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RESEARCH

Development and validation of food frequency questionnaire screener software for sodium intake among palestinian population

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Abstract

Background High sodium intake has been linked to negative health effects, including cardiovascular and renal diseases. Traditional dietary sodium assessment methods are time-consuming and subjected to errors. Using technology may increase the efficiency and accuracy of dietary assessment. The objective of this study is to develop and validate a food frequency questionnaire (FFQ) screener using software to assess sodium intake among the Palestinian population. **Methodology**: The study was conducted in four phases. In Phase 1, Palestinian foods were categorized and subcategorized according to their mode of consumption, sodium content, and food groups. The sodium content values were calculated from Palestinian food composition database. Content validity was done in Phase 2, while in Phase 3, a pilot study was conducted to determine test-retest reliability. In Phase 4, the criterion validity of the screener was assessed by comparing the results of sodium intake from the FFQ screener with the results from a 24-hour urinary sodium test and a 3-day diet recall. Correlations between the sodium intake values from the three methods were analyzed using Pearson correlation tests, and the difference was assessed using the Bland-Altman test.

Results The developed FFQ screener sodium screener included 41 food items categorized into nine groups, with photo-based portion size estimation and frequency of consumption. The reliability test showed a Pearson correlation coefficient of 0.7, $p < 0.01$ using test and retest. For criterion validity, the correlation coefficient between dietary sodium intake using the FFQ screener software and the 24-hour urine sodium test was (0.6, $p < 0.000$). The correlation coefficient between dietary sodium intake using the FFQ screener software and dietary sodium intake using a 3-day recall was (0.3, $p < 0.000$). Sodium intake was significantly correlated with preferences for low-sodium food and previous salt reduction, $p < 0.05$.

Conclusions Using the FFQ screener software was a valid and reliable method for assessing dietary sodium intake. Using the photo-based method to estimate portion size improved precision and accuracy in diet assessment.

Keywords FFQ, Sodium, 24-h recall, 24-h urine and software

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Background

Sodium is an essential electrolyte found predominantly in the extracellular fluids of the blood [1]. It plays a crucial role in maintaining overall bodily well-being [2]. One of the key physiological roles of sodium within the human body is the regulation of fluid balance and blood volume [3]. Additionally, it is widely believed that sodium is essential for the proper functioning of muscles and neurons. Elevated salt consumption has been found to be associated with significant adverse effects on various physiological systems, namely the renal [4], cardiovascular, vascular, certain types of cancer [5] mental health [6] and immunological systems [7, 8]. In addition, high sodium consumption has been observed to induce water retention, heightened oxidative stress, and impaired endothelial function, collectively leading to a diminished production of nitric oxide (NO) [2, 9]. These physiological mechanisms contribute to the development of systemic vascular resistance and arterial stiffness, which are significant factors influencing both systolic and diastolic blood pressure [10].

As per the World Health Organization (WHO), consuming over 5000 mg of sodium daily is associated with the development of severe hypertension and cardiovascular ailments [9]. Cardiovascular diseases (CVDs), particularly ischemic heart disease (IHD) and stroke, are the leading cause of death worldwide and a significant contributor to disability [11]. High blood pressure (BP) is a significant modifiable risk factor for cardiovascular disease (CVD) and all-cause death. According to the World Health Organization (WHO), hypertension causes roughly 9.5 million deaths worldwide each year [12]. The prevalence of ischemic heart disease in Palestine has seen a notable rise of 31.2% over the course of a decade, spanning from 2009 to 2019. The incidence of hypertension is reported to be 27.6%. Furthermore, it is worth noting that only a minority of patients, specifically one-third, are able to effectively control their disease [13]. Hence, it is of utmost significance to prioritize the monitoring of salt consumption in the management of cardiovascular conditions including hypertension [10].

