Reproducibility and validity of a food frequency questionnaire among fourth to seventh grade inner-city school children: implications of age and day-to-day variation in dietary intake

Alison E Field[1,*], Karen E Peterson[2,3], Steve L Gortmaker[5], Lilian Cheung[2], Helaine Rockett[1], Mary Kay Fox[6] and Graham A Colditz[1,4]

[1]Channing Laboratory, Department of Medicine, Brigham and Women's Hospital and Harvard Medical School, USA: [2]Department of Nutrition, Harvard School of Public Health, USA: [3]Department of Maternal and Child Health, Harvard School of Public Health, USA: [4]Department of Epidemiology, Harvard School of Public Health, USA: [5]Department of Health and Social Behavior, Harvard School of Public Health, USA: [6]Abt Associates, USA

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Abstract

Objective: To assess the reproducibility and validity of a semiquantitative food frequency questionnaire (FFQ) to classify children and adolescents in terms of daily servings of fruits and vegetables and intake of calories, protein, fat, carbohydrate, dietary fibre, vitamin C, phosphorous, calcium and iron.
Design: FFQs were collected in the autumn of 1993 and 1994. Four 24-hour diet recalls were collected during the same 1-year period and their mean was compared to the FFQ diet estimates.
Setting: Low income, inner-city state schools.
Subjects: A sample of 109 inner-city fourth to seventh grade students.
Results: The 1-year reproducibility of the FFQ, assessed with Spearman correlations, was lower among the fourth and fifth (range: $r = -0.26$ to 0.40) than the sixth and seventh grade students (range: $r = 0.18$–0.47). After adjusting for day-to-day variation in dietary intake, for most nutrients and foods the correlations between the FFQ and the 24-hour recalls remained greater among the junior high school students (fourth to fifth grade range: $r = 0.0$–0.42; sixth to seventh grade range: $r = 0.07$–0.76).
Conclusions: Inner-city sixth and seventh grade students demonstrated the ability to provide valid estimates of intake of calories, carbohydrate, calcium, phosphorous, iron and vitamin C over the past year. However, children in the fourth and fifth grades experienced some difficulty in completing the FFQ. Our results suggest that, before using this instrument with fourth and fifth grade children, investigators should assess whether study participants can think abstractly and are familiar with the concept of 'average intake'.

Keywords
Diet
Children
Diet assessment

Food frequency questionnaires have been used successfully to assess usual dietary intake among adults; however, questions have been raised about their suitability for children and adolescents[1]. To monitor childhood and adolescent dietary practices and to assess the effectiveness of dietary interventions to reduce fat and/or increase fruit and vegetable intake, relatively inexpensive and brief tools are needed. Although multiple 24-hour recalls collected on non-consecutive days are considered the best measure of usual dietary intake in some circumstances[2,3], they are labour intensive as they must be conducted by a trained interviewer. Thus, it is not economically feasible for large studies to rely on multiple 24-hour recalls to assess diet. Nor are food diaries a viable option because they impose a relatively large response burden and are expensive to transpose into nutrient data. Moreover, dietary behaviours often change when someone is keeping a food diary. Therefore, many studies assessing dietary behaviour of children and adolescents have relied on either a single 24-hour diet recall[4–7] or a FFQ[8,9].

The advantage of 24-hour recalls is that they employ probes (to ensure that foods are not forgotten) and checks (to verify questionable responses). In large samples a single 24-hour recall provides information on the mean, but not the distribution, of intake[2]. On the individual level, a single 24-hour recall may not reflect the average diet of the person; thus, a single recall is more appropriate for comparing group means than for assessing the diets of individuals. The greater the day-to-day variability in dietary intake, the less a single 24-hour recall will reflect the usual diet of an individual. FFQs that assess diet over a relatively long time frame

*Corresponding author: Email: Alison.Field@channing.harvard.edu

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(i.e. past month or past year) are designed to assess usual diet, the area of interest in many epidemiological studies. However, they require abstract thinking as well as basic reading and arithmetic skills, which may be too advanced for young children[10]. To assess the suitability of a FFQ for use in an inner-city population of children and preadolescents, we compared it with the mean of four 24-hour diet recalls collected over a 1-year period.

