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A new FFQ designed to measure the intake of fatty acids and antioxidants in children

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Abstract

Objective: The present paper describes the systematic development of an FFQ to assess the intake of fatty acids and antioxidants in school-aged children. In addition, a validation study applying 24 h dietary recalls was performed.

Design: Using the variance-based Max_r method, a list of eighty-two foods was compiled from data obtained by 3 d weighed dietary records. The foods were used to design an FFQ, the comprehensibility of which was evaluated in a feasibility study. In addition, the FFQ was validated in a subset of 101 children from the German Infant Nutritional Intervention Study (GINI PLUS) against one 24 h dietary recall.

Results: The feasibility study attested a good acceptance of the FFQ. Mean intake of foods compared well between the FFQ and the 24 h dietary recall, although intake data generated from the FFQ tended to be higher. This difference became less apparent at the nutrient level, although the estimated average consumption of arachidonic acid and EPA using the FFQ still exceeded values recorded with the 24 h recall method by 45 % and 29 %, respectively.

Conclusions: On the basis of the systematic selection process of the food list, the established practicability of the FFQ and the overall plausibility of the results, the use of this FFQ is justified in future epidemiological studies.

Keywords
Food-frequency questionnaire
Development
Validation
Dietary recalls

Epidemiological associations between food intake and the incidence of allergic diseases in childhood represent an increasingly prominent focus. The nutrients most commonly proposed to contribute to the aetiology of atopic diseases are fatty acids and antioxidants. While protective effects of fatty acid composition and intake of antioxidants have been reported[1–4], some studies do not confirm these findings[5]. Clarification on the implication of food intake during infancy and childhood on allergic diseases needs to be sought, and this relies on the application of accurate methods to assess food intake.

Methods routinely used to assess dietary intake in children are prone to reporting errors[6] but there is paucity of validation studies in children advocating one particular method over another. Self-administered FFQ provide a practical means for dietary assessment in large population studies as they are associated with low participant burden and ease in data processing relative to other assessment methods. When specific nutrients are the main study focus, the development of the food list and frequency categories demands a careful selection process. It is advantageous if the questionnaire is concise, yet data collected on the nutrients of interest are required at a high level of validity. In Germany, there is currently no known FFQ specifically designed to assess the intake of fatty acids and antioxidants in school-aged children.

The aim of the present study was therefore to develop such a tool while evaluating its validity and feasibility for use in assessing fatty acid and antioxidant intakes in 10-year-old children.

Subjects and methods

Study population

The GINI PLUS Study (German Infant Study on the influence of Nutrition Intervention PLUS environmental and genetic influences on allergy development) was

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designed to study the development of allergic diseases and its determinants. Between September 1995 and June 1998, a total of 5991 term newborns from maternal units across Munich (Bavaria) and Wesel (North-Rhine-Westfalia) were enrolled in this prospective birth cohort study. The aims of the study, the study population and the study design are described in detail elsewhere[7,8]. Within the 10-year follow-up of the study, the FFQ described below was sent out to all parents of children who had participated in either the 2-year or the 6-year follow-up of the study and who had indicated a willingness to participate in the dietary assessment. The FFQ was provided subsequent to the main questionnaire and the medical examinations during a time window of approximately 3 months (September–November 2007). At the time of manuscript preparation, the 10-year follow-up of the GINI PLUS cohort was still ongoing.

Development of the FFQ

The goal of the current project was to develop an FFQ designed to assess the intakes of energy, total fat, linoleic acid, PUFA, vitamin A, β-carotene, vitamin E and vitamin C in 10-year-old children. To that end we used food intake data (3 d weighed food records) from children aged 9–11 years to identify relevant food items in the diet of these children. These food intake data were obtained from the DONALD (Dortmund Nutritional and Anthropometric Longitudinally Designed) Study[9,10]. Weighed dietary records from 547 children were available, with 3071 single food items. All of these foods were manually grouped together based on their energy and nutrient content in a straightforward manner, yielding 193 main food groups.

A subset of foods contributing most to between-person variation was identified using the program Max_r (maximizing Pearson correlation coefficient r) version 3·0 (Bethesda, MD, USA) developed by Mark *et al.*[11]. The Max_r procedure is designed to choose the subset, k, of foods which maximises the Pearson correlation, r, of the nutrient intake based on k foods with the true nutrient intake based on all foods in the database ($T \gg k$). A cumulative Pearson correlation coefficient of $r = 0·9$ was the defined cut-off point for the inclusion of foods into the list. Using Max_r, a subset of food items was identified for each nutrient of interest. Those subsets were combined into one list, yielding eighty-eight foods. Following minor modifications, eighty-two foods were finally included in the FFQ. Figure 1 displays this procedure.

For a number of foods containing high amounts of fats, such as butter, margarine, sausages and dairy products, the accuracy of information was enhanced by including additional questions on the fat content. In addition, subjects were asked to state whether they would generally consume vegetables in a raw or cooked form and what type of salad dressing they usually consume.

