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ORIGINAL ARTICLE

Reliability of Web-Based and Interview-Administered Food Frequency Questionnaires

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ABSTRACT

Background: Web-based food frequency questionnaires (FFQs) can overcome the limitations of paper-based questionnaires by allowing for complex skip patterns, portion size estimation based on food images, and real-time error checking. The aim of this study was to compare web-based and interview-administered FFQs in evaluation of dietary intake, using 24-hour recalls as the gold standard.

Methods: A total of 3,000 subjects were recruited from participants in the Mashhad Stroke and Heart Atherosclerotic Disorder (MASHAD) Cohort Study. Participants were 35-65 years old. Nutritional assessment was conducted using a validated semi-quantitative FFQ consisted of 65 food items. Subjects were allocated to either the web-based FFQ or the interview-administered FFQ groups. Participants completed the web-based FFQ online, while the interview-administered FFQ and 24-hour recalls in paper format. They were completed by trained health professionals through face-to-face interviews.

Results: In both groups, females comprised the majority, representing 66.2% and 63.9% of the web-based FFQ and interview-administered FFQ populations, respectively. A significant correlation was observed between FFQ results and daily intake estimates obtained from 24-hour recalls in both the web-based and interview-administered groups, though the correlation was stronger for the interview-administered FFQ.

Conclusion: The stronger correlations observed for the interview-administered FFQ may be attributed to the fact that paper questionnaires were completed with the assistance of trained interviewers.

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Introduction

Food frequency questionnaires (FFQs) have been widely used in epidemiological studies as a cost-effective method for assessing food and nutrient intake (1, 2). Another approach for dietary assessment is the 24-hour recall (24HR), which has been supported by evidences as a more accurate method for evaluating an individual's food intake (3, 4). The FFQ remains widely used, particularly in large epidemiological studies, as it is designed to capture habitual dietary consumption and can be administered to a large number of participants at a low cost (5, 6). In comparison, the 24HR has been shown to be more accurate than the FFQ (7), although multiple recalls are required when assessing the distribution of intakes within a group or individual dietary patterns.

Advances in technology and the internet have introduced new possibilities for conducting epidemiological studies beyond traditional face-to-face interviews or paper-based questionnaires. Web-based FFQs (WB-FFQs) can improve the efficiency of data collection by enhancing questionnaire presentation, incorporating portion size estimation for more accurate intake assessment, minimizing errors such as skipped questions or multiple responses, reducing paper usage, saving time and effort in data entry, and enabling real-time feedback for healthcare professionals in clinical settings (8, 9). Since dietary assessments play a crucial role in the development of dietary guidelines, improving their accuracy can enhance the quality of recommendations and, consequently, clinical outcomes. Electronic dietary diaries, widely used in various health-related fields, have been shown to be valid and efficient methods of data collection. However, further research is needed to validate innovative dietary assessment tools (10, 11). The aim of this study was to compare a WB-FFQ and an interview-administered FFQ (IA-FFQ) in the evaluation of dietary intake, using 24HR as the reference method.

Materials and Methods

Subjects included in this study were recruited from participants in the Mashhad Stroke and Heart Atherosclerotic Disorder (MASHAD) Cohort Study (n=3000) (12). Participants were allocated to either the IA-FFQ or WB-FFQ group, with a total of 2523 individuals (988 in the WB-FFQ group and 1535 in the IA-FFQ group). The participants aged 35-65 years and were nonsmokers with no history of cardiovascular diseases, type 2 diabetes, dyslipidemia, or any endocrine disorders. All participants provided informed consent. Height, body weight, waist and hip circumferences, and body mass index (BMI) were measured by expert staffs following standardized protocols (13). Height, waist circumference, and hip circumference were measured in centimeters using a tape measure with an accuracy of 0.1 cm. Weight was determined utilizing an electronic scale to the nearest 0.1 kg. BMI was calculated by dividing weight (kg) by height squared (m^2). Waist-to-hip ratio (WHR) was assessed by dividing waist circumference by hip circumference.

A previously validated semi-quantitative FFQ, consisting of 65 food items with five frequency categories (per day, per week, per month, rarely, and never) was employed to evaluate dietary intake over the past year. Additionally, 24HRs recalls were completed for all participants. The WB-FFQ was a self-administered online questionnaire identical to the IA-FFQ, with some key differences including each question to allow only one response, and the questionnaire could not be submitted unless all questions were answered. Participants completed the WB-FFQ either on-site or at home via the internet. The WB-FFQ assessed habitual intake over the previous 12 months. Participants received access to the questionnaire through a direct link sent to their email addresses. For the IA-FFQ, paper-based FFQs were completed by trained health professionals through face-to-face interviews. Data from both the FFQs and 24HRs were entered into the official MASHAD Cohort Study website, which was specifically designed to calculate energy and nutrient intake.

