REVIEW ARTICLE

Developed and validated food frequency questionnaires in Iran: A systematic literature review

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Background: Food frequency questionnaires (FFQs) are inexpensive, easy to administer, and practical tools for dietary assessment in epidemiological studies. Several studies have investigated the validity and reproducibility of FFQs for the Iranian population. This systematic review aimed to assess the developed and validated FFQs for use in the Iranian population and compare their features and the validation studies in this regard. **Materials and Methods:** A comprehensive search was conducted in ISI Web of Knowledge, PubMed, Scopus, and Iranian databases without time constraints to retrieve the relevant English and non-English publications. Studies would be included if they were focused on the design and validation of FFQs in Iran. **Results:** In total, 782 articles were found, 22 of which met the eligibility criteria and evaluated 18 FFQs. Validation studies had been conducted on 18 out of 20 FFQs. The median of the correlation coefficients for the comparison of the FFQ intakes and the dietary reference method by nutrients varied within the range of 0.19–0.65, indicating reasonable validity. The median of the correlation coefficients for the comparison of two FFQs by nutrients was 0.28–0.85, showing appropriate reproducibility. However, low validity was observed in some nutrients and food groups, such as egg, legumes, iron, folate, and α-tocopherol. In seven studies, biomarkers were used for the assessment of nutrient intake using an FFQ with the median correlation coefficient of −0.07–0.42. In addition, the quality of methodology was evaluated in the FFQ validation studies, with 18 out of 20 studies reporting good and excellent quality. **Conclusion:** Although the FFQs used to assess the dietary intake of the Iranian population have different features, they have acceptable validity and reproducibility. Nevertheless, some food groups and nutrients have poor validity and must be considered attentively.

Key words: Food frequency questionnaires, Iran, reproducibility, systematic review, validity

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INTRODUCTION

Dietary intake assessment is a complex task and a significant challenge in epidemiological research.[1] The assessment of dietary intake is fundamental in the study of the interrelations between diets and diseases. Most epidemiological studies use food frequency questionnaires (FFQ) to estimate dietary intakes or evaluate specific dietary patterns and nutrients since these tools are relatively inexpensive and easier to administer and analyze in large sample sizes compared to other dietary intake assessment methods, such as food records.[2] FFQs typically assess the dietary intake within the past year and comprise a list of commonly consumed

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foods with some possible options regarding the frequency of their consumption (e.g., once a day, once a week, once a month). In FFQs, portion size is either standard or selected from the provided portion size images. Other methods of dietary assessment are 24-h recalls, weighted food records, and diet histories.

Currently, no "gold standard" methods are available for dietary intake assessment or the measurement of the intake of specific foods or nutrients. The available methods have specific strengths and limitations and heavily rely on the participants' willingness to cooperate. An FFQ is used to assess the habitual intakes of a population over time and is also expected to rank individuals based on their nutrient intakes.[3] On the other hand, food records or recalls only assess certain days or weeks, and although they are more accurate, they may not fully represent the usual dietary intakes. Moreover, since diet in general but also types of foods consumed vary in different populations, it is imperative to use population-specific FFQs.

In Iran, various FFQs have been designed and validated to evaluate the dietary intake of various age groups in the population based on food records, dietary recalls, or biochemical markers.[4-6] This systematic review aimed to evaluate the FFQs that have been specifically designed to assess the dietary intake of the Iranian population and compare their features and the validation studies in this regard. Our findings could be practical for designing new FFQs and performing validation studies on the Iranian population.

MATERIALS AND METHODS

Search strategy

This systematic review was conducted based on the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses,[7] with the specification of the methods before commencing the literature search. A systematic search for the relevant articles regarding Iranian FFQs was performed up to July 2020 in databases such as ISI Web of Knowledge, PubMed, Scopus, and Iranian SID database using various keywords, including "food frequency questionnaire" OR "FFQ" OR "diet history questionnaire" in combination with "validity" and "Iran." After eliminating duplicate references, the eligibility assessment of the identified studies was carried out independently by two investigators (S. S. A. and Z. Y.).

Eligibility criteria

The eligibility criteria were as follows: (1) study design (design, validation, and reproducibility assessment of FFQs); (2) study participants (all types of study participants included with any age, both patients and healthy participants); (3) type of dietary assessment tool (FFQ and diet history); (4) comparable with questionnaires (dietary reference methods such as food records and recalls), biomarkers, and expert opinion; and (5) English and Persian articles published until July 2020. Review studies were excluded.

Data extraction from eligible studies

The extracted data from the retrieved articles included the aim of the questionnaire design in terms of variable measurement, number of food items, items on frequency and portion size, method of questionnaire design (experience based/data based), reference methods of the validation studies (e.g., dietary reference methods, biomarkers, expert panel), number of the participants, gender and age of the participants, method of questionnaire administration, dietary assessment method in the validation studies (dietary recall or food record), duration of the dietary reference method (record/recall), food group/nutrients, blood biomarkers, urine biomarkers, statistical methods in the FFQ validation studies (e.g., correlation coefficients [high or low validity]),[8] energy adjustment, de-attenuation (adjustment for within-person variation of food intake on different days), reproducibility of food groups/nutrients, and interval between the two administrations of the FFQs in the reproducibility studies.

The methodology quality of the selected studies was scored by two reviewers who used the previously applied scores[9] as adapted from the study by Serra-Majem *et al*.;[10] the highest score was seven (highest quality), and the lowest score was zero (lowest quality). The scores were assigned based on various components, including the samples and sample size (maximum score: 1), type of statistics (score 3), administration method (score 0.5), food grouping details (score 1), frequency scale, and portion size (score: 1), and consideration of seasonality (score: 0.5).[9] The quality of each study was scored as poor (scores ≤2), acceptable (scores 2.5≤–<3.5), good (scores 3.5≤–<5), and excellent (scores 5≤).[9]

The four main methods used in the validation studies were as follows:

1. FFQ data were compared with the actual intake calculated by another dietary reference method (food records/24-h recalls)[11]
2. FFQ data were compared with blood and urine biomarkers, hair, and body tissues[11]
3. Factors could be calculated based on the FFQ data and compared with the factors of the dietary reference method[12-14]
4. The validity of the FFQ items could be calculated by an expert panel, and based on their feedback regarding the essentiality of an item, the content validity ratio would be calculated. In addition, the content validity index would be calculated based on expert opinion regarding

the correlation between the aim of the questionnaire design with an item.[15]

FFQ reproducibility could be assessed by the comparison of the data of two FFQ administrations and the calculation of factors such as the correlation coefficients, intraclass correlation, and Cronbach's alpha. In the selected studies, the median of the correlation coefficients between dietary reference methods and FFQs were summarized to assess validity; if two or more correlation coefficients were observed in one study, their median would be used. Notably, the intraclass correlations were summarized in similar manners.

RESULTS

Study selection

As depicted in Figure 1, 782 studies were identified. After the initial review of the titles and abstracts, 760 articles were excluded, and 22 studies that met the eligibility criteria were selected for further analysis [Figure 1].

Initially, we reviewed the features of the Iranian FFQs, including the aim of the design, methods of developing the FFQ, number of the food items and frequency questions, and portion size calculation. In the next step, the features of the FFQ validation studies were evaluated, including the sample size, sample population, method of FFQ administration, methods of FFQ validation, statistical approaches in the validation studies, quality of the FFQ validation methodology, and FFQ reproducibility assessments.

Food frequency questionnaires features

Table 1 shows the features of the included FFQs. In total, 20 FFQs were identified, which had been developed in Iran.[4,5,12-31] In four articles,[5,19,28,29] the validation studies were focused on the same two FFQs. Notably, 18 FFQs were validated in 20 studies.