Adults should consume no more than 2000 mg of sodium per day, or less than 5 g of salt. According to the WHO, the global average sodium intake for adults is 4310 mg/day, or 10.78 g/day of salt [14]. While the reported salt consumption in Palestine is 7 g per day [15]. Ensuring effective regulation of sodium consumption necessitates the utilization of a reputable and dependable approach for assessing dietary salt intake. Dietary assessment approaches, such as food frequency questionnaire (FFQ), 24-hour recall, and 24-hour record, are widely utilized in the field of nutrition research [16]. In FFQ, individuals are commonly queried regarding the regularity of their consumption of specific food items within a specified duration. The utilization of the FFQ approach in the measurement of dietary intake has several advantages, including its cost-effectiveness, ease of use, and the opportunity for respondents to self-administer the questionnaire [16]. However, FFQ relays on the respondents' memory which might lead to biased reporting of consumed food. Additionally, the inadequate assessment of food portions contributes to the imprecision in quantifying food consumption, potentially affecting the utilization of standardized portion sizes. It is a common practice to use images or food models to improve portion size estimation accuracy [17]. The 24-hour urine sodium evaluation is considered the most trusted approach for evaluating sodium intake. Therefore, it has been employed in scholarly literature as a gold standard for evaluating the accuracy of alternative methods utilized in assessing dietary sodium consumption [18]. Ferreira et al. demonstrated that FFQ is a valid and accurate method for assessing nutritional consumption [19].

There is a documented correlation between the reduction in systolic pressure and a decrease of 4–5% in the relative risk of both ischemic heart disease and cardiovascular death. The limitation of daily sodium consumption, mostly derived from salt, is linked to a decrease in average blood pressure, a reduced prevalence of hypertension, and a lower cardiovascular risk among overall population [20]. This is the first study in Palestine that used an innovative approach (image-based software) adapted to the Palestinian food culture to produce a valid and accurate tool to measure the amount of sodium consumed by Palestinians. And among the few studies that aims to facilitate the diet intake assessment in Palestinian context; diet recall assessment [17, 21]. In addition, Current dietary assessment research in Palestine is primarily based on dietary recall, which is known to be time-consuming, requires personnel training, and is susceptible to bias in the calculation of food portion size. This necessitates the employment of methods that may overcome these challenges and biases. Although using innovative methods in diet assessment such as software and smart mobile apps becoming increasingly popular globally. They are not appropriate for the Palestinian environment, which has a distinct cuisine culture, commodities, and ingredients [21]. Furthermore, the use of technology for assessing important nutrients intake such as Sodium is still rare in Palestine, and its implementation will represent a significant advance in clinical nutrition.

Methodology

Study design

The research was conducted in four phases. The study design was formulated after a comprehensive literature review of previously conducted studies for assessing sodium dietary intake in different countries [18, 19, 22–25]. Based on these investigations, the study four phases are: (1) FFQ screener development (2) content validity assessment (3) pilot study for reliability testing (4) and criterion validity assessment.

Phase 1: FFQ screener development

This phase started with categorizing the Palestinian food items into groups and subgroups depending on food classification and consumption method; i.e., bread bases dishes were all collected and categorized to subgroups according to sodium content, similarly salty snack; nuts, seeds, chips and popcorn they were combined in one group depending on the mode of consumption among Palestinians. Depending on this categorization: thirteen food groups were considered. These groups are listed next: (1) salty snacks consisting of the most popular chips brands in the Palestinian market and popcorn. (2) Nuts, such as almonds, cashews, walnuts, roasted legumes, and seed. (3) Pickles, such as olives, turnips, peppers, "Makdous", carrots, and cauliflower. (4) Pastries in their various types. (5) All varieties of bread, including Arabic, French, Lebanese, wheat, and others. (6) Salads such as Arabic salad, "Tabbouleh", "Fattoush", cabbage salads, chicory, molasses and mayonnaise salads. (7) Dairy products containing salt, such as all types of cheese and "Labaneh". (8) Meat consists of red, white, fresh, processed, and canned forms, as well as its diverse cooking methods, including grilling, frying, and boiling. (9) Dishes with tomato stew, including potato, okra, peas, vegetables, beans, and cowpea stews, and also dishes of "Kofta", eggplant, pasta, and potatoes. (10) Dishes with white sauce, including béchamel, mushroom cream, "Tahini", and yogurt. 11) Palestinian rice dishes including boiled rice, "Makloubah", and others. 12) Soups such as lentil, noodle, and "Freekeh". 13) Others, such as thyme, "Hummus", "Falafel", beans, "Musakhan", ketchup, and mayonnaise, that were not included in the previous categories. Several items, including milk, beverages, fruits, and vegetables, were omitted from the list since their sodium content is less than 30 mg per 100 g.

