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RESEARCH ARTICLE

Development and validation of a quantitative food frequency questionnaire to assess free sugar intake among Sri Lankan preschool children

Shanika Mututanthri[1,2]*, Tharanga Thoradeniya[3] and Rebecca Harris[1]

[1]Department of Public Health Policy and Research, University of Liverpool, Liverpool, UK
[2]Department of Public Health Policy and Research, Ministry of Health Sri Lanka, Liverpool, UK
[3]Biochemistry and Molecular Biology, University of Colombo Faculty of Medicine, Colombo, Sri Lanka

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Abstract

The present study aims to develop a quantitative food frequency questionnaire (FFQ) to assess free sugar intake as a whole and at the food group levels, retrospectively, over the past 3 months among 4 to 5-year-old preschool children in the Colombo district, Sri Lanka. Then, to assess its reliability and relative validity. In the development phase, three 24-hour dietary recalls (24 hDRs) of 518 preschool children were collected from caregivers. Based on that, a 67-item FFQ was developed, including commonly consumed free sugar-containing food items. The validation study was conducted among another 108 preschool children. The relative validity of the FFQ was assessed by comparing it with the 24 hDRs. The test–retest reliability was assessed by repeated application of the FFQ to the same population after 6 weeks. Wilcoxon sign rank test, cross-classification with weighted Kappa statistic, Spearman rank correlation and Bland–Altman plots were used for comparison. Comparing the free sugar intake calculated by the two methods showed no difference ($P = 0{\cdot}13$), a good correlation (0·89), good agreement in cross-classifying participants (78·4 % correctly classified) and a good agreement in Bland–Altman plots. Repeated application of the FFQ yielded; no differences in free sugar intake values ($P = 0{\cdot}45$) a good correlation (0·71), acceptable agreement in cross-classifying participants (52·3 % correctly classified) and acceptable agreement in the Bland–Altman plot. Results were the same for all food groups. According to the results, the newly developed quantitative FFQ provides a relatively valid and reliable measure for quantifying free sugar intake among preschool children as a whole or by food group.

Key words: Development: Food frequency questionnaire (FFQ): Free sugar intake: Preschool children: Relative validation

Introduction

The World Health Organization strongly recommends that the consumption of free sugars should be limited to less than 10 % of energy intake[1]. Free sugars are defined as 'monosaccharides and disaccharides added to food and beverages by the manufacturer, cook or consumer, and sugars naturally found in honey, syrups, fruit juices and fruit juice concentrates'[1]. These do not include sugars found in milk or in fruits and vegetables (intrinsic sugars), since the latter is bound by a cell wall, which reduces their bioavailability[2]. Excess free sugar intake is associated with numerous adverse health outcomes: predominantly non-communicable diseases, for example, obesity, diabetes, cardiovascular diseases, several forms of cancers and dental disease[1,3]. Thus health authorities have looked for mechanisms to facilitate curtailing the intake of sugars in recent years[4].

Free sugar is associated with a number of health problems among children in Sri Lanka. For instance, early childhood dental caries (ECC) is a significant public health issue affecting about 63 % of 5-year-olds which is a long-standing public health issue in the country[5]. In Sri Lanka, obesity is also an emerging health problem among children, affecting 1·2 % of

* **Corresponding author:** Shanika Mututanthri, email shanikaayanthi1976@gmail.com

5-year-olds, and 2·7 % of teenagers at 15 years of age[6]. Among adults, obesity is a serious problem in the country, with 5·9 % obese and 23·4 % overweight[7] which is more prominent in the urban area like Colombo 23·5 % (95 % CI 17·9, 29·1) being obese and 34·8 % (95 % CI 28·5, 41·1) being overweight[8]. It is therefore highly recommended to track free sugar intake at the population level and reduce free sugar intake through population-level approaches. Dietary assessment tools provide a means of comparison of nutrient intake among various populations and evaluating progress towards nutritional goals in a population. For example, the computer-assisted 24-HDRmSACINA tool has allowed the comparison of free sugar consumption between eight European countries[9], showing that less than 20 % of children are within the less than 10 % of energy from free sugars recommendation.

Implementation of these tools in a global health setting such as Sri Lanka however is challenging; firstly because of limited finances dedicated to health monitoring and secondly because of the need to tailor it to the traditional food context. Also, with ECC a key concern in Sri Lanka, a dietary tool that especially reflects the main aetiological factor of dental caries is needed, for population surveillance. Several dietary assessment tools are available in Sri Lanka, although there are no specifically designed tools to assess free sugar intake, particularly among preschool children.