Aim of food frequency questionnaires design

Eight FFQs were developed to assess specific nutrients, including the folate intake in breast cancer patients,[28,29] iron and Vitamins A and C intake in the women of the reproductive age,[27] calcium intake among students,[31] sodium intake in the general population,[23] antioxidant intake among the elderly,[21] and gluten intake in patients with ulcerative colitis.[15] Furthermore, one FFQ was used to assess fruit and vegetable intake,[24] and another FFQ evaluated the foods contributing to cardiovascular diseases.[4] Finally, 12 FFQs were developed to assess the intake of various nutrient and food groups comprehensively.[5,12-14,16-20,22,25,26,30]

Methods of food frequency questionnaires development

The methods of FFQ development were categorized as experience based and data based. In the first approach, experienced dietitians or epidemiologists selected food items from food composition tables. The selected food items had to be popular and have considerable nutrient contents with varied consumption by the general population. The experience-based approach was used in four FFQs.[20-22,31] In the second approach, food items were selected based on the data of other dietary reference methods, such as food records and dietary recalls.[4,5,13-15,17,19,23-30] The data-based approach was classified into three subcategories, as follows:

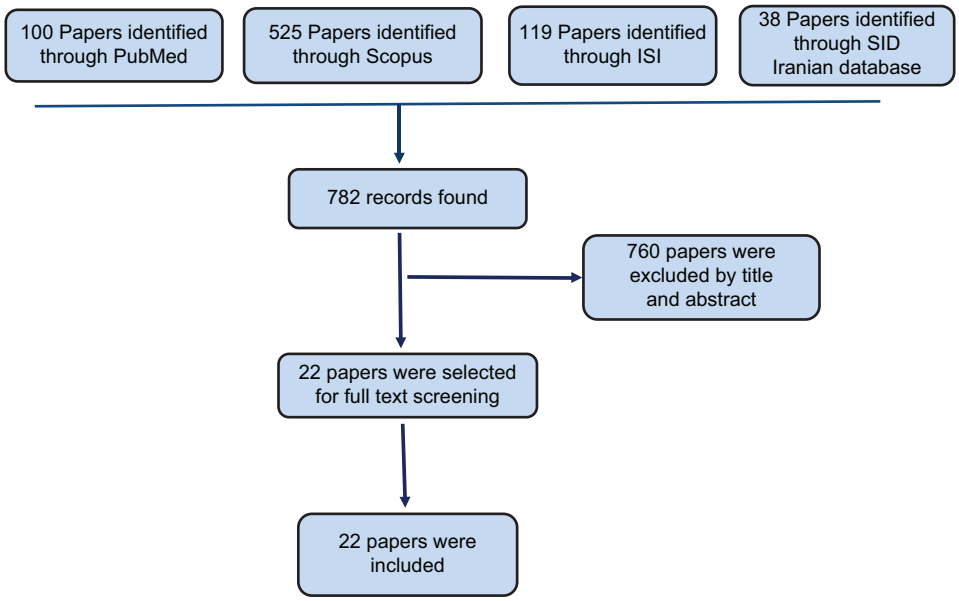

Figure 1: Flowchart of the article selection process

Table 1: Characteristics of food frequency questionnaires designed and validated in Iran (sorted by the number of included food items)

n	Author of reference	Number of food items	Number of response categories of intake frequency	Questions on portion size	Development method	Aim of design	Cohort studies using FFQs	Age (years)	Comment
1	Hadi *et al.*, 2017[15]	40	Open-ended (per day, week, month, and year)	None	Data based (published book on gluten-free regimens in celiac disease)	Assessment of gluten intake in ulcerative colitis patients			The place of study was not mentioned Duration of the study was one month Participants were 10 experts They filled questionnaire 3 times CVR and CVI were calculated For reproducibility, Cronbach's alpha was calculated
2	Omidvar *et al.*, 2002[27]	43	Open-ended (per day, week, month, and year)	None (according to previous data and 24-h recall)	Data based (food items based on previous dietary assessment)	Food providing Vitamin A, Vitamin C, and iron		15-49	East Azerbaijan (Marand) Qualitative questionnaire through interview Food album used in interviews Focus on foods rich in Vitamin A, Vitamin C, and iron Vitamin A component based on Iranian food composition table Participants were women of reproductive age; reproducibility was not included
3	Mohammadifard *et al.*, 2015[4]	48	Open-ended (per day, week, month, and year)	None (according to previous established weight of measure)	Data based (previous questionnaire)	Usual food intake contributing to prevention/ occurrence of cardiovascular diseases	Isfahan cohort study	≥41	Isfahan Simplified food frequency questionnaire Gram weight of food according to food album Participants were divided into four groups based on frequency of consumption Questionnaires through interviews Reproducibility study included
4	Zeyninejad *et al.*, 2015[31]	56	Open-ended (per day, week, month, and year)	Yes	Experience based (commonly used among children in Tehran)	97% of calcium intake in the Iranian diet		9-13	Tehran Designed to assess calcium intake among Iranian students Questionnaires through interviews Previous month Food album and household measurement photographs Iranian food composition table Bland-Altman plot
5	Sharifi *et al.*, 2016[13]	61	Multiple-choice, 10 categories	Yes (standard scale and reported 24-h recalls)	Previous data (data and questionnaires)	Comprehensive assessment in pregnant women		18-40	Qazvin Short questionnaires Pregnant woman with the gestational age of 30-38 weeks 7 dietitians for content validity ratio Exploratory factor analysis (2 determined factors)

Contd...

Table 1: Contd...

n	Author of reference	Number of food items	Number of response categories of intake frequency	Questions on portion size	Development method	Aim of design	Cohort studies using FFQs	Age (years)	Comment
6	Ahmadnezhad *et al.*, 2017[16]	65	Open-ended (per day, week, and month)	Yes (reference serving sizes)	Not mentioned	Comprehensive assessment of dietary intake	MASHAD study	35-65	Mashhad 5 dietitians assessed content validity Questionnaires through interviews
7	Nikniaz *et al.*, 2017[25]	80	Open-ended (per day, week, and month)	Yes (most reported portion sizes)	Data based (food items based on previous dietary 24-h recall)	Comprehensive assessment of dietary intake	LPP	15-65	East Azerbaijan Photographs of household scales Questionnaires through interviews
8	Malekahmadi *et al.*, 2016[21]	89	Open-ended (per day, week, month, and year)	Yes (food record of previous studies)	Experience based	Estimation of antioxidant intake (selenium, zinc, carotene, Vitamin C, and Vitamin E)		60-75	Isfahan Elderly Questionnaires through interviews Antioxidant assessment in elderly with mild cognitive impairment Vitamin E, Vitamin C, selenium, and carotene Reproducibility study included (sub-samples)
9	Keshteli *et al.*, 2014[20]	106	Multiple-choice (like Harvard FFQ), 9 categories	Yes (previous record and expert)	Expert panel (Harvard model)	Comprehensive emphasis on mixed dishes			Dish based Harvard questionnaire as a model Food: Used often, between-person variation, nutrient-rich Self-administered Number of frequency options not constant for all
10	Mohammadifard *et al.*, 2011[24]	110	Open-ended (per day, week, month, and year)	Yes	Data based (previous studies)	Assessment of fruits and vegetables intake	Isfahan Healthy Heart Program	30-60	Isfahan Album of household scales used Questionnaire designed to assess fruits and vegetables Questionnaires through interviews Vegetables sorted in 11 groups Reproducibility study included.
11	Rafat *et al.*, 2011[12]	125	Open-ended (per day, week, month, and year)	Yes	Not mentioned	Comprehensive assessment of dietary intake		18-45	Tehran (north and east) Questionnaires through interviews Food intake pattern
12	Mohammadifard *et al.*, 2016[23]	N/A 136 initial list	Multiple-choice, 10 categories	Yes	Data based (recalls of the previous study)	Assessment of sodium consumption in Iranian population		≥6	Protocol study for FFQ validation without data Initial 136 food items listed Isfahan Questionnaire and recalls through interviews Face and content validity by 10 experts Piloted on 25 volunteers To assess sodium consumption in the Iranian population 24-h urine and spot urine twice

Contd...

