**TITLE**

Evaluation of a quantitative food frequency questionnaire for five-year-old children in an Asian population

**Research Question****:** What is the relative validity of a newly-developed FFQ for assessing nutrient intakes of five-year-old children in an Asian population?

**Key Findings:**

The newly developed FFQ is in reasonable agreement with DR for estimating intakes of calcium, fibre, saturated fat, PUFA, cholesterol and iron. In addition, the FFQ is able to classify children according to quintiles of intakes, with moderate to substantial quintile agreements between FFQ and DR for calcium, iron, fibre, saturated fat, PUFA and beta-carotene.

**ABSTRACT**

**Background** Food frequency questionnaires are often used to assess dietary intakes due to their ability to assess intake over extended periods, their low respondent burden and cost-effectiveness. A quantitative food frequency questionnaire (FFQ), which includes locally appropriate food items for five-year-old children in a multi-ethnic Asian population was developed, but its validity has not previously been evaluated.

**Objective** To evaluate the relative validity of a newly developed FFQ as a dietary assessment tool for five-year-old children in a multi-ethnic Asian population.

**Design** The 112 food item FFQs were administered by trained interviewers to caregivers of children. Frequency of food items consumed in the previous month and portion size information were collected. The FFQs were evaluated against three-day non-weighed diet records (DR) completed by caregivers.

**Participants/setting** The dietary data of 361 children aged five years from the Growing Up in Singapore Towards healthy Outcomes (GUSTO) mother-offspring cohort were collected in 2015-2016.

**Main outcome measures** Nutrients of interest included energy, macronutrients, fibre, cholesterol, vitamin A, beta-carotene, calcium and iron, calculated from the FFQs and DRs.

**Statistical analyses performed** Nutrient intakes according to FFQs in relation to DRs were assessed using Pearson’s correlation, Lin’s concordance, Bland-Altman plots, quintile joint classification and Cohen’s kappa statistics.

**Results** The highest energy-adjusted correlation (Pearson’s r = 0.71) and concordance (Lin’s concordance = 0.69) were observed for calcium. Fibre, saturated fat, PUFA, cholesterol and iron also showed correlation coefficients and concordance of at least 0.40. Bland-Altman plots suggested no substantial bias across ranges of intakes for the nutrients with correlations and concordance of 0.40 or above. Quintiles joint classification showed substantial agreement for calcium (κ = 0.66), and moderate agreement for iron, fibre, saturated fat, polyunsaturated fat and beta-carotene (κ = 0.59, 0.54, 0.49, 0.44, 0.43, respectively).

**Conclusions**

The newly developed FFQ is in reasonable agreement with DR for estimating intakes of calcium, fibre, saturated fat, PUFA, cholesterol and iron. In addition, the FFQ is able to classify children according to quintiles of nutrient intakes, with moderate to substantial quintile agreements between FFQ and DR for calcium, iron, fibre, saturated fat, PUFA and beta-carotene. To assess the remaining nutrients, DR method is recommended instead of the FFQ.

**Background**

Nutrition is one of the key contributing factors influencing the health of children.1 Developing appropriate tools for assessing the dietary habits of children is crucial, so that those at risk of poor nutrition can be identified.2,3 A commonly used tool is the food frequency questionnaire (FFQ), where consumption frequencies of a set of food items over a period of time are ascertained.4 An FFQ can be non-quantitative, only asking the frequencies of foods consumed; semi-quantitative, embedding specific portion sizes in the questions (e.g. “How many times did you eat an egg in the previous month?”); or quantitative, asking respondents to specify their usual portion sizes and the frequencies of foods consumed. Compared to the diet record (DR) method, where individuals record their food intakes at each meal and snack over a period of one or more days, FFQ offers lower respondent-burden and higher completion rates.5 Processing FFQ data also requires less monetary and labour resources, making it a cost-effective dietary assessment tool.6 However, the performance of FFQ in accurately assessing dietary intakes of children varies across populations and settings. The differences may be due to a variety of reasons: the number and variety of food items used; design and ordering of questions; and whether questionnaires were self-administered or interview-guided.4,7–10

FFQs used for assessing children’s intakes have previously been developed and evaluated in the United States, Europe and Australia, but are scarce in Asian countries.4 An FFQ evaluated in Japan specifically assesses diets of children aged five years,11 but a number of the food items included are not relevant to the Singapore context (e.g. cold noodles, miso soup, semi-dried sardine, etc.). Moreover, it does not contain foods groups typically eaten by the Chinese, Malay, and Indian ethnic groups in Singapore.12 An FFQ was developed to assess children’s diets in Malaysia, but it was semi-quantitative in nature and designed to assess over a wide age range (two- to six-year-old).13 Thus, development of a locally appropriate FFQ to assess food intake among five-year-old Singapore children for use in clinical and research settings was conducted. The objective of this study is to evaluate the agreement of the newly-developed FFQ to three days DR in estimating dietary intakes on a continuous and categorical basis.

