REVIEW ARTICLE

Design and Validation of Web-Based or Online Food Frequency Questionnaire for Adults: A Scoping Review

Laila Ruwaida Mohd Zainuddin[1], Che Suhaili Che Taha[1], Mohd Razif Shahril[2]

[1] School of Nutrition and Dietetics, Faculty of Health Sciences, Universiti Sultan Zainal Abidin, Gong Badak Campus, Gong Badak, 21300 Kuala Nerus, Terengganu, Malaysia.
[2] Centre for Healthy Ageing and Wellness (HCARE), Faculty of Health Sciences, Universiti Kebangsaan Malaysia, 50300 Kuala Lumpur, Malaysia.

ABSTRACT

This article aimed to review the design features of web-based or online FFQ developed for adults and statistical analysis used in the validation, comparison, or reproducibility studies. The search identified 863 articles, and 29 studies met the criteria. The number of food list ranges from 12 to 279 items. The food portion size was estimated using images or a standard portion size using household measurement. Web-based FFQ was validated with other dietary assessment tools, Block FFQ and biomarker. Comparison study of web-based FFQ was done using paper-based FFQ and interviewed-administered FFQ. Two studies conducted validation and comparison study using other dietary assessment methods, biomarker and paper-based FFQ. Seven studies conducted reproducibility studies. Overall, web-based FFQs showed acceptable validity with the respective reference method and good reproducibility. Strategies to improve the application of current evidence on best practices in designing and validating a web-based FFQ can improve nutritional epidemiology studies.

Keywords: Web-based, Food Frequency Questionnaire, Validation, Reproducibility, Scoping review

Corresponding Author:
Mohd Razif Shahril, PhD
Email: razifshahril@ukm.edu.my
Tel: +6039287188

INTRODUCTION

FFQ is commonly utilised for assessment of dietary intakes due to its key advantages such as ease of administration and conversion into nutrients, the ability to cover differences in the seasonal intake or occasional intake of foods (1) low compliance and participation rates (2) and low cost (3). Like many other dietary assessment methods, FFQ is traditionally are pen and paper-based format. Over the years, development of technology-based dietary assessment tools has gained momentum (4), such as the development of image-based tools, web-based tools, wearable devices (4) and mobile apps tools (5, 6). These tools are becoming common means of collecting dietary data and even more preferred methods than the traditional dietary assessment method (7). The application of technology in dietary assessment tools helps reduce the cost, increase participation rates, and improve data collected accuracy (8). The use of web-based platforms enables data collection to be conducted across many geographic locations (9-12). Amongst other types of web-based dietary assessment tools, web-based or online FFQ is easier to develop because it does not use complex technology such as text search functionality and extensive food composition database (13). Web-based FFQ has been used to collect data from various population groups. The design features, food list, type of nutrient studied, portion size estimation aids, validation or comparison method used in web-based FFQs differ from each other and generally were developed according to the population of the study.

Different study designs were used to investigate web-based FFQs to accurately assess dietary intake, the most common of which are validation, comparison and reproducibility studies. The comparison study can be defined as investigating a test measure of dietary assessment against alternative dietary recall (interviewed-administered recall) to determine the data collected from the test measure are comparable with the existing method. The validation study is conducted to investigate a test measure's accuracy by comparing the test measure with an objective measure of intake, such as direct observation or using biological markers (14). Assessing the validity of the dietary assessment is fraught with challenges such as the risk of correlated error between the test method and reference method (15), cost and practicality factors associated with the direct observation of intake or the collection of biological samples (14). Weighed food records are often used as 'gold standard' method for dietary assessment, particularly when assessment using biomarkers and direct observation cannot be conducted (16). Reproducibility can be tested by administering the same dietary assessment tool to the same participants and comparing the two responses between them (17). At present, there are numerous web-based FFQ that has been developed, tested and validated worldwide. However, there is a limited study that reviews the design and validation of web-based FFQ among adults. Therefore, this review aimed to examine common designs features amongst web-based FFQs and investigate the methods used to assess the validity, comparability, and reproducibility of these tools.

METHODS

The present study was designed as a scoping review to describe the design and validation of web-based and online FFQ among adults. The review was conducted based on the five-stage scoping review framework, which follows this order; identifying the research questions, identifying relevant studies, study selection, charting the data, and collating, summarising, and reporting the results (18). The review is reported following the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (19).

The research questions used in the first step of the review process were: (a) what are the design of web-based and online food frequency questionnaire and (b) what is the method used to validate web-based and online food frequency questionnaire. An electronic search was conducted on the PubMed database to identify relevant studies. The search was initially conducted in December 2018 to January 2019. The inclusion criteria used were as follows: English-language publications reporting the development, comparison, validation, reproducibility study of web-based and online FFQ for adults. The following search terms were based on the following titles/keywords: design AND validation of web-based AND online FFQ, design OR validation of web-based AND online FFQ, design OR validation of web-based FFQ AND online FFQ, design OR validation of web-based FFQ OR online FFQ. A search of the grey literature on the internet using different combinations of key search terms was conducted to reduce the risk of omitting relevant evidence sources. The researchers independently examined titles, abstracts, keywords for eligibility. The author's information, year of publication, number of foods items in the FFQ, name of the FFQ, portion size estimation method, participants characteristics; age, sample size, FFQ validation method, and supplements use were as outlined in Table I and Table II.

