Development and Validation of Food Frequency Questionnaire for Food and Nutrient Intake of Adults in Butajira, Southern Ethiopia.

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Abstract

Background: To date, there is no culture-specific and validated Food Frequency Questionnaire (FFQ) available in Ethiopia. We developed a FFQ and evaluated its validity as compared to estimates of a food group and nutrient intakes derived from two 24-Hour Dietary Recalls (24-HRs).

Method: A total of 105 adults, of which 43 (41%) were men and 62 (59%) women aged 20-65 years participated in this study. To evaluate the validity of FFQ against two 24-HRs, we used a paired t-test and Wilcoxon- signed rank test to compare mean and median daily nutrient and food intakes obtained from the averages of the two 24-HRs and the FFQ, correlation coefficients to measure the strength and direction of the correlation, Cross-classification and kappa to assess classification agreement and Bland-Altman analysis for assessing limits of agreement between the two methods.

Results: Mean energy and macronutrient intakes obtained from the FFQ were significantly higher than those obtained from the mean of two 24-HRs. For energy and macronutrients, the crude correlation between two instruments ranged from 0.05 (total fat) to 0.32 (carbohydrate). Whereas, for micronutrients, it ranged from 0.1 (calcium) to 0.49 (vitamin B1). The de-attenuated correlation ranged from to 0.10 (total fat) to 0.80 (vitamin A) Visual inspection of the Bland-Altman plots for both energy and macronutrients shows no consistent trend across the intake values. For the majority of the food groups, no significant difference was observed in median intake of foods and nutrients between 24-HRs and FFQ. Crude correlation for food groups ranged from 0.12 (egg) to 0.78 (legumes). The de-attenuated correlation ranged from 0.24 (egg) to 0.10 (Meat/Poultry/Fish). The FFQ showed a fair classification agreement with the 24-HRs for cereals, legumes, and roots and tubers intakes. A systematic trend of overestimation for roots and tubers and under estimation of beverage intakes at higher values was observed when we used FFQ.

Conclusion: The FFQ is valid to assess and rank individuals in terms of intakes of most food groups according to high and low intake categories. Individual level validity was acceptable for energy and most nutrients as indicated by de-attenuated correlation coefficients and Bland-Altman plots. However, group level validity was poor for most nutrients.

Introduction

Nutritional epidemiology principally dietary intake assessment plays an essential role in chronic disease studies and general public health issues (1-3). Besides environmental and life-style factors, improving dietary habits is a major target for the prevention of non-communicable diseases, such as cancer, cardiovascular diseases, diabetes, chronic obstructive pulmonary disease and chronic kidney diseases (4). Several tools and methods have been suggested and used to measure usual dietary intake among adults at the population level. Nevertheless, the accuracy and precision of measuring dietary intake is still a big challenge (5). Due to a substantial burden on respondents and being resource demanding, weighed food records and 24-hour recalls are less applicable in resource poor settings of low- and middle-income countries (6).

Food frequency questionnaire (FFQ) asks respondents about their usual frequency of consumption of each food during a specified time (7). Compared to other dietary assessment methods, such as short-term recall and diet record, FFQ is easier to administer, place less burden on respondents, has a relatively low cost and provide a rapid estimate. This makes FFQ more feasible and best suited for measuring long term dietary intake for most epidemiological studies and large cohort studies (8).

In Non-communicable diseases (NCDs), the conceptual exposure is long term diet and the FFQ is the suitable method for assessing habitual diet intake over longer reference period. In low-income and low-middle income countries there has been a rapid rise in NCDs burden, where almost half of premature NCDs deaths occur (9). Therefore, more research is needed to discover the causes of this rising burden and help governments develop prevention policies.

In Ethiopia, although data related to diet quality remain sparse, a finding from the Global Burden of Disease (GBD) estimated that number of deaths attributable to dietary factors were 60,402 in 2016. The proportion of NCD deaths associated with low fruit consumption slightly increased (from 11.3% in 1990 to 2016 11.9%). In these years, the rate of burden of disease related to poor diet slightly decreased; however, their contribution to NCDs remained stable (10). This indicates that dietary behavior contributes significantly to disease burden in Ethiopia

Interpretation of results from studies of diet-disease that use FFQ is often difficult unless it has been adapted and validated in a population reasonably similar to that being investigated (11). Incorrect information may give rise to false associations between dietary factors and diseases or disease-related markers. The null association could also be attributed to a lack of variation in the dietary exposure in the study population or the inability of the tool to find out existing differences in the diet. Therefore, it is important to assess the degree to which the questionnaire measures the aspect of a diet for which it has been designed (11, 12).

Because of the lack of gold standard in dietary assessment, validation studies cannot compare a test method with absolute truth rather they compare one method with another method that is judged to be superior (13). Among the available and feasible comparison methods to validate FFQ, diet records represent an optimal comparison method because of having the least correlated error with FFQ (11). However, when co-operation or literacy of study subjects is limited, 24-hour recall (24-HR) may be more appropriate (11, 14). Approximately, 75% of the validation studies of the FFQ, are validated against repeated 24HRs, preferred for the accuracy to capture daily consumption of a varied diet, and for their relatively easier administration and analysis compared to other dietary questionnaires (14). In most circumstances, the greatest statistical efficiency is obtained with only two, and at the most five, repeated recalls per subject. In this context, to validate our FFQ against 2 24-HRs seems to be acceptable

To our knowledge, there is no validated standard FFQ in Ethiopia that can help to assess dietary habits among adults. Therefore, this study aimed to develop context-specific FFQ and evaluate the concurrent validity against two 24-HRs methods.