Methods

Instruments

Semiquantitative food frequency questionnaire

The self-administered semiquantitative FFQ assesses dietary intake over the past year[10,11]. The questionnaire was modified from the Willett Food Frequency Questionnaire to include additional snack foods, mixed dishes and other foods consumed commonly by children and adolescents, to have a more child-friendly layout (i.e. more 'white space' and graphics), and to limit the number of response categories to reflect possible true intake (i.e. top category for cereal intake was two times a day; whereas the top category for liver was one or more times per week). The questionnaire asked participants how often, on average, they consumed a specified portion size (e.g. half a grapefruit) of each of the 97 foods listed (such as mixed vegetables, macaroni cheese or peanut butter sandwiches). The database used for the nutrient analyses was a specifically designed program — harvardsffq.111094 (10 November 1994). The foundation of the database is the US Department of Agriculture Handbook No. 8 series (parts 1–21, including yearly updates)[12], with additional information from *McCance and Widdowson's The Composition of Foods* (4th and 5th editions)[13,14], journals and manufacturers. To estimate intake of micro- and macronutrients, the frequency of consumption was multiplied by the nutrient content and summed over all the food items[15]. Similarly, to assess servings per day of fruit and vegetables, the frequency of consumption of each of the 11 fruit and fruit juice items and the 14 vegetable items (not including fried potatoes) was summed. Response categories for fruit and vegetables ranged from less than once per month (counted as 0) to two or more per day (counted as 2). To minimize problems due to reading level, the questions were read aloud to the students in the fourth and fifth grades at baseline by teachers who received a 1-hour training session before each administration. The students in sixth and seventh grades at baseline completed the questionnaire on their own. All children completed the FFQ on their own, without reviewing the responses with an adult. To ensure confidentiality, questionnaires were collected by asking the students to place the questionnaires in an envelope with their ID number printed on the outside.

Twenty-four-hour recalls

The four 24-hour diet recalls were collected by trained interviewers using the University of Minnesota's Nutrient Data System (NDS)[16]. Interviewers completed a 3-day training session and at least 15 practice interviews before being certified to collect 24-hour diet recalls from students in the validation study. Interviews were conducted in private or semiprivate spaces, and household measures and graduated food models were used to elicit descriptions of portions consumed. Photographs and package labels were used as needed to clarify brand name, type and package size for convenience and processed food items. All dietary recalls were reviewed by staff nutritionists before being analysed. Consistent with consensus measures to monitor progress towards the Healthy People 2000 objective for fruit and vegetable intake[2] funded through the National Cancer Institute's (NCI) 5 a Day for Better Health campaign[17], we included all fruits and vegetables consumed in estimating total servings from the 24-hour recalls. Total servings of fruits and vegetables were calculated using the University of Minnesota algorithm[18] that the NCI uses in their 5 a Day for Better Health intervention[17]. The algorithm includes fruits and vegetables that are contained in mixed dishes, but does not count French fried potatoes, potato chips, corn chips, condiments (except salsa), pickles and pickled foods, fruit flavoured drinks, coconut and nuts, tofu, avocado or olives. The algorithm converts the sum of the gram weights of the specific fruits and vegetables consumed throughout the day into servings per day of each fruit and vegetable. Included in the summary measure of servings are the gram weights consumed as part of mixed dishes, side dishes and other minor sources. The four recalls were collected on non-consecutive days approximately 3 months apart. Due to the study design, we assessed subjects in the school. Therefore, recalls were not collected during the summer, nor on Saturdays. However, information on Sunday intake was collected by conducting 24-hour recalls on Mondays. The average nutrient intake and fruit and vegetable servings on the four 24-hour recalls were used as the gold standard against which the validity of the FFQ was assessed.

Sample

The Eat Well and Keep Moving (EWAKM) project is a school-based diet and activity intervention in an inner-city population. When the study was launched in 1993 the sample comprised 1918 fourth and fifth grade students and 1685 sixth to eighth grade students. The sample was 82% African American and 48% male. As

Table 1 Timing of diet recalls and FFQs used in the EWAKM project

FFQ 1	Autumn 1993
Recall 1	Late autumn 1993
Recall 2	Spring 1994
Recall 3	Late spring 1994
FFQ 2	Autumn 1994
Recall 4	Late autumn 1994

part of the project a substudy to assess the validity of the diet and activity measures was undertaken. In 1993, a random sample of 369 fourth to seventh grade students were invited to participate in the validation study that consisted of completing four 24-hour diet recalls on non-consecutive days over a 12-month period and then completing a second FFQ in 1994 (Table 1). The 1994 FFQ was given to all students in the EWAKM project, not simply those in the validation study. The repeat (i.e. second) FFQ was used for the primary validation analyses because it assessed diet over the same period (past year) that the four 24-hour recalls were collected. The first FFQ was used only to assess reproducibility and the stability of the validation results across administrations of the FFQ.