Table 1: Contd...

n	Author of reference	Number of food items	Number of response categories of intake frequency	Questions on portion size	Development method	Aim of design	Cohort studies using FFQs	Age (years)	Comment
13	Pirouzpanah *et al.*, 2012[29]	136	Open-ended (per day, week, month, and year)	Yes	Data based (block questionnaire)	Assessment of dietary folate intake in breast cancer patients		35-85	Tehran Participants were newly diagnosed breast cancer patients Assessment of folate intake Questionnaires through interviews Energy adjustment
14	Pirouzpanah *et al.*, 2014[28]	136	Open-ended (per day, week, month, and year)	Yes (standard)	Data based (block questionnaire)	Assessment of dietary folate intake in breast cancer patients		30-69	Tehran Breast cancer patients Questionnaires through interviews 25 food preparation+25 open-ended questions Colored photos and utensils N4 software Folate, Vitamin B12, and Vitamin B6 (residual method: Calorie adjustment)
15	Bijani *et al.*, 2018[17]	138	Open-ended (per day, week, month, and year)	Yes	Data based (previous questionnaire)+ expert panel	Comprehensive assessment of dietary intake	Amirkola Health and Aging Project	≥60	North of Iran Questionnaires through interviews Pictures of portion size and household units Bland-Altman plot Elderly Reproducibility not included
16	Doustmohammadian *et al.*, 2020[18]	142	Not mentioned	Yes	Not mentioned	Comprehensive assessment of dietary intake		18-65	Tehran 84 food items and 58 mixed dishes Questionnaires through interviews Visual aid of usual household utensils Reproducibility studies included
17	Toorang *et al.*, 2019[30]	146	Multiple-choice	Yes	Data based (previous questionnaire)+ expert panel	Comprehensive assessment of dietary intake		19-60	Tehran Participants were friends and relatives of patients in an Iranian referral cancer center Questionnaires through interviews Reproducibility not included
18	Malekshah *et al.*, 2006[22]	150	Open-ended (per day, week, month, and year)	Yes	Experience based	Comprehensive assessment of dietary intake	Golestan cohort of esophageal cancer	35-65	Golestan province Questionnaires through interviews Photographs to show portion size of some items 4 FFQs every 3 months 2 consecutive days of recall every month 2 blood samples 4 urine samples every 3 months Reproducibility studies included

Contd...

Table 1: Contd...

n	Author of reference	Number of food items	Number of response categories of intake frequency	Questions on portion size	Development method	Aim of design	Cohort studies using FFQs	Age (years)	Comment
19	Nouri *et al.*, 2017[26]	160	Multiple-choice, 9 categories	Yes	Data based (record)	Comprehensive assessment of dietary intake		20-69	Mixed dishes Tehran, Mashhad, Tabriz, Shiraz, and Isfahan Short album at beginning of questionnaire Self-administered questionnaires Bland-Altman plot Blood and urine sampling twice Reproducibility studies included
20	Esfahani *et al.*, 2010[19]	168	Open-ended (per day, week, month, and year)	Yes (USDA)+ household measures	Data based (modified willet questionnaire according to national food consumption survey)	Comprehensive assessment of dietary intake	Tehran lipid and glucose study	20-70	Tehran Questionnaires and recalls through interviews Energy and age adjusted (residual method) Reproducibility studies included
21	Mirmiran *et al.*, 2010[5]	168	Open-ended (per day, week, month, and year)	Yes (standard for Iranian)	Data based (modified Willett questionnaire according to national food consumption survey)	Comprehensive assessment of dietary intake	Tehran lipid and glucose study	20-70	Tehran Questionnaires and recalls through interviews Triad method 4 samples (urine and blood) Reproducibility studies included
22	Ebrahimi-Mameghani *et al.*, 2014[14]	189	Open-ended (per day, week, month, and year)	None	Data based (previous questionnaire)+ expert panel	Comprehensive assessment of food intake		20-60	Tabriz Participants with BMI of≥24.99 Questionnaires through interviews Exploratory factor analysis (3 factors determined)

FFQ=Food frequency questionnaire; CVR=Content validity ratio; CVI=Content validity index; MASHAD=Mashhad Stroke and Atherosclerotic Disorder; LPP=Lifestyle promotion project; BMI=Body mass index; USDA=US Department of Agriculture

1. Six FFQs were modified based on a previous version of the questionnaires, which were shortened to select the food items of target nutrients[4,13,14,17,19,29]
2. Four FFQs were the culturally adapted versions of the validated FFQs used in other countries[5,17,19,28-30]
3. In six FFQs, food items were selected based on food records or 24-h recalls of the previous studies conducted in Iran.[15,23-27] The selected food items defined the intake percentage of target nutrients.

Notably, the method of FFQ development was not mentioned in three articles.[12,16,18]

Number of food items and frequency questions

In the reviewed studies, the number of the selected food items was within the range of 40–189 (mean: 109.4, median: 130.5). The assessment of the frequency of food intake was performed using open-ended questions, and the respondents marked their intake as daily, weekly, monthly, yearly, or never in 14 FFQs.[4,5,12,14-17,19,21,22,24,25,27-29,31] In five FFQs, the response categories of food intake frequency was listed with nine or 10 options,[13,20,23,26,30] while the data collection method for the food intake frequency was not mentioned in one study.[18]

Portion sizes

Data on portion size had been collected in 16 FFQs.[5,12,13,16-26,28-31] In one FFQ,[27] portion size was measured based on the recall portion size of the previous studies conducted in the same location, while in another FFQ, the portion size was determined based on the previously established weight of measures.[4] On the other hand, the portion size was not assessed in two FFQs,[14,15] while eight studies used images to assist participants in the description of portion size.[18,22,24-28,31]

Food frequency questionnaires validation studies

Sample size

The sample size of the validation studies was within the range of 30–498 (mean: 189.6, median: 152).

Sample population

In 11 studies (57.8%), the participants were selected from the general population.[4,5,14,16,18,19,22,24-26,30] The other studies were performed on patients with ulcerative colitis,[15] women of the reproductive age,[27] students,[31] pregnant women,[13] the elderly,[17,21] females aged 18–45 years,[12] and women with recently diagnosed breast cancer.[28,29]

Food frequency questionnaires administration method

In 17 studies, questionnaires were completed by interviewers,[4,5,12,14,16-19,21,22,24,25,27-31] while three studies applied self-administered questionnaires.[13,15,26] The administration method was not reported in the validation studies of two FFQs.[20,23]

Food frequency questionnaires validation methods

The FFQ validation studies are presented in Table 2. Accordingly, four methods were applied to validate FFQs.

Food frequency questionnaires validation based on dietary reference methods

In 14 studies, FFQs were validated based on dietary reference methods, including food records and 24-h recalls. In addition, three FFQs were validated based on food records within the range of 18–24 days,[12,21,26] eight studies used 24-h recalls for 2–24 days,[5,16-19,22,23,27,30,31] and three studies used both methods.[4,24,25]

To validate FFQs, seven studies assessed various food groups,[4,12-14,19,24,29] eight studies assessed nutrient intakes,[5,18,21,22,26,27,30,31] and three studies assessed both parameters.[16,17,25] In the mentioned studies, Pearson's correlation coefficients were calculated to compare the food groups and nutrient intakes using the dietary reference methods (record/recall) and the collected data using FFQs[4,5,16-19,21,22,24-27,30,31] Tables 3 and 4 show the correlation coefficients (r) used for the comparison of the FFQ data with the dietary reference methods for food groups and nutrient intakes, respectively.

