ORIGINAL ARTICLE

Development, Validation, and Reproducibility of a Food Frequency Questionnaire (FFQ) for Adult Population in Brunei Darussalam

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ABSTRACT

Introduction: The dietary intake of adults in Brunei Darussalam has not been thoroughly investigated via the food frequency questionnaire (FFQ). This study aimed to establish, validate and test the reproducibility of an FFQ to determine and evaluate the adult dietary intake in Brunei Darussalam. **Methods:** Participants were divided into; (1) development phase (50 adults); (2) validation phase (100 adults); (3) reproducibility phase (subsample of 40 adults). 3-day dietary record (3DR) was used in development phase to gather food items consumed. 2-day dietary record(2DR) was used as a reference method in validation. Nutrients analyze were energy, macronutrients, calcium, and vitamins A and C. Validation analysis were spearman correlation, mean difference, Bland-Altman plot, cohen's kappa and cross-classification analyses. Reliability analyses were intra-class correlation coefficient (ICC), Cronbach's alpha and cross classification to compare repeat FFQ administered with 1 to 3 months interval. **Results:** The FFQ consisted 138 food items from 12 food groups. In validation, mean difference between FFQ and 2DR exceeded 10%, spearman correlation were significantly strong (r=0.994 to r=0.107). Cross-classification demonstrated > 50% of nutrients were correctly and adjacently classified, Bland-Altman plots were relatively consistent for the two methods. Cohen's kappa ranged from 0.081 to 0.040, demonstrating weak agreement. In reproducibility, ICC outcomes for FFQ1(0.463) and FFQ2(0.978), Cronbach's alpha was > 0.8, and > 95% of the nutrients were correctly or adjacently classified. **Conclusion:** The FFQ designed in this study was valid due to the consistency with the dietary records; hence, a reliable tool to predict the dietary intake of Brunei Darussalam adults.
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Keywords: Brunei Darussalam; food frequency questionnaire; adults; development; validation; reliability

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INTRODUCTION

Brunei Darussalam is the second smallest nation among ASEAN countries, with the second highest obesity rate in the region (1). Brunei Darussalam is at risk of producing more obese individuals, based on the rising obesity rates from 44.4% in 1997 to 62.8% in 2016 (2, 3). The surge in obesity prevalence may result from demographic changes and technological advancement, particularly urbanisation. Consequently, dietary transition and lifestyle changes occur due to work shifts, irregular sleeping patterns, stress, reduced physical activity, age, income, pollution, and social jetlag, resulting in rising obesity rates (4). With that, there has been a paucity findings in relation to age and income with body weight status. As increasing age and income is associated with increase body weight status (6,5). Additionally, due to the increase of diversity and cultural influences, transition of the population's dietary intake can be identified. Additionally, the diverse cultural dishes may change the populations' dietary intake. These transitions significantly impact public health due to the surge of non-communicable diseases, which are currently the leading causes of mortality in Brunei Darussalam (7).

The Ministry of Health (2014) revealed in the 2nd National Health and Nutritional Status Survey (NHANSS) 2014 (7) that Brunei Darussalam adults did not meet their daily dietary requirements. The population exhibited low carbohydrate intake (< 55%), increased protein intake (> 15%) and high fat intake (>30%) of total energy intake. The diversity and changes in the dietary intake of Brunei Darussalam's adults call for a dietary assessment to identify the association between diet and health outcomes. There are several methods of evaluating dietary intake, but each tool has different pros and cons. Consequently, the dietary intake of the

Brunei Darussalam population has not been effectively investigated, resulting in the lack of national surveys and studies among adults in the country. Therefore, developing a dietary assessment tool is essential to estimate the population's food consumption and pattern.

The food frequency questionnaire (FFQ) is a popular, economic and highly-accurate tool to monitor and evaluate individual dietary intake (8). This method is used worldwide and provides lists of common foods based on the dietary consumption pattern of a specific population or country (9). Furthermore, FFQ processes (administration and analyses) are low-cost with impeccable reliability due to the ability to assess and deliver a timeframe based on dietary intake. To date, there was a short FFQ conducted to assess the food consumption pattern of the Brunei Darussalam population (7). Nevertheless, no FFQs have been developed and validated specifically for the Brunei Darussalam adult population to assess their dietary intake. It is vital to validate targeted FFQ due to the population's socio-economic and cultural differences. Thus, this study developed and validated the reliability of a FFQ to evaluate the dietary intake of Brunei Darussalam adults and helps establish health-related measures such as association of dietary exposure and obesity and other health-related outcomes. Moreover, the developed FFQ will ease dietary assessments in the country by measuring the typical dietary intake at the population and individual levels over time. Most importantly, the FFQ findings will reflect the population's consumption of traditional foods instead of using the standards provided by other dietary methods. Therefore, it is crucial to produce a sensitive tool for a specific population to reflect their unique dietary intake and culture.