Figure I show the PRISMA-ScR flow chart of the design and validation of web-based or online FFQ for adults. In the first stage, using database searches, 853 papers were identified, and further 10 papers were found using reference tracking and internet searches. The abstracts

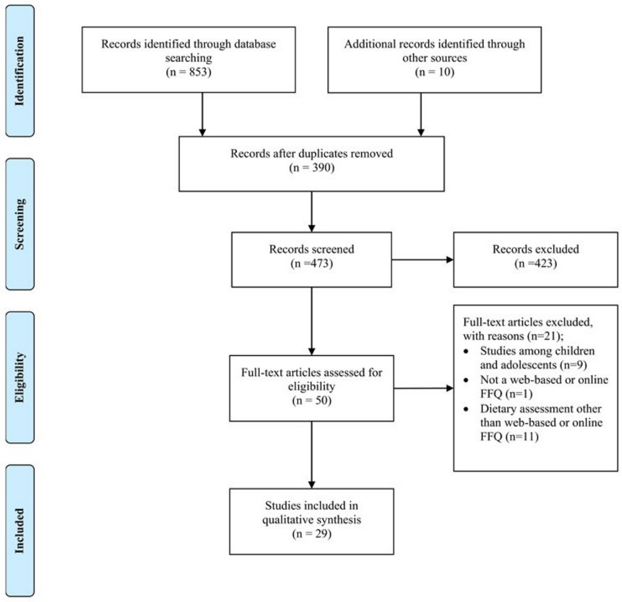

Figure 1: PRISMA Flow Diagram of Design and Validation of Web-Based or Online Food Frequency Questionnaire for Adults

of 863 papers were screened based on the related titles, and in this step, where 390 irrelevant articles were omitted. The abstracts of the remaining 473 articles were screened for eligibility of this study, and other 423 papers were excluded. The remaining 50 papers were searched for their full text and were screened according to exclusion criteria, which were a) FFQ studies among children and adolescents, b) not a web-based and online FFQ, and c) dietary assessment other than web-based and online (such as web-based 24-hour diet recall). Therefore, only 29 articles were found to be relevant to be used in this scoping review.

RESULTS

Characteristics of web-based FFQ among adults

The design and characteristics of web-based FFQ are displayed in Table I. There were 28 web-based or online-based FFQ and one beverage frequency questionnaire (BFQ) developed for adults. Most of the studies (37.9%) were done in Europe (France, Netherlands, Denmark, Spain, United Kingdom (UK), Ireland, and Greece), Sweden (17.2%), Canada (17.2%), United States of America (USA) (10.3%), Norway (3.4%), Australia (3.4%), Japan (3.4%), Brazil (3.4%), and Kuwait (3.4%) respectively. Most of the studies involved free-living people and also involved participants with specific conditions such as pregnant women (20), males with erectile dysfunction (21), cardiometabolic participants (22), diabetic patients (23), trying to conceived participants (TTC) (24), and prostate cancer patients (25). The participants' age ranges were 16 to 90 years old with some studies including elderly participants (10, 26, 27). The number of participants ranged from 40 to 1160 participants.

Table I: Design and characteristics of web-based or online FFQ developed for adults.