**MATERIALS AND METHODS**

**Participants**

The FFQ evaluation study was a sub-study of the Growing Up in Singapore Towards healthy Outcomes (GUSTO) mother-offspring cohort study. In brief, the GUSTO study recruited pregnant Singapore citizens or permanent residents aged 18 years or above during their first trimester visits at two major public maternity units in Singapore, National University Hospital and KK Women’s and Children’s Hospital. To be eligible, the mothers must have homozygous parental ethnic background of Chinese, Malay or Indian (three major ethnic groups in Singapore), and had planned to reside in Singapore for at least five years. The recruitment was done between June 2009 and September 2010, with a response rate of 61.3%. Information on education levels and household income were collected during recruitment. The main objective was to study relationship between in-utero conditions and developments of obesity or non-communicable disease among children. The cohort design and study protocol have been detailed elsewhere.1412 The children were five years of age when their diets were assessed in 2015-2016. In addition to the FFQ, caregivers (parents, grandparents, or other persons familiar with the children’s diet) were also asked to provide three-day diet records of their children. The target was to collect at least two hundred FFQ-DR data pairs to achieve the recommended sample size for an evaluation study comparing single administration of FFQ and DR.5,15

All participants provided written consent for this study and no monetary incentives were given for completion of the FFQs and DRs. Ethical approval was obtained from the Institutional Review Boards of the National University Hospital and the KK Women's and Children's Hospital, both located in Singapore, where the study was based (clinical trial identifier: NCT01174875).

**Diet Record**

Prior to the GUSTO 5-year clinic visit, dietary records were mailed to the caregivers. Written instructions and frequently asked questions regarding diet record keeping were provided in the dietary records to help caregivers complete the records accurately. A telephone call centre operating on weekdays was set up to facilitate answering caregivers’ questions related to filling out the DR. This method was adopted as caregivers had completed similar diet records at previous time points of the study (e.g. month 6, year 1 and 3) and thus should be relatively familiar with completing the DR. Caregivers were instructed to record three days of the children’s diet, comprising two weekdays and one weekend day. Records of consecutive or non-consecutive days were permitted, and caregivers were instructed to choose the days that were typical of their children intake. They were also instructed to write down the timings of food consumed, as well as the types and portion sizes in detail. Portion size information was requested in household serving sizes as presented in the DR booklets (the booklets contain pictures of plates, bowls, cups, spoons, as well as instructions and examples on how to record food intake accurately), or any measurements the caregivers were comfortable with. Estimation of food weight based on the reported portion sizes was done by trained dietitians, since non-weighed DRs were used. For children attending childcare centres, the caregivers were instructed to consult the childcare teachers regarding their children’s diets in the centre. Alternatively, caregivers could ask teachers to complete the DRs. On completion, the caregivers could either mail the completed DRs or return them during the clinic visit.

**Food Frequency Questionnaire**

The FFQ was interviewer-administered to caregivers of all five-year-old children during the clinic visits by trained researchers. DR completion and FFQ administration were typically conducted within two to four weeks intervals. Due to a lack of national survey data on children, the FFQ was developed with reference to dietary data of GUSTO children and their mothers collected at earlier time points of the study.16,17 The list of food items was also verified with paediatric dietitians familiar with the local diets of children. It encompassed 112 items, which were grouped into nine categories: grains (23 food items), bread spreads (6), meat and egg (11), processed meats (3), fish/seafood (11), vegetables and legumes (12), fruits (12), snacks (13), and mixed foods (4: burger, pizza, steamed and fried dim sum); as well as beverages: milk and their related products (10) and other beverages (7). For mixed dishes (e.g. fishball noodle, fish soup, chicken rice), individual items were queried and recorded in the FFQ accordingly. The caregivers were asked to report on the frequencies of food items consumed by their children in the previous month. The average serving of food items consumed were also ascertained using household measurements (slices of bread, boxes of raisins, pieces of chicken, etc.) or standard cups, spoons and plates presented during the interview.

**Nutrient Composition of Food Items**

Nutrient analysis of dietary data obtained from FFQs and DRs were performed using the nutrient analysis software Dietplan.18 A local database of energy and nutrient composition of food was used,19 as well as food label information of food products obtained from local stores.

