ORIGINAL RESEARCH ARTICLE

Development and Validation of a Food Frequency Questionnaire for Use in Epidemiological Studies Among North Karnataka Population

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ABSTRACT

Background: Dietary records, such as food diaries (FD) and food frequency questionnaires (FFQs), are widely employed in large-scale epidemiological analyses. Given the regional diversity in dietary habits, this study aimed to develop and assess the reproducibility and construct validity of a novel FFQ tailored for northern Karnataka (FFQ-NK).

Methodology: A detailed food list was created based on food use and market surveys in the region. Utilizing data from 24-hour diet recalls and a supplemental focus group discussion, a 116-item semi-quantitative FFQ was developed for adults in north Karnataka.

Setting and Subjects: Involving 100 participants from north Karnataka, the FFQ was interviewer administered and the participants also completed three 24-hour dietary recalls (DR), serving as a reference for validity assessment.

Results: Though the FFQ indicated higher food and nutrient intake compared to food records. Significant correlations were found for nutrient intake. Pearson's correlation coefficients between FFQs and DRs ranged from 0.717-0.965 (isoflavonols to energy).

Conclusions: The developed and validated FFQ is a valuable tool for epidemiological studies requiring nutrient intake estimates in the north Karnataka population. It serves as an effective dietary assessment tool for individuals aged 20 and older in large-scale epidemiological studies.

Key-words: Dietary assessment, food frequency questionnaire, validity, epidemiological studies, north Karnataka

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Introduction

Dietary factors are indeed a significant environmental determinant influencing the development of chronic diseases. [1–2] The food frequency questionnaire (FFQ) stands out as the predominant tool for assessing nutrient intake in large epidemiological studies, often employed to investigate the link between diet and chronic diseases.[3–4] Additionally, the FFQ facilitates the categorization of subjects into low, medium, and high consumption tertiles, streamlining the exploration of associations with disease prevalence and mortality data in specific populations.[5] FFQs are cost-effective and practical tools that represent long-term intake of energy, macronutrients, and micronutrients.[6-8]

They have gained popularity as they pose less tribulation to both the investigator and the subjects in comparison to other dietary assessment methods.[9-12]

Though the FFQ are not without limitations, they are popular as their feasibility is the major advantage for use in establishing long-term habitual dietary intake. [13] Given the diverse dietary habits in the Indian population, it is crucial to develop and validate Food Frequency Questionnaires (FFQs) tailored to specific regions and research goals. Dietary patterns, shaped by factors like ethnicity, culture, preferences, and financial status, underline the need for Food Frequency Questionnaire (FFQ) validation against gold standards like specific biochemical markers for precise nutrient intake measurement.[14-16] while biomarkers offer independence from biases, they lack substitution for common dietary components and dietary recommendations. In epidemiological research, FFQs stand out as cost-effective, easily administered tools, surpassing food diaries and biomarkers in utility.[17-19] Despite their widespread use, the less accurate nature of FFQs necessitates data verification against reference techniques, like food diaries, to mitigate biases arising from portion size estimates and memory limitations. The Indian subcontinent is known for its diverse eating habits and the vast variety of foods consumed. The recent transition in the dietary pattern in both traditional food items and with the easy availability of global cuisine has seen a persistent increase in diet-related non-communicable and degenerative diseases.[20–22]

Dietary instruments like the FFQ play a vital role in epidemiological studies investigating the definitive role of nutrition on lifestyle diseases and formulating health policies. This study addresses the need for a validated FFQ tailored to diverse socio-demographic populations in the Indian subcontinent, particularly north Karnataka. The developed FFQ enables investigations into links between dietary patterns and health outcomes in the north Karnataka population, marking the first of its kind for the region, validated against a three-day 24-hour dietary recall.[5]

The study was motivated by the clear need to develop and validate an FFQ that is suitable to assess dietary pattern across heterogeneous socio-demographic populations with varying incomes and categories in the regions of Indian subcontinent and of north Karnataka in particular. The study also aimed to explore differences in habitual dietary intakes that were attributed by age, gender, education, social class and body mass index (BMI).

Methodology

Population setting and cohort recruitment: The FFQ-NK was developed within the diverse population of Vijayapura district in north Karnataka, India, representing both rural and urban demographics. Vijayapura, a prototypical region in north Karnataka, exhibits a dietary pattern cantered around staples such as jowar and rice, complemented by a substantial intake of fresh vegetables and greens in the form of curries and spices. Ethical approval for the study was obtained from the Institutional Ethics Committee of BLDE (du) Shri B M Patil Medical College, Hospital, and Research Centre (Ref: BLDE(DU)/IEC/460/2020-21). Participants were provided with detailed information about the study through an information sheet and provided informed consent. The inclusion criteria encompassed healthy individuals above the age of 18, while those on extreme diets (anyone consuming more calories than the specified range (4200 kcal for men and 3500 kcal for women)) or fasting regimens were excluded. A total of 130 participants were recruited by a purposive sampling technique in which the participants were selected as per the maximum variation sampling technique. On the basis of the participant informant sheet and after exclusion on the predefined criteria the participants were selected based on urban/rural settings, gender, age group, physical activity and BMI. Additionally, their occupational categories (service and homemakers) and annual income of the household and their educational qualification were also considered but with an intention to ensure that the individuals belonged near equitable representation across the various factors which can affect their dietary choices and patterns.

Development of FFQ-NK: The formulation of the FFQ-NK was meticulously conducted by leveraging information from the National Institute of Nutrition, Hyderabad, India's database, which includes nutritive values of commonly consumed food items. [23] The dietary pattern specific to north Karnataka, including infrequently consumed items, and was derived from a reference database developed for the region.[24-25]

Prior to developing FFQ-NK, extensive literature review, diet surveys, and FFQ development studies were examined. The preliminary stage involved formative fieldwork, which was qualitatively followed by a sequenced mixed-methods approach.[26]

Food List Construction and Nutrient Alignment:

The development of the FFQ-NK's food list involved a comprehensive approach, utilizing two primary methods:

1. **Identification of Food Items:** The food list was compiled through a dual approach: firstly, by identifying commonly consumed local, regional, and global foods using 24-Hour Diet Recalls of 50 representative participants aged 18–60 years. Secondly, written free lists were obtained from a purposive sample of adults, encompassing foods available in local stores and from vendors.[27] This combination allowed for a diverse and representative compilation of food items.
2. **Categorization and Review:** The resulting food list was categorized into fourteen groups based on their ingredients and preparation methods. This categorization facilitated a systematic understanding of dietary patterns within the study population.
3. **Database Review for Target Nutrients:** To ensure the relevance of the food list to the study's nutritional goals, each listed food item underwent a meticulous review against a comprehensive nutrient database.[23] This step aimed to align the food list with the intake of 32 nutrients, including energy, protein, fat, carbohydrate, fibre, various fatty acids (saturated, monounsaturated, polyunsaturated), essential minerals (iron, zinc, magnesium), and a spectrum of vitamins (B1, B2, B6, B12, C, A, D, E), among others.
4. **Validation of Nutrient Profiles:** A rigorous validation process affirmed that the food list included items accounting for over 95% of the nutrient profiles used for the epidemiological studies.[28] This validation was conducted through sample analysis, ensuring that the selected food items sufficiently represented the nutritional diversity of the study population.