Country, year, (reference)	Subjects (n)	Age (years)	Tool name	Food list items/ food groups/type of nutrient	Portion size estimation method/ reference period	Validation/ comparison method	Report Supplements intake
Canada, 2019 (39)	200	18-65	Web -FFQ	136 (all basic nutrients)	2- 4 photos/ One month	Comparison with interviewed administered FFQ	No
France, 2018 (40)	223	Mean 47.7 (SD 14.9)	FFeQ	44 (all basic nutrients)	3 photos / one year	Validation with 3 to 6d 24HDR	No
Sweden, 2018 (20)	1160 pregnant women	Mean 31.9 (SD 4.6)	MealQ	174 (vitamin D)	5 photos and standard portion size/ one month	Validation with 4d food record and vitamin D biomarker	No
Canada, 2018 (28)	50	Mean 22 (SD 2.99)	BFQ (Beverage Frequency Questionnaire)	17 (not mentioned)	6 photos/ 1 week	Validation with 7d food record and single-item measure of sugary drink intake	No
Netherlands, 2017 (37)	959	Mean 51 (SD 12)	Flower FFQ	59 – 110 (all basic nutrients)	Natural portion and common household measurement/ One month	Validation with 9d 24HDR, urinary nitrogen, and urinary potassium	No
Kuwait, 2017 (41)	163	18 - 65	eatWellQ8	146 (all basic nutrients)	3 photos/ one month	Not mentioned	No
Japan, 2017 (26)	237	40 -74	Web FFQ	172 (all basic nutrients)	3 photos/ one year	Validation with 12d WFR, comparison with FFQ printed version	No
Norway, 2017 (38)	92	Mean 37	WebFFQ	279 (all basic nutrients)	Portion size based on household units/ 1 year	Validation with 4d 24HDR and DLW	No
Greece, 2017 (21)	350 subjects with ED	18-40	Not mentioned	67 (all basic nutrients)	Not mentioned	Not mentioned	No
Canada, 2017 (31)	492	Mean 56.9 (SD 8.8)	Canadian Diet History Questionnaire II	153 (all basic nutrients)	Not mentioned	comparison with paper-based FFQ	Yes
Ireland, 2017 (32)	40	Mean 32.2 (SD 13.4)	FoodBook24	81 (all basic nutrients)	3 photos	No validation study	Yes
France, 2017 (22)	324 subjects with cardiometabolic diseases	Mean 53.5 (SD 11.5)	Metacardis FFQ	159 (all basic nutrients)	Generic portion size/ One year	Validation with 3d 24HDR	No
Denmark, 2016 (23)	90 diabetic patients (Type 1 and 2)	Mean 50.4 (SD 16.7)	Not mentioned	270 (all basic nutrients)	4-6 photographs/ 3months	Validation with 4d food diary	No
United Kingdom, Ireland, Spain, Netherlands, Germany, Greece, Poland, 2016 (42)	567	Mean 38.7 (SD 13.4)	Food4Me	157 (all basic nutrients)	3 photos/ one month	Not measured	No
Sweden, 2016 (43)	200	50-64	MiniMeal-Q	126 (all basic nutrients)	5 photos and standard size portion/ over few months	comparison with 4d food record, validation with DLW	No
Brazil, 2016 (44)	Not mentioned	Not mentioned	Not mentioned	88 (all basic nutrients)	1 photos/ One year	No validation study	No
Denmark, 2015 (24)	97 subjects TTC	20-42	Not mentioned	220 (all basic nutrients)	7 photos/ one year	Validation with 4d food diary	No
Canada, 2015 (25)	60 subjects with prostate cancer	Mean 60.3 (SD 6.9)	Web- FFQ	136 (fatty acids)	2- 4 photos/ One month	Validation with omega-3 fatty acid in red blood cells	No
Sweden, 2014 (34)	163	Mean 33 (SD 12)	Mini MealQ and mealQ,	126/174 (all basic nutrients)	5 photos and standard portion size/ one month	Validation with 7d WFR	No
Australia, 2014 (33)	97	44.9 (male) 41.3 (female)	Australia Eating Survey (AES)	120 (all basic nutrients)	Portion size based on mean intakes based on age and gender from national survey/6 months	Validation with 3d WFR	Yes
United Kingdom, 2014 (9)	100	Mean 27 (SD 8)	Food4Me	157 (all basic nutrients)	3 photos/ one month	Validation with 4d WFR	No
United Kingdom, 2014 (45)	113	Mean 30 (SD 10.2)	Food4Me	157 (all basic nutrients)	3 photos/ one month	Comparison with EPIC Norfolk printed FFQ	No
USA, 2014 (10)	74	18-69	GraFFS	156 (all basic nutrients)	3 to 6 photos/ 3 months	Validation with 6d 24HDR	No
Sweden, 2013 (35)	167	Mean 33 (SD 12)	Mini MealQ and MealQ	126/ 174 (all basic nutrients)	5 photos and standard portion size/ one month	Validation with 7d WFR and DLW	No
Canada, 2012 (11)	74	Mean 37.1 (SD 14.2)	Web- FFQ	136 (all basic nutrients)	2- 4 photos / One month	Validation with 3d food record and interview administered FFQ	No
Spain, 2011 (46)	50	20-32	Not mentioned	84 (all basic nutrients)	3 photos /one year	Comparison with paper based FFQ	No
Sweden, 2009 (27)	1304	18-84	Not mentioned	12 (fruit and vegetables)	Not mentioned	Not mentioned	No
USA, 2009 (29)	140 females	Mean 49 (SD 15)	Not mentioned	34 (calcium)	Standard portion size/ one day	Validation with 3d food record	No
USA, 2009 (30)	191	Mean 39.9 (SD 11.4)	DASH Online Questionnaire	8 food groups (all basic nutrients)	Not mentioned/ 24 hours (once a week for four weeks)	Validation with Block FFQ	No

SD: standard deviation, TTC: trying to conceive, ED: erectile dysfunction, MS: metabolic syndrome, MO: morbid obesity, T2DM: type 2 diabetes mellitus, CHD: coronary heart disease, WFR; weighed food record, 24HDR: 24 hours diet recall; DLW: doubly labelled water.

Table II: Main findings of the validation/comparison/reproducibility studies of web-based or online FFQ for adults