Sample for analysis

Due to movement within the community, as well as matriculation of many elementary school students (i.e. fifth grade) to a junior high school not in the project, there were substantial losses to follow-up. However, the diets of participants who completed all four 24-hour recalls were no different in terms of calories, protein, carbohydrate or percentage of calories from fat from those who completed less than four 24-hour recalls. Moreover, differences in the reliability correlations (Spearman correlations between 1993 and 1994 assessments) between the full and validation samples were lower in the validation sample of elementary school children, indicating that our estimates may be conservative. The primary reason for exclusion from the sample for analysis was missing FFQ or 24-hour recall data. Students who did not complete the second questionnaire ($n = 74$ in the fourth and fifth grades, $n = 97$ in the sixth and seventh grades), were missing one or more 24-hour recalls ($n = 28$ in the fourth and fifth grades, $n = 11$ in the sixth and seventh grades), or reported implausible intake on the FFQ (reported <500 or >5000 kcal day^{-1}; $n = 32$ in the fourth and fifth grades, $n = 18$ in the sixth and seventh grades) were excluded from the analysis. This left 51 fourth and fifth grade and 58 sixth and seventh grade students in the sample for analysis. The validation sample was 84% African American and 48% male.

Analysis

In the EWAKM project the FFQ is used to measure (i) average daily servings of fruits and vegetables; (ii) intake of calcium, iron, vitamin C, fibre, fat and saturated fat; and (iii) percentage of calories from fat. To estimate the degree of bias in the self-report measure, we compared the daily intake of the nutrients and foods from the four recalls with those from the FFQ by calculating the median of the differences between the two measures. To assess age effects, we stratified the sample by school level (i.e. elementary school = fourth and fifth grade vs. junior high school = sixth and seventh grade) and assessed reproducibility and validity within each stratum. Reproducibility was assessed with Spearman correlations between the 1993 and 1994 administrations of the FFQ. To investigate the stability of the validation estimates (i.e. the recall–FFQ comparisons) over time, Spearman correlations were computed between the average intake from the recalls and each of the FFQs (1993 and 1994 administrations). To ascertain whether participants were averaging their intake over the entire past year, Spearman correlations were computed between each of the four recalls and the second FFQ. A monotonic increasing trend in the magnitude of the correlations would be evidence that the participants were not averaging intake (i.e. most recent intake is biasing estimates of average intake). The variability of dietary intake was estimated with the ratio of within-person to between-person variation (using proc iml in SAS) and intraclass correlation coefficients. All subjects who completed the four recalls, regardless of whether they completed the 1994 FFQ, were used to estimate within- and between-person variation. Log transformation was used to normalize the nutrient data sufficiently to use Pearson correlations (crude and deattenuated for within-person error, using the method of Rosner and Willett[19]) to assess the ability of the FFQ to discriminate between subjects in terms of calories, protein, fat, carbohydrate, fibre, calcium, iron and phosphorous. The servings of fruits and vegetables (alone and together) were neither normally distributed nor truly continuous; therefore Spearman rank correlations between the rank on each of the recalls and the FFQ (crude and corrected for day-to-day variation) (B Rosner, personal communication) were used instead of Pearson correlations for the food-based validation. All analyses were conducted with SAS software[20].

Results

According to the average of four 24-hour recalls, the median percentage of calories from fat intake was relatively high (36.3% among fourth and fifth grade students, 34.6% among sixth and seventh grade students) and fruit and vegetable consumption was low (2.2 servings per day among fourth and fifth grade students, 2.3 servings per day among sixth and seventh grade students) among the 109 students in the

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Table 2 Median daily intake of nutrients and fruits and vegetables as assessed by the mean of four 24-hour recalls and the FFQ and the median difference between the two estimates among 109 inner-city fourth to seventh grade school students