Description and the Frequency response section of FFQ-NK: The FFQ-NK was developed with a 116-item scale that measured food consumption over a year (96 composite food items (i.e., food items containing one or more ingredients) and 20 simple food items). The food list was built and categorized into fourteen food groups based on their ingredients and preparation methods: i. Starchy staples ii. Legumes and Nuts iii. Green leafy vegetables iv. Other vegetables. Egg vi. Flesh foods vii. Milk and dairy products viii. Sweets and desserts, ix. Pickles x. Salads/raw food Fruits xii. Fats and oils xiii. Miscellaneous foods and xiv. Alcoholic beverages

The semi-quantitative FFQ-NK was interviewer-administered to be more precise and had seven frequency categories for food consumption over 1 year, from 2-3 times per day to rarely/never as responses. The participants were also tutored on the normal portion size typically eaten by them. As most of the common fruits are currently available throughout the year, the data capture was done as a single response and was noted as small, medium, and large. The volume, diameter (2.4 to 3.7 cm) of the most commonly consumed size, and number of pieces were standardized for weight equivalence. They were also assisted in estimating their portion size as a multiple of the standard measure by using metal vessels and spoons, as described in earlier studies.[23]

Administration of FFQ: The FFQ-NK was administered to a representative sample of 130 individuals aged 20–70 years. For validation, 3-day, 24-hour diet recall interviews were employed as the reference method due to noted lower overall variance.[29] Trained nutritionists conducted open-ended, prompted interviews over three non-consecutive days, ensuring avoidance of days with significant dietary variations. Respondents provided chronological reports of all food encounters throughout the day.

A follow-up response rate of 100 participants was achieved when study's exclusion criteria were applied for data completeness. The resultant tabulation involved multiplying frequency of intakes by portion size and corresponding nutrient profiles reported by participants.

Statistical Analysis: All statistical analyses were conducted using GraphPad Prism (version 9.2, India) for descriptive statistics, frequency distributions, and graphical representations. For advanced statistical modelling and analyses, JMP 16.2 was utilized. The responses from FFQ were subjected to comprehensive analysis, encompassing mean, median, and standard deviation calculations for various nutrients. Descriptive statistics were employed to elucidate demographic details and frequency distribution, providing a foundational understanding of the acquired responses. Prior to analysis, normal distribution tests were conducted, revealing that most variables exhibited normal distribution. However, VIT E, Flavan-3-ol, Flavones, and Flavanones were log-transformed to enhance comparability. To assess the significance across different parameters, regression analysis was undertaken, focusing on gender, domicile, and per capita income. Associations between nutrient intakes from FFQ and the arithmetic mean of the 3-day DR were evaluated using Pearsons' correlations. One-way ANOVA tested for overall significance, followed by paired t-tests for specific comparisons. Simple linear regression was applied to assess the linear agreement between nutrient scores obtained from FFQ and the arithmetic average from 3-day DRs. The agreement between the two methods was further evaluated using the Bland–Altman method, offering insights into potential bias, reproducibility and limits of agreement

Results

Demographic characteristics (Table 1): BMI, basal metabolic rate; the study cohort demonstrated a balanced gender representation, with males constituting 51% and females 49%. The majority of participants fell within the 30–40 years age group and urban residents (56) accounted for the majority of the study population. A substantial portion of participants exhibited a normal BMI (39%), while 47% were classified as overweight. Notably, the majority of individuals (68%) reported engaging in moderate physical activity.

Summary of the nutrient intakes: The summarized findings, presented in Table 2, provide a detailed overview of the *statistically significant variations in nutrient intakes across gender, domicile, and per capita income groups. Significant variations in nutrient intake were identified between males and females. Total energy, net carbohydrate, total fat, MUFA, and folate were notably higher in males and the differences were statistically significant and also males reported increased mineral intake, particularly iron and calcium. Distinct differences in nutrient intake were observed between urban and rural dwellers. Notably, disparities in the intake of specific nutrients, including vitamin D, B12, folate and iron, were identified, highlighting the potential influence of domicile on dietary patterns. Participants were stratified based on per capita income levels using Prasad's classification. While the overall mean intake of energy, proteins, vitamin D, vitamin C, and minerals such as iron and calcium appeared lower in the lower economic class (EC) compared to middle and high- economic class (EC), these differences were statistically insignificant, except for vitamin C (P value: 0.04), indicating a potential association between income levels and vitamin C intake.

Validity of the Food frequency questionnaire: The validity of the FFQ was evaluated through Pearson correlations between responses from the FFQ and the mean of three 24-hour DR. The Pearson correlation coefficients were computed for each nutrient, providing a quantitative measure of the strength and direction of the linear relationship between the FFQ and the 3-day 24-hour DR.

Table 1: Socio-demographic characteristics of study participants (n = 100)

Demography	Participants (%)
Gender	
Male	51 (51)
Female	49 (49)
Age (years)	
<30	24 (24)
31-40	34 (34)
41-50	22 (22)
51-60	12 (12)
>60	8 (8)
BMI (kg/m²)	
Below 18.5	3 (3)
18.5-24.9	39 (39)
25-29.9	47 (47)
30 and above	11 (11)
Per Capita Income/Month (Rs)*	
Below Rs.773 (V)	33 (33)
773-1546 (IV)	20 (20)
1547-2577 (III)	23 (23)
2578-5155 (II)	9 (9)
5156 and Above (I)	15 (15)
No. of family members	
2-4	45 (45)
5-7	42 (42)
8-10	12 (12)
>10	1 (1)
Domicile	
Urban	56 (56)
Rural	44 (44)
Physical activity	
Active	12 (12)
Moderate	68 (68)
Sedentary	20 (20)

* (Prasad modified classification)