**Statistical Analyses**

Energy and nutrient intakes from the FFQs were calculated to give per day intake values, while those from the three-day DRs were averaged to provide mean daily values. To account for under- and over-reporting of diet data, only FFQs and DRs which fell into the energy intake range of 500 kcal to 4,000 kcal were considered. Those outside this range were considered implausible intakes and excluded from the analysis.12,20,21

With the exception of FFQ energy, DR energy, DR protein, and DR carbohydrates, other nutrients derived from both methods were not normally distributed. Therefore, log transformations of these nutrients were done to fulfil statistical assumptions of normality. All nutrients (except energy) were energy-adjusted using the residual method.15 The FFQ was evaluated by Pearson’s correlations of energy and nutrients of the FFQ against DR as the reference method. Correlations of FFQ and DR nutrients and their 95% confidence intervals were computed using both crude and energy-adjusted values. In addition, to evaluate agreements between two continuous measures (FFQ and DR), Lin’s concordance coefficients and their 95% confidence intervals were computed.22 The limits of agreements and the visual evaluation of bias across nutrient intakes range between FFQ and DR were evaluated using Bland-Altman plots. 5,23

To examine if the FFQ was able to correctly classify energy and nutrients into correct quintiles according to DR, joint classification analysis was performed. Percentages of children classified by the FFQ into same quintile, same or adjacent quintiles and opposite quintiles were calculated. Cohen’s kappa statistics and their 95% confidence intervals were computed as they took into account the observed agreements that were due to chance. The kappa coefficients were reported using quadratic (Fleiss-Cohen)24 weightings. According to the Landis-Koch25 strength of agreement classification, Kappavalues of less than 0.00 indicate poor agreement; 0.00-0.20 slight; 0.21-0.40 fair; 0.41-0.60 moderate; 0.61-0.80 substantial; and 0.81-1.00 almost perfect agreement. All statistical analyses were performed using Stata.26

**RESULTS**

FFQ and DR data were available from 808 and 485 children respectively. After exclusion of incomplete DRs (less than three days of diet recorded, n = 114), and those with implausible energy intakes (either from FFQ or DR, n = 10), 361 FFQ-DR data pairs were available for analysis. Of all participating children, 51.3% were male; with ethnic proportions of 57.6% Chinese, 28.5% Malay and 13.9% Indian; 74.2% of children had at least one parent with post-secondary level education (any junior college, polytechnic, institute of technical education, art-institution or university-level education), which is comparable to the general educational status of Singapore residents.27

Daily nutrient intakes according to DR and FFQ, as well as the limits of agreements, Pearson’s correlations, and Lin’s concordance coefficients are shown in Table 1. Energy-adjustments yielded improvements on correlation coefficients for most nutrients analysed. The highest energy-adjusted correlation and concordance were observed for calcium. Fibre, saturated fat, polyunsaturated fat, cholesterol and iron were found with correlation and concordance of at least 0.40. Bland-Altman plots for those nutrients are displayed in Figure 1. Across range of intakes, FFQ-DR differences were scattered randomly about the value of zero, with no particular bias pattern present.

Joint classification of nutrient intakes into quintiles between FFQ and DR are presented in Table 2. Classification to same or adjacent quintiles was observed in 63-83% of children, while misclassification to opposite quintiles occurred in 1-5% of children. Kappa statistics (Table 2) showed that for calcium, substantial agreement was observed (κ = 0.66, 95% CI: 0.59-0.72). Moderate agreements were found for iron, fibre, saturated fat, polyunsaturated fat, and beta-carotene. Fair agreements were found for cholesterol, vitamin A, monounsaturated fat, energy, fat, protein and carbohydrate.

**DISCUSSION**

The objective of the present study was to evaluate the validity of a newly developed FFQ for five-year-old children in a multi-ethnic Asian population. The aim is to identify nutrients the FFQ are able to assess well, and those that perform unfavourably. This would guide the appropriate use and interpretation of the newly developed FFQ.5,28

In the present study, the correlations of nutrients were comparable with other evaluation studies of FFQ for 4-6 years old children in Japan,29 Spain,30 and Brazil31 – despite methodological differences across studies. In fact, a review evaluating various dietary assessment tools used among children and adolescent found that FFQs generally exhibit a wide range of correlation coefficients: 0.13-0.51 for energy, 0.18-0.34 for protein, and 0.10-0.39 for fat.10 Although recommendations on interpreting correlations coefficients in evaluation studies differ, values below 0.40 would generally suggest that the particular nutrients are not suitable to be assessed by FFQ.4,28,32 Thus for this study, caution should be exercised for carbohydrate, protein, monounsaturated fat, vitamin A and beta-carotene as their correlations were below 0.40. This finding that calcium showed a high correlation is comparable to a review on utilizing FFQs to assess micronutrient in infants, children and adolescents.7 This phenomenon occurred mainly because the variability of calcium intake is largely dependent on intakes of its main food sources (i.e. milk, cheese and yogurt), which are relatively less varied and easier to quantify compared to food sources of other nutrients studied. When comparing various FFQ designs, Cade4 found that having the participants describe their own portion sizes generally produced higher correlations compared to having no portion size specified or using predetermined portion sizes. Similarly, while employing interviewers increases the cost of FFQs, thus somewhat reducing the main advantage of FFQ, higher correlation coefficients are generally achieved compared to use of self-administered FFQ.5 Thus, the relatively high correlation coefficients of this study could be due to a combination of the FFQ being interviewer-administered and quantitative.