According to the findings, the validity of food group consumption was high (median of correlation coefficient of FFQs ≥0.60) for tea and coffee and fruits and refined grains, while it was moderate (median of correlation coefficient: 0.40–0.59) for solid fats, plant protein, whole grains, dairies, vegetables, soft drinks, nuts, sugar, fast foods, salty snacks, plant protein, beverages, poultry, potato, leafy vegetables, and liquid foods, fair (median of correlation coefficient: 0.30–0.39) for vegetable oils, hydrogenated vegetable oils, meat, honey and jam, grains, fruits and vegetables, pickle, and fish, and poor (median of correlation coefficient: <0.3) for egg, legumes, and sweets.

High validity was only observed for sucrose (median of correlation coefficient ≥0.60), while for most nutrients, the median correlation coefficient was within the range of 0.40–0.59, indicating moderate validity. Fair validity (correlation coefficient: 0.30–0.39) was reported for iron, Vitamin C, Vitamin B2, niacin, fiber, polyunsaturated fatty acids (PUFAs), manganese, zinc, sodium, lactose, and trans fatty acids. Poor validity (median of correlation coefficients of FFQs <0.3) was observed for potassium, Vitamin A, Vitamin E, Vitamin B6, Vitamin B12, α-tocopherol, folate, copper, and fructose. Among fatty acids, validity was highest for saturated fatty acids, followed by monounsaturated fatty acids and PUFAs.

Food frequency questionnaires validation based on biomarkers

According to the current review, eight studies used

Table 2: Summary of food frequency questionnaire validity and reproducibility studies in Iran (studies sorted by the number of included food items)

n	Author of validation article	Number of food items	Participants	Dietary recall or food record	Duration of record/recall	Food group or nutrient	Blood biomarker	Urine biomarker	Energy adjustment
1	Hadi *et al.*, 2017[15]	40							
2	Omidvar *et al.*, 2002[27]	43	187 females	Recall (interview)	2 consecutive Days	Nutrient	Retinol	-	
3	Mohammadifard *et al.*, 2015[4]	48	127 males and 137 females	Record (self) Recall (interview)	1 2	Food Group	-	-	
4	Zeyninejad *et al.*, 2015[31]	56	103 boy 103 girl Both	Recall	5	Nutrient	-	-	
5	Sharifi *et al.*, 2016[13]	61	498 females			Food group			
6	Ahmadnejhad *et al.*, 2017[16]	65	13 males and 17 females	Recall	2	Food group Nutrient			
7	Nikniaz *et al.*, 2017[25]	80	93 males and 87 females	Recall (interview) Records (self)	1 2	Food group Nutrient			
8	Malekahmadi *et al.*, 2016[21]	89	86 males and 99 females	Record (self)	6×3 days every 2 months	Nutrient	-	-	+
9	Keshteli *et al.*, 2014[20]	106							
10	Mohammadifard *et al.*, 2011[24]	110	53 males and 48 females	Recall (interview) Record (self)	2×1 days 2×2 days	Food group	Retinol Vitamin C Lipid β-Carotene	-	
11	Rafat *et al.*, 2011[12]	125	150 females	Record	12×2 days	Food group			
12	Mohammadifard *et al.*, 2016[23]	136	167 (6-18 year) 81 boys and 86 girls 198 (≥18 years) 96 males 102 females	Recall	12 days	Food group	-	Ca Na Cl Creatinine	
13	Pirouzpanah *et al.*, 2012[29]	136	152 Females			Food group	Folate	-	+
14	Pirouzpanah *et al.*, 2014[28]	136	149 females				Folate Cobalamin Pyridoxine		
15	Bijani *et al.*, 2018[17]	138	100 males and 100 females	Recall (interview)	2 Days	Food groups and nutrients	-	-	
16	Doostmohammadian *et al.*, 2020[18]	142	230	Recall (interview)	6 days	Nutrients	Retinol β-carotene	-	+
17	Toorang *et al.*, 2019[30]	146	138 males and 106 females Total	Recall (interview)	4 days	Nutrients			+
18	Malekshah *et al.*, 2006[22]	150	51 males and 80 females 131 total	Recall (interview)	12×2 days	Nutrient	Vitamin C Carotenoids Retinol α-tocopherol Cholesterol	24-h Nitrogen	

Table 2: Contd...

n	Author of validation article	Number of food items	Participants	Dietary recall or food record	Duration of record/recall	Food group or nutrient	Blood biomarker	Urine biomarker	Energy adjustment
19	Nouri *et al.*, 2017[26]	160	39 males and 74 females Total	Record	6×3 days	Nutrient	Vitamin A Vitamin E Folate	24-h K 24-h Protein	
20	Hosseini Esfahani *et al.*, 2010[19]	168	61 males and 71 females	Recall (interview)	12 days	Food group	-	-	+
21	Mirmiran *et al.*, 2010[5]	168	61 males and 71 females	Recall (interview)	12 days	Nutrients	Retinol α-tocopherol β-carotene	24-h N 24-h K	+
22	Ebrahimi Mameghani *et al.*, 2014[14]	189	420			Food group			

n	Author of validation article	De-attenuation	Number of nutrient/food group	Cc DR and FFQ for nutrient (range)	Fruits	Vegetable	Cc between 2 FFQs	Fruits	Vegetable	Interval between FFQs	Validity study quality score (/7)
1	Hadi *et al.*, 2017[15]									1 month	3
2	Omidvar *et al.*, 2002[27]		1								3.5
3	Mohammadifard *et al.*, 2015[4]		13	0.315 (0.091-0.473) 0.315 (0.084-0.491)			0.59 (0.47-0.68) 0.62 (0.45-0.69)			2 weeks	4.5
4	Zeyninejad *et al.*, 2015[31]	+	1 (Ca)	0.67 0.47 0.57			0.65 0.64 0.65			1 month	5.5
5	Sharifi *et al.*, 2016[13]		8				(0.516-0.993)			2 weeks (*n*=35)	3.5
6	Ahmadnejhad *et al.*, 2017[16]		15							6 months	5
7	Nikniaz *et al.*, 2017[25]		18	0.4-0.78 0.41-0.72						1 month	5
8	Malekahmadi *et al.*, 2016[21]		5	0.56 (0.35-0.66)			0.54 (0.47-0.62)			3 months (20%)	5
9	Keshteli *et al.*, 2014[20]										-
10	Mohammadifard *et al.*, 2011[24]		Fruits 5 Vegetables 6		0.6	0.58		0.63	0.59	6 months	5
11	Rafat *et al.*, 2011[12]										5
12	Mohammadifard *et al.*, 2016[23]		11							12 months	-
13	Pirouzpanah *et al.*, 2012[29]		10								4.5
14	Pirouzpanah *et al.*, 2014[28]										3.5
15	Bijani *et al.*, 2018[17]		18 food groups and 28 nutrients	0.275 (−0.38-0.53) 0.37 (−0.01-0.71)	0.25 0.35	0.33 0.36					5.5

Contd...