Table 2: Mean nutrient intakes across demographic Factors

Nutrients	Male	Female	'p' value	Urban	Rural	'p' value	Lower EC	Middle EC	'P' value
Energy (kcal)	2397	2338	0.00**	2372	2389	0.04	2599	2636	0.87
Carbohydrate(g)	296.9	292.6	0.00**	291.6	298.9	0.17	322.7	307.1	0.62
Proteins (g)	52.6	49.9	0.6	52.0	53.0	0.02	61.6	54.2	0.29
Fat (g)	123.1	132.4	0.005**	122.3	125.5	0.29	133.7	120.6	0.30
Fibre (g)	46.1	44.5	0.63	46.4	49.1	0.12	44.5	48.9	0.50
Saturated fat (g)	37.0	33.8	0.21	37.4	34.1	0.43	36.3	36.5	0.96
Total MUFA(g)	42.8	36.7	0.002**	39.6	40.2	0.53	43.5	40.5	0.43
Total PUFA(g)	39.5	33.0	0.036	35.9	37.2	0.62	41.1	35.6	0.35
Vitamin A (µg)	462	377.2	0.029	417.8	422.1	0.40	466.8	468.3	0.98
Vitamin C (mg)	284.7	346.8	0.086	316.8	320.2	0.19	253.9	375.1	0.04**
Vitamin D(µg)	71.4	67.9	0.377	69.2	67.2	0.00**	69.1	80.5	0.19
Vitamin E (mg)	40.3	38.6	0.850	38.3	41.7	0.78	40.3	43.0	0.87
Vitamin B1 (mg)	3.18	2.89	0.208	3.0	3.2	0.35	3.1	2.9	0.50
Vitamin B2 (mg)	7.92	6.68	0.115	7.2	7.1	0.04	8.0	7.9	0.96
Vitamin B6 (mg)	6.15	5.76	0.338	5.9	6.1	0.20	6.2	5.8	0.63
Vitamin B12 (µg)	1.65	1.71	0.698	1.6	1.7	0.09**	1.62	1.7	0.60
Folate (µg)	358.9	319.3	0.085**	338.7	348.2	0.09**	364.0	332.3	0.47
Iron (mg)	77.1	53.9	0.020**	65.3	66.8	0.00**	73.1	79.4	0.73
Zinc (mg)	7.9	6.0	1.34	6.9	7.0	0.29	8.1	7.3	0.34
Calcium (mg)	440.4	452.1	.003**	476.2	550.2	0.12	410	447.1	0.043**

SD, standard deviation; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acids. Mean nutrient intakes were derived from the initial administration of the FFQ.

Table 3: Correlation Analysis: FFQ vs. 3-Day 24-Hour Dietary Records

Nutrients	FFQ1		DR		Pearson coefficient (Unadjusted (R))	Pearson Coefficient (Energy Adjusted (R))	'p' Value
	Mean	SD	Mean	SD			
Energy (kcal)	2391.2	632.43	2314.41	586.51	.96	–	
Carbohydrates (g)	296.18	84.14	283.25	82.388	.94	0.89	0.14
Proteins (g)	50.99	17.68	48.61	14.57	.92***	0.85	0.00
Fat (g)	121.37	33.91	121.09	33.50	.96	0.91	0.44
Saturated fat (g)	35.51	12.90	35.25	13.41	.96	0.92	0.10
Total MUFA(g)	39.86	10.49	38.79	9.81	.92	0.85	0.35
Total PUFA(g)	36.32	15.66	34.91	15.12	.94	0.88	0.99
Vitamin A(μg)	420.16	198.03	387.97	177.14	.92	0.85	0.92
Vitamin C(mg)	315.58	183.08	304.29	174.25	.78*	0.60	0.08
Vitamin D(μg)	69.72	20.26	68.66	20.39	.92	0.85	0.29
Vitamin E(mg)	39.42	45.87	37.46	43.53	.85***	0.71	0.00
Vitamin B1 (mg)	3.03	1.15	2.89	1.11	.92	0.84	0.19
Vitamin B2 (mg)	7.26	3.99	7.37	3.75	.90**	0.81	0.01
Vitamin B6 (mg)	5.99	2.16	5.717	1.99	.90	0.80	0.42
Vitamin B12(μg)	1.63	.906	1.74	.747	.93	0.86	0.29
Folate (μg)	339.34	116.59	324.87	108.91	.95	0.90	0.51
Total carotenes-μg	11668.	5069.2	10975.9	4346.6	.94	0.88	0.29
Selenium (μg)	176.49	72.792	174.82	71.881	.76*	0.57	0.08
Omega-6 FA (gm)	47.33	24.772	47.95	24.45	.90*	0.81	0.08
Omega-3FA (gm)	37.92	25.173	39.023	25.01	.86	0.73	0.12
Caffeine(mg)	82.10	53.032	84.72	53.07	.84	0.70	0.12
Magnesium (mg)	878.11	295.24	858.11	281.25	.90	0.90	0.48
Flavan -3-ol(mg)	4.16	2.654	3.56	2.25	.96	0.93	0.66
Flavones(mg)	2.59	2.142	2.35	2.25	.80	0.80	0.81
Flavanols(mg)	7.80	2.981	7.26	3.08	0.77**	0.59	0.00
Flavanones (mg)	6.43	12.440	5.83	12.02	.74***	.54	0.00
Calcium (mg)	440.4	52.1	462.3	63.2	.71	0.50	0.14
Iron (mg)	65.69	50.734	64.21	48.98	.66*	.45	0.08
Fibre (g)	46.08	16.754	42.91	16.59	.90	0.82	0.29
Zinc(mg)	7.05	2.337	6.82	2.18	.87***	0.77	0.00

SD, standard deviation; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acids.

Table 4: Associations with reported intake differences: FFQ vs. 3-Day Dietary Record