	Fourth and fifth grades ($n=51$)			Sixth and seventh grades ($n=58$)		
	Recalls	FFQ	Difference	Recalls	FFQ	Difference
Calories (kcal)	1677	3136	1096	1992	2297	100.6
Protein (g)	60.9	100.9	30.3	67.5	78.6	–0.3
Carbohydrate (g)	223.5	397.2	128.7	251.0	291.6	24.1
Fat (g)	69.9	122.3	44.4	79.9	85.5	–1.1
% Calories from fat	36.3	36.7	1.2	34.6	34.9	0.2
Saturated fat (g)	25.1	43.5	13.9	27.7	30.0	–0.9
Fibre (g)	9.4	23.6	15.0	10.4	18.5	5.5
Calcium (mg)*	717	1160	500	762.4	834.0	33.1
Phosphorous (mg)*	952	1893	780	1171	1291	106.0
Iron (mg)*	10.3	21.1	7.7	12.6	15.3	1.1
Vitamin C (mg)*	81.1	184.2	93.8	96.0	135.2	34.9
Fruit juice (servings)	0.3	0.3	0.1	0.4	0.2	0.0
Fruit (servings)	0.2	1.1	1.00	0.0	0.7	0.5
Vegetables (servings)	1.3	1.3	–0.2	1.4	0.6	–0.4
Fruits and vegetables (servings)	2.2	3.7	1.8	2.2	1.9	0.3

* Including intake from supplements.

validation sample (Table 2). Among the 58 sixth and seventh grade students the estimates from the FFQ were similar to those from the gold standard. However, with the exception of the percentage of calories from fat, the FFQ overestimated dietary intake among the 51 fourth and fifth grade students. For some nutrients, such as fibre and vitamin C, the median difference between the measures was larger than the mean intake from the 24-hour recalls. For all the nutrients, except percentage of calories from fat, the bias was greater among the younger students.

The 1-year reproducibility Spearman correlations of the FFQ ranged from –0.26 to 0.40 among the fourth and fifth grade students and from 0.18 to 0.47 among the sixth and seventh grade students (Table 3). The reproducibility of calories, protein, total fat and saturated fat were similar in both age groups. In contrast, the correlations for calcium, phosphorous, iron, vitamin C and fibre were higher among the sixth and seventh grade students. We observed approximately 3–19 times more variability within than between subjects for all of the nutrients (Table 4). Overall there was more within-person to between-person variation in the younger age groups. Despite the considerable amounts of within-person variation, there was no evidence from the 24-hour recalls that intake of macro- or micronutrients was increasing or decreasing in a consistent pattern over the year (data not shown).

Nutrients

The crude Pearson correlations with the second FFQ were similar among both age groups, with several notable exceptions (Table 5). The younger children

Table 3 Spearman correlations between four 24-hour recalls and the 1993 and 1994 FFQs among 35 fourth and fifth grade and 34 sixth and seventh grade students who completed all four recalls and both FFQs*

	Fourth and fifth grades ($n=35$)			Sixth and seventh grades ($n=34$)		
	1993 FFQ vs. 1994 FFQ	Mean of recalls vs. 1993 FFQ	Mean of recalls vs. 1994 FFQ	1993 FFQ vs. 1994 FFQ	Mean of recalls vs. 1993 FFQ	Mean of recalls vs. 1994 FFQ
Calories (kcal)	0.24	–0.02	0.26	0.21	0.46	0.47
Protein (g)	0.25	–0.01	0.21	0.23	0.46	0.43
Carbohydrate (g)	0.30	0.09	0.22	0.21	0.35	0.47
Fat (g)	0.15	–0.18	0.24	0.18	0.38	0.44
% Calories from fat	0.14	0.15	0.18	0.27	0.09	0.06
Saturated fat (g)	0.15	–0.13	0.31	0.21	0.41	0.32
Dietary fibre (g)	0.06	0.01	0.06	0.19	0.35	0.45
Calcium (mg)†	0.03	–0.09	0.35	0.39	0.44	0.55
Phosphorous (mg)†	0.14	–0.10	0.24	0.27	0.45	0.47
Iron (mg)†	0.19	0.19	0.04	0.47	0.37	0.35
Vitamin C (mg)†	0.19	0.16	0.11	0.32	0.43	0.67
Fruit juice (servings)	0.40	–0.30	–0.04	0.18	0.14	0.40
Fruit (servings)	0.36	–0.16	–0.25	0.33	0.21	0.23
Vegetables (servings)	–0.26	–0.23	0.22	0.28	0.09	0.24
Fruits and vegetables (servings)	0.07	–0.05	0.10	0.29	0.11	0.27

* Subjects reporting <500 or >5000 calories on either FFQ were excluded from the analysis.
† Including intake from supplements.