Despite weighted dietary records being the gold standard in nutritional epidemiology, they have inherent limitations like being costly to use in large-scale community-based studies, requiring great commitment from participants, and having a high burden on them[10]. Oppositely, a food frequency questionnaire (FFQ) is inexpensive and simple to administer particularly for a large cluster imposing less burden on the respondent. Moreover, it captures the habitual day-to-day dietary intake of an individual, over an extended period of time retrospectively, avoiding short-term disparities, like seasonal variations and dietary alterations during the periods of illnesses[11,12] which make the FFQ the tool of choice in the present study. Due to the absence of precise recall of food taken, the respondent burden is also less than that of dietary records. FFQ should be specifically designed for the target population as food and beverages are mostly culture-specific[13,14], and should be assessed for relative validity and reliability prior to use[12,15]. This FFQ was developed for two purposes. First, to assess free sugar intake among preschool children in a broader, more representative sample, compare it to WHO recommendations, and determine factors associated with free sugar intake. Additionally, to assess the relationship between free sugar intake and dental caries status of those children and to identify safe free sugar intake levels that will not increase their risk of dental caries. For the purposes of determining the cariogenic effect of different types of sugary foods, in addition to analysing total free sugar intake, the food group level was also analysed. According to the literature, the majority of FFQs ask about intakes during the past year, but others ask about consumption in recent months[10]. A 3 months period was selected for the current FFQ evaluation considering the minimum adequate period for representation of the child's usual diet without much respondent burden to recall. Hence, the purpose of the present study was to develop a self-administered quantitative FFQ that could be used to estimate preschool children's free sugar intake retrospectively for 3 months as a whole and by food and beverage groups. Following that, to assess the relative validity by comparing it with three 24 h dietary recalls and test–retest reliability will be assessed by repeated application of FFQ.

Experimental methods

The present study had two main phases. In the first phase, the FFQ was developed based on a cross-sectional study of preschool children in order to identify free sugar-containing food and beverages. In the second phase, another preschool-based study to evaluate the relative validity and reliability of the FFQ.

Development phase

Study population. A cross-sectional study was conducted to identify the commonly consumed free sugar-containing food and beverage items by preschool children in the Colombo district. For the initial phase of the study, 518, apparently healthy 4 to 5-year-old preschool children were enrolled randomly from 26 preschools. These twenty-six preschools were selected from the registered preschool list of Colombo as two random preschools from each district secretariat division in the Colombo district using the registered preschool list. The inclusion criteria were those who were residing in the district from birth to avoid district variation in diet and water fluoride levels (important for the next stage of the study), were not on a special diet and a primary caregiver was available for data collection. Simple random sampling was used to select twenty children from each preschool.

Development of the FFQ. During this phase, all the food and beverage consumption data of the included children were collected by face-to-face interviews with the primary caregivers based on 24 h dietary recalls (24 hDRs), covering one weekend day and two weekdays. The food items were identified but not quantified. In Sri Lankan preschools, children take food from home, so caregivers are aware of the child's food intake at preschool. A specific question was asked about the foods to which sugar is added during preparation. Initially, the identified food and beverage items were listed, and then all food and beverage items that contained free sugar were extracted into a separate list. To determine whether sugar is incorporated during the production of each food item, food recipes from manufacturers, reputed Sri Lankan recipe books, and food labels were reviewed. Items consumed by less than 5 % of participants were removed. The final dietary inventory list included sixty free sugar-containing food and beverage items, as well as seven food and beverage items to which caregivers commonly added sugar at the time of consumption. Finally, the identified free sugar-containing food and beverage items were classified into seven groups by two nutrition specialists based on the similarity of consistency and preparation methods[11,16,17] as biscuits (eleven items), bakery products (twelve items), sugar confectionery (nine items), chocolate confectionery (four items), sugar-sweetened beverages (nine items) and desserts (nine items). To emphasise the high intake, biscuits were separated from other bakery items. The remaining items which cannot be classified to above groups were classified as miscellaneous sweets (six items). In the FFQ, these were listed according to descending frequency of intake. The commonly used measures for quantification of each food and beverage item were identified: for example, different sizes of glasses (for beverages), cups (for desserts) and a spoon (for table sugar). For solid foods, some actual food items were identified in available smallest portions in the market, such as toffees, pieces of chocolate, biscuits and more. The presentation included photographs of the actual portion sizes, as well as measuring instruments to demonstrate on a laptop when collecting data. In the relevant column of the FFQ, participants were requested to write 1/2, 1, 1 1/2, etc., as the portion sizes child usually consume based on the PowerPoint presentation.

Frequency options were included as 'never' or 'times per day/per week or per month' for the respondent to write the frequency in numbers in the relevant column. FFQ is also dependent on the evaluation period. According to the literature, the majority of FFQs ask about intakes during the past year, but others ask about consumption in recent months[14]. This FFQ was designed to assess the food intake over the past 3 months The FFQ was originally developed in Sinhala and translated to Tamil and English using forward and backward translation methodology. The FFQ and the PowerPoint presentation were pretested among twenty caregivers of preschool children to ensure clarity of instructions, food names and portion sizes. The participants were selected from adjacent areas to the main study area. Pretesting took place in both languages in which data was collected. According to the findings, a few alterations were done. Approximately 40 to 45 min were taken to complete the FFQ.