To describe the characteristics of the study population and assess nutrient and food intake, means and standard deviations were calculated. Nutrient and food intake values were adjusted based on total energy intake. The two-sample independent t-test/Wilcoxon signed-rank test and the chi-square test were used to assess significant differences between groups. All analyses were conducted separately for the WB-FFQ and IA-FFQ groups. FFQs and 24HRs were compared using absolute differences and relative differences (percentage-based) within the WB-FFQ and IA-FFQ groups. Spearman correlation coefficients and the intra-class correlation coefficient (ICC) were used to examine the relationship between nutrient intake estimates from the FFQ and 24HR. Day-to-day within-person variation may attenuate the correlation coefficients; therefore, the correlation coefficients were de-attenuated by multiplying them by the attenuation factor to correct for within-person measurement error. The de-attenuated correlation coefficient (rtr_trt) was computed as follows:

$$r_t = r_0\sqrt{1 + intera_x/inter_x/n_x}.$$

In this formula, the observed correlation was represented by r_0, while $intera_x$, $inter_x$ donate within person and between-person variances, respectively. The variable n_x represents the number of days of dietary registration. Furthermore, cross-classification analysis using the quartile method was undertaken to evaluate the agreement between the FFQ and 24HR. For this purpose, nutrient intake values were categorized into quartiles, and the proportion of individuals who fell into the same or adjacent quartile was calculated. Additionally, the proportion of individuals classified into opposite quartiles was determined as an indicator of gross misclassification. The weighted kappa (κ) statistic was used to evaluate the performance of the cross-classification method and to determine the level of agreement between the FFQ and 24HR. Finally, Fisher's r-to-Z transformation test was used to compare the correlation coefficients obtained from the WB-FFQ and IA-FFQ. A *p* value of less than 0.05 was considered to indicate statistical significance, relationships, and agreement. Statistical analyses were performed using SPSS software (Version 25.0, Chicago, IL, USA) and R version 4.1.1.

Results

A total of 477 out of 3000 participants were withdrawn from the study due to personal reasons, leaving 2523 completed questionnaires for analysis (988 for WB-FFQ and 1535 for IA-FFQ). The demographic characteristics of the participants are presented in Table 1. In both groups, females constituted the majority, accounting for 66.2% and 63.9% of the WB-FFQ and IA-FFQ populations, respectively. The mean±SD age was 57.92±8.59 years for the WB-FFQ group and 58.38±8.66 years for the IA-FFQ group. Regarding marital status, more than 86% of participants were married (86.3% in WB-FFQ and 89.9% in IA-FFQ). Among the anthropometric measurements, only waist circumference and height showed significant differences between the two groups.

As shown in Table 2, estimated nutrient intakes assessed by the FFQ were generally higher than those obtained using the 24HR. However, certain nutrients, including protein, carbohydrates, starch, sodium (Na), iron (Fe), chlorine (Cl), selenium (Se), iodine (I), retinol, carotene, and vitamin D, were found to have higher estimated intakes when assessed using the 24 HR compared to the FFQ. The Spearman correlation coefficients for FFQ and 24HR were reported in Table 2 for both WB-FFQ and IA-FFQ. The range of Spearman correlation coefficients for WB-FFQ varied from 0.011 (for trans-fat) to 0.411 (for starch), while for IA-FFQ, it ranged from -0.011 (for fat) to 0.392 (for starch). The intra-class correlation (ICC) values ranged from zero (for sucrose and zinc) to 0.350 (for starch) using WB-FFQ, and from zero (for zinc) to 0.374 (for starch) using IA-FFQ. Regarding de-attenuated correlation coefficients, values obtained from WB-FFQ ranged from 0.013 (for trans-fatty acids) to 0.411 (for starch). Similarly, for IA-FFQ, de-attenuated correlation coefficients ranged from -0.013 [for fat and polyunsaturated fatty acids (PUFA)] to 0.663 (for Mn).

In Table 2, dietary intake differences between WB-FFQ and IA-FFQ compared with 24HR indicated an underestimation of macronutrients (fat, sugar, fructose, sucrose, maltose, lactose, fiber, saturated fatty acids (SFA), PUFA, trans-fat, and cholesterol) in the 24HR. As shown in Table 3, the results of the cross-classification analysis (*p* value related to the weighted κ statistic) demonstrated that the agreement was statistically significant for most

Table 1: Demographic characteristics of participants in IA-FFQ and WB-FFQ groups.