Methods

Study design and Participants

We validated the FFQ against the average of two 24-HRs. The FFQ was obtained after the second 24-HR. There was a 15 days interval between the first and the second 24-HR. We have used an interactive, multiple pass 24-HR method adapted and validated for use in developing countries (15). We conducted the study among randomly selected 120 Ethiopian adults aged 20 to 65 in Butajira Health and Demographic Surveillance Site (HDSS), from March to April 2019. We employed simple random sampling to identify study participants. Households with adults aged 20-65 were filtered out from the HDSS data registry to form a sampling frame. From this frame, we randomly selected 120 households with adults aged 20-65. We visited all randomly selected households with adults aged 20- 65 with support from the health extension workers, local guides and study supervisors. To be included in the study, the participants had to complete an FFQ and two 24-HRs and had fewer than 10% of their FFQ items missing. After explanation about the purpose, and related procedures of the study verbal informed consent was obtained from the study participants.

Development of the FFQ

Figure 1 shows the process of FFQ development.We followed five steps to develop the FFQ: choosing appropriate foods, prioritization, and categorization of food items, assembling a list of selected foods, frequency and portion size, and expert review and pre-testing. First, we obtained information on dietary intakes from an unpublished cross-sectional dietary survey of women (n 384) living in rural and urban households of Butajira Health and Demographic Surveillance Site (HDSS), in Southern Nations and Nationalities and Peoples Regional States (SNNPR) from 2018-2019. Information on dietary intake was collected using a single multiple-pass 24-hr technique with women in their own homes. The survey was part of a mother-child cohort study (BUNMAP) in Butajera, Southern Ethiopia which is on "The economic, psychological, safety and quality aspects of food and nutrition and the effects on pregnancy outcomes, child growth and development (16).

We undertook Market and mini-market visits on non-consecutive days to identify common brand names and foods that could be relevant and were added accordingly. Besides, we conducted a focus group discussion in Butajira district two weeks before the interview. It was organized by the principal investigator and field supervisors. We interviewed a group of 6 women about foods consumed in the area. We recruited those women by the help of health extension workers, local guides and study supervisors. The women came from urban and rural areas of Butajira. They were selected purposively. The aim of the focus group discussion was to probe and discuss the food items in that specific area in order to have comprehensive list of food types. We undertook the discussion to identify food items that are typically consumed, including ingredients used and methods of preparation. Second, we combined similar foods and beverages into a single group of food items. Third, we clustered the related food items together. To facilitate dietary reporting, food groupings should fit within respondents' conceptual framework. We clustered related items together, such as traditional food groups. For closely related foods, we placed more specific items before general items. We have used results of our focus group discussion to help construct lists for culturally specific questionnaires or to provide information about which foods should be grouped together.

Forth, we evaluated the frequency of intake based on the usual intake over 1 month before data collection. We included seven frequency categories ranging from daily to never/one less than per month. Three women were involved in the cooking process and portion size estimation. We assigned a portion size for each food item. We employed a pre-specified portion size estimation method for the estimation of portion size in FFQ using local house-hold units such as bowl, plate, spoons of different sizes (tablespoon, teaspoon), coffee-cups, tea-cups, water glasses, as well as using photographs. The data for preparing a pre-specified portion size is based on data obtained from food lists created on step one, focus group discussion and local markets and shops visits. To determine the weight of the food items used we made commonly consumed dishes in the Ethiopian public

Health Institute laboratory. We did the measurement with an Electronic Seca scale and the average of the 3 measurements was taken. We gave codes for different prepared portions. To help standardize participants understanding the interviewer prepared photographs for each measurement done and showed them to the participants.

Fifth, experts reviewed the newly developed FFQ (nutritionist from Addis Ababa University) to confirm its content validity. We have discussed the food list extensively to ensure all relevant food items were included. Pre-test was conducted in a group of 10 randomly selected adult women who are comparable to the study participants in one non-sampled kebele. Some minor changes were made based on the finding of the pre-test.

The developed FFQ consisted of 89 food and drink items. The food groups include cereals, bread and potatoes, Legumes and pulses, Roots and tubers, vegetables, fruits, egg, milk and dairy, fish and fish-products, meat and poultry, fat and oil, sweets, drinks, and fast foods and pastry.

Dietary assessment

24-Hour Dietary Recall

We have used an interactive, multiple pass 24-HR method adapted and validated for use in developing countries (15). We conducted the two 24-HRs on non-consecutive days. We interviewed on weekdays and weekends to capture variance in the intakes across various days of the week. Before data collection, we gave a rigorous training and conducted a pre-test. We recruited three (3) interviewers who had a previous experience in dietary data collection and fluent in local language. Each interview involved a stepwise series of questions.

First, we asked the participants to report everything that they consumed the previous day, including the night. The opening question was; “After you got up this morning/yesterday morning, when was the first time that you had something to eat or drink?” followed by the questions “What did you eat or drink at that time?” and “Did you eat or drink anything else at that time?” The same three questions were repeatedly been asked until the participants recall all the food and drink items consumed over the specified period. The first pass ended with the questions “Can you remember any other times you had something to eat or drink to?” In the second pass, participants were asked to provide additional detailed information about each item of food and drinks consumed. This includes the name of the food item, where they ate it, brand names, cooking methods, amounts served, and the amount consumed. For homemade dishes, participants were asked for the recipes and ingredients.

On the third pass we used common household utensils such as bowl, plate, spoons of different sizes (tablespoon, teaspoon), coffee cups, teacups, water glasses to improve the memory of the respondents and to assist in completing the recall. To estimate portion size, each participant was asked to put amount of food that is equivalent to the actually eaten on food weighing scale. Then the data collectors measured the weight of the food consumed and recorded it. The final pass reviewed all previously recalled information to confirm the accuracy of the record. During the final pass, the data collectors asked the participants to prompt for information about foods and drinks not mentioned that were considered to be easy to forget, such as snacks, fruits, water, and juices (17).