Country, year, reference	Study type and reference method	Statistical method used	Main results for food groups (validation study)	Main results for nutrients (validation study)	Main results for food groups (reproducibility/ comparison study)	Main results for nutrients (reproducibility/ comparison study)
France, 2018 (40)	Validation and reproducibility 3 to 6d 24HDR	• Pearson/ Spearman CCs (CC) • Cross classification • Bland Altman plots	• Unadjusted CC ranged from 0.09 to 0.88. • 73% of subjects were classified in the same/ adjacent quartile. • 1% of subjects were classified in the opposite quartile. • 54% of subjects classified were in the same quartile.	• Unadjusted CC ranged from 0.08 (manganese and copper) to 0.77 (alcohol). • Deattenuated energy-adjusted CC ranged from 0.05 (manganese) to 0.68 (potassium, carotene, and vitamin C).	• Unadjusted Spearman CC ranged from 0.34 (sunflower, groundnut oils) to 0.9 (wine). • ICC ranged from 0.33(sweet, snacks, chocolate, Danish pastries) to 0.72 (poultry, rabbit, fish, and fruit). • 80% of subjects were classified in the same/ adjacent quartile. • 1% of subjects were classified in the opposite quartile.	• Crude CC ranged from 0.58 (iron) to 0.89 (alcohol) • Energy-adjusted Pearson CC ranged from 0.54 (vitamin B) to 0.77 (vitamin E). • ICC ranged from 0.55 (carbohydrate) to 0.73 (Magnesium and Manganese) • 79% of subjects were classified in the same/ adjacent quartile. • 1% of subjects were classified in the opposite quartile.
Sweden, 2018 (20)	Validation 4d food record and Vitamin D biomarker	• Wilcoxon signed-ranks test • Correlation analysis • Methods of triads	Not measured	• Correlations between vitamin D intake from FFQ (r= 0.49, p < 0.001) • The validation coefficient for FFQ was 0.75 • 25% of subjects were classified in the same quartile. • 37% of subjects were classified in the adjacent quartile. • 8% of subjects were classified in the opposite quartile.		Not measured
Canada, 2018 (28)	Validation 7d food record and single-item measure of sugary drink intake	Pearson correlations coefficient Bland Altman plots	Correlations between the number and volume of drinks in the BFQ and food record ranged from 0.13 (coffee/tea without sugar/ cream) to 0.89 (energy drinks)	Not measured	Not measured	Not measured
Netherlands, 2017 (37)	Validation 9d 24HDR, urinary nitrogen, and urinary potassium	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned
Japan, 2017 (26)	Validation and comparison 12d WFR (validation) and FFQ printed version (comparison)	Bland Altman method Spearman's rank CC	Deattenuated energy-adjusted Spearman CC ranged from 0.16 (fungi) to 0.74 (alcoholic beverage) and 0.07 (fats and oils) to 0.77 (green tea) for men and women respectively. < 5% of subjects (both gender) were classified in extreme quintile.	Deattenuated energy-adjusted Spearman CC ranged from 0.10 (iodine) to 0.86 (alcohol) and 0.16 (beta tocopherol) to 0.69 (alcohol) for men and women respectively. < 5% of subjects (both gender) were classified in extreme quintile.	Spearman CC ranged from 0.39 (fats and oil) to 0.81 (alcoholic beverages) and 0.35 (red meat) to 0.79 (coffee) for men and women, respectively. < 5% of subjects (both gender) were classified in extreme quintile. 66% to 91% of male subjects and 60 to 91% of female subjects were classified in the same/adjacent quintile, respectively.	Spearman CC ranged from 0.37 (gamma tocopherol) to 0.89 (ethanol) and 0.16 (beta tocopherol) to 0.69 (alcohol) for men and women respectively. < 5% of subjects (both gender) were classified in extreme quintile. 57% to 97% of male subjects and 64 to 93% of female subjects were classified in the same/adjacent quintile, respectively.
Norway, 2017 (38)	Validation 4d 24HDR and DLW	Pearson/ Spearman correlations Bland Altman plots Cross classification	Deattenuated Pearson's CC ranged from 0·31 (potatoes) to 0·89 (milk, cream, ice cream, and yogurt).	Deattenuated Pearson's CC ranged from 0·22 (fiber) to 0·69 (alcohol). 52% of subjects were classified in the same or adjacent quartile. 21% of subjects were classified in the opposite quartile.	Not measured	Not measured
France, 2017 (22)	Validation, 3d 24HDR	Wilcoxon signed-rank test Bland-Altman plots Spearman CC	Crude CC ranged from 0.155 (egg and egg dishes) to 0.650 (alcoholic beverages)	Adjusted Pearson CC ranged from 0.175 (PUFA) to 0.486 (calcium) Deattenuated CC ranged from 0.212 (vitamin A) to 0.823 (fiber). 44.4% of the subjects were correctly classified. 12.9% of subjects were misclassified in the opposite tertile.	Not measured	Not measured

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Table II: Main findings of the validation/comparison/reproducibility studies of web-based or online FFQ for adults (continued)