MATERIALS AND METHODS

This study was approved by the Medical and Health Research and Ethics Committee, Brunei Darussalam (MHREC/MOH/2020/17(2)). All participants who agreed to participate in this study had to complete the written informed consent before the study was conducted.

Study design and participants

The present study was a cross-sectional study carried out in urban areas, mainly within the city center of Brunei-Muara districts, from November 2020 to June 2021. The convenience sampling method was used to recruit adults aged 18 to 59 at the study sites. Recruitment was done via invitation and voluntary. Participants who agree to participate undergo imperative screening such as age, gender and location. The participants are carefully selected to best represent the entire population. The inclusion criteria were: (1) Brunei Darussalam citizen or permanent resident; and (2) aged between 18 to 59 years old. Meanwhile, the exclusion criteria were: (1) Participants in a weight management program, (2) Pregnant and lactating women, and (3) Individuals who were unable to communicate and illiterate. In addition, information such as age, ethnicity, sex and educational background were also obtained from the participants.

Food frequency questionnaire development

Data collection

A minimum sample size of 50 participants was required for the development phase (10). The FFQ was designed using a 3-days dietary record (3DR) consisting of one weekend and two weekdays. Subsequently, participants were instructed to provide a comprehensive description of all foods and beverages consumed, including detailed information on the product brands, cooking method and meal time. Firstly, a diet analysis was performed using the Nutritionist ProTM software (Axxya System, Woodinville, WA) to generate the total energy and nutrient intake intake per adult. Secondly, Goldberg cut-offs (11) were used to identify under- and over-reporters. In addition, the number of days, basal metabolic rate (BMR), physical activity level (PAL), age-specific PAL, and dietary reference value (DRV) for energy were considered in this study. The exclusion of under- & over-reporters from the datasets introduces unknown bias.

The following equations were used to determine cut-off points to identify energy intake (EI) misreporting in the selected population (12):

Lower and upper 95% confidence limit (CL) = square root of CV2WEI / (d + CV2wB + CV2tP)

where CVwEI = within-subject coefficient of variation in EI across days, d = number of days of diet assessment, CVwB = variation coefficient of repeated BMR measurements or the precision of estimated compared with measured BMR, and CVtP = total variation in PAL, considering between and within-subject variation and methodological errors in PAL (11). The information from 55 adults was analysed after the data cleaning by excluding underreporting (n = 3) and overreporting (n = 2). After ensuring the data is a good representation of the population, 50 adults were eligible for the development phase (10). In addition, images and measurements of household items such as bowls, tableware in varying sizes and food booklets were used as virtual assistance during the interviews to improve the data accuracy.

Development of a food list

The development phase consisted of three primary steps: 1) creating a food list based on the diet records, 2) categorizing and structuring food items, and (3) determining intake frequency and portion sizes. The mean weight of the foods consumed was used to calculate and determine the mean portion sizes, and food items that were frequently consumed were compiled into a food list. A total of 250 food items were selected from the participants' dietary records. First, the food items

were arranged in descending order and comprised 95% of the food list. Secondly, food items mentioned at least 20 times in the dietary record were also considered (13-15). Thirdly, food items that have similar nutrient components were merged into the same category (16). Finally, a list of 138 food items was computed based on the collected data.

The content validity was confirmed by three Health Education Officers and a Senior Dietitian from the Healthy Eating Unit, Health Promotion Centre, Ministry of Health, who are experts and familiar with Brunei Darussalam food. Each validator provided input via a content validation form and interviews, and changes were made to the list based on their feedback. All 138 food items were organised and divided into 12 main groups: 1) grains, cereals and starches, 2) rice and noodles dishes, (3) meat and meat dishes preparation, (4) fish and seafood products, (5) milk and milk products, (6) legumes and nuts, (7) vegetables and vegetable dishes, 8) fruits, 9) beverages, 10) fried snacks/confectionery, 11) condiments, and 12) spreads. Each food group was derived from the Atlas Food Exchanges and Portion Sizes, Malaysia (47) and to estimate the nutrient intake as there was no Brunei Darussalam food portion guide.

The local cuisines were weighed, and the closest representation of Brunei Darussalam's dietary intake was used as a reference in this study. Consequently, nine categories of frequency response format were established as the following: "never or rarely," "1 - 3 times per month," "Once a week," "2 - 4 times weekly," "5 - 6 times weekly," "Once daily," "2 - 3 times daily," "4 - 5 times daily," and "> 5 times daily" and an open-ended response scales for portion size based on the guide of household measurements. This approach demonstrates the most realistic, precise, and accurate representation of the subject's usual dietary intake and portion size based on the reference of household measurements (17, 18, 22).