The reference period of the FFQ was the previous year. Nine different frequency categories were used to assess

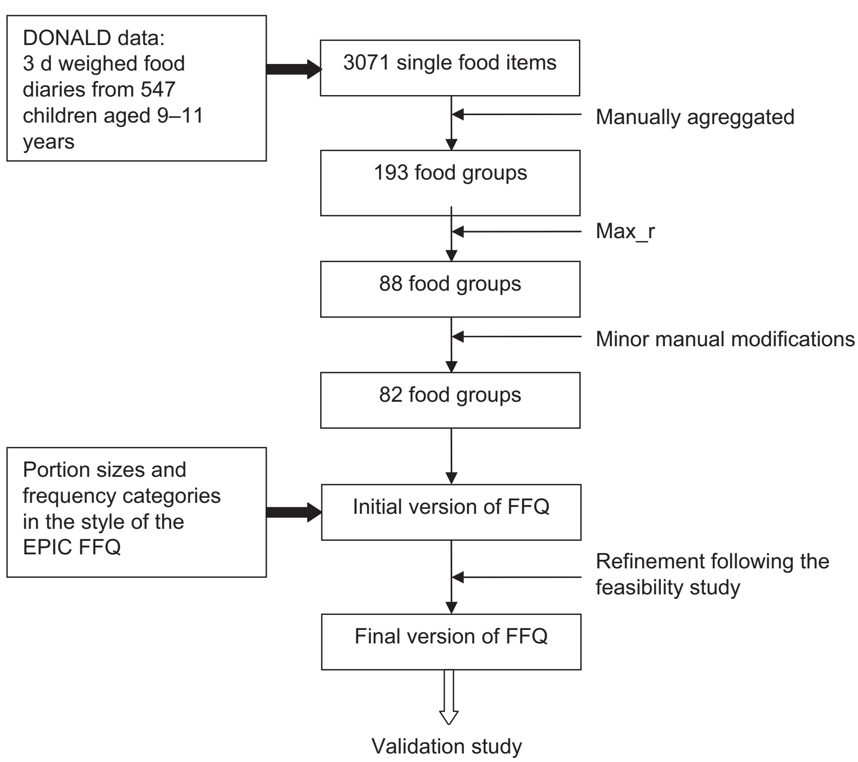

Fig. 1 Flow diagram showing the development of the FFQ (DONALD, Dortmund Nutritional and Anthropometric Longitudinally Designed Study; EPIC, European Prospective Investigation into Cancer and Nutrition)

the consumption frequency of the food items, ranging from 'never' and 'once a month' to 'two to three times a day' and 'four times a day or more'. To enable an estimation of quantities, common portion sizes were given for each food item (e.g. one teaspoon, one tablespoon, one piece, one glass). For foods which are difficult to describe in common household measures (e.g. cheese, meat products, main dishes, salads, desserts and snacks), coloured photographs from the EPIC (European Prospective Investigation into Cancer and Nutrition) study were included[12]. Portion size information for main dishes was presented by showing three food items of different sizes in one picture. Following the EPIC picture presentations, only one picture of a medium size portion was displayed for cheese, meat products, breakfast cereals, spinach and green salad. To further increase the accuracy of portion size estimations for these food items and foods without picture presentation, participants were asked to select whether the marked frequency category refers to 'a quarter of', 'half of', 'all of', 'twice' or 'three times' the given portion size.

Feasibility study

In the feasibility study, comprehensibility and applicability of the initial version of the FFQ were evaluated.

An arbitrarily selected sample of eighty-two children aged 9 to 11 years and their parents from the local community were approached to participate in this study. In total thirty participants completed the FFQ and the accompanying questionnaire on the evaluation of its feasibility. The volunteers were asked to answer questions on the general comprehensibility of the FFQ, the adequacy of portion sizes, and the possibility to accurately derive the amounts of food actually consumed from the combination of portion sizes and frequency categories.

The main outcome of this pilot research showed that the FFQ at this initial stage was judged to have very good or good overall comprehensibility (by 94 % of participants) and that the chosen portion sizes were adequate (76 % of participants), although improved explanation was desired for calculating portion sizes (by 43 % of participants). All questions in the FFQ were further ranked according to how easy or difficult it was to provide answers. Overall, 76 % of the participants considered it not difficult or not difficult at all to fill in the FFQ. On average, subjects had to spend 20–30 min to fill in the whole FFQ.

Following the outcome of this pilot study several modifications were made to the FFQ, including changes in the graphical design, the inclusion of further explanations in the introduction section of the FFQ, the provision of an example on how to appropriately calculate intake values for seasonal foods, and small changes to provide further clarification on specific questions.

The revised version of the FFQ was used in the GINI PLUS study.

Analysis of the FFQ

For all food items, the different combinations of frequency categories and portion sizes were transferred into average consumption in grams per day. Where food portions referred to common household measures rather than photographs, a German list of portion sizes[13] was used for transformation into grams.

On a number of occasions, especially when several similar foods were combined to one food group, portion sizes could not be directly assigned to one FFQ item. This situation arose, for example, for fruits, as the serving size for fruits is very much dependent on the type of fruit consumed. Furthermore, in order to achieve a more valid estimate of the true consumption habits, rather than using the mean of all portion sizes, we decided to use a weighed approach. To that end, more frequently consumed foods (such as bananas) were considered more than foods which are rarely consumed (such as pineapple). The exact quantitative basis for the determination of the respective weights representing the common consumption frequencies was provided by the aforementioned data from the DONALD Study. The same weights were applied for the calculation of energy and nutrient contents of food groups, using the German Food Code and Nutrient Database (Bundeslebensmittelschlüssel, BLS) version II.3.1[14] as the data source for the individual food items.