The next step was determining serving sizes based on household measurements using the Palestinian Atlas (ladle, plate, etc.) [17]. Additionally, each item's image was taken from the Palestinian Atlas to help the user in quantification of the serving size. Then, the sodium content for each food item was extracted from the PALNUT website [17]. PALNUT is Palestinian food composition database owned by Al-Quds University, after submitting an official request to the owner of the food composition table, access to the data was granted. In order to confirm that the sodium content of the food products was appropriate and compatible with the other databases, other widely used databases, such as the USDA database and the Jordanian food composition tables were used [26] Every food item's sodium content was calculated, recorded, and compared across the three sources per 100 g and serving size. Other items, such as pomegranate molasses, beverages, and chips, whose sodium content was not reported in the three databases were calculated by reading their food labels from many brands for the item and then taking the average sodium content. In each group, all foods with similar sodium levels were combined into one item, as long as the difference between them was less than 100 mg. Moreover, several of the categories were merged, resulting in nine groups (41 items) organized as follows: (1) Snacks consisting of chips, flour-coated chips, nuts, seeds, and popcorn. (2) Pickles including pickles in water, pickles in oil, and olives. (3) Bread-based dishes which include bread, "Manakesh", pizza and "Sfeha", baked pastries, and "Mussakhan". (4) Seeds such as boiled rice, "Mahashe", cooked rice with vegetables, cooked "Freikah", and bulgur. (5) Vegetable salads with and without salad dressing, such as pickles, pomegranate sauce, and mayonnaise. (6) Dairy products including white cheese, "Labaneh", cheese fondue, and spreadable cheese. (7) Meat, including burger sandwiches, processed or canned meat, lamb or beef cooked meat, chicken cooked meat, cooked fish, shawarma sandwiches, and KFC chicken. (8) Soups and stews containing soups with chicken broth, tomato or yogurt sauce, and lentil soup. (9) Side dishes such as zaatar, "Hummus", "Fool", "Msabaha", avocado with lemon, "Flafel", olive oil-fried egg, "Kubba", tomato paste, and macaroni.

Phase 2: content validity

Four registered dietitians and three researchers were invited and agreed to review and evaluate the FFQ screener. They were asked to examine and evaluate if the food items grouping, serving and the household measurement were relevant and user friendly. The feedback was discussed in an interview person to person to have final agreement for the best presentation for the food groups, serving size and the frequency of consumption. There was no remark on how the groups operate or their content; rather, clarifications were requested, such as the type of chips. Or a request to identify a quantity, such as determining the number of pickled olives per serving. However, these explanations were resolved by adding photos to illustrate each item. There were no comments that required significant revisions. Most of the comments were requests for clarification in order to confirm the items.

Phase 3: pilot study and reliability

This phase consists of a pilot study to assure the reliability of the screener. Test and retest reliability test was done for reliability evaluation. The participants were selected by convenience sampling, the 22 participants were provided with the screener and they were asked to complete the screener (test), then after 10–14 days they were asked to re-fill the same screener (retest).

Phase 4: criterion validity

The criterion validity was done for the screener by comparing the results of sodium intake from the screener with the sodium intake assessed by gold standard. There were two Gold Standards used for the screener's validity determination: the first gold standard is the 3-day diet recall (3DR), the second is 24-hour urinary sodium. Therefore, in addition to completing the screeners, the participants filled out a 3DR form and collected the urine for 24 h. For the 3DR, participants were asked to record the food items' names and quantities according to household measurements. The 3DR form also included the timings of the day's first and last meals, the number of items consumed, time and place of consumption, whether they were consumed inside or outside the home, and the type of meal (breakfast, lunch, dinner, or snack). Food items consumption quantification was determined based on the food Atlas from Al-Quds University [27], which contains indexed pictures of food items and recipes that indicates the amount food consumed in grams. The diet analysis converting the food into nutrients was done by a registered dietitian specialized in the field. The calculated results of the 3DR for each participant were reported then the average of the three days was considered as the sodium intake.