Validation and reproducibility of FFQ

The first (FFQ1) and second FFQ (FFQ2) were completed via self-administration. A minimum of 100 adults is required for a validation study (10), whereas a minimum of 30 adults was the prerequisite for a reproducibility study (14). Likewise, the validation and reproducibility sample sizes in this study were 100 and 40 adults, respectively. The researcher utilises the picture aids of foods and standard household measurements in the interviews. Subsequently, participants were instructed to describe their food consumption over one month according to average portion sizes and frequency of consumption. Generally, the FFQ takes approximately 20 to 30 minutes to complete. Furthermore, participants were not repeated for the development and validation phases to avoid data replication that could affect the data representation.

Two-Day Dietary Record (2DR)

The FFQ was validated using the 2-day dietary record (2DR) method. Each participant was asked to record the 2DR on a weekday and a weekend. Figure 1 illustrates the flow diagram of the FFQ development, validation and reproducibility phases.

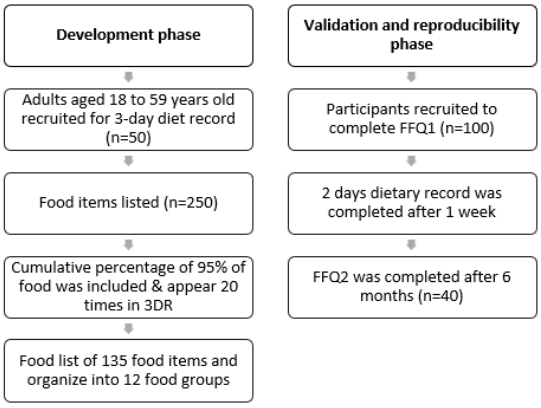


Figure 1: Flow diagram of development phase, validation phase and reproducibility phase

Dietary Nutrient Intake Analysis

The nutrient intake analysis consisted of three steps. First, the FFQ and 2DR food consumption and frequencies were expressed in grams (g), followed by nutrient intake. The Malaysian Food Composition Database (47), Singapore Food composition database (48) and the Atlas of Food Exchanges and portion sizes (47) were used to estimate the nutrient intakes as there was no available Brunei Darussalam food database. Thus, the nutrient information was referred from databases that closely reflect the dishes in Brunei Darussalam. Information for food items such as mixed dishes and local cuisines that were unspecified in the databases was obtained from nutritional food labels and commonly used recipes and entered into the Nutritionist Pro software as references. In the validation phase, Microsoft Excel (Microsoft, USA) was used to compute the dietary intake of total energy and nutrient intake from the FFQ. Nutritionist ProTM software was used to examine the 2DR's dietary data of each participant to acquire the total energy and nutrient intake. The essential nutrients for humans, including energy, macronutrients (protein, carbohydrates, fats) and micronutrients (calcium, sodium, vitamins A and C), were included in the analysis as the information are present in the database. Secondly, the amount of daily food intake was calculated using the formula (19).

Daily food intake = Intake frequency (conversion factor) x serving size x total number of servings x weight of food per serving

Meanwhile, the conversion factor was used to estimate the food intake based on the intake frequency (20).

Statistical analysis

The data collected in this study were analysed using the Statistical Package for Social Sciences (SPSS) version 26.0 (IBM Corp, Armkmonk, NY, USA). The study data were presented in median and interquartile ranges due to the abnormality in the data distribution. In addition, the Spearman correlation was utilised to identify and validate the FFQ against the reference method (2DR), while the Wilcoxon rank test was used to determine the differences between FFQ and 2DR. Subsequently, the cross-classification analysis was performed to determine the classification of nutrient intakes from the FFQ data and 2DR, besides evaluating the ability of both methods to classify the data correctly. Finally, the agreement level between FFQ and 2DR was tested via the Bland-Altman plot, whereas the agreement between individuals for FFQ and 2DR was analysed based on Cohen's Kappa value.

The residual method was used to assess the appropriateness of the regression and achieved by altering the nutrient intake regressed to total energy to reduce the variation of daily intake for each individual (21). Meanwhile, the Wilcoxon Rank test was used to determine the differences between the two methods (FFQ vs 2DR). The correlation coefficient between FFQ vs DR was reduced by considering within-individual variation. Furthermore, the Spearman correlation analysis was conducted by comparing the FFQ with the DR method for validity; the threshold for weak to very strong correlation coefficients was as follows: < 0.3 = weak, 0.30 - 0.39 = moderate, 0.4 - 0.69 = strong, and ≥ 0.7 = very strong (18).

The cross-classification analysis of ≥ 5 quartiles was performed to determine correctly classified, adjacent classified or entirely misclassified (by ≥ 2 quartiles) individuals based on the nutrient intakes from the FFQ and 2DR data. Moreover, Cohen's Kappa was used to explain the degree of consensus between two methods (FFQ vs 2DR) using the following thresholds: strong (r = ± 0.5), moderate (r = ± 0.30), and weak (r = ± 0.10) (22). The Bland Altman plots were also constructed to establish the agreement of nutrient intakes between the methods (FFQ vs 2DR).