A frequently observed problem in dietary assessment using FFQ is an overestimation of food intake[15]. The extent to which this problem occurred with the present FFQ was estimated using summary questions. Towards the end of the FFQ, participants were asked to report the average number of slices of bread and servings of fruits and vegetables they generally consumed per week.

Validation study

Subjects

For the validation study, a random sample of subjects from the GINI PLUS Study, from whom we had obtained a completed FFQ through September 2007 (time of starting the validation study), was identified to conduct an additional 24 h dietary recall by telephone interview. This sample was chosen on the basis of the last digit of the consecutively assigned study number being 3, 7 or 9, and included only those children who were recruited in 1996 in the Munich area (*n* 160). Finally, a total of 101 children participated in the validation study. The study profile is shown in Fig. 2.

24 h dietary recall

In the presence of one parent, the child completed a telephone dietary recall interview within one to three weeks after returning the FFQ. Unannounced recalls were carried out over the telephone by a nutritionist on all days except Sundays and Mondays, i.e. recalls exclusively referred to

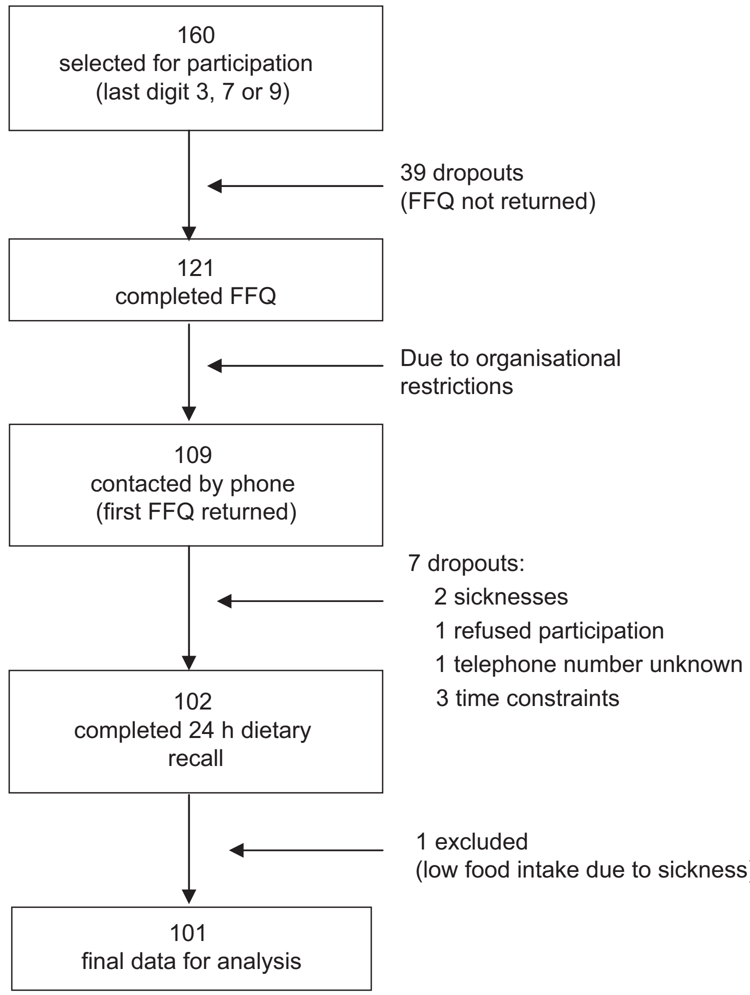

Fig. 2 Recruitment of participants for the validation study (conducted from September to November 2007)

weekdays. The interviewees were asked to recall all foods and beverages consumed the previous day.

While no specific software was used, the standardised structure of the EPIC-SOFT computerised 24 h diet recall interview was followed closely[16,17]. For completeness of information, open-ended questioning techniques and neutral probing methods were used as applied in the INTERMAP study[18]. When foods were not consumed in household measures, subjects referred to a picture book comprising coloured photographs of foods in different portion sizes. The book, provided by the Bavarian Nutrition Survey[19], had been sent out in advance to facilitate the estimation of food quantities. Fifty per cent of the interviews were tape-recorded with interviewee consent for later quality checks.

Household measures or standard units of foods were converted into grams using a list of portion sizes[13]. The 24 h recalls were coded using the German Food Code and Nutrient Database BLS version II.3.1[14] for energy and nutrient intake calculations.

Each food item identified during the interview was assigned to one of the eighty-two groups of the FFQ. Foods for which no concordance could be established were excluded from food group analysis. For analysis at nutrient level, data from the 24 h recalls and the FFQ were analysed separately.

Statistical analysis

Means, standard deviations, and the mean differences and mean standard deviations between the data from the FFQ and the 24 h recall were calculated for the intakes of energy, macronutrients, fatty acids and antioxidants. For macronutrients as well as for fatty acids, intake as a percentage of the total energy intake was calculated. To assess agreement between the data derived from the FFQ and the 24 h recall, the differences between the two methods were plotted against the mean of the two methods, as suggested by Bland and Altman[20]. All computations were performed using the SAS for Windows statistical software package version 9·1 (SAS Institute, Cary, NC, USA).