Compilation of the food composition database. Since the existing food composition databases for Sri Lankan foods do not provide accurate free sugar content of these food and beverage items, the researchers compiled a comprehensive database on the free sugar content of the identified seventy-eight (sixty in the FFQ and eighteen new items identified in the 24 hDRs) food and beverage items employing a number of methods. Mainly free sugar was estimated from the ingredients (recipe calculation). Recipes were collected from the manufacturers of the most frequently used brands and popular bakers and reputed Sri Lankan recipe books. Almost all identified foods and beverages except bottled fruit drinks, jam, cordial, fresh fruit juices and honey have only five ingredients containing free sugar, those were white or brown sugar, icing sugar, high fructose corn syrup (HFCS 55), fructose syrup and glucose syrup. Free sugar was not present in any other ingredient. These syrups were analysed for free sugar content as described below. Based on the amounts in the recipe free sugar concentration for 100 g/100 ml of each food and beverage item was calculated. When there was more than one brand per food or beverage item average value was calculated.

High fructose corn syrup (HFCS 55), fructose syrup and glucose syrup and the food items bottled fruit drinks, jam, cordial, honey and selected three fruit juices were analysed for the free sugar content using random samples from most popular brands and bakers. Approximately ten samples were analysed from each item. The analysis was done by an experienced chemist using the Liquid chromatography technique (Waters HPLC machine with refractive index detector) using the method described by Petkova et al.[18] The free sugar content was calculated by adding up the amounts of all monosaccharides and disaccharides and the average of the samples was used for the database.

Validation phase

To determine the relative validity of the FFQ, 24 hDRs for 3 d, were used as the reference method. In FFQ validation, this is one of the most commonly used methods[15]. The test–retest reliability of the FFQ was determined by administering the same FFQ twice to the same population 6 weeks apart.

Study population. During the validation phase of the study, we recruited an additional 113 preschool children aged 4 to 5 years from 10 preschools, as the minimum sample size required to achieve a 5 % significance level and 80 % power to demonstrate a minimum correlation of 0·3[24] with 10 % of non-response rate. However, only 108 participants completed all three stages of data collection. As the FFQ was developed to assess the free sugar intake of preschool children in the Colombo district in the next phase, to avoid contamination validation study was conducted in two adjacent district secretariats outside the Colombo district. The registered preschool list was collected from the district secretariat of the relevant area and simple random sampling was used to select five preschools from each area. Healthy children who did not follow a special diet and whose primary caregivers were available for data collection were included in the study after receiving informed consent.

Dietary assessment. Data were obtained by meeting with the child's primary caregiver in 3 d in the preschool premises. The same FFQ was completed as a self-administered questionnaire at the first visit (FFQ1) and at the third visit (FFQ2) 6 weeks later. Participants gathered in groups of ten in a hall, and the researcher gave clear instructions to complete the FFQ, followed by exercises with some hypothetical examples. The FFQ was then completed based on the child's usual diet for the past 3 months. As participants completed the FFQ, the researcher presented each food and drink's serving size one by one using a PowerPoint presentation on a laptop. Researchers were able to collect data from each participant simultaneously during the presentation by using a

PowerPoint presentation. Due to the fact that the demonstration was done on a laptop, it was able to display actual-size pictures instead of a projected image.

Following that, the participants were interviewed individually by two interviewers during each visit and three, 24 hDRs were obtained to cover one weekend day and two weekdays. Photographs of same PowerPoint presentation was used for portion size estimation.

Data analysis

Calculation of free sugar intake. First, all the number of portions were converted to grams and millilitres by multiplying them with the weight or volume of the portion.

The daily total free sugar intake of each child was calculated, separately through FFQ1, FFQ2 and the 2 4hDRs.

➢ Using the FFQ, free sugar intake from each food and beverage item was calculated by multiplying the amount of intake, frequency of intake and free sugar concentration of the item.
➢ Daily intake of free sugar was calculated by dividing weekly intake by 7 and monthly intake by 30·4. The total daily free sugar intake was calculated by adding all these daily free sugar intake values.
➢ Using 24 hDRs, free sugar intake was calculated by multiplying the amount of intake by the free sugar concentration of the item.
➢ When free sugar intake from items was added together, the daily free sugar intake was calculated for two weekdays and weekend day. Due to the significant difference in sugar intake between weekdays and weekend days among some participants, the simulated week's free sugar intake was calculated for five weekdays and two weekend days. Next, an average daily intake is calculated.
➢ The same panel of nutrition experts classified eighteen additional food and beverage items identified by 24 hDRs into the same groups as in FFQ.