Nutrients	Age			Sex			Domicile			Per Capita Income		
	R^2	Adj.R^2	P	R^2	Adj.R^2	p	R^2	Adj.R^2	p	R^2	Adj.R^2	p
Energy (kcal)	.039	.029	0.04**	.062	.052	0.01**	1.08	-0.01	0.97	0.0579	0.048	0.01**
Carbohydrates(g)	.014	.004	0.22	.008	-.001	0.35	0.00	-0.00	0.54	0.0027	-0.007	0.60
Proteins (g)	.002	-.008	0.00**	.034	.024	0.06**	0.01	-0.00	0.32	0.0008	-0.009	0.77
Fat (g)	.015	.005	0.00**	.008	-.001	0.35	0.00	-0.00	0.63	0.0299	0.019	0.08**
Fibre(g)	0	-.010	0.90	.050	.040	0.02**	0.00	-0.00	0.47	0.0100	-0.0001	0.32
Total MUFA (g)	2.12	-.010	0.96	.005	-.00	0.46	1.85	-0.01	0.96	0.0524	0.042	0.02**
Total PUFA (g)	.015	.005	0.00**	.029	.019	0.09**	0.00	-0.00	0.74	0.0524	0.042	0.02**
Saturated fat (g)	.003	-.007	0.00**	.0012	.002	0.27	0.00	-.006	0.56	0.0528	0.043	0.02**
Vitamin A (μg)	.005	-.004	0.46	.000	.00	0.85	0.01	0.00	0.23	0.0413	0.031	0.04**
Vitamin C (mg)	.002	-.007	0.61	2.49	-.01	0.96	0.02	0.01	0.12	0.0135	0.003	0.25
Vitamin D(μg)	.000	-.009	0.77	.008	-.001	0.36	0.00	-.005	0.49	0.0135	0.0033	0.25
Vitamin E (mg)	.012	.002	0.27	.001	-.008	0.69	8.55	-0.01	0.92	0.0112	0.0010	0.29
Vitamin B1 (mg)	.017	.007	0.19	.010	.000	0.31	0.00	-0.00	0.83	0.0099	-0.0002	0.32
Vitamin B2 (mg)	.001	-.009	0.73	.027	.017	0.09**	0.01	0.00	0.28	0.0215	0.011	0.14
Vitamin B6 (mg)	.003	-.006	0.54	.013	.003	0.24	0.00	-.009	0.80	0.0266	0.016	0.10
Vitamin B12 (μg)	.001	-.008	0.71	.000	-.00	0.80	0.00	-.006	0.54	0.0103	0.000	0.31
Folate (μg)	.005	-.004	0.46	.006	-.00	0.43	0.04	0.03	0.04**	0.0007	-0.009	0.78
Iron (mg)	.000	-.010	0.91	.005	-.00	0.46	0.00	-.009	0.81	0.0006	-0.009	0.79
Zinc (mg)	.012	.002	0.00**	.060	.05	0.01**	0.00	-0.00	0.53	0.0469	0.037	0.03**
Magnesium (mg)	.012	.002	0.26	.02	.01	0.11	0.0	-0.01	0.9	0.03	0.026	0.05**
Total Carotenes	.0005	-.009	0.82	.010	.00	0.31	0.011	0.001	0.28	0.03	0.028	0.05**

Note: 'R^2' and 'Adj R^2' refer to the coefficients of determination and adjusted coefficients of determination, respectively. 'p' denotes the p-values for significance. '0.00' indicates p-values less than 0.001. '**' denotes significance at the 0.01 level, '*' at the 0.05 level. SD, standard deviation; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acids.

Positive correlation values indicate a positive linear relationship, while negative values suggest an inverse association. A high positive correlation would indicate strong agreement between nutrient estimates from the FFQ and the 3-day 24-hour DR, implying that the FFQ is a reliable tool for capturing dietary patterns. The correlation analysis serves as a validity assessment, offering insights into how well the FFQ estimates align with the more detailed information obtained from multiple 24-hour DRs over three days.

Correlation analysis between the FFQ and 3-day DR: The study investigated associations between personal characteristics and the difference in reported nutrient intakes derived from the FFQ and the 3-Day Dietary Record (3-day DR) as shown in table 5. This analysis aimed to identify potential factors influencing variations in reported dietary information. The coefficient of determination (R^2) varied widely, ranging from as low as 0.1% up to 32%, indicating diverse levels of explained variability in reported nutrient intakes between the Food Frequency Questionnaire (FFQ) and the 3-Day Dietary Record (3-day DR). None of the personal characteristics considered, including age, gender, and socio-economic status, were found to be significant in the models for nutrients (lowest R^2, were noted for iron, vitamin C, vitamin D, vitamin B1, vitamin B12, and vitamin B6). Among the personal characteristics, sex emerged as significant for six nutrients, with men exhibiting larger differences in reported intakes for energy, proteins, fibre, PUFA, vitamin B12, and zinc compared to women. Age was found to be significant for intakes of total energy, protein, total fat, saturated fat, PUFA, and zinc. However, the differences were smaller for the intake of carbohydrates, other minerals, and most vitamins. Socio-economic status played a significant role in intakes of energy, total fat, MUFA, PUFA, saturated fat, vitamin A, magnesium, zinc, and total carotenes. Folate consumption showed a significant increase among the rural population.

Table 5: Bland–Altman Analysis: FFQ vs. 3-Day Dietary record

Nutrient	Bias*	SD	95% CI
Carbohydrates(g)	12.13	27.67	6.64-17.62
Proteins (g)	2.45	7.98	0.87-4.04
Fat (g)	0.99	9.65	-0.91-2.91
Fibre(g)	-2.19	7.61	-0.67- -3.7
Total MUFA(g)	1.31	4.01	0.51-2.11
Total PUFA(g)	1.28	5.27	0.23-2.32
Saturated fat (g)	.292	1950	-0.42-1.00
Vitamin A (µg)	12.7	123.6	-11.7-37.27
Vitamin C (mg)	7.21	69.7	-6.61-21.0
Vitamin D(µg)	0.08	11	-1.37-2.9
Vitamin E (mg)	1.08	18.11	0.03-0.12
Vitamin B1 (mg)	0.14	0.5	0.04-0.24
Vitamin B2 (mg)	-0.03	1.73	-0.38-0.30
Vitamin B6 (mg)	0.27	0.75	0.12-0.42
Vitamin B12 (µg)	0.07	0.22	0.031-0.120
Folate (µg)	631.9	221.7	587.8-675.85
Iron (mg)	1.28	21.25	-2.93-5.50
Zinc(mg)	0.29	0.6	0.16-0.43
Magnesium (mg)	11.73	78.48	-3.83-27.30
Total Carotenes(µg)	552.6	3258.9	-93.9-1199.2

Analysis performed on energy-adjusted nutrient intake; SD, standard deviation; CI, confidence interval; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acids. n.a. * Positive differences in the average discrepancy between the two methods indicate an overestimation of nutrient intake by the FFQ.

Figure 1: Bland–Altman Analysis for total energy and macronutrients (protein and carbohydrate): Each participant's (n=100) difference in nutrient intakes between the FFQ (Y-axis) and the average of the 3-day dietary records is plotted against the mean intake from the two methods (X-axis).

