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Evaluation of paper-based and web-based food frequency questionnaires for 7-year-old children in Singapore

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Abstract

Advances in technology enabled the development of a web-based, pictorial food frequency questionnaire (FFQ) to collect parent-report dietary intakes of 7-year-old children in the GUSTO study. This study aimed to compare intakes estimated from a paper-FFQ and a web-FFQ, and examine the relative validity of both FFQs against 3-day diet records (3DDR). Ninety-two mothers reported food intakes of their 7-year-old child on a paper-FFQ, a web-FFQ and a 3DDR. A usability questionnaire collected participants' feedback on the web-FFQ. Correlations and agreement in energy, nutrients and food groups intakes between the dietary assessments were evaluated using Pearson's correlation, Lin's concordance, Bland-Altman plots, Cohen's kappa and tertile classification. The paper- and web-FFQ had good correlations (≥0.50) and acceptable-good agreement (Lin's concordance ≥0.30; Cohen's kappa ≥0.41; ≥50% correct and ≤10% mis-classification into same or extreme tertiles). Compared to 3DDR, both FFQs showed poor agreement (<0.30) in assessing absolute intakes except micronutrients (web-FFQ had acceptable-good agreement); but showed acceptable-good ability to classify children into tertiles (κ≥0.21; ≥40% and ≤15% correct or misclassification). Bland-Altman plots suggest good agreement between web-FFQ and 3DDR in assessing micronutrients and several food groups. The web-FFQ was well-received (e.g. >89% found it user-friendly), and majority (81%) preferred the web-FFQ over the paper-FFQ. The newly developed web-FFQ produced intake estimates comparable to the paper-FFQ, has acceptable-good agreement with 3DDR in assessing absolute micronutrients intakes, and acceptable-good ability to classify children according to categories of intakes. The positive acceptance of the web-FFQ makes it a feasible tool for future dietary data collection.

Keywords: food frequency questionnaire; internet; diet records; validation study; child

Introduction

Dietary intake of young children is an important determinant of their current and future health [1; 2]. Growing evidence demonstrating the association between poor dietary habits during early childhood and future risks of chronic diseases [1; 2] has made optimizing dietary intakes of young children an increasing priority. Accurate assessment of young children's diets is thus essential to understand their nutritional status and changes in diet over time.

Food frequency questionnaires (FFQs) are commonly used in large cohort studies, as the average long term diet (e.g. intakes over weeks) is conceptually more important in epidemiologic research than intakes over a few specific days (using short term food recalls or diet records) [3]. Having an age appropriate, as well as a reliable and valid FFQ is essential to accurately capture dietary intakes of the population under study [4], as different age groups consume different range and variety of foods. Several FFQs have been developed to capture dietary intake of children younger than 12 years of age [5; 6]. These FFQs are most often completed by a parent or primary caregiver due to children's limited knowledge of foods, and ability to recall foods eaten and estimate portion size. Validation studies of these FFQs have shown that parent-administered FFQs, especially those that involve the child, are relatively valid in assessing the child's dietary intakes when compared to a reference method [5; 6].

The widespread usage of computers or mobile devices with Internet access in recent years has led to the emergence of web-based dietary assessment tools [7; 8]. The development and use of web-based FFQs have been increasingly common in cohort studies [8; 9] due to the lesser demand on manpower for administration and data entry. The accessibility of the Internet means that web-FFQs can be administered at any time and location with Internet access. Additionally, the capacity to incorporate extensive food and portion size photographs can enhance food recognition and portion size estimation by participants, thus eliminating the need for trained interviewers without compromising on data quality [7; 8; 9]. The web-FFQs can also be pre-programmed to check for missing or multiple response and alert participants to correct these errors. Taken together, the web-FFQ represents a more cost-effective method to collect repeated dietary data on a large scale, compared to traditional paper and pencil FFQs.

The web-FFQ is thus advantageous for large cohort studies to assess dietary intakes of participants longitudinally, such as the Growing Up in Singapore Towards healthy Outcomes

(GUSTO) study [10] which aims to track the diets of Singaporean children till adolescence and possibly adulthood. However, some participants within the same study may not be able to complete the FFQ online or may choose to only complete a paper-based version. Differences in the formats of the web- and paper-FFQs raise questions about whether data captured using these different formats can be pooled.

A previously validated paper-FFQ for assessing dietary intakes of 5-year-old children in GUSTO [11] was modified to capture dietary intakes of 7-year-old children. A web-FFQ was then developed based on this modified paper-FFQ. The present study aimed to: (1) compare estimates of intakes obtained using the paper-FFQ with those obtained using the web-FFQ, (2) examine the relative validity of the paper- and web-FFQs against 3-day diet records (3DDR).

Methods

Study sample

The GUSTO study is an ongoing mother-offspring cohort study in Singapore which recruited pregnant women during their first-trimester between June 2009 and September 2010, and followed their offspring prospectively since birth [10]. The primary objective of GUSTO is to study the relationships of early life environmental factors and their influence on offspring's health and development. The cohort design and study protocol have been published previously [10].

The present study is nested within GUSTO's follow-up when the children were 7 years of age, and conducted in a subset who attended clinic visits between June 2017 and June 2018 (the main GUSTO's clinic visits ran from November 2016 to June 2018). All procedures in GUSTO have received ethical approval from the Institutional Review Boards at KK Women's and Children's Hospital (CIRB 2018/2767) and National University Hospital (DSRB D/2009/00021, B/2014/00406) where the participants were recruited, and were conducted in accordance to the Declaration of Helsinki. Written informed consent was acquired from participants at study recruitment and subsequently at each sub-study.

Study design

The main GUSTO follow-up asked all mothers (or main caregivers familiar with the child's diet) to complete one version of the FFQ (paper or web) and a 3DDR at home prior to their visit at the clinic. Mothers were encouraged to complete the dietary assessments together with their child. For this study, mother-child pairs were asked to complete a paper-FFQ, a web-FFQ, and a 3DDR. Mother-child pairs scheduled to attend GUSTO's clinic visits during June-December 2017 were assigned to first complete the paper-FFQ at home and then invited to complete the web-FFQ at the clinic (Group 1). Those scheduled to attend clinic visits during January-June 2018 were assigned to first complete the web-FFQ at home and then invited to complete the paper-FFQ at the clinic (Group 2). This is to account for sequence effect, as mothers may become familiar with the FFQ after completing the first time and become better at completing the second time. Completion of a second version of the FFQ is entirely voluntary. We ceased recruitment after 120 mother-child pairs completed two separate versions of FFQ at home and at the clinic, as well as a 3DDR (following Willett's recommendation of at least 100 participants for a validation study [3]). Out of the 120 who have completed all 3 dietary assessments, only those with no more than 20% missing responses in paper-FFQ and with 3 days of complete data in the 3DDR, were included in this analysis (**Figure 1**).

Either the paper-FFQ or an instruction sheet containing the log-in details to the web-FFQ (e.g. hyperlink, unique username and password) was mailed to participants 7 weeks before their clinic visit depending on the sequence allocated (**Figure 2**). The 3DDR was mailed together with the paper-FFQ or the web-FFQ instruction sheet. Mothers were instructed to only complete the FFQ and 3DDR 2 weeks' prior to their clinic visit. SMS text messaging reminders were sent when the time comes for mothers to complete the FFQ and 3DDR at home. The contact number of a designated research staff was included in the mail package to facilitate answering questions related to filling out the FFQ and 3DDR when at home. Those who completed both the paper- and web-FFQs were asked to complete a usability questionnaire at the clinic.

Additionally, mothers' self-reported ethnicity, highest education attained and monthly household income were collected at the recruitment visit (<14 weeks' gestation). Information on the child's sex was extracted from hospital delivery records. At the Year-7 study visit, child's height was measured to the nearest 0.1 cm using a stadiometer (SECA 213) and weight measured to the nearest gram using calibrated weighing scales (SECA 803). Age and sex-specific BMI z-scores were derived using WHO reference [12]; children with BMI z-scores >1SD were classified as overweight or obese.