The Intra Class Correlation (ICC) analysis and Cronbach's alpha were performed to determine the reproducibility between FFQ1 and FFQ2. The ICC measures the level of agreement between FFQ1 and FFQ2 via the analysis of variance (ANOVA) model for between and within group variations. Furthermore, the ICC values were transcribed as poor (≤ 0.40), fair (0.41 < ICC < 0.59), good (0.60 < ICC < 0.74) and excellent (0.75 < ICC < 1.00) (22). Cronbach's alpha >0.70 indicated as reliable. The value of significance was set at $p < 0.05$.

RESULTS

Development phase

Table I demonstrates participants' socio-demographic data in the development, validation and reproducibility phases. The FFQ development phase involved 55 adults, but only 50 adults completed the 3DR without under- and over-reporting, thus, yielding a response rate of 90.9%. The mean age of the adults was 27.54 ± 7.89 years old, consisting primarily of females (54%) and having tertiary education (62.0%). Furthermore, the FFQ initially consisted of 250 food items, but after rearranging the foods based on the energy and the cumulative percentage of food items, the top 95% of the total food list and those mentioned more than 20 times in the 2DR were included in the FFQ. In addition, common foods such as local delicacies and frequently consumed foods not mentioned during the dietary record were added to the list (ikan rebus, ikan ampap). The final food list was categorised into 12 food groups comprising 138 food items. Meanwhile, 103 adults completed the FFQ1 and 2DR in the validation phase, but only 100 were included due to under-reporting. The participants were 73% female, and 40% had tertiary-level education. Furthermore, the mean age of the adult participants was 33.8 ± 13.1 years old. Subsequently, 40 adults participated in the FFQ reliability phase, mostly females (57.5%) with a mean age of 31.15 ± 11.54.

Table I: Socio-demographic of subjects for development, validity and reliability phase

Characteristics	Development phase (n=50)		Validity phase (n=100)		Reliability phase (n=40)	
	n	%	n	%	n	%
Mean age±years	27.5±7.9		33.4±13.1		31.2±11.5	
Sex,						
Female	27	54	73	73	23	57.5
Male	23	46	27	27	17	42.5
Household income,						
Below $1,000	39	78	58	58	19	47.5
$1,000 - $1,999	8	16	16	16	6	15
$2,000 - $2,999	1	2	8	8	6	15
$3,000 - $3,999	1	2	8	8	3	7.5
>$4,000	1	2	10	10	6	15
Marital Status,						
Single	36	72	60	60	23	57.5
Married	14	28	35	35	15	37.5
Others (Divorced, widowed)	0	0	5	5	2	2.5
Educational level,						
No formal education	2	4	2	2	2	5
Primary school	0	0	3	3	0	0
Secondary school	4	8	38	38	16	40.0
Diploma & certificate	10	20	17	17	7	17.5
Degree & above	34	68	40	40	15	37.5

Validation phase

The validation results are shown in Table II, detailing the nutrient intake from developed FFQ and 3DR. It was found that the FFQ data were significantly higher ($p<0.05$) than the 2DR data, except for vitamin A (0.005). Furthermore, > 10% median difference suggested moderate agreement between FFQ and 2DR, except for vitamin A (-74.8%). The average relative difference was significant ($p<0.05$) and highest for vitamin C (75.7%), while the lowest value was recorded for vitamin A (-74.8%). The energy value difference was 32.9% for FFQ and 3DR. Moreover, in Wilcoxon signed rank, the nutrient intake values in FFQ & 2DR was statistically significant ($p<0.05$)

Based on Table III, the Spearman correlation is justifiable due to the strong correlation between the two methods (FFQ vs DR) for vitamin A (0.994), protein (0.911) and calcium (0.841). Nevertheless, energy (0.096), carbohydrates (0.142), fat (0.172), sodium (0.154) and vitamin C (0.107) exhibited weak correlations. Classification into the same adjacent quartiles was high for all the nutrients (> 97%) except for sodium (96%). Furthermore, minor misclassifications were between calcium (3%) and sodium (4%). Cohen's kappa values indicated a weak agreement for both groups, ranging from -0.081 to 0.00. Based on the Bland Altman plots (Fig. 2), the agreement between both methods (FFQ & 2DR) was acceptable as most scatter plots remained within the level of agreement (mean ± standard deviation (SD)). Overall, the results indicated that the developed FFQ is a verified tool to assess the food and food group intake of adults in Brunei Darussalam (see Table III).