Food Frequency Questionnaire

We evaluated the frequency of intake based on the usual intake over the previous month. We included nine (9) frequency categories ranging from daily to never/one less than per month each food item was assigned a pre-specified portion size.

Calculation of Daily Food and nutrient Intake

We used the Ethiopian food composition table to derive nutrient and energy estimates from the dietary data (18). The names of foods and drinks, their description, cooking methods, and amounts from both 24-HR and FFQ, were coded and entered into NutriSurvey2007. The FFQ consisted of 89 food and drink items. We organized the food lists were into 14 food groups on the basis of prior information. We calculated food estimates from FFQ using the product sum method. We converted the average frequency of food intake per week and month of the FFQ to a daily intake value (e.g., frequency of 2–3 times per month = 2.5/30.5 times per day. Once the frequency of consumption per day was calculated, we computed the daily food intake using the product sum method. Daily food intake =∑ (reported consumption frequency of the food item, converted to times per day) *(portion size consumed of that food).

Statistical test of validity

We checked both the FFQ and 24-HR data for completeness and potential errors. We then entered the data on socio-demographic characteristics using Epi-Data version 3.1 and exported to STATA version 15 for further processing and analysis. Out of 120 study participants, 118 (98.3%) of participants completed 1st 24-HR, 116 (98.6%) completed 2nd 24-HR, 116 (98.6%) completed both 24-HRs and 115 (95.8%) participants completed both the 24-HRs and the FFQ.

We checked the normality of the average intake of nutrient and food groups using the Shapiro-Wilk normality test and visualized using Q-Q plots. We used parametric tests for normally distributed variables, while non-parametric tests were used for most of the variables as the distributions significantly deviated from normality. Those which fulfilled the assumption of normality were described using mean with standard deviation (SD) and those which do not use median with inter-quartile range (IQR).

We evaluated the performance of the FFQ against two 24-HRs using several statistical tests. First, to compare median daily food intakes obtained from the averages of the two 24-HRs and the FFQ, we used the Wilcoxon signed-rank test. To evaluate the agreement between the two methods, we compared the mean daily food intakes obtained from the averages of the two 24-HRs and the FFQ using paired t-test. Second, to measure the strength and direction of the correlation between the two methods, we computed the crude Pearson correlation for normally distributed variables, whereas crude Spearman's rho for those not normally distributed. The cut-off points used for correlation coefficient are as follows; <0.20 as low correlation (poor outcome), 0.20 - 0.49 as moderate correlation (acceptable outcome), and ≥0.50 as high correlation (good outcome) (13).

We have calculated the de-attenuated correlations to remove the within-person variability found in the 24-HRs using the following formula:

$$r_t = r_o\sqrt{1+r/n}$$

r_t is the corrected correlation between energy/nutrient/food group derived from the FFQ and 24-HRs, r_o is the observed correlation, r is the ratio of estimated within-person and between- person variation in energy/nutrient/food group intake derived from the 24-HRs, and n is the number of replicated recalls (n = 2) (11).

Third, for both the test and reference methods subjects were divided into categories relating to the distribution of dietary intake; quartiles of intake. A comparison of the subjects' categories showed whether subjects are classified in the same or different categories by the two methods. The result permitted an assessment of the proportion of subjects who are classified correctly. We used a weighted kappa statistic to account for both the correctly classified percentage and the expected participant proportion classified by chance. The cut-off points used for weighted kappa statistics are as follows; <0.20 as low kappa (poor outcome), 0.20 - 0.60 as moderate kappa (acceptable outcome), and ≥0.50 as high kappa (good outcome) (13). At last, we used a Bland and Altman plot for assessing limits of agreement between the two methods. The Bland-Altman method is preferable to compare two measurements each of which produced some error in their measures (19).

Results

Study Participant Characteristics

Table 1 shows the socio-demographic characteristics of the study participants. Of the 120 participants, 115 (95.8%) completed both the 2 day 24-hour dietary recall and the FFQ. A total of 105 study participants were included in the final analysis, of which 43 (41%) were men and 62 (59%) women. The mean age of participants was 31.9 years (SD: 9.2), 33.3% of them had primary education, and 43 (41%) were housewives.

Relative validity analysis

Table 2 shows the mean (SD), median, and 25th, 75th percentiles daily nutrient intakes estimated by the average of two 24-HRs and the FFQ. The mean energy and macronutrient intakes obtained from the FFQ were significantly higher than the average of two 24-HRs. The highest mean difference was for energy 368 (95%CI: 259.0, 476.1), while the lowest was for total fat intake 4.1 (95%CI: 2.5, 5.7). Similarly, a significant median difference was found in micronutrient intakes between the two measures. The median difference ranged from 0.09mg/day for vitamin B2 to 391.8ugRAE for vitamin A intake.

Table 3 presents the results of correlations between nutrient intakes obtained from the average of two 24-HRs and the FFQ. The Crude Pearson correlation varied from 0.05 (total fat) to 0.32 (carbohydrate). Except for total fat the correlations were statistically significant. Spearman correlation (rho) obtained for micronutrients ranged from 0.1 (calcium) to 0.49 (vitamin B1). A statistically significant correlations was obtained for vitamin A ($p< 0.05$) and vitamin B1 ($p<0.05$). De-attenuation improved correlation for all nutrients. The de-attenuated correlation ranged from to 0.10 (total fat) to 0.80 (vitamin A).