16	Doostmohammadian *et al.*, 2020[18]	+	14	0.38 (0.12-0.51)			0.705 (0.23-0.76)			6 months	5.5
17	Toorang *et al.*, 2019[30]	+	22	0.28 (0.12-0.44) 0.215 (0.07-0.47) 0.315 (0.17-0.55)							4.5
18	Malekshah *et al.*, 2006[22]		12	0.565 (0.25-0.73)			0.65 (0.27-0.88) 0.795 (0.65-0.90) 0.77 (0.66-0.89)			3 months (4 sessions)	4
19	Nouri *et al.*, 2017[26]		9	0.206 (0.032-0.277)			0.727 (0.157-0.863) 0.355 (−0.002-0.6) 0.456 (0.092-0.669)			3 months	3
20	Hosseini Esfahani *et al.*, 2010[19]	+	17		0.71 0.35	0.69 0.50		0.70 0.58	0.46 0.50	14 months	7
21	Mirmiran *et al.*, 2010[5]	+	22	0.585 (0.24-0.71) 0.4 (0.11-0.60)			0.585 (0.41-0.79) 0.625 (0.39-0.74)			14 months	6
22	Ebrahimi Mameghani *et al.*, 2014[14]		36				(0.6-0.97)			2 months	4

FFQ: Food frequency questionnaire; DR: Dietary reference method: record or recall; CC: Correlation coefficients

biomarkers as the reference method,[5,18,22,24,26-29] including five studies that used blood biomarkers[18,24,27-29] and three studies that employed blood and urine biomarkers.[5,22,26] Moreover, two studies used biomarkers as a single reference method,[28,29] and six studies used biomarkers along with a dietary reference method for this purpose.[5,18,22,24,26,27] Table 5 shows the correlation coefficients for the comparison of the FFQ data and biomarkers.

According to the findings, the blood biomarkers that were used in more than one study were retinol,[5,18,22,24,26,27] α-tocopherol,[5,22,26] Vitamin C,[22,24] and β-carotene.[5,18,22,24] In addition, cholesterol was measured in two studies, while the correlation was reported in only one study.[5] The common urinary biomarkers included the 24-h protein excretion (r median: −0.0675).[5,22,26] and potassium excretion (r median: 0.423).[5,26] In most of the reviewed studies, the median correlation coefficients between the FFQs and biomarkers were within the range of 0.30–0.39, indicating fair validity for Vitamin C, cholesterol, folate, 24-h urine nitrogen, and β-carotene. The highest consistency between the FFQs and biomarkers was observed with urinary potassium (r median: 0.423), which indicated moderate validity. On the other hand, poor validity ($r < 0.30$) was denoted with retinol, protein, α-tocopherol, Vitamin A, cobalamin, and pyridoxal-5-phosphate.

Factor analysis

According to the current review, three studies used factor analysis to identify the dietary patterns in FFQs and assess their validity. In this approach, the correlations between the factors of the FFQ and dietary reference methods were calculated as well.[12-14]

Expert panel

In one study, an expert panel calculated the content validity ratio and content validity index in order to the assess validity of FFQs.[15]

Statistical approaches in the validation process

In 16 studies, correlation coefficients were used to compare the FFQ data by a dietary reference method,[4,5,16-19,21,22,24-31] while three studies used the Bland-Altman plot in addition to correlation coefficients.[17,26,31] In one study, the triad method was employed, which is a three-way comparison of the FFQ with detailed measures of dietary intake, such as a dietary record and biochemical measure.[5,11] The content validity index was also used for this purpose in one research.[15] Three studies identified dietary patterns using factor analysis to assess the validity of dietary patterns.[12-14]

Methodology quality of food frequency questionnaires validation studies

In this literature review, the selected studies were

Table 3: Correlation coefficients between food frequency questionnaire data and crude data of dietary reference methods (food groups)

n	Author	Gender of participants	Solid fats	Vegetable oils	Meat	Dairies	Whole grains	Refined grains
3	Mohammadifard *et al*., 2015[4]	127 males and		0.315	0.308	0.457		
		137 females		0.322	0.278	0.467		
				0.319	0.294	0.467		
6	Ahmadnezhad *et al*., 2017[16]	13 males and			0.38	0.57		
		17 females						
7	Nikniaz *et al*., 2017[25]	93 males and		0.39	0.74	0.76	0.72	0.69
		87 females		0.42	0.59	0.71	0.69	0.64
10	Mohammadifard *et al*., 2011[24]	53 males and						
		48 females						
15	Bijani *et al*., 2018[17]	100 males and	0.50	0.4	0.25	0.43	0.44	0.33
		100 females	0.53	0.21	0.13	0.48	0.39	0.41
20	Hosseini Esfahani *et al*., 2010[19]	61 males and	0.48	0.16	0.48	0.73	0.49	0.72
		71 females	0.49	0.38	0.52	0.56	0.45	0.54
	Median		0.5	0.31175	0.38	0.57	0.47	0.63

n	Author	Gender of participants	HVO	Animal fats	Grains	Fruits and vegetables	Beverages	Pickles
3	Mohammadifard *et al*., 2015[4]	127 males and	0.324	0.192	0.183	0.328	0.253	0.091
		137 females	0.346	0.116	0.127	0.315	0.108	0.084
			0.352	0.205	0.226	0.338	0.239	0.105
6	Ahmadnezhad *et al*., 2017[16]	13 males and			0.5		0.47	0.31
		7 females						
7	Nikniaz *et al*., 2017[25]	93 males and		0.45				0.73
		87 females		0.47				0.75
10	Mohammadifard *et al*., 2011[24]	64 males and						
		59 females						
15	Bijani *et al*., 2018[17]	100 males and						
		100 females						
20	Esfahani *et al*., 2010[19]	Males						
		Females						
	Median		0.335	0.307	0.3275	0.3215	0.47	0.31

n	Fruits	Vegetables	Nuts	Legumes	Soft drinks	Tea and coffee	Sugar	Honey and jam	Snacks and dessert	Fast food
3			0.465							0.334
			0.479							0.319
			0.468							0.326
6	0.66		0.3	0.15			0.56	0.36	0.42	0.36
7	0.65	0.69	0.44	0.59	0.75	0.8			0.61	0.66
	0.61	0.64	0.51	0.6	0.71	0.74			0.64	0.6
10	0.60	0.58								0.60
15	0.25	0.33	0.40	0.06	0.10	0.62	0.42	0.38	0.07	
	0.35	0.36	0.36	0.15	0.14	0.53	0.60	0.25	0.16	
20	0.71	0.66	0.51	0.25	0.62	0.79	0.77	0.53	0.54	
	0.31	0.50	0.38	0.28	0.48	0.75	0.65	0.60	0.34	
	0.6	0.58	0.445	0.2075	0.55	0.77	0.56	0.36	0.43	0.5316

Contd...

n	Poultry	Fish	Sweets	Egg	Potato	Salty snacks	Plant protein	Leafy vegetables	Other vegetables	Liquid foods
3			0.108				0.473			
			0.097				0.491			
			0.113				0.480			
6								0.55	0.3	0.49
7	0.76	0.58			0.67					
	0.78	0.6			0.65					
10										
15	0.18	0.06		0.17–0.01						
	0.25	0.15								
20						0.48				
					0.24	0.35				
					0.43					
	0.4925	0.3475	0.1025	0.08	0.4975	0.415	0.482	0.55	0.3	0.49

FFQ=Food frequency questionnaire; CC=Correlation coefficient; HVO=Hydrogenated vegetable oil

scored against a validation study methodology tool.[9] Correspondingly, two studies had acceptable quality,[15,26] eight studies had good quality, and 10 studies were considered to have excellent quality.