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Table 4 The ratio of within-person to between-person variation from four 24-hour recalls among 51 fourth and fifth grade and 58 sixth and seventh grade students who completed all four recalls

	Fourth and fifth grades	Sixth and seventh grades
Calories (kcal)	2.80	2.60
Protein (g)	2.83	3.17
Carbohydrate (g)	3.17	3.75
Fat (g)	3.67	2.75
% Calories from fat	18.65	7.33
Saturated fat (g)	3.43	3.00
Dietary fibre (g)	5.60	5.60
Calcium (mg)*	4.38	4.67
Phosphorous (mg)*	3.17	3.67
Iron (mg)*	4.00	3.67
Vitamin C (mg)*	7.08	5.14

* Including intake from supplements.

more accurately reported their intake of saturated fat, whereas carbohydrates and vitamin C were better reported by the older students. After correction of the correlations for the substantial within-person variation (Table 4), the correlations improved but the confidence intervals became very wide. The corrected correlations ranged from 0.02 to 0.42 among the younger students and from 0.07 to 0.76 among the older ones.

Fruits and vegetables

The Spearman correlations between the servings per day of fruits and vegetables assessed from the recalls and the FFQ were similar and low among both age groups (Table 6). Vegetables were more commonly consumed than fruit or fruit juice. Vegetables accounted for approximately 70% of total fruit and vegetable intake among both age groups (median percentage 68% among fourth and fifth grade students and 75% among sixth and seventh grade students). Although the correlations for total servings of fruits and vegetables were similar ($r = 0.21$ in the fourth and fifth grades; $r = 0.20$ in the sixth and seventh grades), they masked the fact that among the older children the correlations with fruits alone ($r = 0.29$) and fruit juice ($r = 0.32$) were bordering on being acceptable, but the correlation with vegetable intake ($r = 0.17$) was low. Among the fourth and fifth grade children we observed virtually no correlation between the FFQ and recalls in terms of estimates of daily consumption of fruits ($r = -0.01$) or juice ($r = 0.00$). After correction for day-to-day variation in intake, the correlation between the estimates of vegetable servings per day ($r = 0.29$) was higher among the younger children. However, among both the elementary school and junior high school students, there was too much within- to between-person variation in fruit and vegetable intake, as indicated by the width of the confidence intervals, to precisely estimate the true correlations.

To assess whether the students were averaging their intake over the past year, as opposed to biasing the response by more recent dietary intake, we assessed the correlations between the second FFQ and each of

Table 5 Crude and deattenuated Pearson correlation coefficients and 95% confidence intervals between the second FFQ* and the average of four 24-hour recalls among children who completed all four 24-hour recalls

	Fourth and fifth grades ($n = 51$)		Sixth and seventh grades ($n = 58$)	
	Crude	Deattenuated	Crude	Deattenuated
Calories (kcal)	0.26 (–0.02–0.50)	0.34 (–0.03–0.63)	0.34 (0.09–0.55)	0.44 (0.10–0.68)
Protein (g)	0.20 (–0.08–0.45)	0.26 (–0.10–0.56)	0.23 (–0.03–0.46)	0.31 (–0.05–0.59)
Carbohydrate (g)	0.19 (–0.09–0.44)	0.25 (–0.12–0.57)	0.40 (0.16–0.60)	0.56 (0.16–0.80)
Fat (g)	0.26 (–0.02–0.50)	0.36 (–0.04–0.66)	0.24 (–0.02–0.47)	0.31 (–0.03–0.59)
% Calories from fat	0.01 (–0.27–0.28)	0.02 (–0.56–0.59)	0.04 (–0.22–0.30)	0.07 (–0.35–0.46)
Saturated fat (g)	0.31 (0.04–0.54)	0.42 (0.03–0.70)	0.18 (–0.08–0.42)	0.24 (–0.11–0.53)
Dietary fibre (g)	0.21 (–0.07–0.46)	0.33 (–0.13–0.67)	0.21 (–0.05–0.44)	0.33 (–0.10–0.65)
Calcium (mg)†	0.27 (–0.01–0.51)	0.39 (–0.04–0.70)	0.32 (0.07–0.53)	0.47 (0.05–0.75)
Phosphorous (mg)†	0.25 (–0.03–0.49)	0.33 (–0.05–0.63)	0.29 (0.03–0.51)	0.40 (0.03–0.68)
Iron (mg)†	0.20 (–0.08–0.45)	0.28 (–0.12–0.61)	0.29 (0.03–0.51)	0.40 (0.03–0.68)
Vitamin C (mg)†	0.19 (–0.10–0.44)	0.32 (–0.18–0.68)	0.50 (0.28–0.67)	0.76 (0.15–0.95)

* Subjects reporting <500 or >5000 calories on the FFQ were excluded from the analysis.
† Including intake from supplements.