Table 4 shows cross-classification and weighted Kappa statistics of daily intakes of energy, nutrients and food group in quartiles assessed with average of two 24-HRs and the FFQ. The proportion of individuals classified by the FFQ and the average of two 24 hour dietary recalls into the same quartile ranged from 13.4% for total fat to 38.1% for vitamin A. However, the proportion classified into opposite quartiles varied from 3.8% (vitamin B1) to 23.8% (total fat). Weighted kappa values ranged from -0.04 (total fat) to 0.18 (vitamin A).

Table 5 present's median, and 25th, 75th percentiles of daily food group intakes estimated by the average of two 24-HRs and FFQ. Both methods provide similar median intake estimates for fruits, eggs, meat/poultry/fish, and daily products. For roots and tubers, the 24-HR shows a higher estimate of median intake. FFQ provides a higher estimates of median vegetable intake. A statistically significant median difference was only observed for roots and tubers, eggs and vegetable intake.

Table 6 shows the correlations between food group intakes obtained from the average of two 24-HRs and the FFQ. The crude Spearman correlation ranged from 0.12 for egg to 0.78 for legumes. Greater than 0.5 correlations were observed for legumes (r=0.78). Correlation (0.2-0.49) were observed for cereals (r=0.33), Meat/poultry/fish (r=0.47), fruits (r=0.46), dairy products (r=0.45), roots and tubers (r=0.34), vegetables (r=0.3) and beverages (r=0.2). Correlation was low (<0.2) for egg (r=0.12). De-attenuation improved correlation for all food groups. The de-attenuated correlation ranged from 0.24 (egg) to 0.10 (Meat/Poultry/Fish). Greater than 0.5 correlations were observed for all food groups except eggs and beverages.

Table 7 shows cross-classification and weighted Kappa statistics of daily intakes of food groups in quartiles as assessed with average of two 24-HRs and the FFQ. The highest correct classification into the same quartile was observed for “cereals” and “legumes”-i.e., 50.5% and 51.4%, respectively. For the other food groups, the classification into same quartile ranged from 30.5% (beverages) to 40% (roots and tubers). Oppositely classified individuals ranged from 1% (cereals) to 11.4% (beverages). No gross misclassification was observed for intake of legumes. Weighted kappa values ranged from 0.07 (beverages) to 0.35 (legumes).

Figure 2 presents the Bland-Altman plots for energy, protein, carbohydrate, total fat, vitamin B1, vitamin A, vitamin B2, calcium and iron. The Bland-Altman plot was used to evaluate the agreement between the FFQ and 24-HR by plotting for each nutrient the difference between the two methods versus the average of the two methods and calculating the limits of agreement and their corresponding 95% CI. Visual inspection of the Bland-Altman plots for both energy and macronutrients shows no consistent trend across the intake values. The FFQ overestimated energy and macronutrient intakes. Except for total fat intake, increased variability of data points was observed for all nutrients both at low, average and high values (wider limits of agreement). Some outliers were observed for energy and macro-nutrients. Since differences in nutrient intakes were associated with the mean measurement, data related to the micro-nutrient intake were log transformed for Bland and Altman statistics. The result indicates a trend as the FFQ consistently over estimated vitamin A and iron intake at lower value.

Figure 3 shows the Bland-Altman plots for legumes, cereals, vegetables, beverages, roots and tubers, fruits, egg, dairy product and meat/poultry/fish. Data related to roots and tubers was log transformed for Bland and Altman statistics. A systematic trend of overestimation for roots and tubers and under estimation of beverage intakes at higher values was observed when we used FFQ. Majority of the data points are in the 95% of limits of agreement for almost all food groups. A wide limit of agreement was observed for roots and tubers.

Discussion

In this study, we developed and validated a food frequency questionnaire to assess food and nutrient intakes of adults in Ethiopia. We have observed a higher intake of energy and nutrients when the FFQ was used as compared to the average of the two 24-HRs. Bland-Altman plots show an overestimation of energy and macro-nutrients (carbohydrate, protein and fat) for various data points. We found a low to moderate level of agreement (correlation coefficients) for energy and nutrient intakes between the two methods.

We found that the FFQ overestimated energy and nutrient intakes relative to the average of the two 24h diet recalls. Overestimation is a common issue reported in various validation studies (10-15). Overestimation in the present study was moderate for intakes of energy (367.9 kcal), protein (10.5 g) and carbohydrate (77.6 g) and slight for intakes total fat (4.4 g) compared to other validation studies conducted using 24-HRs as their reference method (17, 20-23). Overestimation can be attributed to the subject's tendency to overestimate their actual intake when they are asked to recall the frequency of a large number of foods consumed in an FFQ. Besides, difficulty in conceptualizing the assigned portion sizes and difficulties in reporting the frequencies of usual intake could be an attributing factor(23). It may have also occurred as a result of purposeful over-reporting of food consumption by subjects (15). The use of shorter questionnaires and advances in portion size estimation techniques are suggested to improve overestimation of intakes by FFQs.

This study found moderate crude correlations (0.2-0.49) between the average of the two 24-HRs and FFQ for energy (r=0.24), protein (r=0.22), and carbohydrate (r=0.32) and crude low correlation (<0.2) for fat (r=0.05). The low to moderate crude correlation found between the two methods for energy and macro-nutrient intakes are comparable with other previous validation studies (17, 20, 22, 24). However, our finding was lower than those reported by other studies using 24-HRs as their reference method (17, 20, 22). The observed decrease in crude correlation could be interpreted as being the result of using only a two day 24-HRs as a reference method. However, after correcting for within-person variability, the correlation for all nutrients improved. Moderate to good de-attenuated correlations were reported for the majority of the nutrients. The moderate to good de-attenuated correlation observed were comparable to other FFQs validation studies (17, 23, 25, 26).