Assessment of food frequency questionnaires reproducibility

The reproducibility of FFQs was evaluated in 14 studies[4,5,13-16,18,19,21,22,24-26,31] [Table 2]. With the exception of one study,[22] the other studies had measured FFQ reproducibility twice. The median time interval between the FFQ administrations was 3 months, ranging from 2 weeks to 14 months. Reproducibility was assessed by intraclass correlation coefficients between two FFQs that were administered in most of the studies in this regard,[4,5,12-14,16,18,19,21,22,24-26,31] while the Cronbach's alpha was calculated in one study only.[15] The intraclass correlations between the FFQs were within the range of 0.28 (total sugar) to 0.85 (chloride), with 0.67 calculated as the median for nutrients. As for food groups, the intraclass correlations ranged from 0.30 (beverages) to 0.83 (tea and coffee), 0.85 (sugar), and 0.85 (fish), with the median of 0.65 showing moderate reproducibility. The reported Cronbach's alpha was 0.79 to show acceptable reproducibility.[15]

DISCUSSION

This systematic review was a comprehensive study of the FFQs developed to assess the dietary intakes of the Iranian population. In total, 20 FFQs have been developed so far, 18 of which have been the subject of validation studies. According to our findings, the most commonly used validation method was comparison with another dietary reference method. Correlation coefficients were also used in almost all the validation studies. According to the obtained results, the median correlation coefficient for nutrients between various FFQs and dietary reference methods was 0.39, which is similar to the FFQ applied in Japan,[8] while lower than western countries, where the correlation coefficients have been reported to be within the range of 0.60–0.70.[2] The lower correlation coefficient between FFQs and dietary reference methods in Iran could be due to the complexity of the Iranian diet since it is a combination of traditional dishes, western dishes, fast foods, and local foods. Another source of complexity arises as traditional foods may be similar in terms of description or nomenclature, while the recipes may vary. Moreover, fast foods are most commonly consumed by some populations (e.g., young adults), and local foods are mainly consumed by some ethnicities only and may not be incorporated into the developed questionnaires in this regard.

With regard to validity, the current systematic review revealed that the correlation coefficients between the

Table 4: Correlation coefficients between food frequency questionnaire data and crude data of dietary reference methods (nutrients)

n	Author	Gender of participants	Energy	Protein	CHO	Fats	SFAs	MUFAs	PUFAs	Calcium
2	Omidvar *et al.*, 2002[27]	187 females								
4	Zeyninejad *et al.*, 2015[31]	94 males and 90 females Total								0.5 0.35 0.42
6	Ahmadnejhad *et al.*, 2017	13 males and 17 females	0.61	0.2	0.54	0.63	0.65			0.4
7	Nikniaz *et al.*, 2017[25]	93 males and 87 females	0.63 0.58	0.6 0.63	0.44 0.39	0.41 0.45	0.49 0.56	0.45 0.43	0.47 0.48	0.62 0.58
8	Malekahmadi *et al.*, 2016[21]	86 males and 99 females Total								
15	Bijani *et al.*, 2018[17]	100 males and 100 females	0.53 0.71	0.39 0.55	0.52 0.69	0.49 0.46	0.44 0.46	0.24 0.11	−0.1–0.01	0.25 0.41
16	Doustmohammadian *et al.*, 2020[18]	230 total	0.49	0.51	0.36	0.45				0.43
17	Toorang *et al.*, 2019[30]	138 males and 106 females Total	0.44 0.23 0.51	0.29 0.20 0.42	0.43 0.22 0.55	0.24 0.07 0.17				0.20 0.18 0.29
18	Malekshah *et al.*, 2006[22]	51 males and 80 females Total	0.62	0.73	0.66	0.44	0.61	0.37	0.25	
19	Nouri *et al.*, 2017[26]	39 males and 74 females Total	0.268	0.207	0.206	0.247				
21	Mirmiran *et al.*, 2010[5]	61 males and 71 females	0.56 0.46	0.64 0.48	0.38 0.47	0.62 0.4	0.61 0.37	0.55 0.39	0.37 0.35	0.66 0.32
	Median		0.5575	0.490	0.420	0.445	0.525	0.405	0.305	0.425

n	Author	Gender of participants	Vitamin C	Vitamin D	Vitamin E	Vitamin B6	Vitamin B12	Alpha-tocopherol	Cholesterol	Fiber
2	Omidvar *et al.*, 2002[27]	187 females								
4	Zeyninejad *et al.*, 2015[31]	94 males and 90 females Total								
6	Ahmadnejhad *et al.*, 2017	13 males and 17 females	0.5				0.19		0.56	0.3
7	Nikniaz *et al.*, 2017[25]	93 males and 87 females	0.37 0.32	0.35 0.42	0.37 0.30				0.43 0.41	0.43 0.39
8	Malekahmadi *et al.*, 2016[21]	86 males and 99 females Total	0.54		0.65					
15	Bijani *et al.*, 2018[17]	100 males and 100 females	0.26 0.26		−0.38 0.05	0.09 0.34	0.10 0.40	0.27 0.32	0.25 0.13	0.25 0.19
16	Doustmohammadian *et al.*, 2020[18]	230 total	0.24		0.23				0.40	0.30

Contd...

17	Toorang *et al.*, 2019[30]	138 males and 106 females Total	0.15 0.20 0.22			0.38 0.20 0.30	0.17 0.10 0.17			
18	Malekshah *et al.*, 2006[22]	51 males and 80 females Total	0.52		0.40				0.72	
19	Nouri *et al.*, 2017[26]	39 males and 74 females Total			0.058					0.032
21	Mirmiran *et al.*, 2010[5]	61 males and 71 females	0.42 0.25	0.61 0.65					0.47 0.35	0.68 0.61
	Median		0.340	0.5175	0.2825	0.2525	0.19	0.295	0.415	0.30

No.	Author	Gender of participants	Starch	Total sugar	Glucose	Fructose	Sucrose	Maltose	Lactose	Nonstarch polysaccharides
2	Omidvar *et al.*, 2002[27]	187 females								
4	Zeyninejad *et al.*, 2015[31]	94 males and 90 females Total								
6	Ahmadnejhad *et al.*, 2017	13 males and 17 females	0.57	0.42	0.4	0.42	0.65	0.54	0.37	0.29
7	Nikniaz *et al.*, 2017[25]	93 males and 87 females								
8	Malekahmadi *et al.*, 2016[21]	86 males and 99 females Total								
15	Bijani *et al.*, 2018[17]	100 males and 100 females								
16	Doustmohammadian *et al.*, 2020[18]	230 total								
17	Toorang *et al.*, 2019[30]	138 males and 106 females Total		0.40 0.47 0.46						
18	Malekshah *et al.*, 2006[22]	51 males and 80 females Total								
19	Nouri *et al.*, 2017[26]	39 males and 74 females Total								
21	Mirmiran *et al.*, 2010[5]	61 males and 71 Females								
	Median		0.57	0.4275	0.4	0.24	0.65	0.54	0.37	0.29

n	Iron	Potassium	Vitamin A	Retinol	Carotene	Vitamin B1	Vitamin B2	Niacin
2				0.076				
4								
6	0.29			0.49	0.49	0.38	0.31	
7	0.56		0.48			0.53		0.52
	0.57		0.56			0.57		0.49
8					0.46			
15	0.15	0.28	0.22			0.45	0.34	0.30
	0.10	0.51	0.16			0.67	0.57	0.46
16	0.44					0.50	0.31	
17	0.34	0.34	0.13		0.17			0.34
	0.37	0.14	0.21		0.22			0.17
	0.39	0.34	0.21		0.20			0.44
18				0.57				
19		0.277	0.134					
21		0.33	0.22			0.69	0.64	
		0.31	0.38			0.53	0.42	
	0.355	0.2985	0.190	0.49	0.460	0.550	0.3825	0.380

Contd...