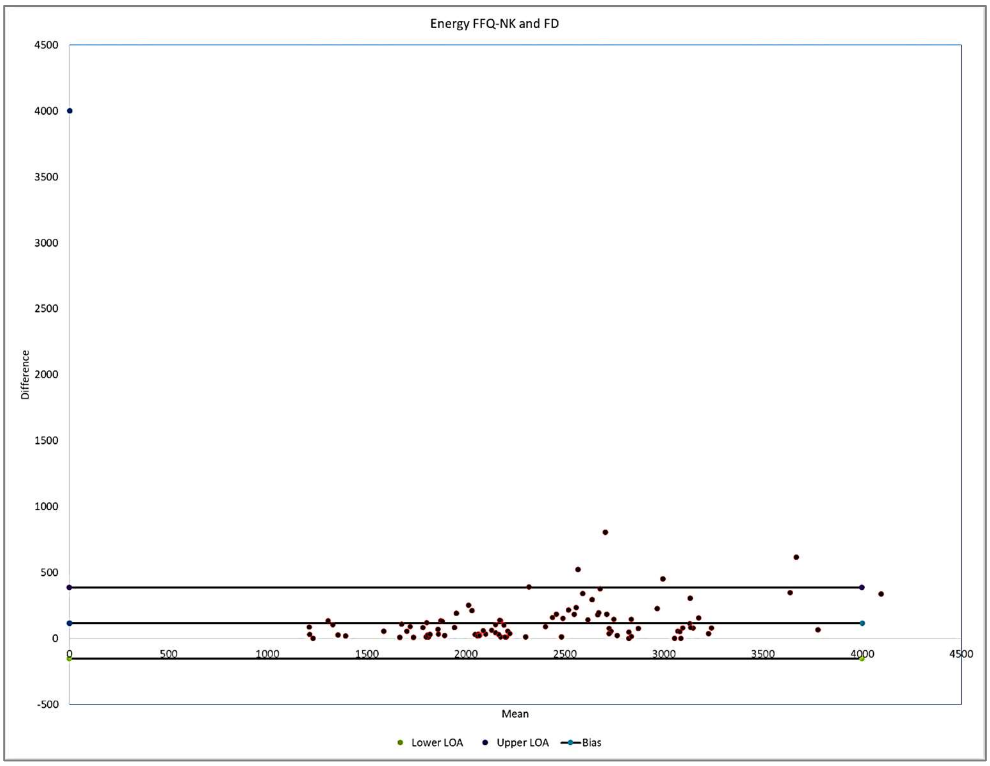

Figure 1(a): Energy (kcal): Mean Difference = 118.0 (95% CI: 90.76-145.24). The Bland–Altman plot for total energy intake shows a mean difference of 118.0, with a 95% CI ranging from 90.76 to 145.24.

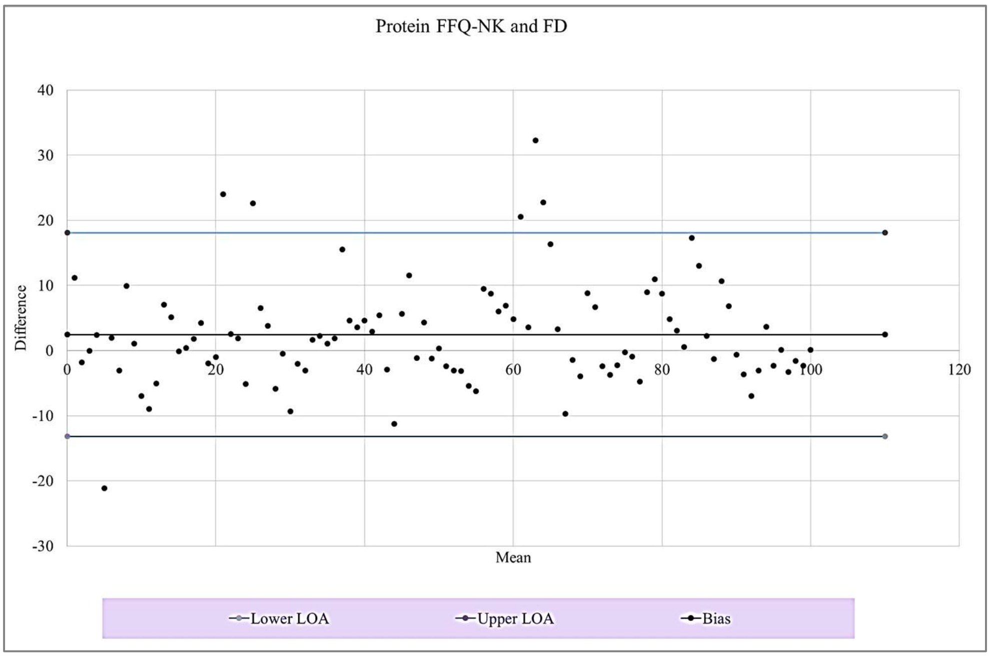

Figure 1(b): Protein (gm): Mean Difference = 2.45 (95% CI: 0.87-4.04). The Bland–Altman plot for protein intake demonstrates a mean difference of 2.45, with a 95% Confidence Interval (CI) ranging from 0.87 to 4.04.

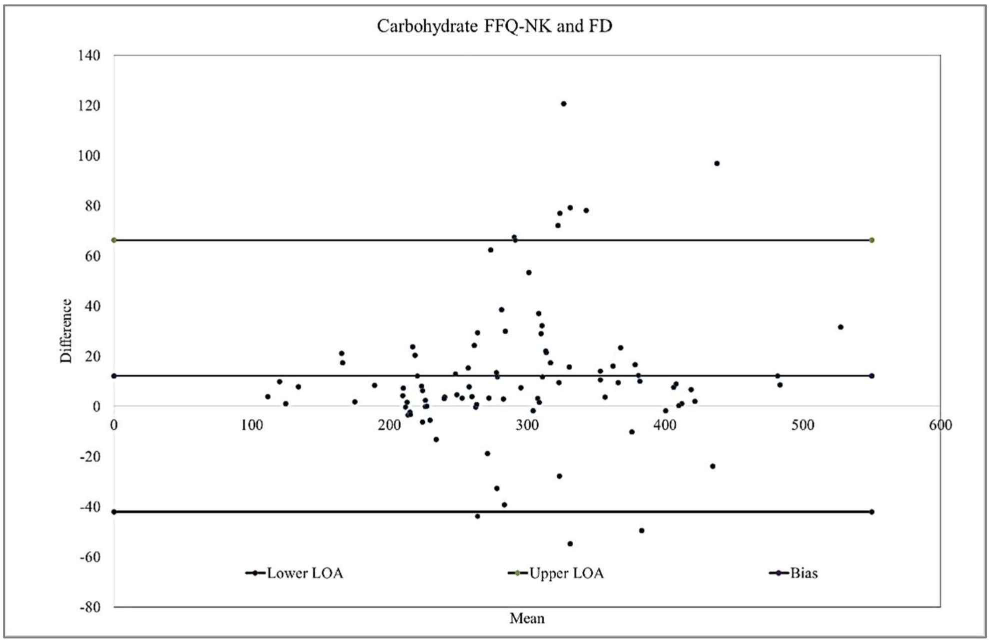

Figure 1(c): Carbohydrate(gm): Mean Difference = 12.13 (95% CI: 6.64-17.62). The Bland–Altman plot for carbohydrate intake reveals a mean difference of 12.13, with a 95% CI spanning from 6.64 to 17.62 The systematic trend indicates that, on average, the FFQ tends to provide higher estimates for protein, carbohydrate, and total energy compared to the 3-day dietary records.