GUSTO Year-7 Paper-FFQ

The paper-FFQ assesses food intake of 7-year-old children over the past 1 month through parent-report. It is a quantitative FFQ, self-administered by mothers or main caregivers familiar with the child's diet. The paper-FFQ was modified from the previously validated paper-FFQ designed to assess dietary intakes of 5-year-old children in GUSTO [11], to more closely reflect dietary habits of children of this age. Further details on the Year-7 paper-FFQ are described in **Supplementary Methods**. In brief, mothers were asked to indicate their child's consumption of 120 food items from 7 frequency options ranging from "never" to "2-3 times per day", and the average amount consumed using household measurements. To assist in portion size estimation, images of standard household utensils (eg, bowls, spoons, and a standard plate), and portion sizes (2-3 photographs per item) of 12 food items (e.g. dessertspoons of meat or vegetables, pieces of fruits, a bowl of cereals, a slice of cake) were provided in a separate sheet.

GUSTO Year-7 web-FFQ

The content of the web-FFQ is identical to the paper-FFQ in terms of wording of questions, number of food items, and number of frequency options, but with an expanded list of portion size options (described below). The web-FFQ was also designed to be self-administered by mothers or main caregivers, and can be completed using computers, tablets or mobile devices. The design of the web-FFQ was guided by a review of literature on existing computer- or web-based FFQs [8; 9; 13; 14; 15], and additionally incorporated automated skipping of infrequently consumed food items, inclusion of food pictures and portion size photographs for each FFQ item, and real-time checking of missing or multiple responses.

With automated skipping, mothers will be taken through different food categories to select foods (each represented with a generic food picture) consumed by their child in the past month, instead of going through a lengthy list of food items as in the paper-based version. Subsequent questions on consumption frequency and portion size will focus on the foods they have selected. Questions on foods they have not selected (ie, infrequently consumed) will be skipped. With this feature, the completion time of the web-FFQ averages 20-30 minutes compared to 45-60 minutes for the paper-FFQ (based on observing those who completed either of the FFQs at clinic visit).

Unlike the paper-FFQ where images were limited to 12 foods and only 2-3 portion size images per food, the web-FFQ had a food picture and 3-6 standardized portion size photographs for every food item in the FFQ (refer to **Supplementary Methods** for detailed photography protocol). The options for portion sizes were based on commonly reported portion sizes of children and their mothers collected at earlier time points of the GUSTO study [11; 16].

By incorporating real-time checking of missing responses, participants will be alerted to indicate a frequency of consumption and a portion size for every food item selected before being able to proceed to answer questions on the next food item.

Prototypes of the web-FFQ were subjected to a few rounds of in-house testing among the research team. The final beta-version was tested among a group of mothers (n=10) with young children (3-7 years of age) not involved in the GUSTO study. During each testing, research staffs reviewed the web-FFQ with the user to identify questions or graphics that were confusing or portion sizes that were too small or large. Any issues identified and feedback obtained during testing were used to inform the final version of the web-FFQ.

3-day diet records

Written instructions (including examples) and answers to frequently asked questions regarding diet record keeping, were provided together with the 3DDR to help mothers complete with sufficient details and precision. Food photographs of standard household measuring utensils and commonly consumed portion sizes were also provided. This method was adopted as mothers would have been coached on how to complete diet records at previous GUSTO time points. Mothers were instructed to record their child's food intake over 2 weekdays and 1 weekend day, and preferably non-consecutive days. Records of 1 weekday and 2 weekend days as well as records of consecutive days were permitted, if mothers found it challenging to record non-consecutive 2 weekdays and 1 weekend day.

Usability questionnaire

We developed a paper-based usability questionnaire by adapting questions used in previous studies [14; 17; 18; 19] to obtain feedback on the format preference of the FFQ (paper- or web-based), as well as the ease of use, attractiveness, clarity, overall completion experience of the web-FFQ. Mothers were asked to rate their level of agreement with 10 usability statements on a 5-point Likert scale, ranging from strongly agree to strongly disagree. The questions alternated between positively-phrased and negatively-phrased statements to reduce acquiescent bias (ie, agreeing to all statements). Percentages for each agreement level were calculated for each question. For easier analysis, agree and strongly agree were merged as well as disagree and strongly disagree.

Dietary data analyses

As aforementioned, paper-FFQ with ≤20% missing responses were included in the validation study. These missing responses were imputed with mode or median values from the whole cohort. Following previous methods [11; 16], nutrient analysis of data from all 3 dietary assessments were performed using the nutrient analysis software Dietplan (Forestfield Software, UK) based on a food composition database containing local foods.

The 120 food items of both FFQs were collapsed into 25 food groups based on similar nutrient profile (**Supplementary Table 1**). The same number of food groups and food group definitions were used for 3DDR. Food groups, identified from any of the dietary assessments, to have a high proportion of participants with no consumption in a day (>33.3% in Supplementary Table 1) were excluded from comparison: spreads, oats and breakfast cereals, other types of cereals, flavored rice dishes, porridge, soup, legumes, nuts and soybean products, dried fruits, processed meat, local steamed snacks, sweetened and non-sweetened drinks. This is such that all food groups intakes can be evenly split across tertiles for calculation of Cohen's kappa and joint cross-classification analysis (described below). The remaining 13 food groups were included in analysis.

Statistical analyses

To account for mis-reporting of dietary intake, children with energy intake outside of 500-5,000 kcal/day [20; 21] assessed by any of the dietary assessments, were excluded from analysis. The distributions of food groups and nutrients were skewed and were log-transformed. All food groups and nutrients (except energy) were energy adjusted using the residual method [3].

Average daily intakes of energy, 11 nutrients and 13 foods groups, estimated using paper-FFQ, web-FFQ and 3DDR were compared using Kruskal Wallis tests with Bonferroni *post hoc* analysis to identify significant differences in intakes among the dietary assessments.

The correlations of energy, nutrients and food groups intakes measured by the paper-FFQ, web-FFQ and 3DDR were examined using Pearson's correlation coefficients. The agreement of the 3 dietary assessments was evaluated using Lin's concordance coefficients and Bland-Altman plots. These methods evaluate dietary variables in a continuous scale [22; 23]. In addition, categorical agreement – the ability to correctly categorize subjects using the dietary assessments, were examined using Cohen's kappa coefficients with quadratic weightings and joint cross-classification analysis which estimates the percentage of children classified by each pairing of dietary assessments into the same or extreme tertiles. Based on cut-offs commonly used in literature, Pearson's correlation coefficients of ≥0.50 were considered good and 0.30-0.49 were considered acceptable [24; 25]. Lin's concordance coefficients were interpreted similar to Pearson's correlation [26; 27]. Cohen's kappa values of ≤0.20 indicate poor-slight agreement, 0.21-0.40 indicate fair agreement, 0.41-0.60 indicate moderate agreement, and >0.60 as substantial-perfect agreement [28]. For percentages of tertile agreement, ≥50% correct classification into the same tertile and ≤10% misclassification into extreme tertiles were considered good [24]; percentages close to recommended (ie, ≥40% correct classification and ≤15% misclassification) were considered acceptable. All statistical analyses were performed using Stata version 14 (StataCorp, TX, USA).

Results

After excluding those with ≥20% missing responses in paper-FFQ, less than 3 days data in the 3DDR, data loss in web-FFQ, and reported energy intakes outside of the plausible range, the final analysis compared dietary intakes of 92 children (Figure 1).

Characteristics of mother-child pairs

The study sample for this analysis consisted of 51.1% male and 48.9% female children, with ethnic proportions of 51.1% Chinese, 31.5% Malay, and 17.4% Indian, respectively. Mothers of most children (73.9%) attained post-secondary educational level, and 31.5% children were of households with the highest monthly income (>SGD $6000). The ethnic profile and socio-economic status of the current study sample were comparable to the larger GUSTO cohort [10]. Approximately 30.4% of these children were classified as overweight or obese.

Comparison between paper- and web-FFQs

Comparing the average intakes between the FFQs, the paper-FFQ significantly over-estimated energy and majority of nutrients, except for fibre, iron and β-carotene (**Table 1**).

However, the paper- and web-FFQs showed good correlations (≥0.50) in estimating energy and nutrients intakes (**Table 2**). Likewise, their concordance for energy and the majority of nutrients intakes ranged between acceptable to good (0.31-0.69), except for carbohydrate, protein and total fat. Based on Cohen's kappa values, both FFQs showed moderate to substantial agreement (0.46-0.69) in classifying according to energy and nutrients intakes. Similarly, ≥50% correct classification into same tertile and ≤10% of misclassification into extreme tertiles was observed for energy and all nutrient intakes.