Country, year, reference	Study type and reference method	Statistical method used	Main results for food groups (validation study)	Main results for nutrients (validation study)	Main results for food groups (reproducibility/ comparison study)	Main results for nutrients (reproducibility/ comparison study)
Denmark, 2016 (23)	Validation 4d food diary	• Spearman/ Pearson's CCs • Bland Altman plot • Cross classification • Kappa statistics (κ)	Not measured	• CC ranged from 0.30 (MUFA) to 0.70 (alcohol). • 69.2% to 92.3% of subjects were classified in the same or adjacent quartiles of macro and micronutrient intake. • Gross misclassification ranged from 1.5% to 7.7% • The κ ranged from – 0.068 (total fat) to 0.384 (alcohol)	Not measured	Not measured
UK, Ireland, Spain, Netherlands, Germany, Greece, Poland, 2016 (42)	Reproducibility	Pearson/ Spearman CC Bland Altman method	Not measured	Not measured	• Unadjusted Spearman CC ranged from 0.42 (tinned fruit or vegetables) to 0.89 (alcoholic beverages). • Energy-adjusted Spearman CC ranged from 0.45 (rice, pasta, grains, and starches) to 0.87 (alcoholic beverages) • 8 % of subjects were misclassified. • 2 % were extremely misclassified.	• Energy-adjusted Spearman CC ranged from 0.59 (total fat) to 0.89 (alcohol). • 88% of subjects were classified in the same or adjacent quartile. • 10 % of subjects were misclassified. • 2 % of the subjects were extremely misclassified.
Sweden, 2016 (43)	Comparison and validation Comparison with web-based 4d food record and validation with DLW	Wilcoxon signed-rank test Pearson/ Spearman CCs Bland–Altman plots. Cohen's weighted κ (κw)	Not measured	• Energy-adjusted CC ranged from 0.20 (saturated fatty acid) to 0.77 (alcohol). • κ value (FFQ vs DLW) = 0.15 • κ value (FFQ vs 4d food record) = 0.21 • 42.5% of subjects were classified in exact same quartile while 17.5% of subjects were classified in extreme opposite quartile (FFQ and DLW). • 32% of subjects were classified in exact same quartile while 5.5% of subjects were classified in extreme opposite quartile (FFQ and 4d food record).	Not measured	Not measured
Denmark, 2015 (24)	Validation 4d food diary	Bland Altman method. Pearson correlation Cross classification	• Deattenuated Pearson CC ranged from 0.25 (fats) to 0.75 (fish). • 55.7 to 80.4% of subjects were classified in the same/adjacent quartile. • 1 to 4.1% of subjects were classified in the opposite quartile.	• Deattenuated Pearson CC ranged from 0.13 (sodium) to 0.93 (vitamin D). • 56.7 to 82.5% of subjects were classified in the same/adjacent quartile. • 1 to 8.2% of subjects were classified in the opposite quartile.	Not measured	Not measured
Canada, 2015 (25)	Validation Blood biomarker	Spearman CC	Spearman CC ranged from -0.085 to 0.559.	Spearman CC ranged from 0.540 to 0.593.	Not measured	Not measured
Sweden, 2014 (34)	Validation / reproducibility (MealQ only) 7d WFR	Wilcoxon signed-rank test Cross-classifications. Bland-Altman plots Spearman rank CCs ICC	Not measured	• Deattenuated Pearson CC ranged from 0.16 (sodium) to 0.69 (fiber) for MealQ. • Deattenuated Pearson CC ranged from 0.31 (calcium) to 0.67 (fiber) for MiniMealQ. • 69 to 90% of subjects were classified in the same/adjacent quartile while 1 to 10% of subjects were classified in the extreme quartile (mealQ). • 67 to 89% of subjects were classified in the same/adjacent quartile while 3 to 11% of subjects were classified in the extreme quartile (MiniMealQ).	Not measured	86 to 97% of subjects were classified in the same or adjacent quartile while 0 to 3% of subjects were classified in the extreme quartile. Crude ICC ranged from 0.45 (riboflavin) to 0.85 (beta carotene). Energy-adjusted ICC ranged from 0.5 (vitamin B6) to 0.80 (potassium)
Australia, 2014 (33)	Validation and reproducibility 3d WFR	• Wilcoxon signed-rank tests • Pearson correlation • ICC	Not measured	Pearson CC ranged from 0.10 (cholesterol) to 0.78 (alcohol)	Not measured	• Pearson CC ranged from 0.49 (protein) to 0.85 (alcohol) • ICC ranged from 0.52 (% energy protein) to 0.88 (alcohol)
United Kingdom, 2014 (9)	Validation and reproducibility 4d WFR	Pearson/ Spearman CC Bland-Altman method Cross classification	• Unadjusted Spearman CC ranged from 0.11 (soups, sauces, and miscellaneous foods) to 0.73 (yogurts) • 18 to 55% of subjects were classified in the same quartile. • 55 to 90% of subjects were classified in the adjacent quartile. • 17% of subjects were classified in the opposite quartile. • 5% of subjects were classified in the extreme quartile.	• Unadjusted Pearson CC ranged from 0.23 (vitamin D) to 0.65 (protein, % total energy) • 22 to 53% of subjects were classified in the same quartile. • 65 to 88% of subjects were classified in the adjacent quartile. • 16% of subjects were classified in the opposite quartile. • 4% of subjects were classified in extreme quartile.	• Unadjusted Spearman CC ranged from 0.55 (tinned fruit) to 0.92 (alcoholic beverages) • 46 to 86% of subjects were classified in the same quartile. • 81 to 99% of subjects were classified in the same/ adjacent quartile. • 7% and 1% of subjects were classified in the opposite quartile respectively.	• CCs ranged from 0.65 (vitamin D) to 0.90 (alcohol). • 45 to 74% of subjects were classified in the same quartile. • 87 to 98% of subjects were classified in the same/ adjacent quartile. • 7% and 1% of subjects were classified in opposite and extreme quartile respectively.