Results

The study population of the validation study consisted of 101 children (forty-nine girls and fifty-two boys) aged

Table 1 Food group estimates (in g/d) from the FFQ and the 24 h dietary recall (*n* 101): German Infant Nutritional Intervention Study (GINI PLUS), Germany, September–November 2007

	FFQ			24 h dietary recall				
Food group	Mean	SD	Median	Mean	SD	Median	$Mean_{diff}$*	SD_{diff}*
Bread	130	91	105	95	78	90	35	120
Butter	7	8	4	12	15	10	−5	14
Margarine	2	4	0	1	4	0	1	4
Cheese	28	39	16	22	35	0	8	43
Meat	51	38	41	53	78	0	−4	82
Meat products	50	44	43	27	63	0	23	73
Breakfast cereals	44	54	28	20	27	0	24	51
Dairy products	308	241	260	223	191	190	85	241
Eggs	10	8	8	9	25	0	0·3	25
Potatoes	45	32	33	25	57	0	19	61
Pasta	43	22	38	54	91	0	−11	92
Rice	16	14	13	18	54	0	−3	55
Pizza	30	20	26	40	94	0	−9	95
Fish	17	12	16	10	37	0	7	37
Vegetables and salad	122	122	86	52	74	20	70	134
Fruit	153	145	112	85	104	60	69	155
Cake and pastry	19	15	15	24	41	0	−5	42
Desserts	9	10	8	15	51	0	−6	52
Chocolate	17	23	10	8	14	0	8	24
Ice cream and fruit gums	10	11	6	4	12	0	6	14
Snacks	3	6	2	3	14	0	−0·4	15
Nuts and seeds	2	3	1	2	11	0	−0·1	11
Vegetable oil	5	6	3	14	97	0	0·9	11
Fruit/vegetable juices	547	619	428	267	262	225	277	560
Soft drinks	80	146	28	89	240	0	−9	262
Tea	93	166	21	152	232	0	−61	213

*Mean difference and standard deviation of dietary intake obtained from the FFQ minus dietary intake obtained from the 24 h dietary recall.

9–11 years. Their average body weight was 40·2 (SD 7·6) kg and their average height was 151·1 (SD 7·4) cm.

Table 1 presents the mean and median food group intakes derived from the FFQ and the 24 h recall, as well as the difference and standard deviation of the difference between these assessments. Compared with values derived from the 24 h dietary recall, food group intakes measured with the FFQ were higher for most foods, an effect which became particularly apparent for the intake of bread, dairy products, vegetables and salads, fruits and juices from vegetables and fruits. Reported consumption measured with the FFQ was 42 % lower for butter, 40 % lower for desserts and 39 % lower for tea than values established from the 24 h dietary recall. For the majority of foods, the median value derived from the 24 h recall was zero owing to the fact that most children did not consume this food on the day the 24 h recall was conducted.

Stratification by sex showed that food group intakes (data not shown due to limited number of observations) measured with the FFQ were either similar between both sexes or higher in boys than in girls, except for some food groups with a higher reported consumption in girls (e.g. fruit, tea). Sex-specific differences in intakes derived from the 24 h recall were similar although not equal.

The higher intake seen with the FFQ at food level was not reflected to the same extent in the data at nutrient level, although carbohydrates, arachidonic acid and EPA were still higher by 54 g, 56 mg and 10 mg, respectively, when assessed with the FFQ (Table 2). Boys showed higher energy intakes in both FFQ and 24 h recall than girls. This was reflected in higher absolute but not relative intakes for most nutrients (data not shown).

Cross-classification of nutrient intake variables derived from the FFQ and 24 h dietary recall into tertiles of intake is shown in Table 3. Classification into the same tertile ranged from 31·7 % for vitamin E (tocopherols plus tocotrienols) to 45·5 % for total fat intake, and extreme misclassification occurred in between 8·9 % for SFA and 23·8 % for MUFA.

The Bland–Altman plots, which show differences between the two methods for each subject, are presented in Fig. 3 and exemplified by energy, fat, SFA, linoleic acid, arachidonic acid and vitamin E intake. The plots showed a heterogeneous picture for most food groups and nutrients. However, the plotted points were predominantly within the 95 % limits of agreement for each food group and each nutrient, with a few exceptions where more points were above or below the upper or the lower limit, respectively.

Compared with the 24 h recall, the FFQ overestimated by more than 10 % the intake of bread (+35 g), margarine (+1 g), cheese (+6 g), meat products (+23 g), breakfast cereals (+24 g), dairy products (+85 g), potatoes (+20 g), fish (+7 g), vegetables and salad (+70 g), fruit (+68 g), chocolate (+9 g), ice cream and fruit gums (+6 g) and fruit/vegetable juice (+280 g), while the intake of the following food groups was underestimated by more than 10 %: butter (−5 g), pasta (−11 g), rice (−2 g), pizza

Table 2 Nutrient intake estimates from the FFQ and the 24 h dietary recall (*n* 101): German Infant Nutritional Intervention Study (GINI PLUS), Germany, September–November 2007