For the second gold standard −24-h urine collection-, each participant was given a urine container to collect urine after being instructed to discard the first morning's urine and then collect urine for 24 h. After that, the volume is recorded [28]. The samples were then stored in the university's refrigerator until a minimum of 15 samples were collected, then they were sent to the Al-Najah university hospital for sodium and creatinine analyses. The unit for calculated sodium intake (from the screener and 3DR) and measured sodium intake (using the 24 h urinary sodium) were standardized from the three methods to be in milligram.

Sodium screener software

The development of software for monitoring sodium intake is considered as a significant advance in self-health management. This software contains 41 food items organized into 9 groups. it aimed to provide accurate information for self-monitoring of sodium consumption. This software contains common Palestinian food recipes, making it simple to control one's own dietary consumption and choose healthful food options.

The software's dietary database is rigorously curated using a range of common and culturally diverse recipes. That makes the software user-friendly and simple. The software provides users with an in-depth understanding of their sodium intake from different sources. It was structured to allow users to acknowledge the high sodium sources by creating 9 food items' groups containing 41 items based on their sodium content. This classification simplifies the entry for users and provides recommendations for minimizing sodium consumption according to their consumption of particular food groups.

Considering important factors such as serving size, frequency of eating, and sodium content of each item, the software creates a personalized health profile based on the entered information. By conducting an accurate analysis of the data, making the sodium screener an accurate and reliable tool. This enables users to make decisions regarding their dietary practices and make positive changes. This software was used to develop a screener mobile application, which is supported by a huge food database and complex analytical tools, which will help individuals to alter their sodium consumption and improve their health.

Subjects characteristics

Study population

For the criterion validity phase: the study population consisted of 81 young, healthy Palestinian adults between the ages of 18 and 40 residing in the West Bank, the data was collected between June and December 2022.

Inclusion criteria

The individuals between the ages of 18 and 40 from the West Bank and did not have any diseases that influenced their urinary sodium levels.

Exclusion criteria

Participants who were pregnant, diabetic, or who have high blood pressure or any disease that may affects urinary sodium level. Participants who didn't collect the total urine in the 24 h were excluded: the exclusion for these participants was done depending on the creatinine in urine results, the creatinine values were compared to the reference ranges established by the Mayo Clinic (men: 13–29 mg/kg/day; women: 9–26 mg/kg/day) [29]. If it was outside the acceptable range, the participant was excluded.

Sampling method and sample size calculation

The sample size was calculated using MEDCALC software for a method comparison study using the Bland-Altman plot. Type one error was 0.05, type two was 20%, the expected mean difference was 120 mg, the expected standard deviation difference was 50 from the previous study by AlKhalaf et al. (2015) the allowed difference was 250. So, the required sample size was 75 participants. The sampling frame was convenient sampling [14].

Data collection for the survey phase

The data was collected by a structured questionnaire that is consisted of five sections: sociodemographic characteristics (gender, education level, place of residence, living nature, marital status, income, current work), medical history and lifestyle (chronic disease, medication, supplements, surgery, working out, walking), participants' salt consumption and preferences (adding salt after cooking, liking salt, reading food labels, preferring less salty food, reducing salt intake), the FFQ screener, and the 3DR.

Study instruments

Twenty-four hours urinary sodium excretion The participants collected urine for 24 h using 24-hour containers of 2–4-liter capacity. If the initial specimen is done, urine from each container is poured into two cups, one for analysis and one for storage. Since 85–90% of consumed sodium is eliminated from the body by the the urine, the 24-hour urine test is the most reliable standard for sodium. Moreover, the over and under collections have been reported using the creatinine reference range [30].

Three-day recall (3DR) Participants were questioned regarding the precise time, place, composition, portion size, and salt quantity of each meal they ate. They were first asked about their main meals -breakfast, lunch, and dinner- then about their snacks. To help the participants remember anything they could have forgotten to mention, they were asked about their everyday activities and whether they had consumed any drinks, eaten outside the house, or had any candy or chips. A previous study showed that, a FFQ and a 24-hour urinary sodium excretion demonstrated a correlation of at least 90%. With this correlation, the difference between predicted and actual sodium, potassium, and protein intakes was 0.39–0.61 compared to 0.35–0.55 for a single FFQ [31].