The paper-FFQ significantly over-estimated majority of food groups intakes except for breads, cruciferous and dark green vegetables, and other vegetables, when comparing the average intakes to those of the web-FFQ (Table 1). Pearson's correlation coefficients of ≥0.50 were observed for majority of food groups except for dairy products (excluding milk) (Table 2). Similarly, acceptable to good concordance (0.43-0.84) were observed for majority of food groups except for dairy products (excluding milk). The kappa values showed fair to substantial agreement (0.34-0.71) between the paper- and web-FFQ in classifying children according to their food groups intakes. Likewise, ≥40% correct classification into same tertile with ≤15% of misclassification into extreme tertiles was observed for all food groups intakes.

Validation of paper-FFQ against 3DDR

When compared against 3DDR, the paper-FFQ significantly over-estimated energy and majority of nutrients, except for fibre and iron (Table 1). The paper-FFQ demonstrated acceptable to good correlations with 3DDR (0.31-0.70) in estimating intakes of energy and most nutrients, but poor correlations (<0.30) in estimating intakes of total fat and specific types of fats (**Table 3**). In contrast, the paper-FFQ had poor concordance with 3DDR in estimating intakes of energy and most nutrients (<0.30), except for vitamin A, beta-carotene and calcium intakes which had acceptable concordance (0.38-0.46). The Bland and Altman plots comparing nutrients with Lin's concordance values of ≥0.40 between paper-FFQ and 3DDR (**Supplementary Figure 1A)** showed no obvious bias pattern with mean differences close to zero for β-carotene intake, however, the differences for calcium intake appears to decrease with increasing intake. As expected, bias patterns began to show and the differences deviated further from zero for nutrients with Lin's concordance values <0.40 (plots not shown). The kappa values showed fair to substantial agreement (0.25-0.61) between the paper-FFQ and 3DDR in classifying children according to tertiles of energy and nutrients intakes, except a poor agreement for polyunsaturated fat (0.20) (Table 3). Results from joint cross-classification analysis are in line, whereby ≥40% of children were correctly classified into the same tertile, and ≤15% of children were mis-classified into extreme tertiles, except for polyunsaturated fat.

Comparing average food groups intakes, the paper-FFQ significantly over-estimated majority of food groups, except for breads, and cruciferous and dark green vegetables (Table 1). The paper-FFQ had acceptable to good correlations (0.30-0.70) with 3DDR in estimating food groups intakes, but poor correlations (<0.30) were observed for desserts and sweet snacks, fast food and fried snacks (Table 3). Poor concordance (<0.30) was observed between paper-FFQ and 3DDR in estimating most food groups intakes, except for cruciferous and dark-green vegetables, and milk which had good concordance (≥0.50). The Bland and Altman plots comparing food groups intakes with Lin's concordance values of >0.40 between paper-FFQ and 3DDR (**Supplementary Figure 2A**) showed no obvious bias pattern with mean differences close to zero for cruciferous and dark green vegetables. Comparing milk intake, however, the differences tended to increase with increasing amounts consumed. As expected, bias patterns began to show and the differences deviated further from zero for food groups with Lin's concordance values <0.40 (plots not shown). The kappa values showed fair to substantial agreement (0.28-0.63) between the paper-FFQ and 3DDR in classifying children according to tertiles of food groups intakes (Table 3), but poor agreement (≤0.20) for noodles and pasta, desserts and sweet snacks as well as fast food and fried snacks. Joint cross-classification analysis yielded similar levels of tertile agreement.

<u>Validation of web-FFQ against 3DDR</u>

Overall, the median intakes from the web-FFQ were similar to the 3DDR except for calcium and β-carotene (Table 1). The web-FFQ demonstrated acceptable to good correlations (0.35-0.70) with 3DDR in estimating intakes of protein, fibre and micronutrients intakes, but poor correlations (<0.30) in estimating intakes of energy, carbohydrate, total fat and specific types of fats (**Table 4**). Results from Lin's concordance are in line with Pearson's correlations. The Bland and Altman plots comparing β-carotene, calcium, fibre and iron intakes between web-FFQ and 3DDR (Lin's concordance ≥0.40) showed no particular bias pattern with the differences scattered randomly about the value of zero **(Supplementary Figure 1B)**. Plots are not shown for nutrients with Lin's concordance values <0.40 as bias patterns with mean differences far from zero are expected. The kappa values showed fair to substantial agreement (0.30-0.61) between web-FFQ and 3DDR in classifying children according to tertiles of energy and nutrients intakes, except a poor agreement (0.20) for carbohydrate (Table 4). Joint cross-classification analysis between web-FFQ and 3DDR showed ≥40% of children correctly classified into the same tertile, and ≤15% of children mis-classified into extreme tertiles of energy and nutrients intakes, except for carbohydrate and saturated fat.

Comparing average food groups intakes, the web-FFQ significantly over-estimated other vegetables, fruits, fish and seafood, eggs, desserts and sweet snacks, fast food and fried snacks; while under-estimated poultry and meat (Table 1). The web-FFQ demonstrated acceptable to good correlations with 3DDR (0.31-0.76) in estimating food groups intakes, except for desserts and sweet snacks, fast food and fried snacks which had poor correlations (<0.30) (Table 4). Acceptable to good concordance (0.32-0.72) between the web-FFQ and 3DDR was observed for 7 of 13 food groups intakes, while poor concordance (<0.30) was observed for breads, fruits, poultry and meat, desserts and sweet snacks, fast food and fried snacks, and dairy products (excluding milk). The Bland and Altman plots comparing intakes of cruciferous and dark green vegetables, milk, noodles and pasta, fish and seafood (Lin's concordance >0.40) between the web-FFQ and 3DDR (**Supplementary Figure 2B**) suggest no bias pattern, and the differences were randomly scattered around zero. Plots not shown for food groups with Lin's concordance values <0.40. The kappa values showed fair to substantial agreement (0.28-0.63) between the web-FFQ and 3DDR in classifying children according to tertiles of food groups intakes (Table 4), but poor agreement (≤0.20) was observed for poultry and meat, desserts and sweet snacks, fast food and fried snacks. Joint cross-classification analysis yielded similar levels of tertile agreement.

Usability results

A total of 89 mothers completed the usability questionnaire. Majority indicated that they preferred the web-FFQ over the paper-FFQ (81%) and agreed that the web-FFQ was interesting and fun to complete (91%), and user-friendly (89%). Most of them also agreed that the images (95%) and instructions (97%) were clear (**Figure 3A**). Only a small percentage of them (7%) indicated that they were not confident in using a web-based tool (**Figure 3B**). Some experienced long loading time (10%) or encountered technical problems (14%) while completing the web-FFQ, whilst 12-13% did not find the portion images helpful or did not like the lay-out of the web-FFQ.

Discussion

Overall, our study results suggest that the paper- and web-FFQs produce comparable estimates; the web-FFQ had acceptable to good agreement whilst the paper-FFQ had poor agreement, with 3DDR when evaluating dietary variables in a continuous scale. Both FFQs had acceptable to good tertile agreement with the 3DDR. Additionally, majority of the participants responded positively to the web-FFQ and preferred to complete the web-FFQ over the paper-FFQ.

Overall, nutrients intakes estimated from both paper- and web-FFQs were comparable in several aspects. The correlation coefficients (0.51-0.75) in our study were similar to those (0.35-0.84) reported in previous studies examining comparability of paper vs. web-FFQs self-administered by adults [29; 30; 31; 32], although these FFQs assessed dietary intakes of adults and not young children. Results from categorical agreement (kappa and cross-classification analyses) were also in line. While our percentages of classification into the same category (43-71%) were slightly lower than a previous study (45-86%) [31], we classified according to tertiles instead of quartiles. Our study additionally showed that both FFQs were in agreement for assessing absolute nutrient intakes except for carbohydrate, protein, and total fat. Likewise, food groups intakes were also comparable between both FFQs. The correlation coefficients (0.47-0.87) and percentages of classification into the same category (49-72%) were similar to previous studies [30; 31] (0.29-0.79 and 35-73%, respectively), except for dairy products (excluding milk). We suspect that collapsing FFQ items with large daily variation in intakes (eg, malt beverages intake: 0-625ml by web-FFQ and 0-1563ml by paper-FFQ) with intakes of items with smaller daily variation (eg, dairy-based drinks intake: 0-54ml by web-FFQ and 0-625ml by paper-FFQ), may have skewed the distributions of dairy products (excluding milk) and affected the comparison results.