	FFQ			24 h dietary recall				
Dietary intake variable	Mean	SD	Median	Mean	SD	Median	$\text{Mean}_{\text{diff}}$*	SD_{diff}*
Energy (kJ/d)	8554	2847	8148	7926	2483	7436	624	3119
Protein (g/d)	71	26	65	61	21	60	10	28
Protein (% of energy)	14	2	14	13	3	13	1	4
Fat (g/d)	68	26	64	75	35	63	−6	38
Fat (% of energy)	30	6	30	35	9	35	−5	9
Carbohydrates (g/d)	280	103	263	225	74	218	54	111
Carbohydrates (% of energy)	55	6	55	48	10	48	6	10
SFA (g/d)	29	11	27	30	15	25	−1	16
SFA (% of energy)	13	3	12	14	6	14	−1	5
MUFA (g/d)	24	10	23	26	14	23	−2	15
MUFA (% of energy)	11	3	11	12	4	12	−1	4
LA (*n*-6) (g/d)	9	4	8	8	5	7	1	6
LA (*n*-6) (% of energy)	4	1	4	4	2	3	0	2
AA (*n*-6) (mg/d)	171	95	152	115	106	83	56	143
AA (*n*-6) (% of energy)	0·08	0·03	0·08	0·06	0·05	0·04	0·01	0·1
EPA (*n*-3) (mg/d)	41	34	34	31	100	6	10	98
EPA (*n*-3) (% of energy)	0·02	0·02	0·02	0·02	0·05	0·00	0	0·1
DHA (*n*-3) (mg/d)	83	57	73	93	238	29	−9	227
DHA (*n*-3) (% of energy)	0·04	0·03	0·04	0·04	0·10	0·01	0	0·1
Vitamin A, RE (μg/d)	1269	990	1000	1023	1014	703	246	1328
Vitamin A, retinol (μg/d)	528	558	380	415	279	317	113	633
β-Carotene (μg/d)	4118	3789	2646	3358	5314	1260	760	6340
Vitamin E, tocopherols + tocotrienols (μg/d)	9991	4657	9551	8600	3983	7489	1390	5874
α-Tocopherol (μg/d)	8954	4428	8377	7721	3796	6784	1234	5580
Ascorbic acid (mg/d)	108	85	91	95	88	71	13	119

LA, linoleic acid; AA, arachidonic acid; RE, retinol equivalents.
*Mean difference and standard deviation of dietary intake obtained from the FFQ minus dietary intake obtained from the 24 h dietary recall.

Table 3 Agreement between nutrient intake data obtained by means of the FFQ and 24 h dietary recall based on classification into tertiles (*n* 101): German Infant Nutritional Intervention Study (GINI PLUS), Germany, September–November 2007

	Same tertile*		Adjacent tertile†		Opposite tertile‡	
Dietary intake variable	*n*/*N*	%	*n*/*N*	%	*n*/*N*	%
Energy (kJ/d)	43/101	42·6	44/101	43·6	14/101	13·9
Protein (g/d)	42/101	41·6	42/101	41·6	17/101	16·8
Protein (% of energy)	40/101	39·6	44/101	43·6	17/101	16·8
Fat (g/d)	46/101	45·5	44/101	43·6	11/101	10·9
Fat (% of energy)	44/101	43·6	40/101	39·6	17/101	16·8
Carbohydrates (g/d)	44/101	43·6	42/101	41·6	15/101	14·9
Carbohydrates (% of energy)	44/101	43·6	38/101	37·6	19/101	18·8
SFA (g/d)	46/101	45·5	46/101	45·5	9/101	8·9
SFA (% of energy)	38/101	37·6	48/101	47·5	15/101	14·9
MUFA (g/d)	43/101	42·6	48/101	47·5	10/101	9·9
MUFA (% of energy)	41/101	40·6	36/101	35·6	24/101	23·8
LA (*n*-6) (g/d)	37/101	36·6	50/101	49·5	14/101	13·9
LA (*n*-6) (% of energy)	40/101	39·6	42/101	41·6	19/101	18·8
AA (*n*-6) (mg/d)	35/101	34·7	46/101	45·5	20/101	19·8
AA (*n*-6) (% of energy)	34/101	33·7	44/101	43·6	23/101	22·8
EPA (*n*-3) (mg/d)	37/101	36·6	44/101	43·6	20/101	19·8
EPA (*n*-3) (% of energy)	35/101	34·7	50/101	49·5	16/101	15·8
DHA (*n*-3) (mg/d)	38/101	37·6	44/101	43·6	19/101	18·8
DHA (*n*-3) (% of energy)	40/101	39·6	46/101	45·5	15/101	14·9
Vitamin A, RE (μg/d)	43/101	42·6	42/101	41·6	16/101	15·8
Vitamin A, retinol (μg/d)	33/101	32·7	52/101	51·5	16/101	15·8
β-Carotene (μg/d)	36/101	35·6	52/101	51·5	13/101	12·9
Vitamin E, tocopherols + tocotrienols (μg/d)	32/101	31·7	52/101	51·5	17/101	16·8
α-Tocopherol (μg/d)	35/101	34·7	48/101	47·5	18/101	17·8
Ascorbic acid (mg/d)	42/101	41·6	48/101	47·5	11/101	10·9

LA, linoleic acid; AA, arachidonic acid; RE, retinol equivalents.
*The two methods categorised nutrient intake into the same tertile.
†The two methods categorised nutrient intake into adjacent tertiles (one method into the first (second) and the other into the second (third) tertile).
‡The two methods categorised nutrient intake into the opposite tertile (one method into the first and the other into the third tertile).