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Table II: Main findings of the validation/comparison/reproducibility studies of web-based or online FFQ for adults (continued)

Country, year, reference	Study type and reference method	Statistical method used	Main results for food groups (validation study)	Main results for nutrients (validation study)	Main results for food groups (reproducibility/ comparison study)	Main results for nutrients (reproducibility/ comparison study)
United Kingdom, 2014 (45)	Comparison EPIC Norfolk FFQ	Cross-classification Bland Altman analysis Spearman's CCs	Not measured	Not measured	Spearman CC ranged between 0.41 (savories) to 0.90 (other fruit). 77 to 99% of subjects were classified in the adjacent quartile.	Unadjusted Pearson CC ranged between 0.43 (PUFA) to 0.86 (alcohol). 77 to 97% of subjects were classified in the adjacent quartile.
USA, 2014 (10)	Validation and reliability 6d 24HDR	Pearson and Spearman CCs	Not measured	Energy-adjusted Pearson CC ranged from 0.30 (zinc) to 0.75 (dietary fiber). Deattenuated Pearson CC ranged from 0.40 (zinc) to 0.92 (beta carotene).	Not measured	Pearson CC ranged from 0.49 (vitamin B12) to 0.87 (alcohol).
Sweden, 2013 (35)	Validation and Reproducibility (MealQ only) 7d WFR and DLW	Wilcoxon signed-rank tests Bland Altman method Pearson CC Cross-classification Intraclass CCs	Not measured	Energy-adjusted Pearson CC ranged from 0.30 (protein) to 0.62 (carbohydrate) for MealQ Deattenuated Pearson CC ranged from 0.18 (energy) to 0.73(alcohol) for MealQ Energy-adjusted Pearson CC ranged from 0.31 (protein) to 0.63 (alcohol) for MiniMealQ Deattenuated Pearson CC ranged from 0.18 (energy) to 0.74 (alcohol) for MiniMealQ 67% of subjects were classified in the same or adjacent quartile for energy (MiniMealQ vs WFR) 70% of subjects were classified in the same or adjacent quartile for energy (MealQ vs WFR) 77% of subjects were classified in the same or adjacent quartile for energy (MealQ vs DLW and MiniMealQ vs DLW).	Not measured	85 to 96% of subjects were classified in the same or adjacent quartiles. Crude ICC ranged from 0.43 (saturated fat) to 0.92 (alcohol). Energy-adjusted ICC ranged from 0.57 (total fat) to 0.90 (alcohol)
Canada, 2012 (11)	Validation and reproducibility 3d food record and interview administered FFQ	Pearson correlation Bland–Altman method Cross classification	Not measured	Deattenuated Pearson CC ranged from 0.12 (MUFA) to 0.98 (vegetable protein). An average of 77% of subjects was classified in the same or adjacent quartile.	Not measured	Energy-adjusted Pearson CC ranged from 0.48 (vitamin C) to 0.90 (EPA). An average of 90% of subjects was classified in the same or adjacent quartile.
USA, 2009 (29)	Validation 3d food record	Pearson's correlation Bland Altman method	Not measured	The CC was r= 0.37, P< 0.001	Not measured	Not measured
USA, 2009 (30)	Validation Block FFQ	Pearson CC Weighted kappa statistics	Unadjusted CC ranged from 0.31 (vegetables) to 0.8 (nuts/seeds/legumes).	Unadjusted CC ranged from 0.44 (zinc) to 0.69 (phosphorus, riboflavin, and magnesium) Deattenuated energy-adjusted CC ranged from 0.31 (zinc) to 0.74 (magnesium) A moderate agreement (κ = 0.48) was observed.	Not measured	Not measured

*Footnotes; ALA: linolenic acid, d: day, CC: Correlation coefficient, DASH OLQ: Dietary Approaches to Stop Hypertension Online Questionnaire, DHA: docosahexaenoic acid, DLW: doubly labelled water, EPA: eicosapentaenoic acid, ICC: interclass correlation coefficients, PUFA: Polyunsaturated fatty acid, MUFA: monounsaturated fatty acid, SSB: sugar-sweetened beverage, WFR: weighed food record, 24HDR: 24 hours diet recall.

The majority of the study (79.3%) focus on assessing the intake of all food groups. Several studies that focus on specific nutrient or food groups such as vitamin D (20); beverage intake (28); fatty acids (25); fruits and vegetables (27); calcium (29), sodium (30), respectively. The length of the web-based FFQ ranged from 17 to 279 food questions/items. Four of these web-based FFQ (13.8%) classified as short FFQ consisting of less than 50 food questions/items, and the majority of the web-based FFQ (86.2%) classified as long FFQs comprised of more than 100 food questions/items. The time frame covered by web-based FFQs varied. Eight studies (27.6%) used FFQ measuring long-term intake (more than six months), while another 17 studies (58.6%) measured short-term intake (less than six months), and the rest of the FFQ (13.8%) did not mention the duration of the reference period.

Portion size estimation was usually done using photos, standard portion size, and household measurement. The majority of the studies (55.2%) used photographs to determine portion size (ranged from one to seven photos per food item), five studies (17.2%) used standard portion size, four studies (13.8%) used a combination of photos and standard portion size or household measurement, while another four studies (13.8%) did not mention the type of aid used for portion size estimation. Most of the web-based FFQs were validated using various methods that include 24-hour diet recall, food diary/record, weighed food record, and biomarker. The most common method used in the validation study was a combination of another dietary assessment method and biomarker (35.3%), 24-hour diet recall (17.6%), food record (17.6%), weighed food record (17.6%), biomarker (5.9%) and Block FFQ (5.9%). Four studies (13.8%) did comparison study using paper-based FFQ and interviewed-administered FFQ. Two studies (6.9%) did both validation and comparison study using food record, weighed food record, biomarker and paper-based FFQ. Six studies (20.7%) did not mention or perform any validation/comparison study. The number of days taken to complete the reference method ranged from three to 12 days. Only three studies (10.3%) reported supplement intake (31-33) in their web-based FFQ.