Statistical analysis

Relative validity was assessed through the comparison of free sugar intake calculated from FFQ1 with the mean free sugar intake calculated from the 24 hDRs, while reliability was assessed by comparing the free sugar intake values calculated from FFQ1 and FFQ2 (repeated application of the same FFQ). For comparison, we looked at the free sugar intake from different groups of foods and beverages separately, as well as the total amount of free sugar intake. The results were interpreted according to the criteria established by Lombard et al.[19]

Data were analysed using SPSS version 21. The following statistical methods were used for the comparison; by comparing two measurements, the Wilcoxon sign rank test determines the level of agreement between the two methods at the group level. Cross-classification of participants into quartiles based on their free sugar intake levels indicates the capacity of the dietary assessment method to rank participants according to their free sugar intake levels, which is further investigated using the weighted kappa statistic. Spearman rank correlation was used to measure the degree to which the two administrations are related. The agreement across the range of intakes was assessed using Bland–Altman plots[11,19,20]. In addition, the intraclass correlation coefficient (ICC) was used only for the assessment of reliability. Several statistical approaches were utilised simultaneously as they analyse various aspects of relative validity and reliability. A P-value of less than 0·05 was considered to be statistically significant.

Results

Although 4- to 5-year-old (48–71-month-old) children participated in both the development and validation phases, the majority were belonged to the age group 48–59 months. There is a relatively high percentage of females participating, and the majority of participants come from the Sinhala ethnic group (Table 1).

Free sugar intake data as a total and group level according to FFQ1, FFQ2 and the 24 hDRs create an asymmetrical, skewed curve on a graph. The median values for total free sugar (interquartile range) of 64 (40–112) g/d, 57 (29–103) g/d and 62 (41–98) g/d, respectively. The Wilcoxon sign rank test demonstrated no significant difference between total free sugar intake measured through the FFQ1 and the 24hDRs ($P = 0·13$), and FFQ1 and FFQ2 ($P = 0·45$), which was also observed at the levels of food and beverage groups as shown in Table 2. None of the differences were statistically significant.

As shown in Table 3, in assessing reliability, for total free sugar, the percentages correctly classified into the same quartiles were 78·4 %, and for sugary food groups, the percentages ranged from 60·7 % to 72·9 %. However, the percentages misclassified into the opposite quartiles were 4·6 % for total free sugar and varies from 3·2 % to 11·2 % for groups. The weighted kappa coefficient value was 0·81 for total free sugar and 0·58 to 0·77 at the group level when comparing FFQ1 with the 24 hDRs.

In assessing relative validity, total free sugar intake measured by two applications of FFQ, 52·3 % were correctly classified

Table 1. Basic demographic characteristics of the participants

	Development study (N 518)		Validation study (N 108)	
Variable	Number	Percentage	Number	Percentage
Age				
48–59 months	353	68·1	77	71·3
60–71 months	165	31·9	31	28·7
Sex				
Girl	275	53·1	57	52·8
Boy	243	46·9	51	47·2
Ethnicity				
Sinhala	394	76·1	86	79·7
Tamil	77	14·9	11	10·1
Moor	43	8·3	09	8·3
Other	04	0·7	02	1·9
Total	**518**	**100**	**108**	**100**

Table 2. Median free sugar intake from different food groups according to FFQ1, FFQ2 and the 24 hDRs; significance of differences (*N* 108)

	FFQ1*		FFQ2*		The 24 hDR*			
Food and beverage group	Median	IQR**	Median	IQR**	Median	IQR**	Significance FFQ1 *v.* the, 24 hDRs	Significance FFQ1 *v.* FFQ2
Biscuits	5·81	2·05–13·88	8·09	4·2–16·09	5·70	3·09–13·44	*P* = 0·76	*P* = 0·78
Bakery products	13·89	6·65–28·68	11·87	5·12–23·97	17·55	7·25–25·18	*P* = 0·40	*P* = 0·46
Sugar confectionery	5·78	2·15–21·79	6·21	2·43 16·02	6·47	3·21–18·86	*P* = 0·20	*P* = 0·40
Chocolate confectionery	5·98	0·42–4·18	1·08	0·36–3·80	1·24	0·00–5·18	*P* < 0·01	*P* = 0·03
Sugar-sweetened beverages	3·72	1·85–6·2	2·83	1·14–6·86	3·21	1·28–6·37	*P* = 0·08	*P* = 0·04
Desserts	4·31	1·93–8·07	4·00	1·69–6·84	4·56	2·31–7·89	*P* = 0·33	*P* = 0·63
Miscellaneous sweets	0·37	0·09–1·12	0·37	0·09–1·12	0·49	0·00–1·27	*P* < 0·01	*P* = 0·36
Table sugar	11·25	0·00–0·19	10·1	4·00–6·00	6·84	2·09–8·19	*P* = 0·23	*P* = 0·08
Total free sugar	64·46	39·9–111·52	56·95	29·38–102·77	61·78	41·33–97·82	*P* = 0·13	*P* = 0·45

* Free sugar intake was measured in g/d (median and IQR).
** IQR, interquartile range.
Z, *Z*-value on Wilcoxon sign rank test; *P*, probability value.

into the same quartiles, while 46·3–58·9 % were classified correctly at the group level. Total free sugar misclassification was 6·7 and group misclassifications ranged from 7·4 % to 11·4 %. The weighted kappa coefficient for total free sugar was 0·58 and varied from 0·44 to 0·55 for the group level.