Bland–Altman Analysis: FFQ vs. 3-Day DR: To assess the agreement between reported nutrient intakes from the Food Frequency Questionnaire (FFQ) and the 3-Day DR, a Bland–Altman analysis was conducted. This method provides insights into the extent of agreement, potential biases, and variability between the two dietary assessment tools. Differences in nutrient intake between the FFQ and the 3-day FR were plotted against the mean nutrient intakes of the two methods. Positive differences in the average discrepancy indicated an overestimation of nutrient intake by the FFQ. A larger value of bias, reflected by wider limits of agreement (as indicated by the 95% Confidence Interval), suggested a greater extent of overestimation by the FFQ. For macronutrients such as carbohydrates and fats, as well as a range of micronutrients, there was a bias towards positive differences. This implies that the FFQ tended to provide higher estimates of certain macro- and micronutrients compared to the 3-day food diary. Bland–

Altman plots indicated a systematic trend towards higher estimates with the FFQ for certain nutrients compared to the food diary records. This suggests a consistent pattern of overestimation by the FFQ. The summarized results of the Bland–Altman analysis, including bias, limits of agreement, and other relevant metrics, are tabulated in Table 5.

Discussion

The authors have made a sincere effort to develop an FFQ to capture the dietary pattern, which can be representative of the one widely prevalent among the population of north Karnataka (FFQ-NK), also termed inland north Karnataka (Belgaum, Bagalkot, Bijapur, Gulbarga, Bidar, Gadag, Dharwad and Bellary). The pattern can also be extrapolated to the population of nearby regions like inland central Maharashtra (Nanded, Hingoli, Parbhani, Jalna, Aurangabad, Beed, Latur) and inland eastern Maharashtra (Buldana, Akola, Amravati, Wardha and Nagpur), where sorghum is still important in the consumption basket and a staple along with rice and wheat. A conscientious attempt was made to include a comprehensive list of the food items consumed among the sample population, which could be representative for group comparisons as they tend to capture the habitual intake of the population in north Karnataka over a given period. To the best of our knowledge, this 116-item FFQ-NK is the first to be developed and validated for use in population of Karnataka.[5, 9-11, 26]

The above-validated FFQ-NK shall serve as an important tool to register dietary patterns and average energy and nutrient intake in the region of north Karnataka. It can further serve to design studies that investigate the association between the dietary pattern and common diseases of interest prevalent in this region. Registering energy and nutrient intake is key to obtaining more reliable evidence for diet-health relationships from nutritional cohort studies. In the present study, 100 participants completed all of the questionnaires (i.e., 1 FFQ and three 24-hr dietary recalls). It was validated against a 24-hr diet record as a reference tool, as no truly gold standard exists.[29] In comparison with the 24-hour diet record, the FFQ-NK tends to overestimate nutrients unadjusted, as in previous studies.[9, 22]

Socioeconomic factors like the income of the family also had stronger associations, particularly with the average protein intake and nutrients like vitamin D, vitamin C, calcium, and zinc, than the total energy intake. Age and sex were the other determinants that significantly affected the intake of certain nutrients.

The present study also found that the high- and middle-income sectors had higher intakes of average total energy and most of the micronutrients in comparison to those in the lower income sector. Future researchers should be aware of the likely cumulative impact of the suggested differences and relationships. The majority of research conducted in India has hitherto generally explored pricing and expenditure as significant determinants of food consumption patterns, with socio-economic and regional factors receiving less attention and as possible determinants of variations in food consumption patterns. Higher income groups are generally linked to healthier eating habits, which include consuming a variety of fruits and vegetables and more sources of proteins like dairy, poultry, meat, and oil. People in higher income levels tend to consume more of these foods than those in lower income classes, likely because higher income levels correlate with higher socioeconomic standing, which raises awareness of health issues and nutritious dietary options.[30-32]

Moreover, studies have also reported that low purchasing power, either due to a lack of regular employment or lower socio-economic status, is another possible factor for the lower consumption, as is also the lack of education about the nutritional benefits of fruits and vegetables.[33-35]

The average of the 3-day DR was considered to correlate with the FFQ derived nutrient values for validation. The correlation coefficient (energy adjusted) that was discerned between the FFQ and 3-day DR (0.45 to 0.93) was comparable to those reported by similar validation studies conducted in Trivandrum, South Kerala (0.34 to 0.72)[35] and also by studies set in rural villages in Ernakulum district, Kerala (ranging from 0.32 to 0.61) [5] and in Gujarat (ranging from 0.55 to 1.00)[9] Additionally, some other studies have also demonstrated a range of coefficients that appeared to be similar to our range.[26,34,36] The findings of this study indicate that macronutrients like total fats and proteins have the largest association, whereas trace elements like iron, selenium, and calcium and vitamins like vitamin C have lesser correlations.[37,38] and the flavonols (0.59) and flavanones (0.54) also had lesser correlations. As previously established, these nutrients may tend to have weaker correlation coefficients and significant within-person variability in validation studies since they are not concentrated in most diets.[5,37]

Certain macronutrients, such as carbohydrates and proteins, and others, such as folate, total carotenes, zinc, iron, selenium, and magnesium, were overestimated by the FFQ compared to the 24-hour dietary record. Also, vitamins like A, D, E, C, B1, and B6 were overestimated by the FFQ, whereas vitamins B2 and B12, along with copper and zinc, were underestimated by the FFQ compared to the food record. It is noted that the independent sociodemographic factors may account for 32% of the variation in the difference between the two assessment techniques. For the majority of them, gender was a significant explanatory factor, with men over reporting intakes in comparison to women for total energy, proteins, fibre, PUFA,vitamin B12, and zinc, whereas other researchers noted a reportedly increased intake by women for most of the nutrients.[39] Dietary fibre intakes have been linked to lower family incomes in previous studies[40] that looked at the relationship between income and dietary fibre intake. Similarly, our findings discerned an increased intake of dietary fibre by the middle- and higher-income groups and those belonging to the rural setting. Apart from being the first to develop a FFQ for use in the north Karnataka population, our study has some significant strengths. First, a wide range of tests were used to assess the validity of the FFQ, correlation coefficients in conjunction with the Bland-Altman approach. When assessing the validity and reproducibility of a food frequency questionnaire, the Bland-Altman method has been found to be more effective than correlation analysis. Furthermore, the study's sample size was adequate to estimate the limits of agreement for the Bland-Altman analysis, which is a prerequisite for evaluating the validity of the FFQ.[29]