Variable		WB-FFQ (n=988) Mean±SD N (%)	IA-FFQ (n=1535) Mean±SD N (%)	*P* value
Age		57.92±8.59	58.38±8.66	0.17
Sex	Male	335 (33.9)	558 (36.4)	0.21
	Female	653 (66.1)	977 (63.6)	
Marital status	Single	6 (0.6)	10 (0.7)	0.07
	Married	857 (86.7)	1380 (89.9)	
	Widow	17 (1.7)	21 (1.4)	
	Divorce	108 (10.9)	123 (8.0)	
Weight		72.43±13.41	73.14±13.23	0.23
Height		159.77±9.72	160.44±9.25	0.065
WC		93.52±11.20	91.62±10.34	<0.001
HC		103.12±10.58	102.17±9.64	0.034

WB-FFQ: Web-based food frequency questionnaire, IA-FFQ: Interview-administered food frequency questionnaire. Mann-Whitney U test was used for continues variables and Chi-square test was used for qualitative variables. Mean±SD was used for continues and percent for qualitative variables.

items, except for fat, saturated fat, PUFA, trans fat, copper (Cu), vitamin E, niacin, and folic acid in the WB-FFQ. Similarly, in the IA-FFQ, the agreement was statistically significant for most items, except for fat, PUFA, trans-fat, sodium (Na), zinc (Zn), and vitamin E.

Starch from both WB-FFQ and IA-FFQ showed the highest level of agreement, with 71.52% and 70.67% agreement, respectively. In other words, starch was well classified into the same or adjacent quartiles. Furthermore, the cross-classification analysis revealed that the lowest level of agreement was observed for fat (56.54% agreement) in WB-FFQ and vitamin E (55.89% agreement) in IA-FFQ. The proportion of individuals classified into the same or adjacent quartile of nutrient intakes was 61% (95% confidence interval: 60.1–61.9) in the WB-FFQ group and 60.9% (95% confidence interval: 60.0–61.9) in the IA-FFQ group. Moreover, the total gross misclassification of nutrient intakes averaged 2.5% and 32.6% in the WB-FFQ and IA-FFQ groups, respectively.

Table 2: Summary of WB-FFQ and IA-FFQ analysis.

Variable		**FFQ**	**24HR**	**Difference**	**Relative Difference (%)**	**Spearman Correlation Coefficient**	**ICC**	**De-attenuated Spearman Correlation Coefficient**	***P* value (Comparing WB and IA)**
Water	WB	1951.6±938.7	1189.8±687.2	761.8	64.0	0.166**	0.159**	0.192	0.651(S)¶
	IA	1894.2±770.2	1096.3±632.1	797.8	72.7	0.148**	0.089**	0.184	0.081 (I)§
									0.853 (D)#
Total nitrogen	WB	9.5±1.8	9.5±4.1	0.06	0.6	0.134**	0.105**	0.133	0.499 (S)
	IA	9.0±2.1	9.8±4.4	-0.8	-8.3	0.161**	0.112**	0.162	0.862 (I)
									0.454 (D)
Protein	WB	62.8±11.4	64.0±28.9	-1.1	-1.8	0.125**	0.076**	0.124	0.728 (S)
	IA	59.6±12.7	66.8±29.8	-7.2	-10.8	0.111**	0.074**	0.113	0.960 (I)
									0.798 (D)
Fat	WB	76.8±22.2	45.3±28.5	31.4	69.4	-0.015	-0.001	-0.020	0.922 (S)
	IA	80.3±25.0	47.2±30.2	33.0	69.9	-0.011	0.016	-0.013	0.677 (I)
									0.882 (D)
Carbohydrate	WB	226.7±53.2	318.3±151.6	-91.5	-28.7	0.232**	0.092**	0.263	0.639 (S)
	IA	222.7±54.0	306.3±144.6	-83.6	-27.2	0.250**	0.112**	0.280	0.620 (I)
									0.639 (D)
Starch	WB	140.8±57.0	147.0±69.8	-6.2	-4.2	0.411**	0.350**	0.411	0.579 (S)
	IA	136.8±56.3	147.05±75.4	-10.2	-6.9	0.392**	0.374**	0.393	0.498 (I)
									0.616 (D)
Total sugar	WB	87.3±38.9	66.8±53.1	20.4	30.6	0.154**	0.089**	0.160	0.156 (S)
	IA	87.4±34.3	64.2±46.8	23.1	36.0	0.210**	0.150**	0.223	0.129 (I)
									0.106 (D)
Fructose	WB	21.2±12.8	17.2±16.1	4.0	23.5	0.178**	0.137**	0.180	0.095 (S)
	IA	21.9±11.6	15.7±15.5	6.2	39.7	0.243**	0.181**	0.253	0.268 (I)
									0.058 (D)
Sucrose	WB	28.8±24.9	22.4±30.8	6.4	28.7	0.081*	0.000	0.081	0.711 (S)
	IA	28.3±23.0	20.2±25.1	8.0	39.9	0.096**	0.055*	0.098	0.177 (I)
									0.669 (D)
Maltose	WB	4.9±3.1	3.4±8.1	1.5	44.8	0.102**	0.018	0.103	0.655 (S)
	IA	4.6±3.5	4.4±9.1	0.1	4.3	0.120**	0.084**	0.119	0.105 (I)
									0.68 (D)
Lactose	WB	7.6±7.2	5.0±7.9	2.6	52.7	0.250**	0.202**	0.256	0.315 (S)
	IA	7.8±7.1	5.1±7.5	2.7	54.1	0.288**	0.240**	0.295	0.327 (I)
									0.290 (D)
Fiber	WB	23.9±9.1	12.6±8.0	11.3	89.3	0.112**	0.047**	0.150	0.584 (S)
	IA	23.7±9.7	13.4±9.6	10.3	76.7	0.134**	0.068**	0.164	0.605 (I)
									0.721 (D)
Saturated fat	WB	29.5±11.1	16.2±11.7	13.3	82.0	0.052	0.027	0.066	0.712 (S)
	IA	30.4±12.3	16.4±11.1	14.0	85.3	0.067**	0.057**	0.085	0.461 (I)
									0.633 (D)