The lower crude correlation for iron and vitamin intakes observed in our study is not uncommon in FFQ validation studies (17, 20, 21, 23, 27). A meta-analysis of FFQ validation studies showed that pooled crude correlation coefficients of nutrient intakes (total fat, protein, carbohydrate, alcohol, calcium, iron and vitamins) were lower for FFQ validated against 24-HRs rather than food record (28). The possible reason for a low correlation for the vitamin is that vitamin intake tends to vary greatly from day to day (as many vitamins are found in only a small selection of foods)(17).

We observed a moderate to good crude correlation for almost all food groups. This is in good agreement with previous validation studies assessing food group intakes (17, 20, 29, 30). The good correlation found for vegetable intakes in our study is higher than those reported by other validation studies (17, 20, 22). This may have occurred because of ease of quantifying vegetable intakes as they are often consumed independently in Butajira. The lower correlation of egg intake in our study, in contrast to other studies (20, 21) may have occurred because of not consuming egg on the days where 24-HR was conducted. De-attenuation improved the correlation for most food groups; the highest correlation was found for dairy products (r=1.00) and meat/poultry/fish (r=1.00) and the lowest for eggs (0.24).

The Bland-Altman plot showed a moderate agreement between the two methods for energy and macro-nutrients. Trend was not observed across the intake level in energy and macronutrient intakes. Similarly, another study also showed a moderate level of agreement with no persistent trend across intake levels using a Bland-Altman plot (22, 25). However, ranges for limits of agreement were relatively wide as opposed to another study (23). The observed wide limits of agreements between FFQ and the reference method are common, hence highlighting the limitation of the FFQ in assessing absolute nutrient intake due to wide variability in how the FFQ measured energy and macronutrient intake relative to the average of the two 24-HRs (12).

A tendency towards a poorer agreement in Vitamin A and iron intake between methods was observed with lower levels of intake as shown by the Bland-Altman plot. This poor agreement in iron intake is also reported in another validation study (31). As indicated by a Bland-Altman plots, a systematic mean difference was not observed across the intake levels of Cereals, legumes, vegetables and beverages. Most of the data points are found between the 95% limits of agreement. However, the plot indicated wide limits of agreement which occurs as a result of increased variability.

The present study showed that the FFQ did not adequately classify subjects with respect to energy, macro-nutrients and most of the micro-nutrients as indicted by cross-classification and weighted kappa results (percentage of individuals in same quartile < 50 , K values < 0.2) (13). However, the FFQ showed a fair quartile classification agreement for cereals, legumes, and roots and tubers (K values 0.2-0.6). This finding is consistent with previous studies which reported cross-classification and kappa by categorizing intakes into quartiles (20, 21, 31). We found lower values for energy and nutrients with respect to those reported by other studies using similar intake categories (17, 22, 23, 32). The misclassification and low kappa reported in our study may have occurred due to the insensitivity of FFQ to classify individuals into intake categories. The use of a Food diary as a reference method may have also increased classification agreement in the previous studies. FFQ showed a fair quartile classification agreement for cereals, legumes, and roots and tubers (K values 0.2-0.6). Similarly, other studies reported a fair classification agreement for this particular food group(23, 29). For beverage intake, our study indicated a misclassification (30.5%) into opposite quartile supported by low kappa value (k value <0.2) showing the poor outcome. Other study reported a similar finding for beverage intake (29).

The present study has some limitations that must be acknowledged. First, given that we used a 24-HR dietary assessment method as our reference method, the sources of error between 24-HR and FFQ may tend to be correlated due to conceptualization of portion sizes. However, to lessen this effect we have used a salted replica of actual foods, pictures and calibrated equipment to estimate portion size. Second, we conducted two 24-HRs per participant due to financial and logistic constraint. Third, participants may have purposefully over reported their intake due to social desirability. However, we gave a detailed explanation for the interviewers on how to explain the purpose of the FFQ to the participants using role-playing, small group exercises, and discussions. Fourth, we did not administer FFQ at the onset of the study; therefore, we cannot assess the reproducibility of the instrument. Fifth, seasonal variation was not taken into account. Two 24HR has limitations, particularly for estimating usual intakes of foods not consumed on a daily or regular basis such as egg intake. Therefore, the relative validity results should be interpreted with caution as low correlations and large differences may also be due to this issue. Therefore we recommended a further research be undertaken to assess this effects.

The strength of the present study are the development of the FFQ based on the latest local dietary survey, focal group discussions, pre-test, and expert reviews, the use of comprehensive statistical analysis, to assess the validity of the FFQ and the use of an interactive, multiple-pass 24-HR adapted and validated for use in developing countries as our reference method.

Conclusions

The study showed that FFQ had good validity to capture intakes of cereals, legumes, vegetables, and beverages both at individual and group levels. However, intakes of root and tuber and beverages are associated with potential systematic bias. Therefore, caution must be exercised when using FFQ for this particular food groups.

The FFQ is capable of classifying cereals, legumes, roots and tubers and vegetable intake into quartiles. The supporting individual level validity was acceptable for energy and most nutrients as indicated by de-attenuated correlation coefficients and Bland-Altman plots. However, group level validity was poor for most nutrients.

Declarations

Ethics approval and consent to participate

Ethical clearance was obtained from the institutional review board of School of Public Health, College of Health Sciences, Addis Ababa University. Informed written consent was obtained from the study participants. The study is in compliance with the principles of the declaration of Helsinki.

Consent for publication

Not applicable

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to the confidentiality regulations of our University, but are available from the corresponding author upon request.

Competing interests

The authors declare that they have no competing interests.

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The study did not receive funding. All participants voluntarily agreed to take part.