The FFQ was administered by the interviewers, who were registered and experienced nutritionists practicing at the institute, and we believe that this is the study's strength preventing underreporting and enhancing consistency. The participants were also trained to understand portion sizes. The guidance on portion size will be implemented as a pre-requisite for all future administrations of the current validated FFQ. A 116-item FFQ could have been lengthy, which may have led to participant enervation and also nutrient overestimation at times. Some of the recognized sources of error we would like the researchers to be wary of are predetermined and set food lists, intra-individual variations due to memory and interview fatigue, and also errors in interpreting the questions and portions of the food items listed.[41]

Additionally, though DR and 24-hour food diaries are often used as the most accepted reference tools for validating the FFQs, they are not known to be without limitations due to reporting errors attributable to gender and differences in BMI of the individuals.[36] Omission of validated biomarkers for nutrient assessment represents a notable limitation in our study, impacting the comprehensive validation of nutrient intake data. The absence of direct biomarker measurement may affect the accuracy and reliability of nutritional assessments, warranting cautious interpretation of the results. Future researchers can strengthen the findings of the current study by including biomarkers specific to the nutrients for cross-validation studies. In summary, the creation and validation of the present Food Frequency Questionnaire (FFQ) constitute a critical first measure that enables us to employ it as a key instrument in epidemiological research to evaluate food intakes, dietary patterns, and associations with disease attributes in the people of North Karnataka, India. It would be wise to evaluate the prospects of the application of this FFQ in the regions of north Karnataka where the populace has similar dietary habits.

Conclusion

In summary, the authors have successfully developed and validated the first Food Frequency Questionnaire (FFQ-NK) for the population of north Karnataka, India, providing a valuable tool for assessing dietary patterns and nutrient intake in the region. The FFQ-NK, comprising 116 items, demonstrates associations with socioeconomic factors, age, and sex, highlighting disparities in nutrient intake among different income groups. Despite certain limitations, such as potential overestimation and reliance on self-reporting, the FFQ-NK offers a robust foundation for future epidemiological research in understanding dietary influences on health in this specific population.

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References

1. Willett WC. Reproducibility and validity of food-frequency questionnaires. Nutritional epidemiology. 1998.
2. Gibson RS. Principles of nutritional assessment. Oxford university press, USA; 2005.
3. Zulkifli SN, Stella MY. The food frequency method for dietary assessment. Journal of the American dietetic association. 1992 Jun 1; 92(6):681-6.
4. Briefel RR, Flegal KM, Winn DM, Loria CM, Johnson CL, Sempos CT. Assessing the nation's diet: limitations of the food frequency questionnaire. Journal of the American Dietetic Association. 1992 Aug 1; 92(8):959-63.
5. Hebert JR, Gupta PC, Bhonsle RB, Murti PR, Mehta H, Verghese F, Aghi M, Krishnaswamy K, Mehta FS. Development and testing of a quantitative food frequency questionnaire for use in Kerala, India. Public Health Nutrition. 1998 Jun;1(2):123-30.
6. Rockett HR, Berkey CS, Colditz GA. Evaluation of dietary assessment instruments in adolescents. Current Opinion in Clinical Nutrition & Metabolic Care. 2003 Sep 1; 6(5):557-62.
7. Slater B, Enes CC, López RV, Damasceno NR, Voci SM. Validation of a food frequency questionnaire to assess the consumption of carotenoids, fruits and vegetables among adolescents: the method of triads. Cadernos de saude publica. 2010; 26:2090-100.
8. Jayawardena R, Swaminathan S, Byrne NM, Soares MJ, Katulanda P, Hills AP. Development of a food frequency questionnaire for Sri Lankan adults. Nutrition j. 2012 Dec; 11:1-6.
9. Hebert JR, Gupta PC, Bhonsle RB, Sinor PN, Mehta H, Mehta FS. Development and testing of a quantitative food frequency questionnaire for use in Gujarat, India. Public Health Nutr 1999; 2:39–50.
10. Sudha V, Radhika G, Sathya RM, Ganesan A, Mohan V. Reproducibility and validity of an interviewer-administered semi-quantitative food frequency questionnaire to assess dietary intake of urban adults in southern India. International journal of food sciences and nutrition. 2006 Jan 1; 57(7-8):481-93.
11. Bharathi AV, Kurpad AV, Thomas T, Yusuf S, Saraswathi G, Vaz M. Development of food frequency questionnaires and a nutrient database for the Prospective Urban and Rural Epidemiological (PURE) pilot study in South India: methodological issues. Asia Pacific journal of clinical nutrition. 2008 Mar 1; 17(1):178-85.
12. Iqbal R, Ajayan K, Bharathi AV, Zhang X, Islam S, Soman CR, et

al. Refinement and validation of an FFQ developed to estimate macro- and micronutrient intakes in a south Indian population. Public Health Nutr 2009; 12:12–18.

13. Willett W. Nutritional epidemiology. Oxford university press; 2012 Nov 7.

14. Kim YJ, Kim OY, Cho Y, Chung JH, Jung YS, Hwang GS, Shin MJ. Plasma phospholipid fatty acid composition in ischemic stroke: importance of docosahexaenoic acid in the risk for intracranial atherosclerotic stenosis. Atherosclerosis. 2012 Dec;225(2):418-24.

15. Lim S, Shin H, Kim MJ, Ahn HY, Kang SM, Yoon JW, Choi SH, Kim KW, Song JH, Choi SI, Chun EJ. Vitamin D inadequacy is associated with significant coronary artery stenosis in a community-based elderly cohort: the Korean Longitudinal Study on Health and Aging. The Journal of Clinical Endocrinology & Metabolism. 2012 Jan 1;97(1):169-78.