Polyun-saturated fatty acid	WB	13.1±5.1	11.5±17.4	1.5	13.4	0.030	0.016	0.029	0.281(S)
	IA	14.3±5.7	12.3±14.5	1.9	15.7	-0.014	-0.014	-0.013	0.462 (I)
									0.295 (D)
Trans-fat	WB	1.9±0.9	0.6±1.5	21.4	14.8	0.011	0.024	0.013	0.339 (S)
	IA	1.8±1.1	156.1±149.1	5.3	3.4	0.050*	0.040**	0.063	0.694 (I)
									0.212 (D)
Cholesterol	WB	165.9±71.8	144.5±121.7	1.2	173.3	0.130**	0.104**	0.131	0.228 (S)
	IA	161.4±78.8	0.5±1.1	1.2	214.9	0.178**	0.118**	0.178	0.728 (I)
									0.233 (D)
Na	WB	1673.7±596.3	4401.1±4868.3	-2727.3	-61.9	0.099**	0.014	0.112	0.175 (S)
	IA	1576.3±568.7	5003.3±5867.3	-3426.9	-68.4	0.044	0.003	0.051	0.787 (I)
									0.134 (D)
K	WB	2895.0±845.8	2497.9±1322.2	397.0	15.8	0.063**	0.066*	0.064	0.882 (S)
	IA	2825.4±733.5	2446.2±1270.8	379.2	15.5	0.069**	0.047*	0.070	0.640 (I)
									0.869 (D)
Calcium	WB	787.1±264.8	748.8±436.1	38.2	5.1	0.190**	0.120**	0.190	0.722 (S)
	IA	756.6±251.8	779.1±509.5	-22.4	-2.8	0.176**	0.091**	0.175	0.472 (I)
									0.722 (D)
P	WB	1146.8±244.2	994.2±407.7	152.6	15.3	0.105**	0.066*	0.109	0.823 (S)
	IA	1091.2±263.4	1039.3±453.9	51.8	4.9	0.096**	0.065**	0.096	0.980 (I)
									0.763 (D)
Fe	WB	9.4±2.8	11.2±5.7	-1.8	-16.4	0.124**	0.049*	0.129	0.842 (S)
	IA	9.01±3.0	11.7±6.8	-2.7	-23.2	0.132**	0.065**	0.139	0.694 (I)
									0.784 (D)
Cu	WB	1.7±0.3	0.8±0.6	0.9	109.7	0.052	0.018	0.082	0.272(S)
	IA	1.6±0.3	1.0±3.1	0.6	59.0	0.096**	0.002	0.098	0.695 (I)
									0.686 (D)
Zn	WB	72.4±1.6	7.8±17.0	64.6	823.8	0.066*	0.000	0.260	0.572 (S)
	IA	72.1±1.9	7.6±8.4	64.4	841.1	0.043	0.000	0.319	1.000 (I)
									0.113 (D)
Cl	WB	2908.8±973.9	5758.8±4773.2	-2850.0	-49.4	0.082**	0.013	0.095	0.805 (S)
	IA	2761.1±945.7	6152.7±5468.9	-3391.5	-55.1	0.072**	0.009	0.084	0.922 (I)
									0.794 (D)
Mn	WB	54.7±2.3	4.7±2.1	50.0	1049.3	0.147**	0.001**	0.153	0.617 (S)
	IA	54.6±2.4	4.9±2.6	49.6	1002.9	0.127**	0.001**	0.663	1.000 (I)
									<0.001 (D)
Se	WB	38.0±10.5	52.3±25.0	-14.3	-27.3	0.256**	0.118**	0.285	0.695 (S)
	IA	36.3±10.1	54.9±29.4	-18.6	-33.8	0.241**	0.088**	0.276	0.457 (I)
									0.819 (D)
I	WB	81.6±53.0	122.8±89.4	-41.1	-33.5	0.109**	0.078**	0.116	0.747 (S)
	IA	81.6±52.0	122.3±92.5	-40.7	-33.3	0.096**	0.071**	0.102	0.863 (I)
									0.744 (D)
Retinol	WB	223.2±175.8	261.2±1275.4	-38.0	-14.5	0.248**	0.003	0.248	0.256 (S)
	IA	191.3±111.3	380.3±4369.1	-188.9	-49.6	0.204**	0.003	0.204	1.000 (I)
									0.259 (D)
Carotene	WB	1750.9±1465.9	2258.9±3762.5	-507.9	-22.4	0.153**	0.028	0.154	0.745 (S)
	IA	1737.1±1190.9	2205.2±3732.9	-468.1	-21.2	0.140**	0.021	0.140	0.863 (I)
									0.741 (D)
Vitamin D	WB	0.2±0.4	0.8±1.1	-0.5	-71.6	0.094**	0.053*	0.102	0.085 (S)
	IA	0.1±0.4	0.9±1.4	-0.8	-83.2	0.163**	0.057**	0.183	0.921 (I)
									0.041 (D)
Vitamin E	WB	11.8±8.4	7.7±13.5	4.1	53.5	0.039	0.020	0.040	0.524 (S)
	IA	13.3±10.0	8.0±11.1	5.2	65.3	0.013	-0.002	0.013	0.590 (I)
									0.522 (D)
Thiamin	WB	1.8±0.3	0.9±0.7	0.9	92.0	0.079*	0.017	0.115	0.473 (S)
	IA	1.8±0.3	1.0±0.7	0.7	77.8	0.108**	0.039**	0.147	0.589 (I)
									0.415 (D)