In general, when compared to 3DDR as the reference method, the relative validity of the paper-FFQ in examining absolute energy and nutrients intakes is considered weak. Although the overall correlation coefficients (0.31-0.70) are comparable (except for fats) to those reported in a recent meta-analysis of studies examining relative validity of caregiver- or child-administered paper-FFQ (0.35-0.56) [6], results from Lin's concordance and Bland-Altman plots suggest an overall poor agreement when examining absolute intakes. This finding concurred with previous studies assessing validity of FFQs in children, that FFQs generally have poorer level of agreement in absolute intakes [33; 34; 35; 36]. Nevertheless, the ability of the paper-FFQ to classify children according to categories of energy and nutrients intakes is mostly acceptable to good (except polyunsaturated fat). Our percentages of classifications were somewhat similar to previous studies considering the differences in number of categories (5-14% mis-classified into extreme tertiles in our study vs 0-15% mis-classified into extreme quartiles/quintiles in previous studies [35; 37; 38; 39]). Very few studies have calculated Cohen's k statistics for adequate comparison. The relative validity of the paper-FFQ against 3DDR in assessing food groups intakes follows a similar pattern to energy and nutrients intakes. The paper-FFQ were adequately robust in classifying children according to food groups intakes except for noodles and pasta, desserts and sweet snacks, fast food and fried snacks; but the overall relative validity in estimation of absolute food groups intakes is weak despite similar correlation coefficients (0.22-0.70) to previous studies (0.07-0.76 [36; 40; 41]).

The relative validity of the web-FFQ against the 3DDR in examining absolute intakes of protein, fibre and micronutrients is acceptable to good but for energy, carbohydrate and fats is weak. Our correlation coefficients (0.19-0.67) were within the ranges (0.12-0.98) reported in previous studies examining relative validity of a web-FFQ self-administered by adults or children/adolescents [15; 33; 42; 43; 44; 45]. In line with previous studies [33; 44; 45], there was a generally poor agreement in absolute intakes between the web-FFQ and the reference method judging from Lin's concordance and Bland-Altman plots; however, it was encouraging to observe acceptable to good agreement for micronutrients. In contrast, the web-FFQ was able to classify children according to categories of energy and nutrients intakes with acceptable to good agreement (except carbohydrate). Our kappa values (0.20-0.61) were within the range reported in previous studies (-0.07-0.39 [33; 43]), and percentages of classification (36-58% same tertile) is comparable to one study which calculated tertile agreement (38-51% same tertile)[44]. Our correlation coefficients for food groups (0.19-0.67) were similar to previous studies (0.03-0.88 [33; 42; 43; 44; 46; 47]). There were acceptable to good agreement between web-FFQ and 3DDR in estimating absolute intakes of several food groups. Likewise, the web-FFQ were adequately robust in classifying children according to most food groups intakes except for poultry and meat, desserts and sweet snacks, fast food and fried snacks; and our kappa values (0.12-0.63) were comparable to previous studies (0.04-0.51 [33; 43]). None of these studies have performed cross-classifications into tertiles to allow direct comparison. The inclusion of portion size photographs for all food items in the web-FFQ likely improved the estimation of amounts consumed, which is in line with a previous review showing image-assisted dietary assessment to produce closer estimates to the reference method [48].

Taken together, we observed that both FFQs had poor relative validity with 3DDR in estimating macronutrients intakes especially carbohydrate and fats. This finding remisnisce several FFQ validation studies in Asian populations reporting poorer relative validity for macronutrients, which the authors speculate to be due to a much greater variation in foods/snacks which are high in carbohydrate and fat [49; 50]. Furthermore, both FFQs had poor relative validity with 3DDR in estimating intakes of desserts and sweet snacks, fast food and fried snacks. As compared to diet records over a few days, the habitual consumption of less frequently consumed foods may have been more accurately captured by FFQs which assesses consumption over the past month [3]. Thus, it is questionable whether 3DDR is a good reference method for validation of foods not commonly consumed on a daily basis such as desserts and sweet snacks, fast food and fried snacks intakes [15].

Although our results suggest both paper- and web-FFQs to have similar relative validity when compared to a 3DDR as the reference method, the overall positive acceptance of web-FFQ, as reflected by responses in the usability questionnaire, suggests that the web-FFQ is a feasible tool for future dietary data collection. Additionally, the web-FFQ addressed several limitations of the paper-FFQ: (1) more accurate estimation of food intakes with the help of portion size photographs evidenced by having similar median intakes and better concordance with 3DDR, (2) shorter time spent in completing the web-FFQ, and (3) absence of missing responses (with the exception of data loss due to technical issues). Furthermore, direct capture of data by the web system eliminates the need for data entry unlike the paper-FFQ.

The strength of this study includes counter-balancing the sequence of completing the dietary assessments, thus reducing the bias due to repeated administrations. Several limitations were noted that could affect the validation results. The use of a 3DDR as a reference method in our validation study makes interpretation of results challenging, as DRs are also subjected to self-reporting bias and only capture foods consumed over a few days thus not representative of foods consumed in a whole month [51]. Nonetheless, results from this study can be useful to guide choosing of most appropriate way to examine dietary intakes estimated using either FFQs (e.g. examining intakes as categorical variables, and focusing on micronutrients and certain food groups that have consistently shown acceptable-good relative validity). There may be fatigue in completing 3 dietary assessments within a span of 2 months thus affecting reporting accuracy. Another issue unique to children of this age group is the large variability in knowledge or information the mother has on foods that are eaten outside of their supervision such as when the child is in school.

In conclusion, our study demonstrates that the paper- and web-FFQs produce comparable estimates of dietary intakes, indicating that data collected from both FFQs can be combined. Both FFQs were relatively valid compared to a 3DDR in classifying children according to intakes of energy, nutrients and most food groups. Additional refinements and calibrations are needed in order to investigate absolute intakes estimated using both FFQs, although the web-FFQ demonstrated acceptable to good relative validity against 3DDR in assessing absolute intakes of micronutrients and several food groups. Nevertheless, the ability of our FFQs to accurately classify according to categories of intakes may be more conceptually important to examine in nutrition epidemiology rather than the absolute intakes. In addition, the web-FFQ has added advantages in terms of being more usable and preferred, shorter completion time, few missing responses, and less labour intensive; thus the web-FFQ is a feasible tool in replacement of the paper-FFQ to assess dietary intakes of GUSTO children.

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Authorship: JSL and MFFC designed the research. JSL and JL performed statistical analysis and wrote the manuscript. MFFC reviewed and edited the manuscript. JSL and MFFC had primary responsibility for final content. JYT and MTC contributed to the development of dietary assessments, data collection and cleaning. RS contributed to statistical analysis and data interpretation. KHT, FY, YSC and KMG led the GUSTO study. All authors critically reviewed the manuscript for scientific content, read and approved the final manuscript; agreed to be accountable for all aspects of the work.

References

1. Brisbois TD, Farmer AP, McCargar LJ (2012) Early markers of adult obesity: a review. *Obes Rev* **13**, 347-367.

2. Dwyer J (2006) Starting down the right path: nutrition connections with chronic diseases of later life. *Am J Clin Nutr* **83**, 415S-420S.

3. Willett W (2012) *Nutritional Epidemiology*. 3rd ed. New York: Oxford University Press.

4. Shim J-S, Oh K, Kim HC (2014) Dietary assessment methods in epidemiologic studies. *Epidemiology and health* **36**, e2014009-e2014009.

5. Olukotun O, Seal N (2015) A Systematic Review of Dietary Assessment Tools for Children Age 11 Years and Younger. *Infant Child Adolesc Nutr* **7**, 139-147.

6. Saravia L, Miguel-Berges ML, Iglesia I *et al.* (2020) Relative validity of FFQ to assess food items, energy, macronutrient and micronutrient intake in children and adolescents: a systematic review with meta-analysis. *Br J Nutr* **125**, 792-818.

7. Garcia-Segovia P, Gonzalez-Carrascosa R, Martinez-Monzo J *et al.* (2011) New technologies applied to food frequency questionnaires: a current perspective. *Nutr Hosp* **26**, 803-806.

8. Storey KE (2015) A changing landscape: web-based methods for dietary assessment in adolescents. *Curr Opin Clin Nutr Metab Care* **18**, 437-445.

9. Long JD, Littlefield LA, Estep G *et al.* (2010) Evidence review of technology and dietary assessment. *Worldviews Evid Based Nurs* **7**, 191-204.