Authors’ Contributions

Conceptualization, I.F., B.S.E., S.H.G., and E.H.; methodology, I.F., B.S.E., S.H.G., and E.H.; software, I.F., B.S.E., S.H.G., and E.H.; validation, I.F., B.S.E., S.H.G., and E.H.; formal analysis, I.F., B.S.E., S.H.G., E.H., and H.Y.H.; investigation, I.F.; writing original draft preparation, I.F., B.S.E., S.H.G., E.H., and H.Y.H.; writing, review and editing, I.F., B.S.E., S.H.G., E.H., and H.Y.H. All authors approved the final version to be submitted.

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Tables

Table 1. Socio-demographic characteristics of study participants (n=105)

Characteristics of participants	Frequency	Percent
Sex		
Male	43	41
Female	62	59
Age category		
20-29	49	46.7
30-39	35	33.3
40-49	13	12.4
50-65	8	7.6
Education		
Primary	35	33.3
Secondary	21	20
College/university	10	9.5
No formal education	39	37.2
Occupation		
Farmer and housewife	5	4.8
Housewife	43	41
Employee/private	3	2.9
Merchant	25	23.8
Daily laborer	8	7.6
Unemployed	8	7.6

Table 2. Mean (SD), median, and 25th, 75th percentiles of daily Energy and nutrients intakes estimated by the average of two 24-Hour dietary recalls and FFQ

Energy and nutrients	Average of 24-Hour Dietary Recalls		FFQ			
	Mean	SD	Mean	SD	paired t-test	P-value
Energy (Kcal)	1449.50	421.60	1817.10	482.30	367.60 *	0.000
Protein (g)	39.40	12.20	49.90	12.50	10.50*	0.000
Total fat (g)	17.20	5.70	21.30	6.10	4.10*	0.000
Carbohydrate (g)	297.60	92.30	375.20	109.30	77.60*	0.000
	Median	**IQR (25%, 75%)**	**Median**	**IQR (25%, 75%)**	**Wilcoxon signed Rank test**	
Calcium (mg)	463.10	337.60, 587.90	684.40	518.00, 796.80	0.000**	
Iron (mg)	56.00	41.90, 83.70	67.40	54.30, 86.80	0.009**	
Vitamin A (ugRAE)	259.30	51.50, 581.40	651.10	295.90, 976.60	0.000**	
Vitamin B1 (mg)	0.70	0.49, 0.98	0.81	0.54, 1.17	0.002**	
Vitamin B2 (mg)	0.70	0.54, 0.84	0.79	0.64, 0.94	0.002**	

*p-value ≤ 0.05 **p- value < 0.01

Table 3. Correlations of daily Energy and nutrient intakes when comparing the FFQ to the average of two 24-Hour dietary recalls

			Bland-Altman statistics	
Macro-nutrients	Pearson correlation (95% CI)	De-attenuated correlation	Mean Difference (95% CI)	95% Limit of Agreement
Energy (Kcal)	0.24*(0.05,0.41)	0.38	367.6 (259.0, 476.1) *	-731.9, 1467.1
Protein (g)	0.22* (0.03, 0.36)	0.36	10.5 (7.6, 13.5) *	-19.7, 40.8
Total fat (g)	0.05 (-0.14, 0.24)	0.10	4.4 (2.5, 5.7) *	-13.7, 22.5
Carbohydrate (g)	0.32* (0.14, 0.48)	0.51	77.6 (54.5, 100.6) *	-155.9, 311
Micro-nutrients	Spearman correlation (95% CI)	De-attenuated correlation	Bland and Altman statistics for Log transformed data	
			Mean Difference (95% CI)	95% Limit of Agreement
Calcium (mg)	0.10 (-0.09, 0.29)	0.20	0.15 (0.11, 0.18) *	-0.26, 0.55
Iron (mg)	0.12 (-0.07, 0.30)	0.23	0.06 (0.007, 0.11) *	-0.45, 0.61
Vitamin A (ugRAE)	0.45* (0.28, 0.59)	0.80	0.5 (0.34, 0.66) *	-1.1, 2.1
Vitamin B1 (mg)	0.49* (0.33, 0.62)	0.75	0.1 (0.02, 0.11) *	-0.4, 0.5
Vitamin B2 (mg)	0.17 (-0.02, 0.35)	0.35	0.05 (0.01, 0.09) *	-0.41, 0.51

*p-value ≤ 0.05 **p- value < 0.01

CI: Confidence Interval;

Table 4. Cross-classification and Weighted Kappa statistics of daily Energy and nutrient intakes of in quartiles as assessed with the average of two 24-Hour dietary recall and the FFQ.

Energy and nutrients	Cross-classification		Kappa statistics
	% in same quartile individuals	% in opposite quartile of individuals	Kappa value
Energy (Kcal)	34.3	8.6	0.13
Protein (g)	33.4	8.6	0.11
Total fat (g)	13.4	23.8	-0.04
Carbohydrate (g)	34.3	8.6	0.12
Calcium (mg)	25.7	7.6	0.09
Iron (mg)	28.6	9.5	0.05
VitaminA (ugRAE)	38.1	5.7	0.18
Vitamin B1 (mg)	33.3	3.8	0.11
Vitamin B2 (mg)	33.3	8.6	0.11

Table 5. Mean (SD), median, and 25th, 75th percentiles daily food group intakes estimated by the average of two 24-Hour dietary recalls and FFQ

	Average of 24-Hour Dietary Recalls		FFQ		
Food group	Median	(25%, 75%)	Median	(25%, 75%)	P-value
Cereals (g)	710	(548.5, 817)	648	(520.9, 852)	0.997
Legumes (g)	94.5	(0, 145.5)	93	(21, 134.9)	0.347
Roots and Tubers (g)	24.5	(0, 45)	11.2	(0, 31.3)	0.013*
Vegetables (g)	79.5	(23.5, 156)	109	(45.3, 159)	0.048*
Fruits (g)	0.0	0.0	0.0	(0, 15.4)	0.367
Eggs (g)	0.0	0.0	0.0	0.0	0.000**
Dairy products (g)	0.0	0.0	0.0	(0, 4.9)	0.087
Meat/Poultry/Fish (g)	0.0	0.0	0.0	0.0	0.068
Beverages (g)	243	(152, 334)	230.4	(183, 320.6)	0.971

Wilcoxon signed Rank test *p-value ≤ 0.05 **p- value < 0.01

Table 6: Correlations of food group intakes when comparing the FFQ to the average of two 24-Hour dietary recalls.