n	Selenium	Zinc	Folate	Magnesium	Beta-carotene	Manganese	Copper	Phosphorus	Sodium	Chloride
2										
4										
6		0.31	0.25			0.22	0.19	0.35	0.51	0.52
7	0.52	0.58						0.45		
	0.51	0.63						0.44		
8	0.6	0.57								
15	0.29	0.21	0.16	0.36		0.46	0.29	0.34		
	0.49	0.31	0.17	0.55		0.31	0.31	0.55		
16		0.24	0.12							
17	0.33	0.27	0.20	0.41					0.32	
	0.28	0.11	0.25	0.12					0.23	
	0.51	0.32	0.30	0.39					0.44	
18					0.56					
19			0.076							
21		0.59	0.68	0.63	0.33			0.7		
		0.46	0.49	0.38	0.22			0.42		
	0.4225	0.310	0.195	0.455	0.4175	0.3025	0.245	0.445	0.3025	0.52

No.	Unsaturated fats	Trans fatty acids
2		
4		
6	0.24	0.38
7		
8		
15		
16		
17		
18		
19		
21		
	0.24	0.38

FFQ=Food frequency questionnaire; CC=Correlation coefficient; CHO=Carbohydrates; SFA=Saturated fatty acid; MUFA=Monounsaturated fatty acid; PUFA=Polyunsaturated fatty acid

Table 5: Correlation coefficients between food frequency questionnaire data and biomarkers

n	Author	Gender of participants	Vitamin C	Retinol	β-carotene	α-tocopherol	Urine nitrogen	Folate	Protein	Cholesterol	Potassium	Vitamin A	Pyridoxine	Cobalamin
2	Omidvar *et al.*, 2002[27]	187 females		0.194										
10	Mohammadifard *et al.*, 2011[24]	53 males and 48 females Total	0.52	0.35	0.45									
13	Pirouzpanah *et al.*, 2012[29]	152 females						0.33						
14	Pirouzpanah *et al.*, 2014[28]	149 females						0.324					0.033	0.240
16	Doustmohammadian *et al.*, 2020[18]	230 Total		0.26	0.13									
18	Malekshah *et al.*, 2006[22]	51 males and 80 females Total	0.25	0.27	0.35	0.07	0.35							
19	Nouri *et al.*, 2017[26]	39 males and 74 females Total				−0.045		0.149	−0.345		0.476	−0.019		
21	Mirmiran *et al.*, 2010[5]	61 males and 71 females Total		0.21	0.38	0.28			0.21	0.31	0.37			
	Median		0.385	0.26	0.365	0.07	0.35	0.324	−0.0675	0.31	0.423	−0.019	0.033	0.24

FFQs and dietary reference methods varied in terms of food groups, which could be due to the differences in the number and clarity of the food items, portion sizes, and interpersonal variability. Food groups such as tea and coffee, refined grains, and fruits could be assessed with high validity, which may be attributed to their frequent consumption and the fact that they could be easily remembered by the individual. In the reviewed studies, dairy products had moderate validity, which may be due to their frequent consumption and inclusion of sufficient items with detailed questions in the questionnaires. There seems to be better consistency between FFQs and other dietary assessment methods in terms of the foods that are consumed frequently (e.g., rice, bread, vegetables, sugar, soft drinks, and fast food) rather than seasonally compared to the foods that are consumed less frequently. According to our findings, the median of the correlation coefficients for nuts was 0.445, which indicated moderate validity probably due to the high interpersonal variability in nut consumption. On the other hand, solid fats had moderate validity (median of correlation coefficients: 0.5), which animal fats had lower validity (median of correlation coefficients: 0.3), which could be due to the presence of hydrogenated vegetable oils in solid fats. Compared to the other studies in this regard, the consistency between FFQs and reference methods was slightly lower in Iran in terms of total fats (0.51 vs. 0.44), Vitamin C (0.50 vs. 0.0.34), Vitamin A (0.37 vs. 0.19), calcium (0.56 vs. 0.42), and iron (0.47 vs. 0.35).

According to the current systematic review, the validation of 70% of FFQs was based on another dietary reference method, which compares well to the study conducted by Cade *et al.*, in which the value was reported to be 75%.[32] Among Iranian validation studies, 40% have been performed based on biomarkers, which are considered to be a "gold standard" method.[2] This rate is higher compared to the reported values in the studies conducted in other countries, in which the validation of only 19% of FFQs has been based on biomarkers.[32] The more frequent use of biomarkers in Iran may be attributed to the lack of national food composition tables, which in turn leads to the preference of biomarker-based validation studies.[2] Nevertheless, the use of biomarkers has some limitations since not only these factors are influenced by diet but also by the degree of absorption and metabolism.[2] Therefore, the correlation between biomarkers and questionnaires is expected to be less significant than the correlation between questionnaires and dietary reference methods. As it was predicted, our findings showed a nonsignificant correlation between biomarkers and nutrient intake, and the correlation coefficients were within the range of −0.07–0.42.

In the reviewed articles, the expected intraclass correlation for the reproducibility of functional FFQs was within the range

of 0.5–0.7,[2] which indicated acceptable reproducibility. Commonly consumed food groups (e.g., tea and coffee) were observed to have higher correlation coefficients. Notably, the seasonal variation in the food intakes, which affected reproducibility, was investigated in only few studies,[5,12,16,18,19,22,24] and the lack of this item may cause false reproducibility due to systematic error.

In the current review, the methodology quality of the validation studies was considered acceptable in 90% of the reviewed articles, which is higher than the value reported in a similar study (59%)[9] and regarded as an advantage of Iranian validation studies. Furthermore, most of the questionnaires (90%) were administered through face-to-face interviews, which shows the superiority of this method for the Iranian population. It is expected that the questionnaires administered through interviewers have higher correlations owing to the guidance of the interviewer. In the self-administered questionnaire used by Nouri *et al*.,[26] the correlation coefficients of nutrients were lower than the interviewer-administered questionnaires. In the review of the foreign validation studies conducted by Cade *et al*.,[32] 67% of the questionnaires were interviewer-administered and resulted in higher correlation coefficients for some nutrients. Although interview administration and the immediate assessment of the responses is an advantage, the costs of the recruitment and training of interviewers may be disadvantageous.

According to the current review, the mean food items in the FFQs was 109.4, which is higher than the findings of the worldwide systematic review study by Cade *et al*.;[32] the value was estimated at 88 in the mentioned research. The discrepancy could be due to the complexity of the Iranian diet. The mean sample size of the FFQ validation studies was 189.6 (range: 30–498), while the mean sample size of international FFQ validation studies has been estimated at 255 (range: 6–3750).[32] Nevertheless, it seems that a larger sample size has no significant impact on the correlation coefficients in validation studies.[32]

Strengths and limitations

This systematic review aimed to assess the features and validation studies of Iranian FFQs. The quality of the reviewed studies was scored to better judgment in the generalizability of study results. The major limitation of this review was the heterogeneity of the reported data in the reviewed studies. Although adjustment for energy intake and within-person variation (de-attenuation) would make the data more accurate, we used crude correlation coefficients since adjustment was not performed in all the studies.