Statistical analysis

All statistical analyses were performed by the Statistical Package for the Social Sciences (SPSS) version 26.0 software. The alpha value for all statistical tests employed in the study was set at 0.05 [32]. Shapiro-Wilk Test was used to assess the continuous variables for normality. To evaluate the data, descriptive statistics including means and standard deviations were employed. Using percentages, the category data were described. The bivariate correlation test was used to correlate FFQ screener results with 3DR and 24-hour urine collection results. One-way ANOVA was applied to assess the relationship between sodium practice questions and sodium intake FFQ results. The Bland–Altman plot is used to illustrate the variation in FFQ screener, 3DR, and urine sodium results.

The Bland-Altman plot is an excellent starting point for comparing two measurements of the same variable. The Y-axis represents the difference between the two values, while the X-axis represents their mean. If one method consistently produces excessively high results, for instance, the chart will depict all points as being either above or below the zero line. It may also reveal that a specific method tends to overestimate large quantities and underestimate small ones. The presence of points above and below zero on the Bland-Altman plot indicates there is no apparent bias favoring one method over another [33].

Ethical consideration

Al-Najah University's Internal Review Board for Research Ethics authorized the study protocol number Bse July, 2022\28. The questionnaire included a section stating that they had given their written approval where participants were asked to sign. There was no reward for the participants. When using the study methodologies, regulations were compiled to. The data was kept private and was solely utilized for study.

Results

Test and retest reliability results

A total of 25 participants were included in the test and retest reliability. Three of them failed to complete the survey. The test and retest results of 22 participants are presented in Table 1. The results revealed significant correlation between the first and the second results, the correlation coefficient was (0.77, $p<0.001$). The minimum sodium level between them was 1258.6, but the maximum findings had a minor difference (test 5469.9 and retest 5068.1). Mean and standard deviation between the two tests were comparable, with test mean of 3549.5 ± 1093.7 and a retest mean of 3542.3 ± 1050.5.

Criterion validity results

Socio-demographic characteristics

The total number of criterion validity participants was 81. Due to missing data, two of them were excluded. 22 participants were excluded from of the 24-hour urine samples because they fell outside of the Mayo Clinic's range [29]. The results of criterion revealed the age mean is 29.37 ± 9.16. Table 2 presents the sociodemographic characteristics of the sample in frequencies and

Table 1 Results of sodium FFQ screener conducted as part of the pilot study

	Minimum	Maximum	Mean	Std. deviation	*p*- value	Correlation coefficient
Test	1258.6	5469.9	3549.5	1093.7	0.000	0.77
Retest	1258.6	5068.1	3542.3	1050.5		

Table 2 Sociodemographic characteristics of criterion validity participants

Variable		*n*	%
Gender	Male	22	27.2
	Female	59	72.8
Educational level	Ninth grade	7	8.9
	High school	18	22.8
	Bachelor	53	67.1
	Post graduate	1	1.3
Place of residence	City	30	38
	Camp	4	5.1
	Village	45	57
Living nature	Own	55	69.6
	Tent	5	6.3
	Hostel	7	8.9
	With family	12	15.2
Marital status	Single	39	50.0
	Married	39	50.0
	Divorced	0	0.0
	Widow	0	0.0
Income	Less than1500	30	38.0
	1500 to 3000	15	19.0
	3400 to 5000	22	27.8
	More than 5000	12	15.2
Current work	Full time	21	26.6
	Part time	11	13.9
	Not work	47	59.5

Table 3 Medical history and life style of criterion validity participants

Variable		*N*	%
Chronic disease	Yes	5	6.3
	No	74	93.7
Medication	Yes	10	12.7
	No	69	87.3
Supplements	Yes	20	25.3
	No	59	74.7
Surgery	Yes	30	38.0
	No	49	62.0
Working out	Yes	13	16.5
	No	66	83.5
Walking	Yes	34	43.0
	No	45	57.0