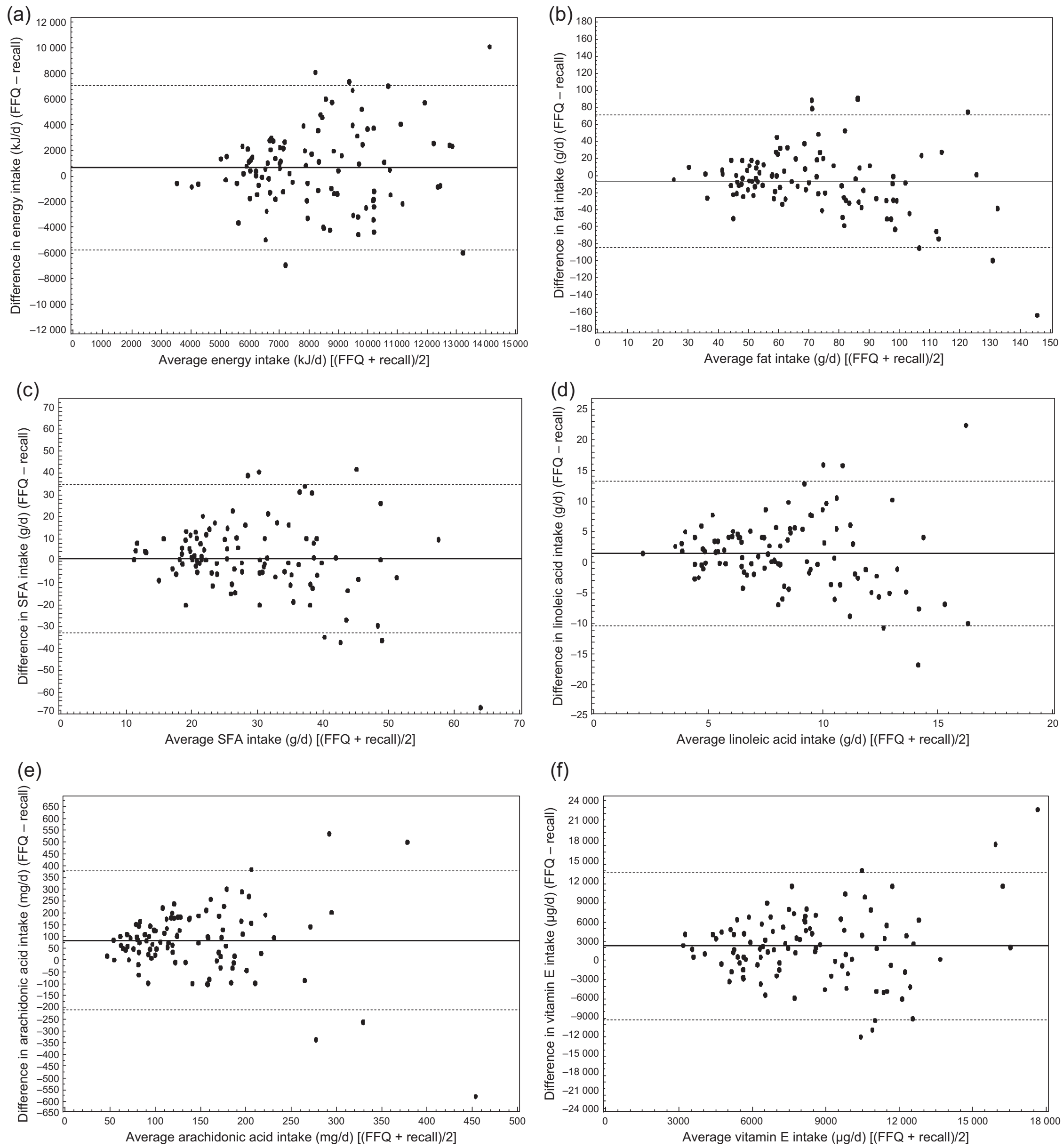

Fig. 3 Bland–Altman plots (difference *v.* mean) showing agreement between the FFQ and the 24 h recall for intake estimates of (a) energy, (b) fat, (c) SFA, (d) linoleic acid, (e) arachidonic acid and (f) vitamin E: German Infant Nutritional Intervention Study (GINI PLUS), Germany, September–November 2007

(−10 g), cake and pastry (−5 g), desserts (−6 g), vegetable oil (−9 g), soft drinks (−9 g) and tea (−59 g).

In general, the spread around the mean reflected systematic bias of intakes for some food groups and nutrients, but not for all. As mean intakes increased for pasta, pizza and cakes and pastry, differences between the data from the FFQ and the 24 h recall increased negatively. The opposite appeared to emerge for the intake of fruit and vegetable juices, as differences tended to increase with increasing intakes, showing systematically higher estimates with the FFQ (data not shown). At nutrient level, the distribution of the plots indicated that as mean intakes increased, differences between the two methods increased both negatively and positively.

The three summary questions on the total amount of bread, fruit and vegetables consumed on average every week were compared with data based on individual questions in the FFQ. The analysis of the summary questions yielded a daily consumption of 2·3 (SD 2·0) slices of bread, 1·4 (SD 1·0) portions of fruit and 0·7 (SD 0·4) portions of vegetables as compared with the results of the individual questions, showing values of 2·0 (SD 1·9) slices of bread, 1·1 (SD 1·0) portions of fruit and 0·9 (SD 0·7) portions of vegetables.

Discussion

The aim of the present study was to describe the development of a new FFQ to measure the intake of fatty acids and antioxidants in school-aged children. In addition, the validity of the FFQ was evaluated relative to one 24 h dietary recall carried out shortly after completion of the FFQ.