Reproducibility phase

A subsample of 40 adults participated in FFQ1 and FFQ2 from validation phase. Median, ICC, Cronbach alpha and cross-classification were performed to test the reliability of both methods (see Table IV). The median for FFQ1 was slightly higher than FFQ2, except for sodium (3430 mg), which may be due to the participants' awareness of result repetition and participants' variations that led

Table II: Comparison of median nutrient intakes between two methods for validity phase (FFQ vs 2DR) (n=100)

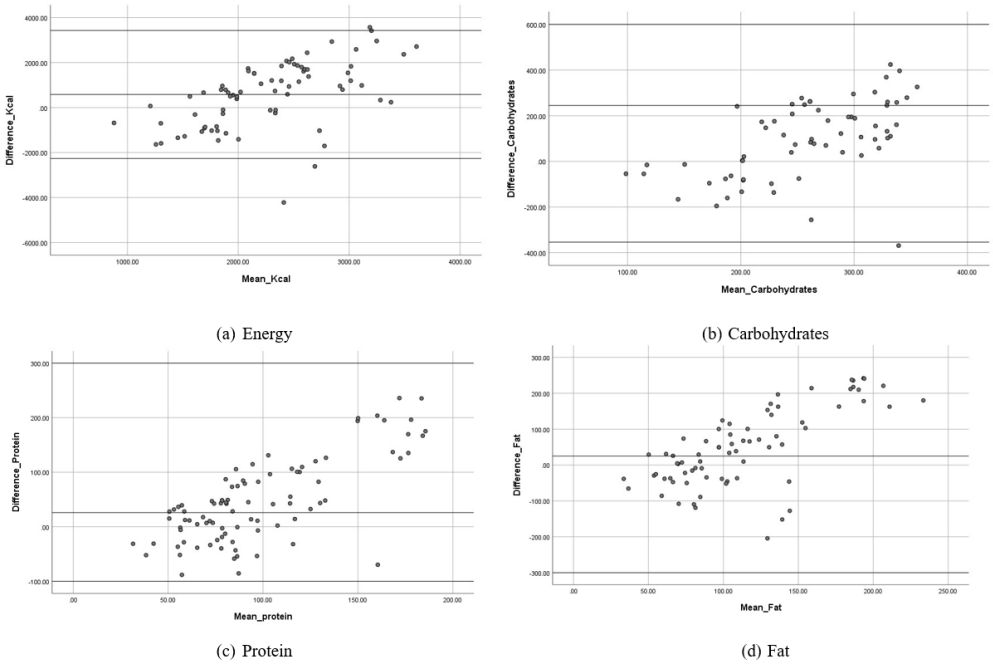
Nutrients	FFQ	2DR	Median difference	Relative difference (%)	Wilcoxon signed rank [a] (p-value)
	Median (I.Q.R)	**Median (I.Q.R)**			
Energy (kcal)	2698.3 (1453.6-3469.0)	1812.3 (4519.0-2224.5)	886.0	32.9	0.001*
Carbohydrates (g)	393.6 (297.2-655.4)	207.7 (152.9-256.0)	185.9	47.2	<0.001*
Protein (g)	107.4 (69.9-184.6)	68.3 (54.2-92.8)	39.1	36.4	<0.001*
Fat (g)	121.7 (71.5-217.9)	83.1 (67.9-110.6)	38.6	31.7	0.001*
Calcium (mg)	775.8 (430.4-1327.6)	347.7 (219.5-467.6)	428.1	55.2	<0.001*
Sodium (mg)	3560.2 (2096.5-6996.0)	2348.8 (1727.1-2936.4)	1211.4	34.0	<0.001*
Vitamin A (µg)	451.2 (202.6-688.1)	788.5 (404.3-1139.1)	-337.3	-74.8	0.005*
Vitamin C (mg)	137.8 (71.1-225.2)	33.5 (14.9-61.48)	104.26	75.7	<0.000*

Median difference = median food frequency questionnaire – median of 2day dietary record (Koo et al. 2020)
Formula of percentage median difference: ((median FFQ1 – median 2DR) / median FFQ) X 100 (Koo et al. 2020)
[a]Wilcoxon signed-rank test, $p<0.05$ **

Table III: Spearman correlation coefficient, cross-classification and Cohen's Kappa for comparison between two methods (FFQ vs 2DR) (n=100)

Nutrient	Spearman Correlation [b]		Cross-classification into quartiles (%)			Cohen's Kappa
	Unadjusted	**Energy-adjusted**	**Correctly classified**	**Classified adjacently**	**Grossly misclassified**	
Energy (kcal)	0.096	0.470	61	37	2	-0.080
Carbohydrates (g)	0.142	0.131	60	38	2	-0.107
Protein (g)	0.911	0.911	60	38	2	0.040
Fat (g)	0.172	0.736	40	57	3	0.027
Calcium (mg)	0.841	0.841	60	38	2	0.000
Sodium (mg)	0.154	0.116	40	56	4	-0.013
Vitamin A (µg)	0.994	0.990	60	38	2	-0.027
Vitamin C (mg)	0.107	0.098	60	38	2	0.040