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Table 6 Crude and corrected Spearman correlation coefficients and 95% confidence intervals between the second FFQ* and four 24-hour recalls among children who completed all four 24-hour recalls

	Fourth and fifth grades ($n=51$)		Sixth and seventh grades ($n=58$)	
	Crude	Corrected	Crude	Corrected
Fruit juice (servings)	0.00	†	0.30	0.32 (0.04–0.56)
Fruits and juice (servings)	–0.01	†	0.25	0.29 (–0.02–0.55)
Vegetables (servings)	0.16	0.29 (–0.32–0.73)	0.13	0.17 (–0.19–0.49)
Fruits and vegetables (servings)	0.12	0.21 (–0.31–0.63)	0.15	0.20 (–0.16–0.51)

* Subjects reporting <500 or >5000 calories on the FFQ were excluded from the analysis.
† Correlations too close to zero to meaningfully deattenuate.

the four 24-hour recalls. The lack of pattern between the magnitude of the correlation and the recency of the recall (data not shown) suggests that the estimates were not biased by recent intake.

Discussion

Among a sample of inner-city youths we observed that according to the mean of four 24-hour recalls the intake of fruits and vegetables was lower and the percentage of calories from fat higher than the goals specified in Healthy People 2000[21]. However, due to a tendency of the fourth and fifth grade students to overreport dietary intake on the FFQ, fruit and vegetable intake appeared higher among the younger children. In contrast, the sixth and seventh grade students reported intakes that were much closer to the median food or nutrient intake averaged from the four 24-hour recalls. For example, the median difference in estimated calcium intake between the recalls and FFQ was 500 mg among the fourth and fifth grade sample, but only 33 mg among the older students.

Our observation that younger children overreported dietary intake is consistent with the literature on dietary assessment in young children. Domel *et al.* observed overreporting of fruits and vegetables among a sample of fourth and fifth grade students[22]. Similarly, Knuiman *et al.*[23] found that 8–9-year-old boys substantially overestimated their lunch intake. Baranowski and Domel[24] suggest that overestimation in young children may be due to children inferring that they ate commonly consumed foods more often than they did or in reporting 'a standard number of servings rather than the number actually eaten'. This latter explanation is particularly likely on a semiquantitative FFQ where participants are assumed to consume a standard portion size.

Another possible explanation for the difficulty that younger children had in reporting their intake is that they had not progressed to the developmental stage characterized by the ability to think abstractly[25] and were not familiar with the concept of averaging or reporting 'usual' patterns. The sizeable amount of day-to-day variation in dietary intake of the students, particularly those in elementary school, makes the ability to average paramount to accurate completion of the FFQ.

We observed that intake of fruits and fruit juice was quite low. In both age groups the median intake was less than one serving per day. Moreover, the range of intake was limited. The combination of these two facts may partially explain the near-zero correlations among the elementary school students. Among the junior high school students, the FFQ did a better job of assessing fruits and juice than vegetables. However, the correlations with fruits and juice were still low and only bordering on acceptable. The relatively low crude correlation between vegetables assessed by the FFQ and the recalls is partially due to the FFQ not including vegetables in mixed dishes, since as much as 29% of vegetables are consumed in mixed dishes[26]. However, vegetables in mixed dishes may be forgotten unless the dish is classified by the person as a vegetable dish (i.e. part of a broccoli casserole, as opposed to part of a meat stew). Alternatively, vegetables in mixed dishes may be eaten in smaller portions than what is perceived as a serving. Thus it is plausible that respondents did not report vegetables in dishes such as soups and stews as servings of vegetables on questionnaires. Because in this sample vegetables accounted for approximately 75% of total fruit and vegetable intake, the low correlation with vegetables translated into a low correlation with total fruit and vegetable intake.

Although one of the goals of the EWAKM project was to decrease the percentage of calories from fat, we were unable to thoroughly investigate the validity of the FFQ estimate of that parameter. The distribution of percentage of calories from fat was narrow. On both the recalls and the FFQs (1993 and 1994), there was a 5% difference between the 25th and 75th percentiles of the distribution. For example, from the mean of four

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recalls collected from the fourth and fifth grade students, the 25th percentile was 33.4% and the 75th percentile was 38.9%. Due to the suboptimal between-person variation, correlation coefficients between percent of calories from fat assessed by the recalls and the FFQ are difficult to interpret.