			Bland-Altman statistics			
Food groups	**Spearman correlation (95% CI)**	**De-attenuated correlation**	**Mean Difference (95% CI)**	**95% Limit of Agreement**		
Cereals	0.33* (0.15, 0.49)	0.62	9.9 (-41.9, 61.8)	535.3, -515.5		
Legumes	0.79* (0.71, 0.85)	1.60	2.6 (-8.9, 14.1)	-113.8, 118.9		
Vegetables	0.33* (0.15, 0.49)	0.62	7.1 (-15.7, 29.8)	-223.7, 237.8		
Beverages	0.20* (0.01,0.38)	0.40	2.9 (-30.9, 36.6)	-339, 344.7		
			Bland and Altman statistics		**Bland and Altman statistics for Log transformed data**	
	Spearman Correlation (95%CI)	**De-attenuated correlation**	**Mean Difference (95% CI)**	**95% Limit of Agreement**	**Mean Difference (95% CI)**	**95% Limit of Agreement**
Roots and Tubers	0.34* (0.16, 0.45)	0.55	16.2 (6.2,26.3) *	-87.5, 120.1	-0.04(-0.23,0.15)	-1.96, 1.88
Fruits	0.46* (0.23, 0.56)	0.90	7.9 (1.4, 14.6) *	-60.2, 76.2	0.15 (0.01,0.29) *	-1.25, 1.55
Eggs	0.12 (-0.07, 0.30)	0.24	-2.1 (-3.4,0.8) *	-15.9, 11.7	0.19 (0.11,0.27) *	-0.64, 1.03
Dairy products	0.45* (0.29, 0.59)	1.00	6.2 (1.9, 10.4) *	-37.8, 50.1	0.04 (-0.07, 0.14)	-1.03, 1.1
Meat/Poultry/Fish	0.47* (0.31, 0.61)	1.00	3.8 (-0.8, 8.4)	-43.2, 50.8	0.06 (-0.01, 0.13)	-0.68, 0.8

*p-value ≤ 0.05 **p- value < 0.01

Table 7. Cross-classification and Weighted Kappa statistics of daily intakes of food group in quartiles as assessed with the average of two 24-Hour dietary recall and the FFQ

Food groups	Cross-classification		Kappa statistics
	% in same quartile individuals	% in opposite quartile of individuals	Kappa value
Cereals	50.5	1	0.32
Legumes	51.4	0	0.35
Roots and Tubers	40	7.6	0.18
Vegetables	38.1	6.7	0.17
Beverages	30.5	11.4	0.07