[b]Spearman Correlation Coefficient, $p<0.05$**



(a) Energy (b) Carbohydrates (c) Protein (d) Fat

Figure 2: The Bland-Altman plots agreement between FFQ1 and 2DR for energy, carbohydrates, proteins and fats

Table IV: Reproducibility phase- comparison of median, intra-class correlation (ICC), cross classification and Cronbach's alpha (n=40)

Nutrients	FFQ1	FFQ2	ICC	Cronbach Alpha	Cross-classification into quartiles (%)		
	Median (I.Q.R)	**Median (I.Q.R)**			**Correctly classified**	**Classified adjacently**	**Grossly misclassified**
Energy (kcal)	2738.9 (1811.6-3469.6)	2821.0 (1903.4-3469.6)	0.871	0.885	100	0	0
Carbohydrates (g)	392.3 (299.4-533.1)	392.2 (295.5-535.8)	0.908	0.910	60	30	10
Protein (g)	104.3 (67.9-143.9)	84.3 (67.6-118.6)	0.463	0.505	100	0	0
Fat (g)	196.6 (87.9-333.8)	172.2 (72.6-198.5)	0.954	0.954	60	25	15
Calcium (mg)	704.5 (381.6-921.1)	619.8 (273.3-976.9)	0.978	0.977	100	0	0
Sodium (mg)	3200.6 (1326.5-4638.6)	3430.9 (1683.8-464.4)	0.961	0.960	60	35	5
Vitamin A (µg)	506.3 (174.5-625.6)	260.6 (171.8-440.6)	0.892	0.891	100	0	0
Vitamin C (mg)	147.5 (72.5-210.5)	38.9 (26.5-46.4)	0.985	0.986	60	35	5

to under-reporting or over-reporting. The ICC values for the nutrients were energy (0.871), carbohydrates (0.908), proteins (0.463), fat (0.954), calcium (0.978), sodium (0.961), vitamin A (0.892) and vitamin C (0.985), while a Cronbach's kappa of > 0.80 indicated excellent reliability. Consequently, > 95% of the nutrients were classified correctly or adjacently into the same quartiles.

DISCUSSION

This study developed and examined the validity and reliability of the FFQ specifically designed to analyse dietary intake of Brunei Darussalam's adults. FFQ has gained popularity for effectively assessing dietary intake at a low cost compared to other methods (8). Previously, a short FFQ consisting of 17 food items was developed in Brunei Darussalam to assess food consumption patterns of those between 5 to 75 years old, focusing on fruits, vegetables, eating-out meals, breakfast frequency, beverages intake (milk, sweetened drinks, instant drinks, oil and coconut milk), malay kuih or dessert intake, fried food, nasi katok, instant noodles, snacks, and food supplements intake (7). Despite that, the FFQ may not be appropriate for evaluating Brunei adults' dietary intake due to age differences, food accessibility and cultural influences. To the best of our knowledge, this is the first validated FFQ developed for a dietary intake assessment of Brunei Darussalam adults. This FFQ was designed to reflect the current dietary intake of Brunei Darussalam adults, including local foods and the cultural

influences on dietary intake, such as westernised foods, for example, pizza and pasta, etc due to nutritional transition and urbanisation (16).

This study developed and validated a 138-food items FFQ that evaluated and identified the dietary intake of Brunei Darussalam adults. A total of 50 adults (aged 18 to 59) were included in the FFQ development to establish an updated list of food items. Generally, the selected participants were considered a good representation of the Brunei Darussalam adult population with a fair amount of distribution across genders, household income, marital status and educational level at all phases. The majority of the Brunei Darussalam population is in the second quantile in terms of socio-economic status, with an income of < $2,757 (23). Furthermore, most participants have higher education due to the selected age group (18 to 59 years old) (24).

This study utilised the 3DR method in the development phase. Dietary records are ideal as the method does not depend on memory and prospectively captures the actual dietary intake within two or three days (24). For instance, (18) used 2DR and yielded better results in assessing energy, macronutrients, micronutrients and mineral intakes than the Malaysia Adults Nutrition Survey (MANS) (20) that utilised the 24-h recall method, which could lead to underreporting of nutrients. Visual aids such as household measurements and food images also improved the recall of portion size, consistency, and accuracy of the 3DR.

A typical FFQ contains between 100 and 200 items (18). The current FFQ has an ideal length of 138 food items, consistent with studies various studies with 137 and 163 food items (26,27), respectively. Selecting and compiling relevant food items are essential in identifying the population's dietary intake. Food items could range from five to 350, but a longer list could cause an overestimation, whilst a short one could lead to an underestimation of the findings. Furthermore, the food list length could impact the participants' food choices by prompting them to choose more or limiting their food choices (10). The FFQ developed covered > 95% of the total population's dietary intake, hence, a good representation of Brunei Darussalam adults' dietary intake. Moreover, the FFQ would take approximately 10 to 15 minutes to complete and does not burden the participants.