Riboflavin	WB	2.1±0.4	0.9±0.7	1.1	123.3	0.071*	0.017	0.116	0.960 (S)
	IA	2.1±0.4	0.9±0.7	1.1	121.1	0.069**	0.019	0.110	0.960 (I)
									0.889 (D)
Niacin	WB	15.3±4.6	14.9±7.5	0.4	2.9	0.063*	0.068*	0.063	0.199 (S)
	IA	14.5±4.8	15.5±8.6	-0.9	-5.8	0.115**	0.072**	0.115	0.921 (I)
									0.192 (D)
Vitamin B6	WB	2.0±0.4	0.9±0.7	1.09	119.2	0.083**	0.013	0.132	0.843 (S)
	IA	1.9±0.3	0.9±0.9	1.0	103.5	0.075**	0.007	0.106	0.883 (I)
									0.521 (D)
Vitamin B12	WB	2.4±1.4	2.0±5.7	0.3	19.3	0.185**	0.022	0.185	0.326 (S)
	IA	2.3±1.4	2.7±18.2	-0.3	-14.3	0.146**	0.005	0.145	0.677 (I)
									0.324 (D)
Folic acid	WB	287.3±89.5	278.6±280.9	8.7	3.1	0.057	-0.004	0.057	0.658 (S)
	IA	275.7±73.4	280.4±252.7	-4.7	-1.6	0.075**	0.007	0.074	0.787 (I)
									0.665 (D)
Pantothenic acid	WB	5.8±1.4	4.2±2.1	1.5	37.4	0.151**	0.084**	0.173	0.396 (S)
	IA	5.6±1.3	4.4±2.8	1.2	28.8	0.117**	0.035	0.125	0.228 (I)
									0.234 (D)
Biotin	WB	46.8±23.7	19.3±28.8	27.5	142.2	0.109**	0.019	0.134	0.728 (S)
	IA	43.1±19.1	18.7±20.5	24.4	130.3	0.123**	0.026*	0.161	0.863 (I)
									0.494 (D)
Vitamin C	WB	187.0±122.5	86.1±81.7	100.9	117.1	0.128**	0.050*	0.153	<0.001 (S)
	IA	197.4±118.8	90.9±87.1	106.4	117.1	0.274**	0.149**	0.327	0.014 (I)
									<0.001 (D)

24HR: 24-hour recalls; WB: Web-based; IA: Interview-administered; FFQ: Food frequency questionnaire; ICC: Intra class correlation. ¶(S): Comparing WB and IA FFQ based on Spearman correlation, §(I): Comparing WB and IA FFQ based on ICC, #(D): Comparing WB and IA FFQ based on de-attenuated correlation.

