fed than formula-fed infants, the FFQ provided an estimate of intakes that would be useful in surveys where it is not feasible or appropriate to employ weighed diaries. Specifically, the Spearman rank correlation coefficients, which compared the FFQ's ability to rank an individual's intake of energy and nutrients with that of the WD, indicated good agreement between FFQ and WD values. Adjusting nutrient intakes for energy intake, a measure of nutrient density, strengthened the majority of coefficients (r_a), demonstrating an increase in agreement between methods. This improvement may arise because energy adjustment may partially correct for measurement error[22].

Comparison with other studies

Our correlation coefficients compared favourably with other FFQ validation studies for young children. Reported correlation coefficients for energy and nutrients were 0·18–0·72 at 1 year, and 0·26–0·63 for 1- to 5-year-olds[23,24]; and in a study of 6-month-old infants, comparing nutrient intakes from beverages[25], published coefficients for calcium and vitamin D intakes of 0·49 and 0·80 were similar to ours of 0·62 and 0·86, respectively.

A comparison of median values of energy intake per kilogram of body weight from the FFQ (424 kJ) and WD (370 kJ) with those from the dietary reference values (DRV) for formula-fed infants in the UK (400 kJ)[26] and energy requirements per kilogram for all infants determined from DLW studies (339 kJ)[27] showed that the FFQ energy intake was 6 % and 25 % higher than the DRV and DLW values, respectively, and the WD energy intake was 7·5 % lower and 9·1 % higher than the DRV and DLW values, respectively. Thus, both the FFQ and the WD produced median energy intakes per kilogram that are comparable with standard values.

Strengths and weaknesses

The ability of the FFQ to rank intakes of energy and all nutrients accurately is enhanced by the quality and detail of the information collected and by its short period of recall (1 week), which allows capture of the diet during a period of dietary flux. This FFQ records both the amount consumed and the frequency of consumption of all foods and drinks, and information about brands and types of baby foods and milks used. In addition, trained personnel, able to code baby foods and milks, and demonstrate the 'amount consumed' aids, administered the questionnaire.

Another strength of this study is that the sub-sample comprised a stratified random sample of infants and their families who were representative of the SWS population, which, in turn, is comparable to the UK population[11]. However, there was a higher rate of breast-feeding at 6 months (28 %) in our sub-sample and among SWS infants generally (29 %) than in the UK (21 %)[28]. In addition, possible discrepancies between methods, which cannot be quantified, arise from inbuilt differences between the FFQ and WD: in methodology (retrospective vs. prospective), in time scale (7 vs. 4 d), and from the WD commencing after the FFQ had been completed.

As in other UK infant dietary studies[6,29], we used an algorithm to estimate human milk intake, which relates length of suckling to intake, for the FFQ and WD. Although regression analysis showed that human milk consumption did not have any consistent effect on difference in energy intakes, the wider distribution of points associated with intakes of breast-fed infants in the Bland–Altman plots for energy and calcium – compared with those who were not breast-fed at 6 months – indicates that the intakes of breast-fed infants were less precisely characterised than those of formula-fed infants.

In common with other studies[23,30], our FFQ tended to produce higher values for actual intakes of energy and nutrients when compared with the WD. The only nutrient with a higher median intake from the WD than from the FFQ was sodium. This results from the gradual change in infant diet over time; compared with the previously collected FFQ, during WD completion more babies were consuming small amounts of non-baby foods, such as cheese and cow's milk, which have higher sodium contents than human milk, formula milks and baby foods. Overall, agreement between actual intakes from the two methods was reasonable, the exception being for vitamin B_{12}; again, the small changes in infant diet, especially the variation in breast-feeding patterns over time, reduced the agreement between methods.

Conclusion

The comparison of results from the FFQ with those obtained from the WD confirms that our FFQ is a useful tool for assessing the dietary intakes of large groups of infants about 6 months old. While it tended to produce higher median intakes for energy and most nutrients, the magnitudes of the differences were small and the ranking of the infants in terms of intakes was comparable. This interviewer-administered FFQ enables the assessment of energy and nutrient intakes in 6-month-old infants.

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S.E.B. devised the FFQ; H.M.I., K.M.G., C.M.L., S.M.R. and L.D.M. planned the diary study; L.D.M. carried out the fieldwork and, with S.M.R., was responsible for the nutritional analysis; J.P. and H.M.I. performed the statistical analysis. L.D.M. wrote the first draft of the manuscript with contributions from all individual authors.

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