10. Soh SE, Tint MT, Gluckman PD *et al.* (2014) Cohort profile: Growing Up in Singapore Towards healthy Outcomes (GUSTO) birth cohort study. *Int J Epidemiol* **43**, 1401-1409.

11. Sugianto R, Chan MJ, Wong SF *et al.* (2020) Evaluation of a quantitative food frequency questionnaire for 5-year-old children in an Asian population. *J Acad Nutr Diet* **120**, 437-444.

12. de Onis M, Onyango AW, Borghi E *et al.* (2007) Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ* **85**, 660-667.

13. Kristal AR, Kolar AS, Fisher JL *et al.* (2014) Evaluation of web-based, self-administered, graphical food frequency questionnaire. *J Acad Nutr Diet* **114**, 613-621.

14. Beasley JM, Davis A, Riley WT (2009) Evaluation of a web-based, pictorial diet history questionnaire. *Public Health Nutr* **12**, 651-659.

15. Labonte ME, Cyr A, Baril-Gravel L *et al.* (2012) Validity and reproducibility of a web-based, self-administered food frequency questionnaire. *Eur J Clin Nutr* **66**, 166-173.

16. Lim HX, Toh JY, Tan KH *et al.* (2019) Validation of a semi-quantitative FFQ for 18-month-old toddlers: the Growing Up in Singapore Towards Healthy Outcomes (GUSTO) study. *Public Health Nutr* **22**, 1990-2000.
17. Vereecken C, Covents M, Maes L *et al.* (2014) Formative evaluation of the dietary assessment component of Children's and Adolescents' Nutrition Assessment and Advice on the Web (CANAA-W). *J Hum Nutr Diet* **27 Suppl 1**, 54-65.
18. Vereecken CA, Covents M, Matthys C *et al.* (2005) Young adolescents' nutrition assessment on computer (YANA-C). *Eur J Clin Nutr* **59**, 658-667.
19. Carter MC, Albar SA, Morris MA *et al.* (2015) Development of a UK online 24-h dietary assessment tool: myfood24. *Nutrients* **7**, 4016-4032.
20. Moghames P, Hammami N, Hwalla N *et al.* (2016) Validity and reliability of a food frequency questionnaire to estimate dietary intake among Lebanese children. *Nutr J* **15**, 4.
21. Preston AM, Palacios C, Rodriguez CA *et al.* (2011) Validation and reproducibility of a semi-quantitative food frequency questionnaire for use in Puerto Rican children. *P R Health Sci J* **30**, 58-64.
22. Lin L (1989) A concordance correlation coefficient to evaluate reproducibility. *Biometrics* **45**, 255-268.
23. van Stralen KJ, Dekker FW, Zoccali C *et al.* (2012) Measuring agreement, more complicated than it seems. *Nephron Clin Pract* **120**, c162-c167.
24. Masson LF, McNeill G, Tomany JO *et al.* (2003) Statistical approaches for assessing the relative validity of a food-frequency questionnaire: use of correlation coefficients and the kappa statistic. *Public Health Nutr* **6**, 313-321.
25. Willett WC (1994) Future directions in the development of food-frequency questionnaires. *Am J Clin Nutr* **59**, 171s-174s.
26. Altman DG (1990) *Practical Statistics for Medical Research.* London: CRC Press.
27. Akoglu H (2018) User's guide to correlation coefficients. *Turk J Emerg Med* **18**, 91-93.
28. Landis JR, Koch GG (1977) The measurement of observer agreement for categorical data. *Biometrics* **33**, 159-174.
29. Al-Shaar L, Yuan C, Rosner B *et al.* (2020) Reproducibility and Validity of a Semiquantitative Food Frequency Questionnaire in Men Assessed by Multiple Methods. *Am J Epidemiol* **190**, 1122-1132.
30. Apovian CM, Murphy MC, Cullum-Dugan D *et al.* (2010) Validation of a web-based dietary questionnaire designed for the DASH (dietary approaches to stop hypertension) diet: the DASH online questionnaire. *Public Health Nutr* **13**, 615-622.

31. Forster H, Fallaize R, Gallagher C *et al.* (2014) Online dietary intake estimation: the Food4Me food frequency questionnaire. *J Med Internet Res* **16**, e150.

32. Lo Siou G, Csizmadi I, Boucher BA *et al.* (2017) The Comparative Reliability and Feasibility of the Past-Year Canadian Diet History Questionnaire II: Comparison of the Paper and Web Versions. *Nutrients* **9**.

33. Tabacchi G, Filippi AR, Breda J *et al.* (2015) Comparative validity of the ASSO - Food Frequency Questionnaire for the web-based assessment of food and nutrients intake in adolescents. *Food Nutr Res* **59**.

34. Kunaratnam K, Halaki M, Wen LM *et al.* (2018) Reliability and comparative validity of a Diet Quality Index for assessing dietary patterns of preschool-aged children in Sydney, Australia. *Eur J Clin Nutr* **72**, 464-468.

35. Marcinkevage J, Mayén A-L, Zuleta C *et al.* (2015) Relative Validity of Three Food Frequency Questionnaires for Assessing Dietary Intakes of Guatemalan Schoolchildren. *PLoS One* **10**, e0139125.

36. Vereecken C, Covents M, Maes L (2010) Comparison of a food frequency questionnaire with an online dietary assessment tool for assessing preschool children's dietary intake. *J Hum Nutr Diet* **23**, 502-510.

37. Rodriguez CA, Smith ER, Villamor E *et al.* (2017) Development and Validation of a Food Frequency Questionnaire to Estimate Intake among Children and Adolescents in Urban Peru. *Nutrients* **9**, 14.

38. Matos SM, Prado MS, Santos CA *et al.* (2012) Validation of a food frequency questionnaire for children and adolescents aged 4 to 11 years living in Salvador, Bahia. *Nutr Hosp* **27**, 1114-1119.

39. Scagliusi FB, Garcia MT, Indiani AL *et al.* (2011) Relative validity of a food-frequency questionnaire developed to assess food intake of schoolchildren living in the Brazilian Western Amazon. *Cad Saude Publica* **27**, 2197-2206.

40. Lillegaard ITL, Øverby NC, Andersen LF (2012) Evaluation of a short food frequency questionnaire used among Norwegian children. *Food Nutr Res* **56**.

41. Saeedi P, Skeaff SA, Wong JE *et al.* (2016) Reproducibility and Relative Validity of a Short Food Frequency Questionnaire in 9–10 Year-Old Children. *Nutrients* **8**, 271.

42. Deierlein AL, Bihuniak JD, Nagi E *et al.* (2019) Development of a Technology-Assisted Food Frequency Questionnaire for Elementary and Middle School Children: Findings from a Pilot Study. *Nutrients* **11**, 17.

43. Bjerregaard AA, Halldorsson TI, Kampmann FB *et al.* (2018) Relative validity of a web-based food frequency questionnaire for Danish adolescents. *Nutr J* **17**, 9.

44. Verger EO, Armstrong P, Nielsen T *et al.* (2017) Dietary Assessment in the MetaCardis Study: Development and Relative Validity of an Online Food Frequency Questionnaire. *J Acad Nutr Diet* **117**, 878-888.

45. Christensen SE, Moller E, Bonn SE *et al.* (2013) Two new meal- and web-based interactive food frequency questionnaires: validation of energy and macronutrient intake. *J Med Internet Res* **15**, e109.

46. Alawadhi B, Fallaize R, Franco RZ *et al.* (2021) Web-Based Dietary Intake Estimation to Assess the Reproducibility and Relative Validity of the EatWellQ8 Food Frequency Questionnaire: Validation Study. *JMIR Form Res* **5**, e13591.

47. Fallaize R, Forster H, Macready AL *et al.* (2014) Online dietary intake estimation: reproducibility and validity of the Food4Me food frequency questionnaire against a 4-day weighed food record. *J Med Internet Res* **16**, e190.

48. Boushey CJ, Spoden M, Zhu FM *et al.* (2017) New mobile methods for dietary assessment: review of image-assisted and image-based dietary assessment methods. *Proc Nutr Soc* **76**, 283-294.

49. Whitton C, Ho JCY, Tay Z *et al.* (2017) Relative Validity and Reproducibility of a Food Frequency Questionnaire for Assessing Dietary Intakes in a Multi-Ethnic Asian Population Using 24-h Dietary Recalls and Biomarkers. *Nutrients* **9**, 1059.