CONCLUSION

According to the results of this systematic review, the FFQs in Iran may be representative of the regular Iranian diet and have acceptable validity and reproducibility despite the variations in their features. Furthermore, the validation studies had acceptable quality. The FFQs also had some limitations; for instance, they had low validity for some food groups and nutrients, such as egg, legumes, sweets, potassium, Vitamin E, Vitamin A, Vitamin B6, Vitamin B12, α-tocopherol, folate, copper, and fructose. Therefore, Iranian FFQs may not be applicable in some cases, and FFQ validity must be assessed for the intended items before the selection of the questionnaire.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Chen Y, Ahsan H, Parvez F, Howe GR. Validity of a food-frequency questionnaire for a large prospective cohort study in Bangladesh. Br J Nutr 2004;92:851-9.
2. Willett WE. Reproducibility and validity of foodfrequency questionnaires. In: Willet W, editor. Nutritional Epidemiology. 2nd ed. New York, Oxford: Oxford University Press; 1998. p. 101-47.
3. Barclay AW, Flood VM, Brand-Miller JC, Mitchell P. Validity of carbohydrate, glycaemic index and glycaemic load data obtained using a semi-quantitative food-frequency questionnaire. Public Health Nutr 2008;11:573-80.
4. Mohammadifard N, Sajjadi F, Maghroun M, Alikhasi H, Nilforoushzadeh F, Sarrafzadegan N. Validation of a simplified food frequency questionnaire for the assessment of dietary habits in Iranian adults: Isfahan Healthy Heart Program, Iran. ARYA Atheroscler 2015;11:139-46.
5. Mirmiran P, Esfahani FH, Mehrabi Y, Hedayati M, Azizi F. Reliability and relative validity of an FFQ for nutrients in the Tehran lipid and glucose study. Public Health Nutr 2010;13:654-62.
6. Mirmiran P, Azadbakht L, Azizi F. Dietary behaviour of Tehranian adolescents does not accord with their nutritional knowledge. Public Health Nutr 2007;10:897-901.
7. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Ann Intern Med 2009;151:264-9, W64.
8. Wakai K. A review of food frequency questionnaires developed and validated in Japan. J Epidemiol 2009;19:1-1.
9. Golley RK, Bell LK, Hendrie GA, Rangan AM, Spence A, McNaughton SA, *et al*. Validity of short food questionnaire items to measure intake in children and adolescents: A systematic review. J Hum Nutr Diet 2017;30:36-50.
10. Serra-Majem L, Frost Andersen L, Henríque-Sánchez P, Doreste-Alonso J, Sánchez-Villegas A, Ortiz-Andrelluchi A, *et al*. Evaluating the quality of dietary intake validation studies. Br J Nutr 2009;102 Suppl 1:S3-9.
11. Willett WL. Reproducibility and validity of food frequency questionnaire. In: Willet W, editor. Nutritional Epidemiology. 3rd ed., Vol. 40. New York, Oxford: Oxford University Press; 2013. p. 96-145.
12. Rafat R, Hoshyarrad A, Rezazadeh A, Hosseini Z, Behruz M. Validity and reproducibility of a food frequency questionnaire for assessing dietary patterns in 18-45 years old women supported by health care in the North and East of Tehran. Iran J Endocrinol

Metabol 2011;13:58-66.
13. Sharifi SF, Javadi M, Barikani A. Reliability and validity of short food frequency questionnaire among pregnant females. Biotechnol Health Sci 2016;3:e34608.
14. Ebrahimi-Mameghani M, Behroozi-Fared-Mogaddam A, Asghari-Jafarabadi M. Assessing the reliability and reproducibility of food frequency questionnaire and identify major dietary patterns in overweight and obese adults in Tabriz, Iran. J Mazandaran Univ Med Sci 2014;23:46-57.
15. Hadi F, Somi M, Ghavamzadeh S. Validity and reliability of a 40-items Food Frequency Questionnaire to Measure the Consumption of Gluten in Patients with Ulcerative Colitis. Iran J Nutr Sci Food Technol 2017;12:1-9.
16. Ahmadnezhad M, Asadi Z, Miri HH, Ferns GA, Ghayour-Mobarhan M, Ebrahimi-Mamaghani M. Validation of a short semi-quantitative food frequency questionnaire for adults: A pilot study. J Nutr Sci Diet 2017;3:49-55.
17. Bijani A, Esmaili H, Ghadimi R, Babazadeh A, Rezaei R, G Cumming R, *et al*. Development and validation of a Semi-quantitative food frequency questionnaire among older people in north of Iran. Caspian J Intern Med 2018;9:78-86.
18. Doustmohammadian A, Amini M, Esmaillzadeh A, Omidvar N, Abtahi M, Dadkhah-Piraghaj M, *et al*. Validity and reliability of a dish-based semi-quantitative food frequency questionnaire for assessment of energy and nutrient intake among Iranian adults. BMC Res Notes 2020;13:1-7.
19. Esfahani FH, Asghari G, Mirmiran P, Azizi F. Reproducibility and relative validity of food group intake in a food frequency questionnaire developed for the Tehran Lipid and Glucose Study. J Epidemiol 2010;20:150-8.
20. Keshteli A, Esmaillzadeh A, Rajaie S, Askari G, Feinle-Bisset C, Adibi P. A dish-based semi-quantitative food frequency questionnaire for assessment of dietary intakes in epidemiologic studies in Iran: Design and development. Int J Prev Med 2014;5:29-36.
21. Malekahmadi M, Naeini AA, Shab-Bidar S, Feizi A, Djazayery A. Development, validity, and reliability of a food frequency questionnaire for antioxidants in elderly Iranian people. J Res Med Sci 2016;21:14.
22. Malekshah AF, Kimiagar M, Saadatian-Elahi M, Pourshams A, Nouraie M, Goglani G, *et al*. Validity and reliability of a new food frequency questionnaire compared to 24 h recalls and biochemical measurements: Pilot phase of Golestan cohort study of esophageal cancer. Eur J Clin Nutr 2006;60:971-7.
23. Mohammadifard N, Khosravi AR, Esmaillzadeh A, Feizi A, Abdollahi Z, Salehi F, *et al*. Validation of simplified tools for assessment of sodium intake in Iranian population: Rationale, design and initial findings. Arch Iran Med 2016;19:652-8.
24. Mohammadifard N, Omidvar N, Houshiarrad A, Neyestani T, Naderi GA, Soleymani B. Validity and reproducibility of a food frequency questionnaire for assessment of fruit and vegetable intake in Iranian adults(*). J Res Med Sci 2011;16:1286-97.
25. Nikniaz L, Tabrizi J, Sadeghi-Bazargani H, Farahbakhsh M, Tahmasebi S, Noroozi S. Reliability and relative validity of short-food frequency questionnaire. Br Food J 2017;119:1337-48.
26. Nouri M, Ghazizahedi S, Amir Reza Mohajeri S, Norouzy A, Nematy M, Shalaey N, *et al*. Relative validity and reproducibility of a semi-quantitative food frequency questionnaire among Urban Iranians. Int J Health Life Sci 2017;3:60-70.
27. Omidvar N, Ghazi-Tabatabie M, Harrison GG, Eghtesadi S, Mahboob SA, Pourbakht M. Development and validation of a short food-frequency questionnaire for screening women of childbearing age for vitamin A status in northwestern Iran. Food Nutr Bull 2002;23:73-82.
28. Pirouzpanah S, Taleban FA, Mehdipour P, Atri M, Hooshyareh-rad A, Sabour S. The biomarker-based validity of a food frequency questionnaire to assess the intake status of folate, pyridoxine and cobalamin among Iranian primary breast cancer patients. Eur J Clin Nutr 2014;68:316-23.
29. Pirouzpanah S, Taleban FA, Sabour S, Mehdipour P, Atri M, Farrin N, *et al*. Validation of food frequency questionnaire to assess folate intake status in breast cancer patients. Razi J Med Sci 2012;18:31-41.
30. Toorang F, Sasanfar B, Razeghi Jahromi S, Ebrahimpour Koujan S, Narmcheshm S, Rafei A, *et al*. Validation of diet history questionnaire in assessing energy and nutrient intakes of Iranian population. Iran J Public Health 2019;48:1074-81.
31. Zeyninejad E, Omidvar N, Neyestani T, Houshiarrad A, Eshraghian MR, Stormer A. Development and validation of a food frequency questionnaire for assessing dietary calcium in children. Nutr Food Sci Res 2015;2:35-45.
32. Cade JE, Burley VJ, Warm DL, Thompson RL, Margetts BM. Food-frequency questionnaires: A review of their design, validation and utilisation. Nutr Res Rev 2004;17:5-22.