The principal aim when using an FFQ is to rank individuals according to their nutrient intake rather than the quantitative interpretation of values. In the cross-classification between the 24 h recall and the FFQ, about 40 % of participants were allocated into the same tertile and about 10–15 % into the adjacent tertile. If the classification was by chance, the expected values would have been 33 % and 22 %, respectively. According to Bland–Altman analyses, the FFQ overestimated intakes for several food groups compared with the single 24 h recall, particularly for rarely consumed foods. However, the FFQ did not show significant systematic bias for intakes of all food groups and nutrients but seemed to be affected by random error, with a certain proportion of subjects having different intakes between the FFQ and the 24 h recall. Thus, there is some, although weak, indication for an association between the two methods of dietary assessment. The main reason for this result is probably the inability of one single 24 h dietary recall to characterise usual food intake at the individual level.

We purposefully abstained from calculating correlation coefficients, a common procedure in validation studies. The rationale behind this is that, due to a high day-to-day variation in food intake, data derived from one single 24 h dietary recall cannot be expected to show good correlation with the FFQ. As mentioned before, we are well aware of the fact that the significance of the validation study has to be questioned on an individual level. It is, however, extremely difficult to measure the true validity of a dietary assessment method. While most validation studies do lend apparent assurance to the view of their method being well validated, method-specific behavioural changes in reported food intakes are inevitable. General difficulties associated with dietary assessment in children and adolescents, independent of the methods used[21], may aggravate this problem. Nevertheless, we believe the validation study provided sufficient data to judge the overall ability of the FFQ to collect meaningful data.

Overall, the ability of the FFQ to estimate food intake was good, although overestimation occurred in a few cases. This may reflect difficulties in translating the presented portion sizes into the truly consumed quantities. An overestimation of the intake of fruits, vegetables and fruit juices, as observed in our study and by others[22–24], seems to be a common problem of dietary assessment using the FFQ.

We believe our carefully developed FFQ has matured sufficiently to exhibit a number of strengths. First of all, it is the first tool developed to specifically investigate the intake of fatty acids and antioxidants in school-aged children and thereby bridges a gap in the pool of currently available FFQ. Second, the conducted feasibility study attests the applicability and comprehensibility of the FFQ. This is particularly important with the young age of the subject group in mind, as we endeavoured to get mutual impact from both the child and one parent to maximise accuracy in reporting. Third, both the data of the validation study and the comparison with the DONALD data support the notion that data collected with the FFQ are highly plausible. The outcome of this study attests the effectiveness of the FFQ to collect dietary data to draw inferences concerning the effect of nutrient intake on disease states.

As can be seen from the general literature on dietary validation studies[25], there are a number of limits to the determination of the validity of FFQ. In a validation study, the accuracy of the reference method is of foremost importance. The use of 24 h recalls in itself is associated with a number of problems, which need to be taken into account. One concern when using 24 h dietary recalls is that they rely on the participants' ability to remember every item of foods and beverages consumed the previous day. The use of 24 h recalls to validate an FFQ is thus somewhat troublesome. Due to the retrospective nature of the data collection process, in both methods error might result from memory problems and could be correlated. Moreover, in the light of both seasonal and day-to-day variations in food intake, one single 24 h dietary recall cannot give a complete picture of the usual food consumption and is thus a major limitation of the study. All 24 h dietary recalls were conducted one to four weeks after completion of the FFQ, thus referring to a different time period. Therefore, in any case, multiple dietary recalls should have been conducted to draw final conclusions on an individual level. Furthermore, the repeatability of the questionnaire should have been assessed, although any systematic error occurring can still not be disentangled.

Although still prone to random and systematic errors[26], the use of biochemical indicators of diet, such as doubly labelled water to assess energy expenditure and adipose tissue biomarkers of fatty acid intake, would be the only available method to fully resolve this matter. However, in particular fatty acids underlie a complex metabolism involving genetic, environmental and lifestyle factors influencing the nutrient level in the biological specimen. Previously, we have shown that fatty acid metabolism is under strong genetic control by the *FADS* gene cluster. We therefore refrained from using biochemical indicators as markers of validity for this specific reason.

To summarise, the careful selection process of the food list and approved comprehensibility of the questionnaire with respect to the target group of school-aged children might justify the use of this newly developed FFQ in epidemiological studies among children.