One reason that the correlations between FFQs and 24-hour recalls or dietary records may be lower in children and adolescents than in adults is that there is greater day-to-day variation in their diets[27]. In this inner-city population, we observed more day-to-day variability in dietary intake than we have seen in a less economically disadvantaged population of children and adolescents[28]. In low income, inner-city populations, insufficient purchasing power and limited transportation or availability of fresh foods may result in chronic or sporadic food insufficiencies[29–31]. After we adjusted the correlations for day-to-day variation, the confidence intervals became very wide. To obtain more precise estimates, future validation studies conducted in children should use more than four 24-hour recalls. For micronutrients, such as vitamin C, considerably more recalls are needed due to the extreme day-to-day variability.

Overall, we observed that among sixth and seventh grade students, the FFQ did an adequate job of ranking subjects in terms of intake of calories, carbohydrate, calcium, phosphorous, iron and vitamin C over the past year. Moreover, on the group level the FFQ provides estimates of calories, protein, fat, saturated fat, percentage of calories from fat, fibre, iron and servings of fruits and vegetables that are very similar to those from the mean of four 24-hour recalls. The correlations we observed were at least as high as, if not greater than, those observed by Jenner *et al.*[32] in a sample of 11–12-year-old Australian children. However, with the exception of calories, Rockett observed correlations of greater magnitude between the FFQ and the mean of three 24-hour recalls among 9–13-year-old children of nurses participating in the Nurses' Health Study II[28]. One limitation of the current study is that the school lunch programme tried to keep the calories and percent of calories from fat within certain limits for all menus. One result of this goal was that the between-person variation in macronutrients was dampened. However, because we assessed average diet, not just intake during weekday lunches, there was ample between-person variation in dietary intake as assessed by FFQs and 24-hour recalls. For example, among both the elementary school and junior high school students, according to the mean of four 24-hour recalls, the range of energy intake was from approximately 1080 to 3500 cal day^{-1}.

Another limitation of the current study was that there were large losses to follow up, partially due to matriculation from elementary school to a junior high school not included in the study. Therefore, the final sample may be slightly biased. However, we observed that the reliability coefficients were lower in the elementary school children in the validation sample than those in the larger study, thus indicating that our results may underestimate the true associations. The results from the younger age group emphasize the need for children to have mastered basic reading and maths skills and to have progressed to abstract thinking in order to accurately complete the questionnaire. Consistent with our findings, among the 98 adults in the Treatwell 5 a Day Validation Study, KE Peterson *et al.* (personal communication) observed that education level was inversely related to the magnitude of the difference between the mean of three 24-hour recalls and a FFQ. Based on these results, we recommend that caution be used when interpreting dietary data collected with this instrument in samples of elementary school students in school districts where reading and maths levels may be low for grade.

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References

1 Randall E. Measuring food use in school-aged children. *J. School Health* 1991; **61**: 201–3.
2 Consensus workshop on dietary assessment: nutrition monitoring and tracking the year 2000 objectives. US Department of Health and Human Services, Public Health Service/Centers for Disease Control and Prevention, National Center for Health Statistics, 1993.
3 Nicklas TA. Dietary studies of children and young adults (1973–1988): the Bogalusa Heart Study. *Am. J. Med. Sci.* 1995: **310** (Suppl. 1): S101–8.
4 Kimm SYS, Gergen PJ, Malloy M, Dresser C, Carroll M. Dietary patterns of U.S. children: implications for disease prevention. *Prev. Med.* 1990; **19**: 432–42.
5 Nicklas TA, Farris RP, Srinivasan SR, Webber LS, Berenson GS. Nutritional studies in children and implications for change: the Bogalusa Heart Study. *J. Adv. Med.* 1989; **2**: 451–74.
6 Farris R, Nicklas T. Characterizing children's eating behavior. In: Suskind R, Suskind L, eds. *Textbook of Pediatric Nutrition*, 2nd edn. New York: Raven Press, 1993: 505–16.
7 Luepker RV, Perry CL, McKinlay SM *et al.* Outcome of a field trial to improve children's dietary patterns and physical activity. *JAMA* 1996; **275**: 768–76.
8 Merzenich H, Boeing H, Wahrendorf J. Dietary fat and sports activity as determinants of menarche. *Am. J. Epidemiol.* 1993; **138**: 217–24.
9 Field AE, Wolf AM, Herzog DB, Cheung L, Colditz GA. The relationship of caloric intake to frequency of dieting among preadolescent and adolescent girls. *J. Am. Acad. Child. Adolesc. Psychiatry* 1993; **32**: 1246–52.