50. Noor Hafizah Y, Ang LC, Yap F *et al.* (2019) Validity and Reliability of a Food Frequency Questionnaire (FFQ) to Assess Dietary Intake of Preschool Children. *Int J Environ Res Public Health* **16**, 4722.

51. Kirkpatrick SI, Baranowski T, Subar AF *et al.* (2019) Best Practices for Conducting and Interpreting Studies to Validate Self-Report Dietary Assessment Methods. *J Acad Nutr Diet* **119**, 1801-1816.

Table 1: Average daily energy, nutrients and food groups intakes estimated from the paper- and web-based food frequency questionnaires, and 3-day diet records in the Growing Up in Singapore Towards healthy Outcomes cohort (n=92).

	Paper-FFQ		Web-FFQ		3-day DR		*P*
	Median	IQR	Median	IQR	Median	IQR	
Energy/Nutrients							
Energy, kcal/day	2110	1486, 2707	1448†	1135, 1893	1425†	1201, 1626	<.001
Carbohydrate, g/day	272.8	250.5, 296.3	206.0†	192.2, 218.2	197.6†	166.7, 226.6	.03
Protein, g/day	75.9	66.4, 84.7	51.2†	47.2, 54.3	50.8†	44.0, 61.4	.02
Total fat, g/day	66.4	58.0, 73.6	45.4†	41.5, 51.0	47.0†	36.4, 55.1	.03
Saturated fat, g/day	26.0	22.0, 29.7	17.9†	15.7, 20.7	17.4†	14.4, 20.5	<.001
Monounsaturated fat, g/day	21.7	13.2, 28.8	13.5†	9.9, 19.2	13.9†	10.6, 18.1	<.001
Polyunsaturated fat, g/day	8.8	7.4, 10.2	6.1†	5.5, 7.1	6.7†	5.6, 8.1	<.001
Fibre, g/day	13.1	11.2, 15.2	9.4	7.9, 11.2	8.7	7.5, 10.7	.97
Calcium, mg/day	752.0	599.3, 1011.6	570.6	443.8, 730.5	499.5	369.8, 698.9	<.001
Iron, mg/day	12.0	10.6, 14.1	9.2	7.7, 10.4	8.3	6.8, 10.2	.70
β-carotene, µg/day	788.8†	494.0, 1363.4	836.7†	458.5, 1287.4	596.2	312.3, 1099.0	.04
Vitamin A, IU/day	2226	1701, 2994	1836†	1331, 2344	1878†	1074, 2664	.004
Food groups (g/day)							
Breads	52.8	26.2, 82.8	41.8	22.5, 70.3	43.3	25.7, 73.8	.17

Rice	200.0	101.5, 280.0	128.6†	78.6, 232.1	133.3†	74.7, 218.9	.003
Noodles and pasta	122.4	52.3, 230.5	78.4†	42.8, 159.6	32.8†	75.8, 128.0	.007
Cruciferous and dark-green vegetables	2.9	0.6, 9.3	6.0	1.5, 13.1	8.5	0.0, 19.0	.11
Other vegetables	9.0†	3.1, 20.1	9.5†	4.3, 18.2	5.4	0.0, 25.8	.004
Fruits	129.1	64.0, 210.4	98.3	51.5, 158.1	42.4	0.0, 93.8	<.001
Poultry and meat	30.0	13.6, 54.9	8.8	4.8, 15.4	17.5	3.5, 40.4	<.001
Fish, seafood, and products	26.1	11.9, 56.3	14.3	8.1, 27.0	10.0	0.0, 23.1	<.001
Eggs	31.0	20.0, 52.7	22.6	11.9, 43.5	16.0	0.0, 32.6	<.001
Desserts and sweet snacks	62.5	30.2, 99.6	47.4	22.8, 69.7	32.2	9.9, 53.3	<.001
Fast food and fried snacks	39.2	28.2, 60.3	29.1	19.1, 45.9	19.3	0.0, 52.9	<.001
Milk‡	250.0	98.2, 500.0	158.0†	53.6, 318.8	159.0†	50.0, 300.0	.01
Dairy products (excluding milk)‡	146.7	59.0, 251.6	104.1†	54.4, 231.3	100.0†	2.5, 183.3	0.008

FFQ, food frequency questionnaire; DR, diet records, IQR, inter-quartile range

**P*-values are for Kruskal Wallis tests of differences between groups (†median values in a row without a common symbol differ, $P<.05$ based on Bonferroni post hoc analysis).

‡Intakes are expressed in units of millilitres/day instead of grams/day

Table 2: Pearson's correlation, Lin's concordance, Cohen's kappa, and cross-classification of tertiles between the paper- and web-based food frequency questionnaires in the Growing Up in Singapore Towards healthy Outcomes cohort (n=92).

	r*	95% CI	r_c*	95% CI	κ	95% CI	% correct tertile	% extreme tertiles
Energy/Nutrients								
Energy	0.60	0.45, 0.72	0.46	0.33, 0.58	0.53	0.34, 0.67	56.5	6.5
Carbohydrate	0.54	0.38, 0.67	0.16	0.09, 0.22	0.51	0.33, 0.68	57.6	7.6
Protein	0.57	0.42, 0.70	0.13	0.08, 0.18	0.46	0.25, 0.62	57.6	9.8
Total fat	0.51	0.34, 0.65	0.18	0.10, 0.25	0.49	0.31, 0.66	62.0	9.8
Saturated fat	0.62	0.47, 0.73	0.31	0.21, 0.41	0.48	0.30, 0.64	53.3	7.6
Monounsaturated fat	0.63	0.49, 0.74	0.31	0.22, 0.41	0.51	0.33, 0.67	57.6	7.6
Polyunsaturated fat	0.68	0.55, 0.78	0.32	0.22, 0.41	0.69	0.56, 0.81	65.2	2.2
Fibre	0.56	0.40, 0.68	0.32	0.21, 0.43	0.57	0.41, 0.70	56.5	4.4

Calcium	0.72	0.61, 0.81	0.60	0.49, 0.71	0.69	0.55, 0.79	65.2	2.2
Iron	0.63	0.49, 0.74	0.36	0.25, 0.46	0.40	0.32, 0.64	55.4	7.6
β-carotene	0.69	0.56, 0.78	0.69	0.58, 0.80	0.46	0.26, 0.60	51.1	7.6
Vitamin A	0.75	0.64, 0.83	0.65	0.54, 0.75	0.69	0.53, 0.80	68.5	3.3
Food groups								
Breads	0.50	0.33, 0.64	0.43	0.28, 0.56	0.55	0.40, 0.64	53.1	4.4
Rice	0.66	0.53, 0.76	0.60	0.46, 0.71	0.63	0.50, 0.73	61.1	3.5
Noodles and pasta	0.47	0.30, 0.62	0.47	0.29, 0.61	0.45	0.28, 0.60	48.7	7.1
Cruciferous and dark-green vegetables	0.69	0.56, 0.78	0.68	0.56, 0.78	0.55	0.40, 0.69	58.4	6.2
Other vegetables	0.68	0.55, 0.78	0.68	0.56, 0.78	0.34	0.11, 0.49	50.9	13.2
Fruits	0.72	0.60, 0.81	0.58	0.48, 0.67	0.45	0.32, 0.58	43.4	5.3

Poultry and meat	0.81	0.73, 0.87	0.70	0.60, 0.78	0.56	0.42, 0.70	55.7	4.7
Fish, seafood, and products	0.63	0.49, 0.74	0.59	0.47, 0.69	0.45	0.30, 0.60	56.6	9.7
Eggs	0.80	0.71, 0.86	0.75	0.66, 0.82	0.56	0.45, 0.67	52.8	3.8
Desserts and sweet snacks	0.54	0.38, 0.67	0.51	0.35, 0.64	0.42	0.13, 0.56	50.9	9.4
Fast food and fried snacks	0.77	0.68, 0.85	0.72	0.62, 0.80	0.49	0.30, 0.61	57.6	8.5
Milk	0.87	0.81, 0.91	0.84	0.77, 0.89	0.71	0.59, 0.82	71.7	3.5
Dairy products (excluding milk)	0.23	0.03, 0.42	0.23	0.03, 0.40	0.51	0.33, 0.63	55.7	7.1

r, Pearson's correlation coefficient; r_c, Lin's concordance coefficient; κ, Cohen's kappa coefficient

*Based on log-transformed, energy-adjusted values

Table 3: Pearson's correlation, Lin's concordance, Cohen's kappa, and cross-classification of tertiles between the paper-based food frequency questionnaire and 3-day diet records in the Growing Up in Singapore Towards healthy Outcomes cohort (n=92).