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References

1. Chatzi L, Torrent M, Romieu I, Garcia-Esteban R, Ferrer C, Vioque J, Kogevinas M & Sunyer J (2007) Diet, wheeze, and atopy in school children in Menorca, Spain. *Pediatr Allergy Immunol* **18**, 480–485.
2. Sausenthaler S, Koletzko B & Heinrich J (2006) Dietary fat intake and allergic diseases. *Curr Nutr Food Sci* **2**, 351–359.
3. Sausenthaler S, Koletzko S, Schaaf B, Lehmann I, Borte M, Herbarth O, von Berg A, Wichmann HE & Heinrich J (2007) Maternal diet during pregnancy in relation to eczema and allergic sensitization in the offspring at 2 y of age. *Am J Clin Nutr* **85**, 530–537.
4. Weiss ST (1997) Diet as a risk factor for asthma. *Ciba Found Symp* **206**, 244–257.
5. Almqvist C, Garden F, Xuan W, Mihrshahi S, Leeder SR, Oddy W, Webb K & Marks GB (2007) Omega-3 and omega-6 fatty acid exposure from early life does not affect atopy and asthma at age 5 years. *J Allergy Clin Immunol* **119**, 1438–1444.
6. Livingstone MB, Robson PJ & Wallace JM (2004) Issues in dietary intake assessment of children and adolescents. *Br J Nutr* **92**, Suppl. 2, S213–S222.
7. von Berg A, Koletzko S, Grubl A, Filipiak-Pittroff B, Wichmann HE, Bauer CP, Reinhardt D & Berdel D (2003) The effect of hydrolyzed cow's milk formula for allergy prevention in the first year of life: the German Infant Nutritional Intervention Study, a randomized double-blind trial. *J Allergy Clin Immunol* **111**, 533–540.
8. von Berg A, Koletzko S, Filipiak-Pittroff B, Laubereau B, Grubl A, Wichmann HE, Bauer CP, Reinhardt D & Berdel D (2007) Certain hydrolyzed formulas reduce the incidence of atopic dermatitis but not that of asthma: three-year results of the German Infant Nutritional Intervention Study. *J Allergy Clin Immunol* **119**, 718–725.
9. Kroke A, Manz F, Kersting M, Remer T, Sichert-Hellert W, Alexy U & Lentze MJ (2004) The DONALD Study. History, current status and future perspectives. *Eur J Nutr* **43**, 45–54.
10. Sichert-Hellert W, Kersting M & Manz F (2001) Changes in time-trends of nutrient intake from fortified and non-fortified food in German children and adolescents – 15 year results of the DONALD study. Dortmund Nutritional and Anthropometric Longitudinally Designed Study. *Eur J Nutr* **40**, 49–55.
11. Thomas DG & Mark SD (1997) Max_r: an optimal method for the selection of subsets of foods for the measurement of specific nutrient exposures. *Comput Methods Programs Biomed* **54**, 151–156.
12. Bohlscheid-Thomas S, Hoting I, Boeing H & Wahrendorf J (1997) Reproducibility and relative validity of food group intake in a food frequency questionnaire developed for the German part of the EPIC project. European Prospective Investigation into Cancer and Nutrition. *Int J Epidemiol* **26**, Suppl. 1, S59–S70.
13. AID (1991) *Auswertungs- und Informationsdienst für Ernährung, MONICA Mengenliste*. Bonn: Landwirtschaft und Forsten.
14. Hartmann BM, Bell S, Vásquez-Caiquedo AL, Götz A, Erhardt J & Brombach C (2005) *Der Bundeslebensmittelsschlüssel. German Nutrient Data Base*. Karlsruhe: Federal Research Centre for Nutrition and Food (BfEL).
15. Haraldsdottir J (1993) Minimizing error in the field: quality control in dietary surveys. *Eur J Clin Nutr* **47**, Suppl. 2, S19–S24.
16. Slimani N, Ferrari P, Ocke M *et al.* (2000) Standardization of the 24-hour diet recall calibration method used in the European Prospective Investigation into Cancer and Nutrition (EPIC): general concepts and preliminary results. *Eur J Clin Nutr* **54**, 900–917.
17. Voss S, Charrondiere UR, Slimani N, Kroke A, Riboli E, Wahrendorf J & Boeing H (1998) EPIC-SOFT: a European computer program for 24-hour dietary protocols. *Z Ernährungswiss* **37**, 227–232.
18. Robertson C, Conway R, Dennis B, Yarnell J, Stamler J & Elliott P (2005) Attainment of precision in implementation of 24 h dietary recalls: INTERMAP UK. *Br J Nutr* **94**, 588–594.
19. Schaller N, Seiler H, Himmerich S, Karg G, Gedrich K, Wolfram G & Linseisen J (2005) Estimated physical activity in Bavaria, Germany, and its implications for obesity risk: results from the BVS-II Study. *Int J Behav Nutr Phys Act* **2**, 6.
20. Bland JM & Altman DG (1986) Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* **1**, 307–310.
21. Livingstone MB & Black AE (2003) Markers of the validity of reported energy intake. *J Nutr* **133**, Suppl. 3, 895S–920S.
22. Deschamps V, Lauzon-Guillain B, Lafay L, Borys JM, Charles MA & Romon M (2009) Reproducibility and relative validity of a food-frequency questionnaire among French adults and adolescents. *Eur J Clin Nutr* **63**, 282–291.
23. Erkkola M, Karppinen M, Javanainen J, Rasanen L, Knip M & Virtanen SM (2001) Validity and reproducibility of a food frequency questionnaire for pregnant Finnish women. *Am J Epidemiol* **154**, 466–476.
24. Shu XO, Yang G, Jin F, Liu D, Kushi L, Wen W, Gao YT & Zheng W (2004) Validity and reproducibility of the food frequency questionnaire used in the Shanghai Women's Health Study. *Eur J Clin Nutr* **58**, 17–23.
25. Willett WC (1994) Future directions in the development of food-frequency questionnaires. *Am J Clin Nutr* **59**, 1 Suppl., 171S–174S.
26. Blanck HM, Bowman BA, Cooper GR, Myers GL & Miller DT (2003) Laboratory issues: use of nutritional biomarkers. *J Nutr* **133**, Suppl. 3, 888S–894S.