We compared the calculated Spearman correlation coefficient for each nutrient intake (correlation between FFQ and 24HR) in the WB-FFQ and IA-FFQ groups using Fisher's r-to-Z transformation test (Table 2). No significant differences were observed among correlations, except for vitamin C ($p<0.001$). When comparing ICC values, a significant difference was observed only for vitamin C. Similarly when comparing de-attenuated Spearman correlation coefficients; significant differences were found for manganese (Mn), vitamin D, and vitamin C. However, if $\alpha=0.1$ is considered, significant differences were also observed in Spearman correlation coefficients for fructose and vitamin D, in ICC values for water, and in de-attenuated Spearman correlation coefficients for fructose.

Discussion

This study was conducted with the aim of comparing a WB-FFQ and an IA-FFQ for the evaluation of dietary intake using 24HR as the gold standard. The results demonstrated significant correlations between FFQs and participants' daily intakes obtained from 24HR for both WB-FFQ and IA-FFQ, with more promising results for the IA-FFQ. Among the analyzed items from both FFQs and 24HR, sucrose, maltose, saturated and trans-fatty acids, thiamin, and biotin showed significant correlations in the IA-FFQ, whereas no such correlations were observed in the WB-FFQ. This suggests that FFQs completed on paper by a health professional more closely resembled daily intake from 24HR.

Additionally, in the IA-FFQ, all nutrient items, except for fat, PUFA, trans-fatty acids, sodium, and zinc showed significant agreement with their corresponding values from 24HR. Furthermore, nutrient items with significant agreement had lower misclassification rates for their respective or adjacent quartiles compared to those without significant agreement. In the WB-FFQ, fat, saturated fat, PUFA, trans-fatty acids, potassium, copper, and folic acid did not reach a significant level of agreement with their corresponding 24HR values. Moreover, these nutrients exhibited higher misclassification rates compared to other items that showed significant agreement.

In a study conducted by Alawadhi and colleagues, the level of agreement between the IA-FFQ and the WB-FFQ was found to be moderate. These results are likely due to the fact that when completing a paper questionnaire, individuals may intentionally skip certain questions or miss them unintentionally. In contrast, electronic questionnaires prompt respondents to answer any unanswered questions, thereby improving the completion rate.

Table 3: Cross-classification analysis of intake by WB/IA-FFQ and the 24HR.