While the most common method adopted by FFQ evaluation studies is the computation of Pearson’s correlation,4,9,15 correlation itself measures linearity of relationship between two methods of measurements, and is not a true measure of agreement between two methods. More recently, Lin’s concordance analysis has increasingly been used in FFQ evaluation studies.33–35 Lin’s approach evaluates the orthogonal squared distance of data from the line of agreement, such that Lin’s concordance values closer to one indicates the data as very close to the line of agreement.22 In this study, the line of agreement corresponds to FFQ giving same values as DR. Bearing in mind that Lin’s concordance values below 0.4 suggest considerable disagreement between FFQ and DR, evaluation of energy, fat, monounsaturated fat, protein, carbohydrate, vitamin A and beta carotene intakes on continuous scale should not be done using the FFQ.

Bland-Altman plots are very useful in the evaluation of FFQ to detect the presence and direction of bias between FFQ and DR. Agreement between methods can thus be assessed across a range of intakes, which can be difficult to evaluate using correlation coefficient and joint classification analysis.4 For the energy-adjusted nutrients with Pearson’s correlation and Lin’s concordance values of 0.40 or above, reasonable agreement between FFQ and DR was also observed using Bland-Altman plots. This suggests that the FFQ tendency of over or underestimation across a range of intakes for these nutrients were not observed.

In studying diet-disease relationships, important consideration is placed on the ability of FFQ to correctly categorize individuals based on their intake levels.36,37 Concerning this aspect of categorical agreement, misclassification of FFQ to opposite quintiles of DR was encountered in 5% or less children. While the results showing the ability of FFQ to correctly classify children into same or adjacent quintiles seems promising, agreement due to chance is likely to happen in 52% of children (5 same + 8 adjacent quintiles, divided by 25 total possible quintiles = 52%). Therefore, evaluation of kappa inter-rater agreements is recommended to take into account those chance agreements.4 Substantial agreement for calcium, and moderate agreements for iron, fibre, saturated fat, polyunsaturated fat and beta-carotene were observed, which reflect the ability of FFQ to categorize children relatively well for those nutrients.

While this FFQ was developed and evaluated to assess dietary intakes of five-year-old children in the GUSTO study, the findings could be generalized to children in the general population in Singapore, due to the comparable characteristics of these participants and children in the general population. The FFQ age range could be reasonably extended to children aged between four and six, as diets are not expected to differ significantly.

Four limitations of this study should be considered. First, reference biomarkers in the present study were not collected, due to the challenges of obtaining blood samples from the children in this age group, thus resulting in FFQ not being compared to biomarkers.3 Second, DR data should ideally be collected prior and after FFQ administration, as recording diet might influence food items reported in the FFQ.15 This was not done due to logistical constraints. However, the two weeks intervals between DR collection and FFQ administration was imposed to alleviate this issue. Third, measurement error in DR may arise due to possible tendency for caregivers to report ‘socially desirable’ healthier diets. Fourth, immediate checks of DR upon return to review food intakes and clarify questionable records were also not performed due to resource constraints.

**Conclusion**

The newly developed FFQ is in reasonable agreement with DR for estimating intakes of calcium, fibre, saturated fat, PUFA, cholesterol and iron, based on Pearson’s correlation and Lin’s concordance. In addition, the FFQ is able to classify children according to quintiles of intake, with moderate to substantial quintile agreements between FFQ and DR for calcium, iron, fibre, saturated fat, PUFA and beta-carotene. Caution should be taken when using this FFQ to assess the other nutrients with lower correlation, concordance or kappa values. Currently, the use of interviewer to administer this FFQ is recommended, since the performance of this FFQ in self-administered format is unknown.

For future application of this FFQ, calibration using diet records can be performed to reduce the measurement errors of FFQ, therefore producing less biased nutrient intake information and disease associations. Additionally, information from the diet records can be used to improve the food list and the portion size options in the FFQ.

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