Characteristics of the validation studies

Table II presents the results of web-based FFQ validation/comparison/reproducibility studies of web-based FFQ among adults. Out of 29 studies, only 19 studies (65.5%) undertake validation using various reference methods such as 24 hours' diet recall, food record, biomarker, food diary, Block FFQ and weighed food records. Four studies (13.8%) conducted comparison studies, and the method of choice was interviewer-administered FFQ and paper-based FFQ. Out of all studies, only eight studies (27.6%) conducted a reproducibility study on their web-based FFQ.

There are various statistical methods used in validation/comparison/reproducibility of web-based FFQs such as Bland-Altman plots, Wilcoxon signed-rank test, Pearson/Spearman correlation coefficients, triangulation method, cross-classification, and kappa statistics. The most common statistical analysis used was Pearson/Spearman correlation coefficients (95.2%), Bland-Altman plot (71.4%), cross-classification (42.9%), Wilcoxon signed-rank test (28.6%), kappa statistic (14.3%), and triad method (4.8%) respectively. Statistical methods used in the reproducibility study were interclass correlation coefficient (ICC) and cross-classification. However, only three studies (14.3%) did the ICC test (28, 34, 35).

The determination of validity, reproducibility, or comparison of web-based FFQ is insufficient by using only statistical tests. Therefore, most of the studies used a combination of several statistical tests. Nine studies (42.9%) used three statistical tests; five studies (23.8%) used two statistical tests; two studies (9.5%) used four statistical tests, two studies (9.5%) used five statistical tests, and two studies (9.5%) used one statistical test.

The validation studies' correlation coefficients ranged from -0.085 to 0.89 for food groups and 0.08 to 0.98 for nutrients, respectively. Correlation coefficients can be categorised into several categories; more than 0.50 is considered good, ranging between 0.20 to 0.49 is considered acceptable, and less than 0.20 is considered poor (36). Weighted kappa statistics can be classified as follows; <0.20 (poor result), 0-20-0.60 (acceptable result), and >0.60 are considered a good result (36). The weighted kappa coefficients ranged from -0.068 to 0.48, thus suggesting an acceptable outcome. The proportion of participants in the same quartile ranged from 18 to 90% for food groups and 25% to 89% for nutrients, respectively. Cross classification of participants into groups shows the degree of the dietary assessment method rank participants correctly and showing agreement at the individual level. Based on this method, the percentage of participants in the same tertile should be more than 50% and less than 10% of participants should be classified in the opposite tertile (36). However, only six studies (25,26,31,32,37,38) achieved the recommended percentage of participants grouped in the same tertile, while only one study (34) showed 11% of participants in the opposite tertiles.

In the reproducibility study, correlation coefficients ranged from 0.30 to 0.90 and 0.16 to 0.92 for food groups and nutrients, respectively, indicating a good correlation. A total of 44.4 to 99% of participants were grouped in the same quartile for food groups, and 57% to 93% of participants were grouped in the same quartile for nutrients, respectively. Inter class coefficients ranged from 0.43 to 0.92.

DISCUSSION

The age range of participants involved in the web-based FFQ studies (27,29,30,31) shows that this method applies to most of the population, including among the elderly. Investigators did not mention any modification made to web-based FFQ such as using a larger format or font size to be easier to be used by older participants. However, the web-based FFQ is categorised as a short FFQ, that focuses on one or specific nutrient (47), and based on a short time frame (40), which may give less burden for participants. The food list of an FFQ can range from five to 350 food items (17). Most of the web-based FFQ reported by the investigators were long FFQ as long FFQ has been observed with a higher correlation coefficient (48,49). Nonetheless, a short FFQ designed to measure specific nutrients can also show a high percentage of nutrient intake (49,51). Several factors that determine the length of an FFQ is the objective of the study, the type of nutrient studied (52), and the participant's characteristics (53). The recall period of the FFQ relies on the objective of the study and the type of nutrients studied, and it can range from several days to a year. The recall period of one month is commonly used to assess macronutrient intake (54), as the intake from the past month is indicative of the average intake of them (55). Most investigators used the shorter recall period because recall bias is more likely to be increased with longer recall periods (56). A shorter recall period also put less burden on the participants. Albeit this, several investigators used a reference period of one year. A recall period of a year is used to determine long-term food intake as diets appear to stay consistent throughout the period, and intake of food items consumed seasonally can be reported (57). The main advantage of using web-based FFQ is digital food images, which facilitates portion size estimation. This feature is also essential in epidemiology studies to reduce printing and transportation costs to different sampling locations (58). A variety of portion size estimation aid was used for the web-based FFQ, with the most typically used was the series of food images. Improved accuracy in food reporting in studies that used digital food images up to 8 images per food (59,60).