In comparing the FFQ1 with the 24 hDRs, the Spearman rank correlation coefficient (SCC) was 0·89 for total free sugar and ranged from 0·70 to 0·88 for food and beverage groups. Repeated application of the FFQ resulted in a SRC of 0·71 for total free sugar, and a range of 0·50–0·71 for food and beverage groups. In addition, ICCs were calculated to assess reliability between repeated application of the FFQ was 0·61 (95 % CI 0·51, 0·69) for total free sugar and ranged from 0·44 to 0·86 for food and beverage groups (Table 4).

The agreement between the two methods was evaluated graphically by plotting the Bland–Altman plots for total free sugar intake. Comparisons of free sugar intake values from FFQ1 with the 24 hDRs (Fig. 1) by visual inspection of the graphs showed no difference throughout the range of intake and less than 5 % of participants were found outside the limits of agreement. Furthermore, the Bland–Altman plot (Fig. 2) indicated a good agreement free sugar intake from repeated application of FFQ (FFQ1 and FFQ2) and only 5 % of participants were found outside the limits of agreement. In both instances, the limits of agreements are wide.

Discussion

The literature on the development of FFQ for the assessment of sugar intake is sparse, and most were designed for various age groups, and the types of sugar they were referring to were different, which makes it hard to compare them to the current FFQ.

The Wilcoxon sign rank test between FFQ1 and the 24 hDRs and between the two applications of FFQ reveal no significant difference in total free sugar intake or at food group levels. It can therefore be established that the FFQ was relatively valid and reliable for estimating free sugar intake at the group level.

The Spearman rank correlation is often used to measure the relationship between the first FFQ applications and the 24 hDRs. All these values were above 0·7, which can be considered a good agreement on an individual basis[15]. These values were almost compatible with the other FFQ validation studies[21,11]. Current findings were higher than those of the FFQ development study that assessed free sugar intake among Australian toddlers[22]. This may be due to the inconsistent dietary intake patterns of toddlers compared with the present study population, which targets children between the ages of 4 and 5.

All food and beverage groups and total free sugar have Spearman rank correlation coefficients above 0·5. ICCs were

Table 3. Percentage of cross-classification of free sugar intake into quartiles assessed by FFQ1, FFQ2 and the 24 hDRs (*N* 108)

	FFQ1 and the 24 hDRs			FFQ1 and FFQ2		
Food and beverage group	Same quartile	Opposite quartile	Weighted Kappa (κ)	Same quartile	Opposite quartile	Weighted Kappa (κ)
Biscuits	69·1 %	5·1 %	0·70	46·3 %	9·3 %	0·48
Bakery products	72·4 %	3·2 %	0·77	52·8 %	9·3 %	0·55
Sugar confectionery	71·5 %	5·2 %	0·76	57·7 %	11·4 %	0·52
Chocolate confectionery	65·6 %	11·2 %	0·61	58,9 %	8·7 %	0·48
Sugar-sweetened beverages	60·7 %	8·8 %	0·60	50·3 %	7·4 %	0·48
Desserts	72·9 %	7·8 %	0·64	49·9 %	12·3 %	0·46
Miscellaneous sweets	61·7 %	9·6 %	0·61	48·3 %	10·4 %	0·44
Table sugar	62·8 %	8·8 %	0·58	51–2 %	9·4 %	0·44
Total free sugar	78·4 %	4·6 %	0·81	52·3 %	6·7 %	0·58

Table 4. Spearman rank correlation coefficient between the intake of free sugar intake according to the FFQ1, FFQ2 and the 24hDRs (*N* 108)

	Validity		Reliability			
	(FFQ1 and the 24hDR)		(FFQ1 and FFQ2)		ICC**	
Food group	SCC	*P*-value	SCC*	*P*-value	(FFQ1 and FFQ2)	95 % CI
Biscuits	0·85	<0·01	0·71	<0·01	0·86	0·71–0·91
Bakery products	0·88	<0·01	0·58	<0·01	0·60	0·42–0·74
Sugar Confectionery	0·86	<0·01	0·63	<0·01	0·58	0·45–0·89
Chocolate Confectionery	0·72	<0·01	0·68	<0·01	0·50	0·33–0·67
Sugar-sweetened beverages	0·81	<0·01	0·55	<0·01	0·51	0·28–0·68
Desserts	0·70	<0·01	0·58	<0·01	0·65	0·46–0·98
Miscellaneous sweets	0·85	<0·01	0·50	<0·01	0·62	0·44–0·79
Table sugar	0·78	<0·01	0·51	<0·01	0·44	0·33–0·59
Total free sugar	0·89	<0·01	0·71	<0·01	0·61	0·51–0·69

* SCC, Spearman rank correlation coefficient.
** ICC, intraclass correlation coefficient.

calculated because they account for both within- and between-subject variability[23] and are the most appropriate test for assessing the agreement between the repeated FFQs in ranking individuals by their intake of free sugar. Interestingly, all of these values have shown a good correlation with a minimum of 0·5 and these findings were compatible with the ICC values obtained in another study for Asia-Pacific region[21].