	*r**	95% CI	r_c*	95% CI	κ	95% CI	% correct tertile	% extreme tertiles
Energy/Nutrients								
Energy	0.31	0.11, 0.48	0.17	0.06, 0.28	0.28	0.04, 0.47	46.7	14.1
Carbohydrate	0.38	0.19, 0.54	0.08	0.04, 0.12	0.30	0.09, 0.51	48.9	14.1
Protein	0.39	0.31, 0.63	0.16	0.09, 0.23	0.39	0.20, 0.58	52.2	10.9
Total fat	0.26	0.06, 0.45	0.09	0.02, 0.16	0.25	0.04, 0.41	47.8	13.0
Saturated fat	0.19	0.01, 0.39	0.09	0.01, 0.17	0.25	0.09, 0.48	42.4	12.0
Monounsaturated fat	0.22	0.02, 0.41	0.11	0.01, 0.19	0.28	0.03, 0.53	50.0	13.1
Polyunsaturated fat	0.23	0.03, 0.42	0.15	0.02, 0.28	0.20	0.01, 0.50	43.5	17.4
Fibre	0.45	0.28,	0.24	0.13,	0.46	0.29,	44.6	5.4

		0.60		0.35		0.60		
Calcium	0.70	0.58, 0.79	0.46	0.35, 0.56	0.61	0.44, 0.74	64.1	5.4
Iron	0.50	0.33, 0.64	0.23	0.13, 0.31	0.44	0.26, 0.59	48.9	7.6
β-carotene	0.46	0.28, 0.60	0.40	0.25, 0.56	0.31	0.03, 0.46	50.0	13.0
Vitamin A	0.46	0.28, 0.61	0.38	0.24, 0.53	0.44	0.24, 0.63	55.4	9.8
Food groups								
Breads	0.44	0.26, 0.59	0.26	0.14, 0.37	0.33	0.17, 0.44	44.1	11.2
Rice	0.30	0.11, 0.48	0.27	0.09, 0.43	0.28	0.08, 0.40	44.1	13.4
Noodles and pasta	0.34	0.14, 0.51	0.28	0.12, 0.44	0.17	0.03, 0.30	46.4	19.0
Cruciferous and dark-green vegetables	0.52	0.36, 0.66	0.52	0.35, 0.65	0.40	0.25, 0.53	54.2	10.0
Other vegetables	0.35	0.16, 0.52	0.26	0.11, 0.40	0.33	0.19, 0.51	49.2	12.9
Fruits	0.52	0.35,	0.21	0.17,	0.45	0.33,	53.1	8.9

		0.65		0.30		0.58		
Poultry and meat	0.43	0.25, 0.59	0.31	0.17, 0.43	0.38	0.21, 0.50	44.1	8.9
Fish, seafood, and products	0.47	0.29, 0.61	0.31	0.18, 0.44	0.37	0.24, 0.46	44.7	9.5
Eggs	0.43	0.25, 0.58	0.25	0.13, 0.36	0.33	0.19, 0.46	47.5	12.3
Desserts and sweet snacks	0.22	0.02, 0.41	0.15	0.01, 0.29	0.20	0.08, 0.35	42.5	16.2
Fast food and fried snacks	0.28	0.07, 0.45	0.06	0.02, 0.11	0.14	0.01, 0.26	39.7	17.9
Milk	0.70	0.57, 0.79	0.69	0.58, 0.77	0.63	0.56, 0.74	57.5	2.2
Dairy products (excluding milk)	0.34	0.14, 0.51	0.17	0.07, 0.26	0.38	0.23, 0.51	49.2	10.6

r, Pearson's correlation coefficient; r_c, Lin's concordance coefficient; κ, Cohen's kappa coefficient

*Based on log-transformed, energy-adjusted values

Table 4: Pearson's correlation, Lin's concordance, Cohen's kappa, and cross-classification of tertiles between the web-based food frequency questionnaire and 3-day diet records in the Growing Up in Singapore Towards healthy Outcomes cohort (n=92).

	r*	95% CI	r_c*	95% CI	κ	95% CI	% correct tertile	% extreme tertiles
Energy/Nutrients								
Energy	0.26	0.06, 0.44	0.23	0.06, 0.41	0.31	0.11, 0.50	44.6	12.0
Carbohydrate	0.21	0.01, 0.40	0.19	0.01, 0.38	0.20	0.01, 0.40	45.7	17.4
Protein	0.35	0.15, 0.51	0.32	0.14, 0.48	0.34	0.14, 0.53	55.4	14.1
Total fat	0.28	0.08, 0.46	0.28	0.09, 0.47	0.30	0.07, 0.44	43.5	13.1
Saturated fat	0.19	0.01, 0.38	0.18	0.01, 0.35	0.31	0.11, 0.51	35.9	12.0
Monounsaturated fat	0.29	0.09, 0.47	0.29	0.09, 0.46	0.46	0.28, 0.60	51.1	9.8
Polyunsaturated fat	0.24	0.04, 0.43	0.22	0.04, 0.39	0.36	0.19, 0.56	45.7	13.0
Fibre	0.44	0.26,	0.44	0.27,	0.30	0.09,	46.7	14.1

		0.59		0.60		0.46		
Calcium	0.67	0.54, 0.77	0.61	0.49, 0.73	0.61	0.51, 0.71	53.3	3.3
Iron	0.52	0.35, 0.65	0.47	0.32, 0.62	0.51	0.32, 0.70	57.6	7.6
β-carotene	0.53	0.37, 0.67	0.47	0.32, 0.61	0.36	0.19, 0.56	41.3	10.9
Vitamin A	0.39	0.20, 0.55	0.35	0.18, 0.51	0.39	0.16, 0.53	44.6	9.8
Food groups								
Breads	0.31	0.11, 0.49	0.27	0.10, 0.43	0.31	0.20, 0.46	45.4	12.4
Rice	0.33	0.13, 0.51	0.32	0.12, 0.50	0.39	0.30, 0.54	48.1	9.7
Noodles and pasta	0.36	0.17, 0.53	0.40	0.26, 0.52	0.30	0.18, 0.42	47.4	13.5
Cruciferous and dark-green vegetables	0.58	0.42, 0.70	0.57	0.43, 0.71	0.43	0.33, 0.56	53.5	9.7
Other vegetables	0.41	0.23, 0.57	0.32	0.17, 0.45	0.36	0.21, 0.48	51.9	12.4
Fruits	0.40	0.21,	0.26	0.18,	0.42	0.30,	54.2	10.0

		0.55		0.34		0.54		
Poultry and meat	0.36	0.16, 0.52	0.29	0.13, 0.43	0.20	0.04, 0.35	41.1	15.7
Fish, seafood, and products	0.51	0.34, 0.64	0.40	0.26, 0.53	0.29	0.17, 0.42	43.8	13.0
Eggs	0.44	0.25, 0.59	0.33	0.18, 0.46	0.37	0.26, 0.48	48.1	10.8
Desserts and sweet snacks	0.21	0.01, 0.39	0.16	0.01, 0.32	0.12	0.01, 0.24	38.4	18.4
Fast food and fried snacks	0.23	0.02, 0.41	0.05	0.01, 0.09	0.20	0.05, 0.36	46.0	17.3
Milk	0.76	0.65, 0.83	0.72	0.62, 0.81	0.63	0.54, 0.74	59.5	2.7
Dairy products (excluding milk)	0.36	0.22, 0.49	0.14	0.01, 0.26	0.34	0.20, 0.46	49.7	12.4

r, Pearson’s correlation coefficient; r_c, Lin’s concordance coefficient; κ, Cohen’s kappa coefficient