percentages. The majority of the participants were female (72.8%, $n=59$), while males constituted 27.2% of the sample ($n=22$). Most of the sample ($n=53$, or 67.1%) held a bachelor's degree. Additionally, 22.8% ($n=18$) had a high school diploma, 8.9% ($n=7$) were in ninth grade, and only one (1.2%) was a postgraduate. The most common place of residency was the village ($n=45$, 57%), followed by the city ($n=30$, 38%), and then the camp ($n=4$, 5.1%). A total of 69.6% of participants resided in their own homes ($n=55$), while 6.3% ($n=5$) and 8.9% ($n=7$) lived in tents and hostels, respectively. There were no divorced or widowed participants. Single and married participants were equally represented (50%, $n=39$ each). Income was less than 1500 shekels for 38% ($n=30$) of the participants, followed by 3400 to 5000 shekels for 27.8% ($n=22$). Furthermore, 19.0% ($n=15$) received a salary between 1500 and 3000 shekels, while 15.2% ($n=12$) received more than 5000 shekels. The majority of participants were unemployed (59.5%, $n=47$), and 26.6% ($n=21$) had full-time work. The remaining participants had part-time work (13.9%, $n=11$).

Table 4 Sodium results of criterion validity participants

Sodium (mg)	Min	Max	Mean	SD
24 h Urine	461.7	5720.4	2274.2	1150.6
3DR	1171.0	7661.9	3236.1	1338.1
FFQ	1167.0	6908.9	2972.7	1203.3

Medical history and life style characteristics

The medical history and lifestyle characteristics are presented in Table 3. 93.7% ($n=74$) of the participants had no chronic diseases, whereas 6.3% ($n=5$) had non-sodium-related chronic diseases that had no effect on blood pressure, kidneys, or cardiovascular health, such as osteoporosis and ulcers. 12.7% ($n=10$) of them reported using non-sodium-related medications such as Nexium and Atozet, whereas 87.3% ($n=69$) did not. 25% of participants (25.3%) were taking supplements, primarily vitamin D3, meanwhile 59 participants (74.7%) did not. 38.0% of them had previous surgery which is cesarian or appendectomy, while 49 (62%) had not. Regarding lifestyle, 16.5% ($n=13$) engage in physical activity whereas 43.0% ($n=34$) walk as a working out.

Sodium intake results

The minimum value of urine volume was 370 ml and the maximum value was 3300 ml, with a mean of 1144.7±613.9 ml. Creatinine readings ranged from 308,4 to 2953.9 mg, with a mean of 994.1±467.7 mg. The sodium results are described in Table 4, where sodium levels from FFQ screener ranged from 1167.0 to 6908.9 mg, it ranged in urine from 461.7 to 5720.4 mg, and in 3DR from 1171.0 to 7661.9 mg. Mean sodium levels were as follows: 2247.2 mg in urine, 2972.7 mg in FFQ, and 3236.1 mg in 3DR. There is no substantial difference between their standard deviations. FFQ screener standard deviation was 1203.3 mg, urine sodium standard deviation was 1150.6 mg, and 3DR standard deviation was 1338.1 mg.

Correlation between the three methods

Correlation tests were conducted for both 24-hour urine collection and the 3DR. The two-tailed p-value for the correlation between FFQ screener and urine sodium was 0.000, with a Pearson correlation coefficient of 0.6.

Figure 1 displays the Altman plot illustrating the difference between the FFQ screener and urine sodium values.

The *p*-value for the association between FFQ screener and the 3DR sodium values was 0.01, and the Pearson correlation coefficient for all participants was 0.3. Figure 2 shows the Altman plot depicting the difference between the FFQ screener and 3DR sodium values (Table 5).

Table 6 describes the differences between sodium values obtained from the FFQ screener and 3DR for all participants. The second set of data illustrates the differences in mean, standard deviation, and standard error between sodium values from the FFQ screener and from 24-h urine collection, after excluding samples with creatinine levels outside the acceptable range. The number of samples included was 57 for each. The results show a clear convergence.

The graph in Fig. 1 compares the difference between FFQ screener sodium values and 24-hour urine collection sodium values which appear on y-axis to the mean of two measurements on x-axis. The 598.485-unit bias is represented by the distance between the x-axis corresponding to zero differences and the x-axis parallel line at 598.5. Colored lines indicate the outliers (mean ± Std.× 1.96) with a lower limit of -1676.6 and an upper limit of 2873.6. There are three outlier values, and the majority of the values align with the middle of the figure between the outliers.