By classifying participants by both test and reference methods into quartiles, we can calculate the percentage of participants correctly classified into the same quartile and the percentage misclassified into the opposite quartile. This indicates the ability of the dietary assessment method to rank the participants correctly, reflecting the agreement on the individual level. In the comparison of the two methods, the percentages correctly classified into the same quartiles for different sugary food groups were over 50 % and the percentages misclassified into the opposite quartile were less than 10 %, when comparing FFQ1 with the 24 hDRs and weighted kappa coefficient values were above 0·60 for almost all the food groups (Table 2). These findings were almost identical to those found in the previous study of Pacific Islanders in South Auckland[21]. However, chocolate confectionary group and table sugar indicated a less agreement than other food groups.

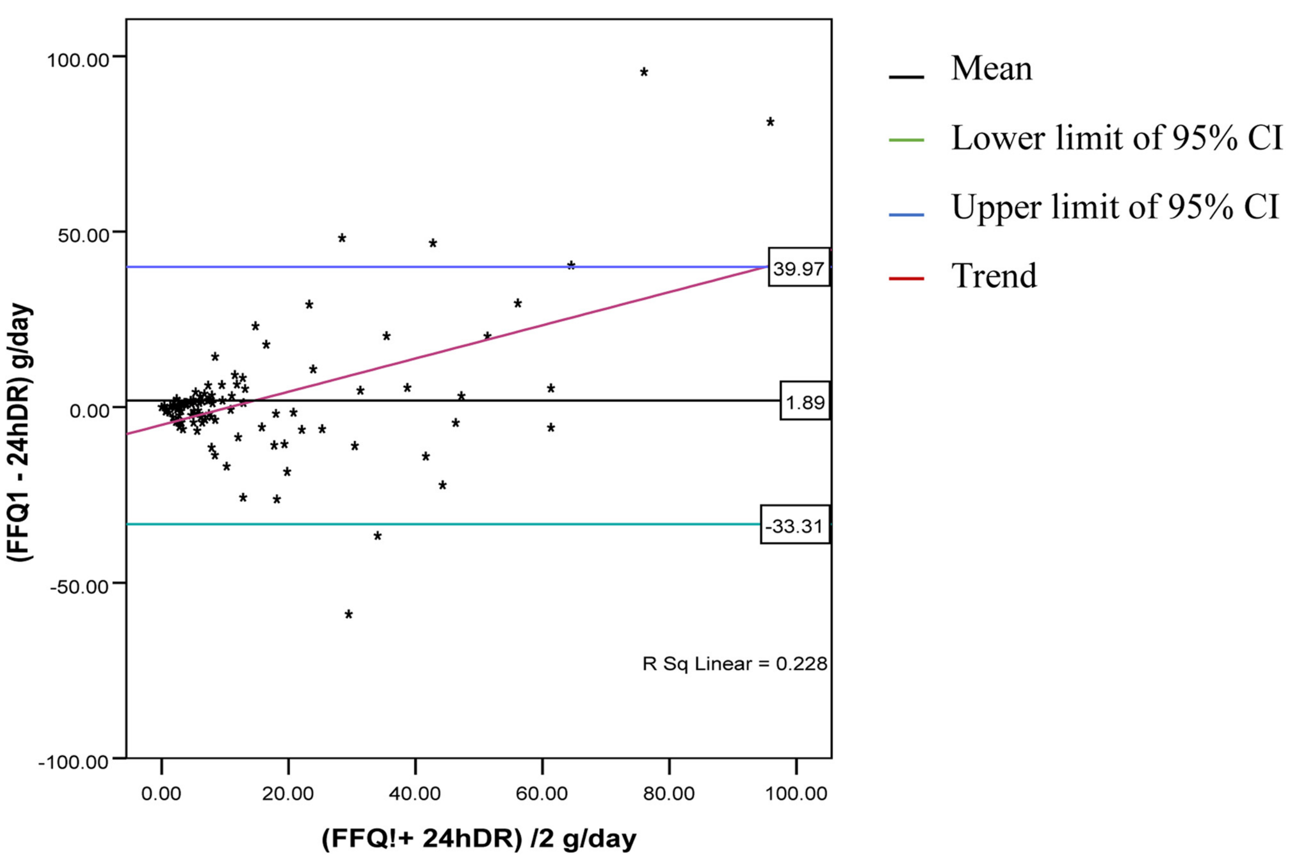

Fig. 1. Bland–Altman plot comparing free sugar intake measured by FFQ1 and the 24 hDRs.