16. Shim JS, Oh K, Kim HC. Dietary assessment methods in epidemiologic studies. Epidemiology and health. 2014;36.

17. Collins, C.E.; Boggess, M.M.; Watson, J.F.; Guest, M.; Duncanson, K.; Pezdirc, K.; Rollo, M.; Hutchesson, M.J.; Burrows, T.L. Reproducibility and Comparative Validity of a Food Frequency Questionnaire for Australian Adults. Clin. Nutr. 2014, 33, 906–914

18. Wild CP, Andersson C, O'Brien NM, Wilson L, Woods JA. A critical evaluation of the application of biomarkers in epidemiological studies on diet and health. Br J Nutr. 2001;86 Suppl 1:S37–S53

19. Popkin BM, Horton S, Kim S, Mahal A, Shuigao J. Trends in diet, nutritional status, and diet-related noncommunicable diseases in China and India: the economic costs of the nutrition transition. Nutrition reviews. 2001 Dec 1;59(12):379-90.

20. Branca, F.; Lartey, A.; Oenema, S.; Aguayo, V.; Stordalen, G.A.; Richardson, R.; Arvelo, M.; Afshin, A. Transforming the Food System to Fight Non-Communicable Diseases. BMJ **2019**, 364, l296.

21. Booth, S.L.; Sallis, J.F.; Ritenbaugh, C.; Hill, J.O.; Birch, L.L.; Frank, L.D.; Glanz, K.; Himmelgreen, D.A.; Mudd, M.; Popkin, B.M. et al. Environmental and Societal Factors Affect Food Choice and Physical Activity: Rationale, Influences, and Leverage Points. Nutr. Rev. **2001**, 59, S21-S65

22. Hebert, J.R.; Gupta, P.C.; Mehta, H.; Ebbeling, C.B.; Bhonsle, R.R.; Varghese, F. Sources of Variability in Dietary Intake in Two Distinct Regions of Rural India: Implications for Nutrition Study Design and Interpretation. Eur. J. Clin. Nutr. 2000, 54, 479–486.

23. National Institute of Nutrition. National Nutrition Monitoring Bureau Report of Repeat Surveys (1988–90). Indian Council of Medical Research. Hyderabad, India: NIN, 1991

24. Vernekar, Sunil & Somannavar, Manjunath & Mastiholi, Shivanand & Dhaded, Sangappa & Goudar, Shivaprasad & Revankar, Amit & Lander, Rebecca. (2018). Generic Recipes of Rural North Karnataka with Nutrient Values.

25. Longvah, T.; Ananthan, R.; Bhaskarachary, K.; Venkaiah, K. Indian Food Composition Tables; National Institute of Nutrition: Hyderabad, India, 2017.

26. Shaikh N, Frediani J, Ramakrishnan U, Patil S, Yount K, Cunningham S. Development and Evaluation of a Nutrition Transition FFQ for Adolescents in South India. The FASEB Journal. 2016 Apr;30:1153-4.

27. Borgatti S (1999) Elicitation techniques for cultural domain analysis. In Ethnographer's Toolkit. vol. 3: Enhanced Ethnographic Methods: Audiovisual Techniques, Focused Group Interviews, and Elicitation Techniques, pp. 115–151 [JJ

28. Shivappa, N., Steck, S. E., Hurley, T. G., Hussey, J. R., & Hébert, J. R. Designing and developing a literature-derived, population-based dietary inflammatory index. *Public health nutrition* 2014; *17*(8): 1689–1696. https://doi.org/10.1017/S1368980013002115.

29. Cade, J.; Thompson, R.; Burley, V.; Warm, D. Development, Validation and Utilisation of Food-Frequency Questionnaires–A Review. Public Health Nutr. 2002, 5, 567–587.

30. Deshmukh-Taskar P., Nicklas T.A., Yang S.J., Berenson G.S. Does Food Group Consumption Vary by Differences in Socioeconomic, Demographic, and Lifestyle Factors in Young Adults? the Bogalusa Heart Study. J. Am. Diet. Assoc. 2007; 107:223–234.

31. Prattala R.S., Groth M.V., Oltersdorf U.S., Roos G.M., Sekula W., Tuomainen H.M. Use of Butter and Cheese in 10 European Countries: A Case of Contrasting Educational Differences. Eur. J. Public Health. 2003;13:124–132.

32. Panwar B., Punia D. Food Intake of Rural Pregnant Women of Haryana State, Northern India: Relationship with Education and Income. Int. J. Food Sci. Nutr. 1998;49:243–247.

33. Dubowitz T., Levinson D., Peterman J.N., Verma G., Jacob S., Schultink W. Intensifying Efforts to Reduce Child Malnutrition in India: An Evaluation of the Dular Program in Jharkhand, India. Food Nutr. Bull. 2007;28:266–273.

34. Shu X.O., Yang G., Jin F., Liu D., Kushi L., Wen W. et al. Validity and Reproducibility of the Food Frequency Questionnaire used in the Shanghai Women's Health Study. Eur. J. Clin. Nutr. 2004;58:17–23. doi: 10.1038/sj.ejcn.1601738.

35. Vijay A, Mohan L, Taylor MA, Grove JI, Valdes AM, Aithal GP, Shenoy KT. The Evaluation and Use of a Food Frequency Questionnaire Among the Population in Trivandrum, South Kerala, India. Nutrients. 2020 Jan 31;12(2):383. doi: 10.3390/nu12020383.

36. Pandey D, Bhatia V, Boddula R, Singh HK, Bhatia E. Validation and reproducibility of a food frequency questionnaire to assess energy and fat intake in affluent north Indians. The National medical journal of India. 2005 Sep 1;18(5):230-5.

37. Toft U, Kristoffersen L, Ladelund S, Bysted A, Jakobsen J, Lau C, Jørgensen T, Borch-Johnsen K, Ovesen L. Relative validity of a food frequency questionnaire used in the Inter99 study. European journal of clinical nutrition. 2008 Aug;62(8):1038-46.

38. Chen Y, Ahsan H, Parvez F, Howe GR. Validity of a food-frequency questionnaire for a large prospective cohort study in Bangladesh. British journal of nutrition. 2004 Nov; 92(5): 851-9.

39. Lee H, Kang M, Song WO, Shim JE, Paik HY. Gender analysis in the development and validation of FFQ: a systematic review. British Journal of Nutrition. 2016 Feb;115(4):666-71.

40. Storey M, Anderson P. Income and race/ethnicity influence dietary fiber intake and vegetable consumption. Nutrition Research 2014; 34:844–50. Doi: 10.1016/j.nutres.2014.08.016.

41. Santos RDO, Gorgulho BM, Castro MAD, Fisberg RM, Marchioni DM, Baltar VT. Principal Component Analysis and Factor Analysis: differences and similarities in Nutritional Epidemiology application. Rev Bras Epidemiol 2019;22:e190041. Doi: 10.1590/1980-549720190041.