Variable	WB-FFQ (n=988)						IA-FFQ (n=1535)					
	Agreement±1 quartile		Total gross misclassification		Weighted Kappa	*P* value	Agreement±1 quartile		Total gross misclassification		Weighted Kappa	*P* value
	n	%	n	%			n	%	n	%		
Water	672	61.60	316	31.98	0.14	<0.001	1029	61.30	506	32.96	0.12	<0.001
Total nitrogen	661	59.99	327	33.10	0.12	<0.001	1045	62.34	490	31.92	0.16	<0.001
Protein	668	60.60	320	32.39	0.12	<0.001	1015	60.25	520	33.88	0.10	<0.001
Fat	615	56.54	373	37.75	-0.01	0.684	943	56.66	592	38.57	-0.02	0.471
Carbohydrate	711	65.45	277	28.04	0.22	<0.001	1096	66.05	439	28.60	0.24	<0.001
Starch	772	71.52	216	21.86	0.39	<0.001	1170	70.67	365	23.78	0.35	<0.001
Total sugar	675	61.91	313	31.68	0.15	<0.001	1077	62.62	458	29.84	0.18	<0.001
Fructose	702	64.44	286	28.95	0.17	<0.001	1100	65.41	435	28.34	0.22	<0.001
Sucrose	644	58.27	344	34.82	0.07	0.029	1012	60.25	523	34.07	0.09	<0.001
Maltose	666	61.00	322	32.59	0.10	0.001	1062	63.90	473	30.81	0.11	<0.001
Lactose	716	67.06	272	27.53	0.24	<0.001	1106	66.83	429	27.95	0.26	<0.001
Fiber	644	58.17	344	34.82	0.10	0.002	1026	59.87	509	33.16	0.11	<0.001
Saturated fat	649	59.58	339	34.31	0.05	0.109	997	59.86	538	35.05	0.06	0.011
Polyunsaturated fatty acid	631	57.45	357	36.13	0.01	0.839	953	56.41	582	37.92	-0.01	0.564
Trans fat	630	57.65	358	36.23	0.00	0.899	986	57.72	549	35.77	0.04	0.103
Cholesterol	670	61.80	318	32.19	0.13	<0.001	1062	62.74	473	30.81	0.16	<0.001
Na	665	61.60	323	32.69	0.09	0.006	996	58.63	539	35.11	0.04	0.157
K	632	58.76	356	36.03	0.06	0.05	1007	59.35	528	34.40	0.06	0.019
Calcium	692	62.83	296	29.96	0.17	<0.001	1088	63.08	447	29.12	0.18	<0.001
P	665	59.99	323	32.69	0.11	0.001	1012	58.58	523	34.07	0.08	0.001
Fe	662	60.49	326	33.00	0.12	<0.001	1044	60.60	491	31.99	0.13	<0.001
Cu	633	58.26	355	35.93	0.04	0.169	1028	61.36	507	33.03	0.10	<0.001
Zn	646	59.27	342	34.62	0.08	0.009	974	56.81	561	36.55	0.04	0.108
Cl	651	60.18	337	34.11	0.08	0.017	1018	59.48	517	33.68	0.07	0.004
Mn	678	60.61	310	31.38	0.13	<0.001	1025	60.78	510	33.22	0.10	<0.001
Se	718	65.66	270	27.33	0.24	<0.001	1102	64.76	433	28.21	0.22	<0.001
I	661	60.79	327	33.10	0.10	0.002	1024	59.42	511	33.29	0.09	<0.001
Retinol	717	66.76	271	27.43	0.25	<0.001	1055	62.22	480	31.27	0.18	<0.001
Carotene	678	61.21	310	31.38	0.15	<0.001	1022	59.23	513	33.42	0.12	<0.001
Vitamin D	656	59.68	332	33.60	0.10	0.002	1049	62.02	486	31.66	0.16	<0.001
Vitamin E	638	57.96	350	35.43	0.04	0.186	955	55.89	580	37.79	0.01	0.672
Thiamin	636	59.56	352	35.63	0.07	0.024	1032	60.65	503	32.77	0.10	<0.001
Riboflavin	663	60.09	325	32.89	0.08	**0.017**	1010	59.09	525	34.20	0.06	0.016
Niacin	639	57.96	349	35.32	0.05	0.093	1019	58.97	516	33.62	0.09	<0.001
Vitamin B6	658	59.89	330	33.40	0.08	0.009	1023	59.94	512	33.36	0.07	0.005
Vitamin B12	695	64.53	293	29.66	0.18	<0.001	1030	60.65	505	32.90	0.13	<0.001
Folic acid	645	59.27	343	34.72	0.05	0.109	999	57.79	536	34.92	0.07	0.006
Pantothenic Acid	664	61.39	324	32.79	0.14	<0.001	1015	59.74	520	33.88	0.12	<0.001
Biotin	665	61.20	323	32.69	0.10	0.001	1037	61.56	498	32.44	0.11	<0.001
Vitamin C	666	61.20	322	32.59	0.11	<0.001	1107	65.54	428	27.88	0.26	<0.001
Mean±SD	666.2±30.6	61.0±3.0	321.7±30.655	32.5±3.1	-	-	1033.7±46.4	60.9±3.0	501.2±46.4	32.6±3.0	-	-
95% CI	(656.7, 675.7)	(60.1, 61.9)	(312.2, 331.2)	(31.6, 33.5)	-	-	(1019.3, 1048.1)	(60.0, 61.9)	(486.8, 515.6)	(31.7, 33.5)	-	-

24HR: 24-hour recalls; WB: Web-based; IA: Interview-administered; FFQ: Food frequency questionnaire.

This, in turn, enables researchers to collect more comprehensive data (11). Zazpe and colleagues conducted a 10-year prospective cohort study comparing online and paper FFQs with 24HR. Participants completed the questionnaires both at the beginning and at the end of the follow-up period. Their findings indicated that the quality of data obtained from electronic questionnaires was not inferior to that of paper-based ones in educated adults. Moreover, they observed that younger participants were more inclined to complete online questionnaires, leading to fewer missing data (15).