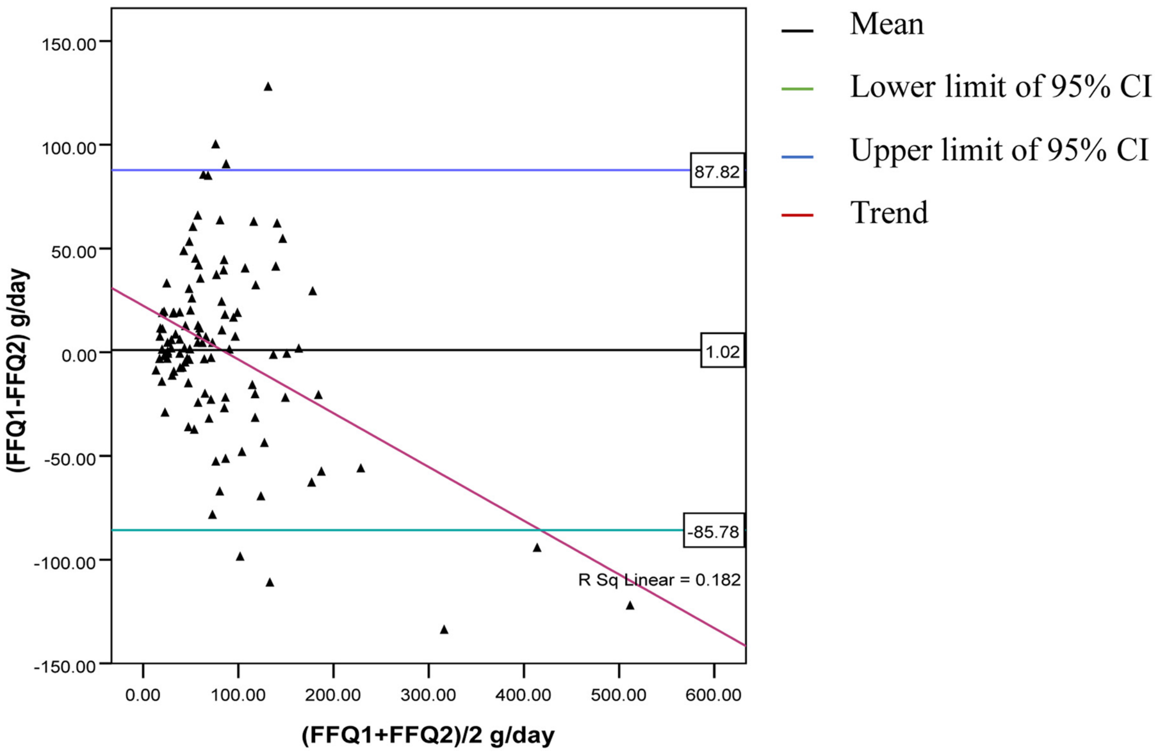

Fig. 2. Bland–Altman plot comparing free sugar intake measured by repeated application of FFQ (FFQ1 and FFQ2).

Bland–Altman plots were used to visually compare the two methods and determine to what extent they agree across a wide range of intakes. It can identify systematic differences (bias) between two comparison methods throughout the range of values and calculate the limits of agreement. Free sugar intake values were in good agreement between the two methods with no observable difference within the range of intake, which was consistent with previous studies done on Australian toddlers[22] and Malaysian adults[11]. Despite the Bland–Altman plot showing good agreement in the group, there are wide limits of agreement, varied between negative and positive values showing that free sugar intake is both over and underestimated by FFQ compared with the 24 hDRs. With regard to children's sugar intake, this is a relatively high level of uncertainty. The difference between methods tends to get larger as the average increases. There appears to be some inconsistency between the two methods at the individual level.

Although the FFQ was selected because it is the only feasible dietary assessment method available for assessing the diet of a large number of individuals over a long period of time retrospectively with minimal participant burden, there are inherent limitations. For FFQ to be an effective self-administered questionnaire, it needs to be refined for ease of use with examples. As both FFQ and the 24 hDRs depend on memory, overestimation and underestimation are possible. The test–retest reliability results may have been affected by learning bias. The parents may not always be aware of their child's full dietary intake since feeding duties can be shared with others, especially working mothers. Validation of FFQ was done using the 24 hDRs, but these two methods are not comparable since FFQ evaluates diet over a long period, while the 24hDRs consider 3 d only. At the individual level, the Bland–Altman plot also showed a large discrepancy with both underestimation and overestimation. Nevertheless, this is a reasonable option, since it is not feasible to use more advanced reference methods as dietary biomarkers. Due to financial and time constraints and the complexity of sample preparation for solid food items, a limited number of ingredients and food items were analysed chemically.