*Based on log-transformed, energy-adjusted values

Figure Legends

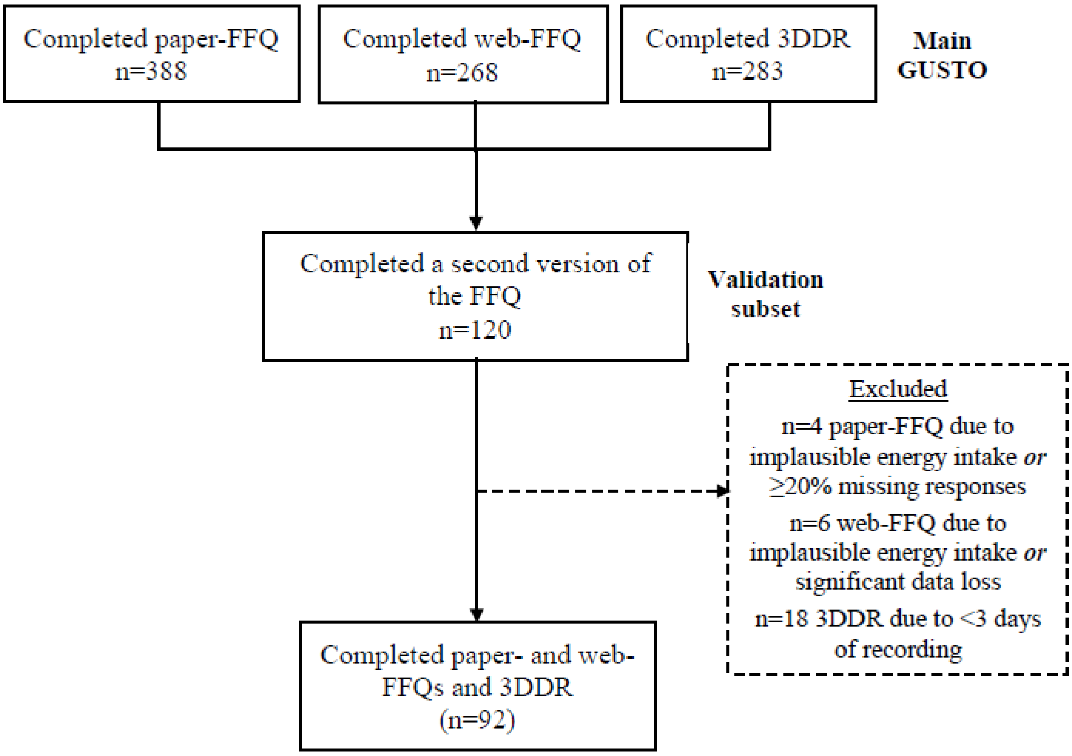

Figure 1: Flow chart of mother-child pairs included in evaluation of the food frequency questionnaires in the Growing Up in Singapore Towards healthy Outcomes study. 3DDR, 3-day diet records; FFQ, food frequency questionnaire; GUSTO, Growing Up in Singapore Towards healthy Outcomes

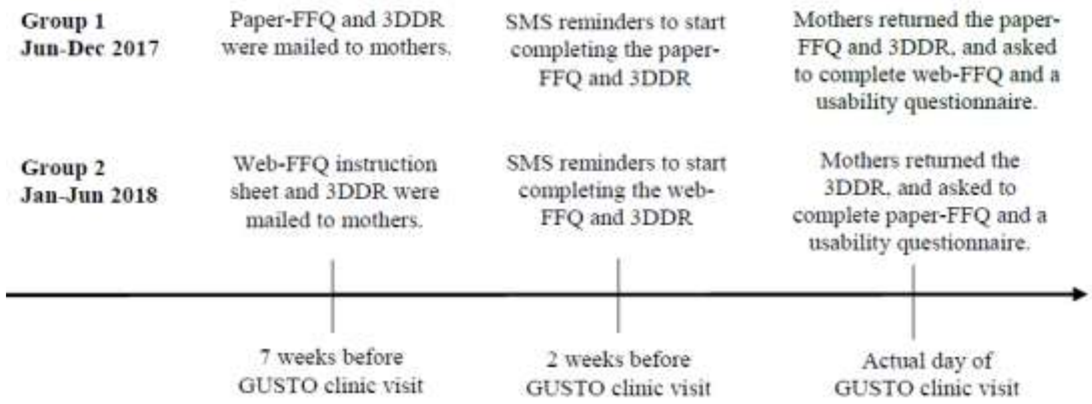

Figure 2: Timeline of food frequency questionnaires and diet records administration for evaluation of the web-based, pictorial food frequency questionnaire in the Growing Up in Singapore Towards healthy Outcomes study. 3DDR, 3-day diet records; FFQ, food frequency questionnaire; GUSTO, Growing Up in Singapore Towards healthy Outcomes; SMS, short message service

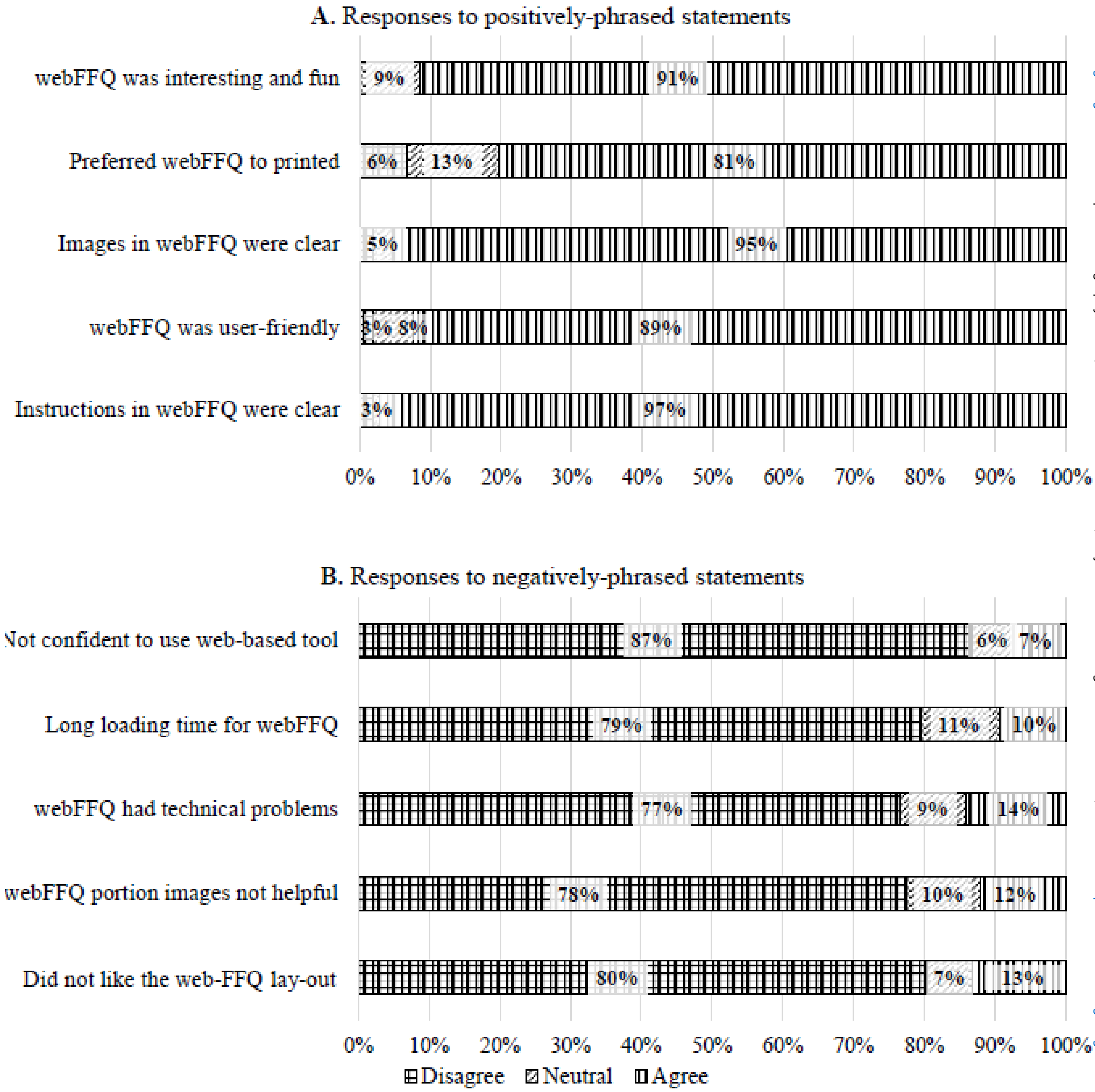

Figure 3: Percentages of participants (n=89) agreeing or disagreeing to positively-phrased (A) and negatively-phrased (B) usability questionnaire statements for web-FFQ. FFQ, food frequency questionnaire