Figures

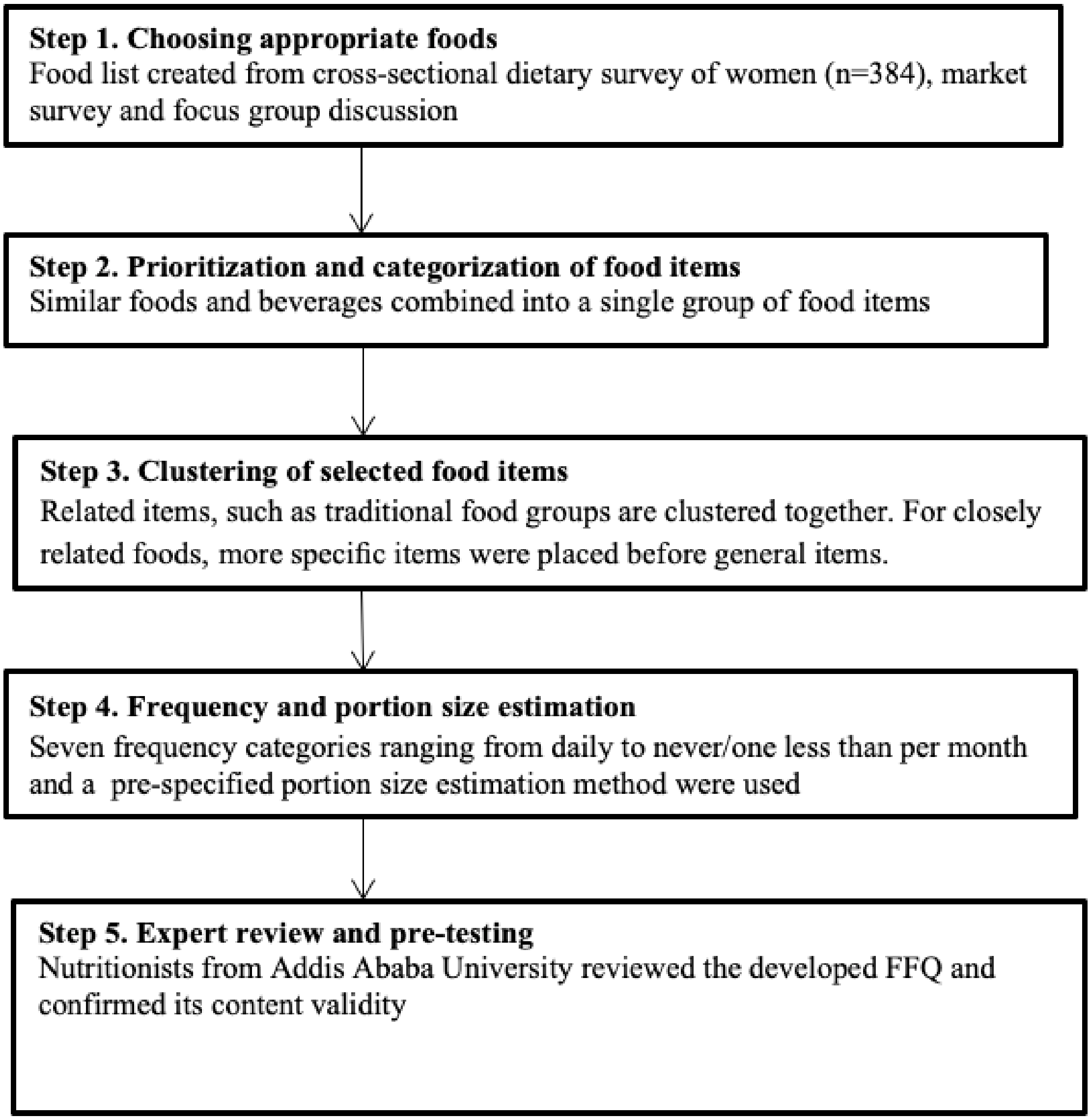

Figure 1

Food Frequency development

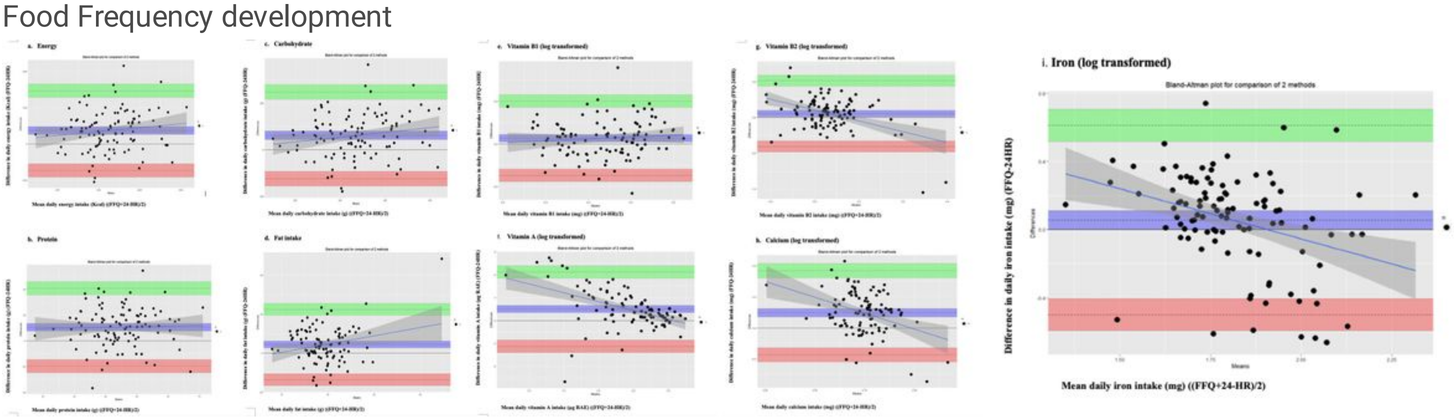

Figure 2

Bland Altman analysis plot of (a) energy, (b) protein, (c) carbohydrate, (d) total fat, (e) vitamin B1, (f) vitamin A, (g) vitamin B2, (h) calcium and (i) iron as predicted by FFQ and average of two 24 Hour dietary recall.

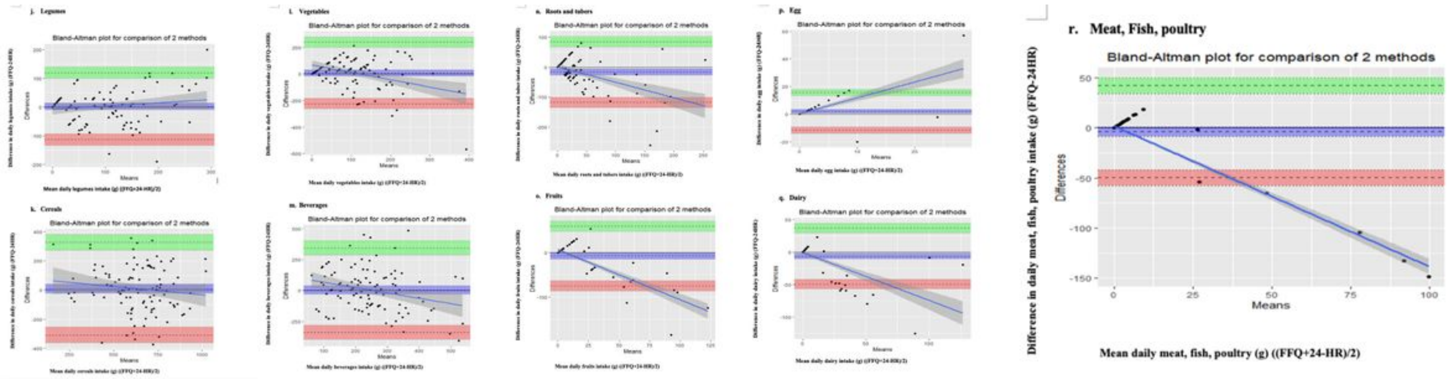

Figure 3

Bland Altman analysis plot of (j) legumes, (k) cereals, (l) vegetables, (m) beverages, (n) roots and tubers, (o) fruits, (p) egg, (q) dairy product and (r) meat/poultry/fish as predicted by FFQ and average of two 24 Hour dietary recall