The findings of studies conducted by Lai *et al.* and Bjerregaard *et al.* differed from ours in that they focused on a younger population. Their results suggested that online questionnaires had higher acceptance rates and completion rates, as well as improved data quality. Bjerregaard *et al.* reported no significant difference between paper and online questionnaires, whereas Lai *et al.* found a higher correlation of 0.50 between the two formats (16, 17). Another study conducted on the Snart Forældre cohort population revealed that the correlation coefficients for dietary components between paper and electronic questionnaires ranged from 0.33 to 0.93. Additionally, participants were often correctly classified into their own or adjacent quintiles in terms of food intake grouping. These findings suggested that electronic questionnaires could serve as a promising alternative in future studies (18).

The inconsistency between our results and those of previous studies may be attributed to the relatively high mean age of our participants (approximately 58 years in both groups), which could have influenced their familiarity with internet use and technology. Moreover, the wide range of correlation coefficients between the WB-FFQ and 24HR may have resulted from variations in participants' accuracy when estimating their dietary intake. The precision of reported amounts for some macronutrients could also have been overestimated, as participants may have reported ingredient quantities used for preparing multiple servings rather than a single serving. Furthermore, we observed an underestimation of macronutrient intake in 24HR for fat, SFA, trans-fat, cholesterol, PUFA, fiber, sugar, fructose, sucrose, maltose, and lactose. This could be due to a common tendency among individuals to underreport dietary fat and carbohydrate intake, which is one of the inherent limitations of dietary assessment tools in accurately estimating nutrient intake.

Another significant factor that may have influenced the results is the duration of the reference measure in our case of the 24HR. A one-day record of food intake may not have captured enough information regarding an individual's true consumption, especially for foods that are seldom eaten. While the 24HR can reflect daily nutrient intake, it may not be sufficient to represent usual food intake. For this reason, Apovian *et al.* suggested that increasing the frequency of daily food records could enhance the correlation (19). Kristal *et al.* demonstrated that the measurement properties of a graphical FFQ are capable of capturing an individual's food intake with the same quality as most paper-based FFQs. This could be attributed to the use of pictures in their WB-FFQ, which helps participants better understand their intake and provides more accurate dietary assessments (20). The discrepancies in our study may also be attributed to the older mean age of the participants (approximately 58 years), which could have influenced their familiarity and comfort with using the internet. Furthermore, the varying degrees of correlation between WB-FFQs and 24HRs could be due to differences in participants' ability to accurately estimate their dietary intake. Overestimation or underreporting of certain nutrients, especially fats and carbohydrates, is a well-known issue with dietary assessments.

Our study had some strengths and limitations. The strengths of our study were use of the 24HR method, as a validated tool for dietary intake assessment that helped ensure the accuracy of comparisons between the FFQs (paper and web-based) and actual food intake, providing reliable evidence for the validity of the FFQs. With the large population, the study results provided valuable information that could be applied to future researches and dietary assessments in other populations, contributing to the body of knowledge on dietary intake methods. The limitations were the average age of the participants in this study (around 58 years) that may affect their ability to use technology and the internet. This could reduce the accuracy of results in the WB-FFQ group (electronic questionnaire), especially if participants have less familiarity with digital devices, potentially leading to lower completion rates or errors in responses. In the WB-FFQ group, challenges like internet access or unfamiliarity with technology may result in lower completion rates or difficulties in answering the questionnaire, affecting data quality.

For future studies, one additional factor to consider is the repetition of answering questionnaires. As noted by other researchers, increasing the frequency of completing 24HR and FFQs can improve the quality and reliability of the data extracted. This practice also broadens the scope of analysis by allowing comparisons of the same type of questionnaires across different time points for each individual. Furthermore, considering time intervals for answering questions could compensate for the variation in food consumption across different seasons. Additionally, incorporating pictures in FFQs may help ensure more accurate responses (21-25).

Conclusion

IA-FFQs administered by trained interviewers appear to offer stronger correlations with 24HRs compared to WB-FFQs, which may be influenced by the familiarity of participants with technology. However, WB-FFQs remained a promising alternative in populations with greater familiarity with the internet and technology. Further researches, including studies with more diverse populations and technological innovations, are needed to improve the accuracy and usability of dietary assessment tools.

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Authors' Contribution

Conceptualization: (HE); Methodology: (MA); Formal analysis: (NT, SD); Investigation: (MMB, ZA, HH, MA); Writing - original draft: (HP, ZK); Writing - review & editing: (GAF); Supervision: (MGM). All authors were involved in the interpretation of the data and contributed to writing the manuscript. All authors read and approved the final manuscript.

Conflict of Interest

The authors reported no competing interests.

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