The web-based FFQ was validated against other self-reported dietary assessment methods and biomarkers. The selection of reference methods may be based on practical reasons such as cost (61) or study designs. Reference methods such as weighed food records and food records associated with higher burdens were used in studies with fewer participants (9, 26,33-35). 24-hour diet recall did not put much burden on participants (62); therefore, it was used in studies with many participants. Assessing dietary intake using classical approaches are likely to have measurement error. To address this issue, researchers are now focusing on using biomarkers in their validation studies to measure the food intake objectively (63). Doubly labelled water (DLW) is considered as the gold-standard method to validate self-reported intakes (64), while other types of biomarkers such as urinary nitrogen (65) and urinary potassium (66) can also be used. Of all the web-based FFQ in this review, only six investigators used biomarkers to assess the validity. Limited studies use biomarkers due to several reasons, such as cost (55), logistic factors (67), and the degree of invasiveness (52). Combining biomarkers and reference methods in a validation study enables the investigators to conduct a triangular approach. The strength of applying this method is biomarkers, which carries independent errors compared to other dietary assessment methods (68). However, only a few studies conducted this approach mainly due to the limitation of cost.

For the majority of the web-based FFQ included in this review, the investigators concluded that the performance of the respective tool was acceptable when compared with reference methods (comparison/validation studies). However, it is difficult to compare the validity of web-based FFQ across the board due to different study designs and statistical methods used. One statistical method is insufficient to determine the validity of any dietary assessment method (15). In this review, statistical methods are compared in isolation across studies due to variation and a combination of statistical methods used across studies. The most common statistical test used is the correlation coefficient. Comparing the ranges of correlation coefficients for food groups and nutrient reported across the web-based FFQs, WebFFQ (38) had the strongest r values at 0.89 (milk, cream, ice cream and yogurt) and WebFFQ (11) had the highest r values at 0.98 (vegetable protein) respectively. Some food groups showed low correlation coefficients due to foods groups that are rarely consumed (whole-grain pasta, rice and wheat, legumes) or consisted of mixed items (sweet snacks, chocolate, Danish pastries) thus making difficult to estimate (40). Food groups such as alcoholic drinks and fruit may have been under – and overestimated due social desirability (69, 70). Overall, it is difficult to compare the validity of foods groups due to the various ways of classification of food groups (24).

Investigators observed a wide variation in correlation coefficients between the web-based FFQs and reference methods, that may raise the questions of the ability of the participants to estimate their dietary intake of some food items more accurately such as alcoholic drinks (71, 72). Low correlation for certain nutrient such as sodium is due to the difficulty to estimate the intake (40). Correlation coefficients may also change after energy adjustments (11). Energy adjustment can increase the correlation coefficients when the variability of the nutrient intake is related to energy intake, or it can decrease when the variability of the nutrient is subject to systematic errors of under or overestimation of reported food consumption (73). Correlation coefficients cannot be used solely in the validation study as it only reflects the strength of the association between two variables (74,75) Therefore, correlation coefficients are usually used in combination with Bland Altman method. Investigators should be mindful when choosing the type of statistical test to determine validity (14). In certain cases, Lombard and colleagues (15) suggested using more than three statistical tests to assess the validity of dietary assessment measures. Investigators found that comparison studies between web-based FFQ with paper-based FFQ show that web-based FFQ showed a moderate agreement. Therefore, it is essential to increase the quality of web-based tools as efficient web-based tools are important for epidemiological study (39).

Reproducibility is an important issue when developing FFQ. Several factors influenced the reproducibility of web-based FFQ. Participants who report their portion sizes using FFQ with food photographs showed a higher tendency to get higher correlation coefficients between two administrations of FFQ (17). Lower correlation coefficients were found when the FFQ were readministered after a long-time-interval (six months to one year) compared with a shorter time interval (one to six months). This might be due to changes in participants dietary habits, which are more likely to occur with longer time intervals (76). If time intervals between FFQ administrations are very short, the participants can recall and copy their answers rather than reporting their diet intake accurately (77).

This evaluation has several strengths. This review included several attributes in terms of web-based FFQ characteristics, the validation/ comparison/ reproducibility methods, and findings from these studies. However, there were also several limitations in this scoping review. After the review was completed, there is a possibility that more recent publications have not been included in our review. This study also was done using only one search engine due to inaccessibility to other search engine, thus might result in fewer papers related to web-based FFQ be found.

CONCLUSION

In conclusion, web-based FFQ is a cost-effective dietary assessment tool and a useful method for assessing dietary intake. This review also shows that web-based FFQ can be used to assess dietary intake of different kinds of nutrients and also applicable to be used for healthy adults and participants with specific type diseases (diabetes mellitus, cancer) or conditions (pregnancy and trying to conceive). This review pinpoints some findings which may be beneficial when designing and assessing the validity/reproducibility of web-based FFQ in the future. The overall validity of web-based FFQ is challenging to determine because, in many studies, direct comparisons cannot be made. Although most of the web-based FFQ is validated with reference methods, further validation using biomarkers will strengthen the validity of web-based FFQ. In this review, only a few studies conducted the reproducibility test. It is essential to determine the reproducibility of web-based FFQ to increase the confidence in administrating the web-based FFQ for reporting dietary intakes (42).

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