A total of 100 adults had completed the FFQ1 and 2DR, which is sufficient for validation, as confirmed by several studies (21,28). Therefore, the 2DR was used as a reference tool against FFQ to determine the validity of the questionnaire. Furthermore, the duration of the 2DR method was good enough to represent the average habitual intake of each individual over time (9). Currently, there is no agreement on the best dietary assessment (29,30) but biomarkers analysis is recommended due to the high accuracy. Despite that, biomarker analysis is molecular technique that is costly; thus, the dietary record remains the second most common dietary assessment, offering accuracy, simplicity and inexpensive (29, 31).

The findings also revealed the nutrient median differences between the two methods, where FFQ recorded a higher median intake than 2DR. This outcome was expected because over-reporting or over-estimation is common in FFQ, resulting from a large amount of food items and intake over a month instead of days (13, 25, 32, 33). These outcomes were consistent with earlier studies, where FFQ nutrient intake was higher than the DR (25, 31). Moreover, there were major mean differences between the two methods for energy (32.9%), carbohydrates (47.2%), protein (36.4%), and fats (31.7%) in the present study. Likewise, (29) reported that the mean differences in energy (53.0%), carbohydrates (47.4%), protein (44.0%) and fats (74.1%) when validating the FFQ to assess the dietary intake among preschool children. In another study, reported similar findings where the mean difference was slightly higher for energy (22.9%), carbohydrates (30.8%), protein (16.1%), and fat (11.9%) on an FFQ developed to evaluate multi-ethnic, primary school children (13). Therefore, the percentage mean differences found in the present study were acceptable.

Brunei Darussalam is an equatorial and tropical country with sunshine and rain throughout the year; thus, food consumption is not influenced by seasonal changes. Moreover, fresh produce such as fruits and vegetables are mostly imported into the country, hence, constantly available for the locals. Notably, the median difference for vitamin A was higher in 2DR (788.5µg) than in FFQ (451.2µg). This finding may be caused by consuming vitamin A-rich foods (vegetable juices) during the 2DR, leading to an overestimation. Consequently, the food items rich in vitamin A (green leafy vegetables, meat, eggs and fish) were revised and included in the FFQ to accurately represent the high vitamin A levels in the study outcome. Furthermore, calcium and vitamin C were higher in FFQ (775.8 mg and 347.7 mg) than in 2DR (137.8 mg and 33.5 mg). This outcome may be attributed to the longer FFQ duration (one month) compared to the 2DR (two days, one weekday and one weekend), thus, causing an overestimation of calcium and vitamin C. This occurrence is also fairly common in FFQ (16,18). In addition, food consumption at different periods could influence the FFQ completion, thus, affecting reporting outcomes and representation of the individual dietary intake (34).

The current study findings demonstrated that the developed FFQ was acceptable due to the strong correlation with 2DR (0.098 to 0.911), and most values were > 0.4. The energy-adjusted data enhanced the correlation of nutrient intakes, particularly for energy and fat, between the two methods. A correlation

coefficient between 0.5 to 0.7 are generally desirable for a validation study (14). Furthermore, the present results were similar to another FFQ validation study that conducted a 24 h dietary recall among 161 participants aged 18 to 80 (correlation coefficient = 0.15 to 0.80), with two-thirds> 0.30 (35). Similarly, a study performed in China among adults reported correlation values between 0.19 to 0.58 (35). The duration of FFQ and 2DR should not be too near or variable; thus, dietary intake data should be obtained within two to three consecutive days (18) within 15 days to a year for accurate estimation and correlation. Despite that, one month between the two questionnaires and dietary assessment methods was considered acceptable (37). Additionally, correlation values could be improved via interview-based FFQ and by increasing the frequency of FFQ administration (38). Nonetheless, the FFQ performance should not depend solely on the correlation analysis.

Fig. 2. shows Bland-Altman plots depict the degree of agreement between the two methods (FFQ vs 2DR). These plots were established to identify the differences between FFQ and 2DR, with a 95% degree of agreement. It is uncommon to report a positive mean difference and systematic bias of over-estimation for energy and nutrient intake and the presence of outliers, despite the strong agreement and correlation between the two methods (16). Variations are expected for foods consumed rarely or never due to the nature of the FFQ, as assessing such foods from the 2DR is low due to the inability to capture the natural dietary intake (35). Therefore, increasing the number of days for food records per person is advisable to achieve better agreement with the FFQ. In addition, the current finding was consistent with (21), who evaluated the dietary intake of Malaysian Punjabis using 2DR and (18), who studied the multi-ethnic Malaysian population. Both studies reported an overestimation in FFQs compared to the mean of dietary recalls.