10 Rockett HRH, Wolf AM, Colditz GA. Development and reproducibility of a food frequency questionnaire to assess diets of older children and adolescents. *J. Am. Diet. Assoc.* 1995; **95**: 336–40.
11 Rockett HR, Colditz GA. Assessing diets of children and adolescents. *Am. J. Clin. Nutr.* 1997; **65**: S1116–22.
12 US Department of Agriculture. *Composition of Foods*. Agriculture Handbooks Nos. 8-1 to 8-21. Washington, DC: US Department of Agriculture, 1976–92.
13 Paul AA, Southgate DAT. *McCance and Widdowson's The Composition of Foods*, 4th edn. London: HMSO, 1976.
14 Holland B, Welch AA, Unwin ID, Buss DH, Paul AA, Southgate DAT. *McCance and Widdowson's The Composition of Foods*, 5th edn. Cambridge, UK: Royal Chemical Society and Ministry of Agriculture, Fisheries and Food, 1991.
15 Willett WC, Sampson L, Stampfer MJ *et al.* Reproducibility and validity of a semiquantitative food frequency questionnaire. *Am. J. Epidemiol.* 1985; **122**: 51–65.
16 Nutrition Coordinating Center, University of Minnesota. Minnesota Nutrition Data System (NDS) v. 2.0. Minneapolis: University of Minnesota, 1993.
17 Havas S, Heimendinger J, Reynolds K *et al.* 5 a Day for Better Health: a new research initiative. *J. Am. Diet. Assoc.* 1994; **94**: 32–6.
18 Smith SA, Campbell DR, Elmer PJ, Martini MC, Slavin J, Potter JD. The University of Minnesota Cancer Prevention Research Unit vegetable and fruit classification scheme. *Cancer Causes Control* 1995; **6**: 292–302.
19 Rosner B, Willett WC. Interval estimates for correlation coefficients corrected for within-person variation: implications for study design and hypothesis testing. *Am. J. Epidemiol.* 1988; **127**: 377–86.
20 SAS Institute. *SAS User's Guide: Statistics*, 5th edn. Cary, NC: SAS Institute, 1980.
21 US Public Health Service. *Healthy People 2000: National Health Promotion and Disease Prevention Objectives*. DHHS Publication No. PHS 91–50212. Washington, DC: US Department of Health and Human Services, 1991.
22 Domel SB, Baranowski T, Davis H, Leonard SB, Riley P, Baranowski J. Fruit and vegetable food frequencies by fourth and fifth grade students: validity and reproducibility. *J. Am. Coll. Nutr.* 1994; **13**: 33–9.
23 Knuiman JT, Rasanen L, Ahola M, West CE, van der Snoek L. The relative validity of reports of food intake of Dutch and Finnish boys aged 8 and 9 years. *J. Am. Diet. Assoc.* 1987; **87**: 303–7.
24 Baranowski T, Domel SB. A cognitive model of children's reporting food intake. *Am. J. Clin. Nutr.* 1994; **59** (Suppl.): S212–17.
25 Flavell JH, Miller PH, Miller SA. *Cognitive Development*, 3rd edn. Englewood Cliffs, NJ: Prentice-Hall, 1993.
26 Krebs-Smith SM, Cook A, Subar A, Cleveland L, Friday J. US adults' fruit and vegetable intakes, 1989 to 1991: a revised baseline for the Healthy People 2000 objective. *Am. J. Public Health* 1995; **85**: 1623–9.
27 Nelson M, Black AE, Morris JA, Cole TJ. Between- and within-subject variation in nutrient intake from infancy to old age: estimating the number of days required to rank dietary intakes with desired precision. *Am. J. Clin. Nutr.* 1989; **50**: 155–67.
28 Rockett HRH, Breitenbach M, Frazier AL *et al.* Validation of a youth/adolescent food frequency questionnaire. *Prev. Med.* 1997; **26**: 808–16.
29 Crockett EG, Clancy KL, Bowering J. Comparing the cost of a thrifty food plan market basket in three areas of New York state. *J. Nutr. Educ.* 1992; **24**: S72–9.
30 Smith PK, Hoerr SL. A comparison of current food bank users, non–users, and past users in populations of low income single mothers. *J. Nutr. Educ.* 1992; **24**: S59–66.
31 Anon. Improving federal efforts to assess hunger and food insecurity. *Fam. Econ. Nutr. Rev.* 1996; **9**: 56–7.
32 Jenner DA, Neylon K, Croft S, Beilin LJ, Vandongen R. A comparison of methods of dietary assessment in Australian children aged 11–12 years. *Eur. J. Clin. Nutr.* 1989; **43**: 663–73.