Overall, the FFQ contains a reasonable representation of food and beverage items to assess free sugar intake among preschool children as a group in the district of Colombo, Sri Lanka. By slightly modifying the food and beverage list to fit the local context, this can be adapted to other parts of the country. Filling out this FFQ need some skill thus prior instructions and guidance is needed cannot use as fully self-administered questionnaire. The new quantitative FFQ was proven to be a relatively valid and reliable tool to measure free sugar intake of a population and rank participants accordingly. Additionally, it is adequately suited to assessing the amount of free sugar consumed by different free sugar-containing food and beverage groups. Consequently, this tool can be used to assess free sugar intake at the population level.

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Authors have no conflicts of interest.

Ethical approval to conduct the study was gained from the Ethics Review committee, Faculty of Medicine, University of Colombo prior to data collection (EC-17-001). According to our confirmation, all methods followed relevant guidelines and regulations.

Written informed consent was obtained from the primary caregivers of all study participants.

Supplementary material

The supplementary material for this article can be found at https://doi.org/10.1017/jns.2023.5.

References

1. World Health Organization (2015) Guideline: Sugars intake for adults and children. *WHO Libr Cat Data* **26**, 34–36.
2. Englyst KN & Englyst HN (2005) Horizons in Nutritional Science Carbohydrate Bioavailability. Published online.
3. Steyn K & Damasceno A (2006) *Lifestyle and Related Risk Factors for Chronic Diseases*. Washington, D.C: The International Bank for Reconstruction and Development / The World Bank.
4. Popkin BM & Hawkes C (2016) Sweetening of the global diet, particularly beverages: patterns, trends, and policy responses. *Lancet Diabetes Endocrinol* **4**, 174–186.
5. Ministry of Health Sri Lanka (2018) *National Oral Health Survey Sri Lanka 2015–2016*. Sri Lanka: Ministry of Health.
6. Department of Census and Statistics. Demographic and Health Survey, Sri Lanka.
7. Sri Lanka | World Obesity Federation Global Obesity Observatory.
8. Somasundaram N, Ranathunga I, Gunawardana K, *et al.* (2019) High prevalence of overweight/obesity in urban Sri Lanka: findings from the Colombo Urban Study. *J Diabetes Res* **2019**. Published online. doi10.1155.2019;2046428. PMID:32886278; PMCID:PMC6893241
9. Graffe MIM, Pala V, De Henauw S, *et al.* (2020) Dietary sources of free sugars in the diet of European children: the IDEFICS study. *Eur J Nutr* **59**, 979–989.
10. Ortega RM, Perez-Rodrigo C & Lopez-Sobaler AM (2015) Dietary assessment methods: dietary records. *Nutr Hosp* **31**, 38–45.
11. Shanita NS, Norimah AK & Hanifah AS (2012) Food frequency questionnaire (FFQ) for sugar. *J Nutr* **18**, 283–293.
12. Sauvageot N, Alkerwi A, Albert A, *et al.* (2013) Use of food frequency questionnaire to assess relationships between dietary habits and cardiovascular risk factors in NESCAV study: Validation with biomarkers. Published online, 1–11.
13. Shim J-S, Oh K & Kim HC (2014) Dietary assessment methods in epidemiologic studies. *Epidemiol Health* **36**, e2014009.
14. Welch AA (2013) Dietary intake measurement: methodology. *Encycl Hum Nutr* **2–4**, 65–73.
15. Cade J, Thompson R, Burley V, *et al.* (2002) Development, validation and utilisation of food-frequency questionnaires – a review. *Public Health Nutr* **5**, 567–587.
16. Sheehy C, McNeill G, Masson L, *et al.* (2008) Survey of sugar intake among children in Scotland. *Food Stand Agency Scotl.* Published online.
17. O'Connor L, Imamura F, Brage S, *et al.* (2018) Intakes and sources of dietary sugars and their association with metabolic and inflammatory markers. *Clin Nutr* **37**, 1313–1322.
18. Petkova T, Nadezha B, Annick M, *et al.* (2013) HPLC analysis of mono- and disaccharides in food products. *Sci Work* **LX**, 761–765.
19. Hafizah YN, Choo Ang L, 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.
20. Lombard MJ, Steyn NP, Charlton KE, *et al.* (2015) Application and interpretation of multiple statistical tests to evaluate validity of dietary intake assessment methods. *Nutr J* **14**, 40.
21. Boniface OT (2013) Validation of a Short Food Frequency Questionnaire Which Ranks Individuals by Sugar Intakes in Pacific Islanders in South Auckland, New Zealand.
22. Devenish G, Mukhtar A, Begley A, *et al.* (2017) Development and relative validity of a food frequency questionnaire to assess intakes of total and free sugars in Australian toddlers. *Int J Environ Res Public Health* **14**, 5–7.
23. Koo TK & Li MY (2016) A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med* **15**, 155.