A cross-classification analysis of nutrients was performed to test the agreement between FFQ and 2DR further. The FFQ demonstrated that > 95% of items were correctly and adjacently classified into quartiles, with a small degree of misclassification (2 - 4%). The findings are comparable to a Malaysian study on children aged 7 - 12 years, where more than 70% of the participants were correctly classified and < 7% were grossly misclassified (12). Likewise, a study on a similar population group in France and reported a misclassification of < 5% whilst correctly classifying 55% to 95% of the participants (39). It is ideal that 50% are correctly classified and < 10% of misclassification is present to validate the FFQ (40). Therefore, the agreement between the two methods via correlation and cross-classification validated the FFQ developed in the present study. Cohen's kappa was also conducted to test the agreement between the two methods. A weak agreement was obtained between the FFQ and 2DR, ranging from -0.080 to 0.00. This indicated that the data are 15 to 35% reliable (41). Similarly, (42) indicated poor agreement level for the relative validity of short FFQ conducted on 848 middle-aged participants. Nonetheless, the FFQ performance and validity do not solely depend on Cohen's kappa analysis

The FFQ was administered twice to the same participants for the reproducibility test. The reproducibility phase requires a minimum sample size of 30 participants (10). In this study, 40 adults were selected, and the FFQ1 and FFQ2 were distributed within one to three months to improve the consistency and reduce the day-to-day variations in dietary intake. A short time interval may affect the reliability of FFQs as repetition will likely occur as participants remember their responses, while a long time interval causes an alteration in dietary intake due to seasonal, cultural and festivities changes (39,34). Furthermore, the FFQ1 and FFQ2 were administered between one to three months to avoid the discrepancy and to ensure no major dietary changes caused by festivities such as Hari Raya celebration that could affect the FFQ reliability. The ICC, Cronbach's alpha and cross-classification were performed to test the reproducibility of the FFQ.

There was strong reliability for energy (0.871), macronutrients (0.463 - 0.954) and micronutrients (0.892 - 0.985) in the present study. A similar study conducted among Punjabis in Malaysia reported an acceptable range of reliability energy (0.68), macronutrients (0.46 - 0.73) and micronutrients (0.29 - 0.92) (21). The outcome is expected as the administration time was six months apart, hence, the presence of day-to-day variations. Meanwhile, Cronbach's alpha in this study ranged from 0.505 to 0.986, and most values were > 0.900. Likewise, a study on Malaysian school children also demonstrated a strong Cronbach's alpha of 0.995 (16).

According to (44), Cronbach's alpha of > 0.70 indicates that the FFQ is reliable. Therefore, the FFQs developed in the current study exhibited excellent reliability. Additionally, the cross-classification indicated that > 50% of the adult's nutrient intake was classified into the same quartile or adjacently, and < 10% were misclassified, except for fat (15%). Furthermore, previous studies used various time intervals (days, months, years) to test the reproducibility of FFQ1 to FFFQ2 (26,39,21). The study outcome could reflect the alterations in dietary habits for a certain period due to the nature of the FFQ (34).

Despite the favorable results, there were several limitations of the developed FFQ. First, the 3DR and 2DR methods were cost-effective but not without weaknesses. This limitation could be addressed by prolonging the duration of dietary records to capture and increase the accuracy of the individual's dietary intake. Alternatively, biochemical measurements of nutrients in blood or other tissue could be considered due to the high level of accuracy. Nevertheless, this analysis is costly

as it is a laborious procedure. For example, cost on the lab analysis, chemical uses, the apparatus, equipment's needed to conduct the analysis. Secondly, Cohen's kappa analysis indicated poor agreement in this study, despite moderate to strong agreement in other analyses. Cohen's Kappa test is often applied to quintile data due to the sensitivity to unequal answers. Additionally, (42) stated that Cohen's kappa value decreases as the expected chance of agreement increases. Since there is a 50% chance that a variable will fall into one of the two categories, dichotomous variables are given lower predicted kappa values. Therefore, the poor agreement level may not reflect the agreement between FFQ1 and FFQ2.

The current study also has several strengths. First, the FFQ developed in this study was the first to be validated for the adult population in Brunei Darussalam. In addition, the FFQ was detailed and comprehensive, and reproducibility was ensured by taking all the necessary measures. Furthermore, the data collection for the development phase was conducted via interviews to obtain prompt feedback and advice from the researcher. Participants were able to estimate the portion sizes accurately aided by household measurements. Therefore, the developed FFQ is highly recommended for the Brunei Darussalam adult population to ascertain their dietary intake over time. Moreover, this validated FFQ could aid future studies in understanding the dietary intake and pattern of Brunei Darussalam adults.

CONCLUSION

The FFQ developed in this study was the first validated tool to assess and estimate the dietary intake of Brunei Darussalam adults. Therefore, this FFQ could be utilised in future population-based or large-scale epidemiological studies for adults aged 18 to 59 to determine and assess their dietary intake and pattern.

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