Figure 2 graph compares the difference in sodium values obtained from the FFQ screener app and the 3DR on y-axis to the mean of two measurements on x-axis. The 263.4-unit bias is represented by the distance between the x-axis corresponding to zero differences and the parallel x-axis line at 263.4. Colored lines indicate the outliers (mean ± Std. × 1.96) with a lower limit of -2,725.9 and an upper limit of 3,252.7. There are three outlier values, two of values on the lower outlier, and the majority of the values align with the middle of the figure between the outliers. Figure 3 demonstrates in boxplot graphs the differences between sodium intake values from FFQ screener and FFQ screener after exclude the participants with low Creatinine values, 3DR, and urine.

Relationship between salt intake practice and sodium intake values from FFQ screener

There was a significant relationship between generally preferring less salty food and the sodium intake values obtained from the FFQ screener among participants ($p < 0.05$). Participants who always or sometimes prefer salty foods were found to consume 2742.4 mg

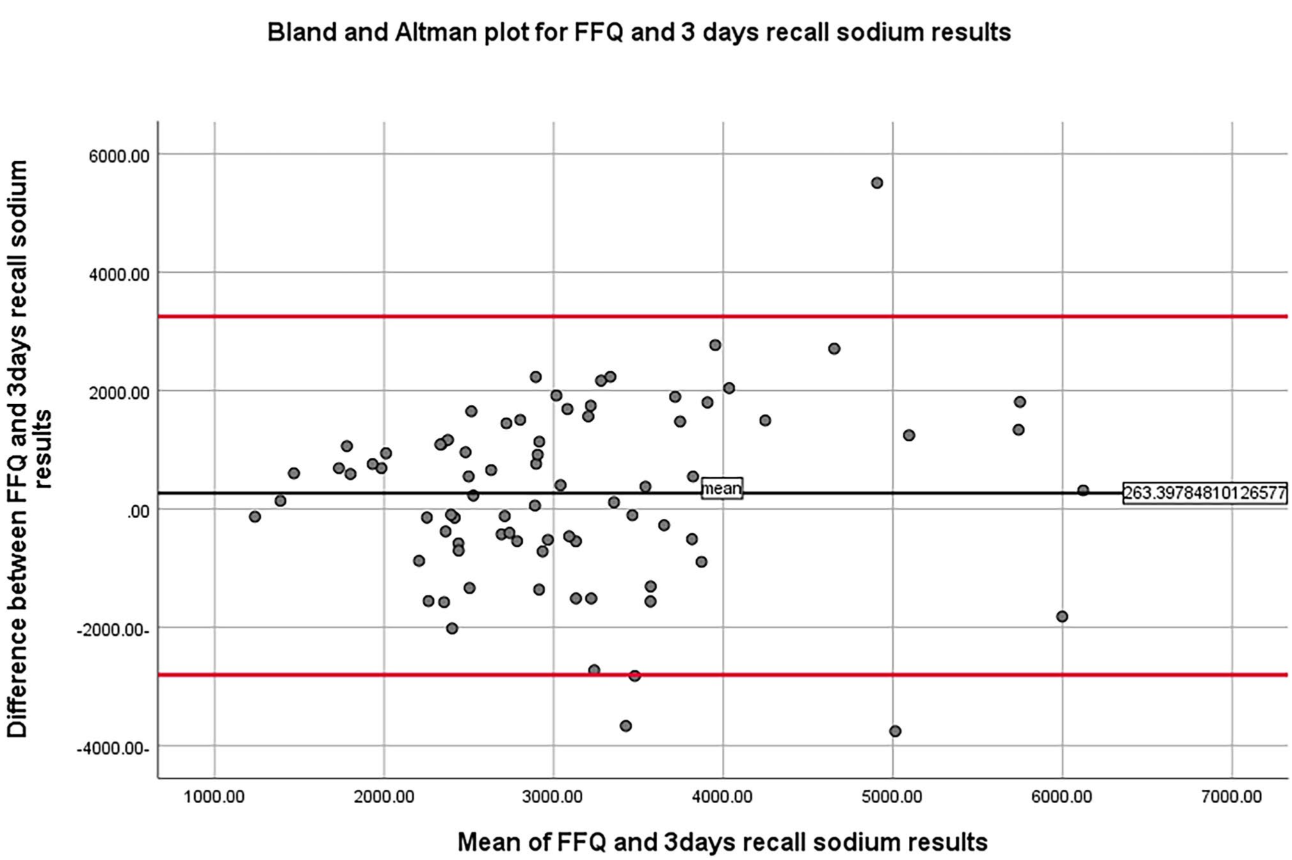

Fig. 1 Bland and Altman plot for FFQ screener and 24-h urine sodium results

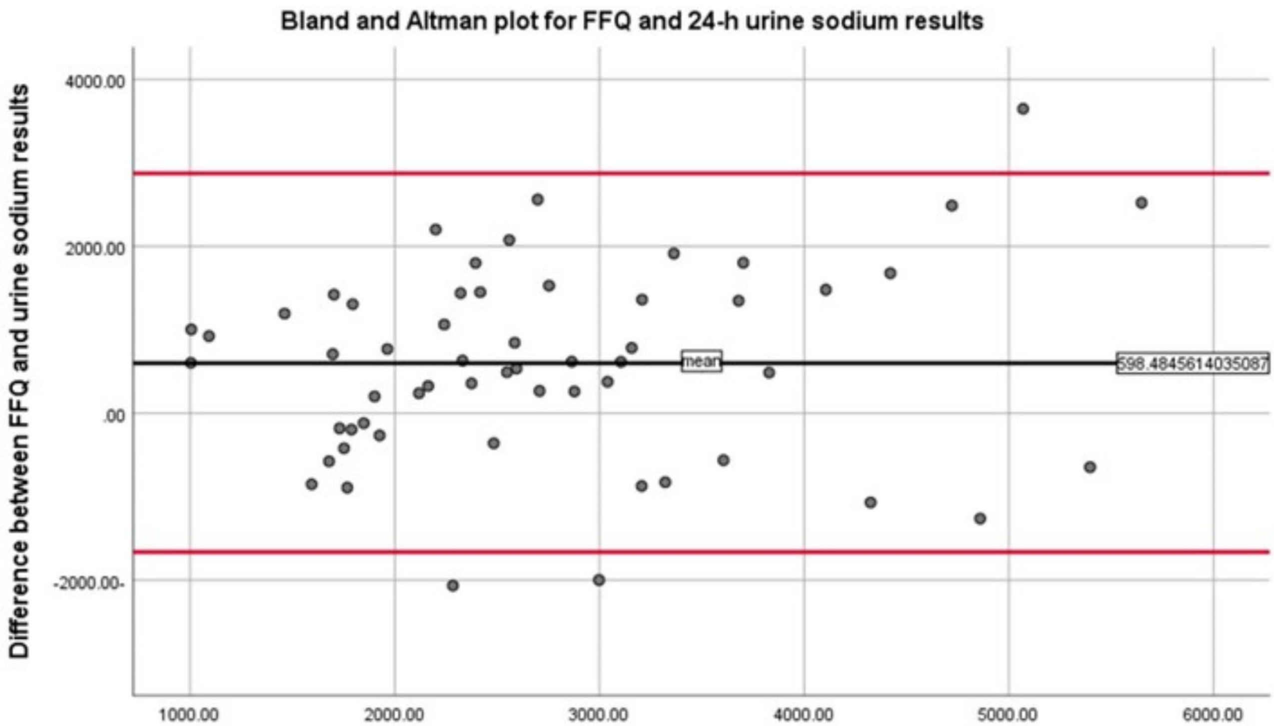

Fig. 2 Bland and Altman plot for FFQ screener and 3 days recall sodium results

Table 5 Correlations between 3DR, urine, and FFQ screener sodium values

		3DR	Urine
FFQ	Pearson correlation	0.300	0.600
	p-value	0.010	0.000

Table 6 Mean differences between sodium values in the FFQ screener, urine, and recall

		Mean	*n*	SD	SD-error
Pair 1	FFQ	2972.7	79	1203.3	135.4
	3DR	3236.1	79	1338.1	150.6
Pair 2	FFQ	3035.6	57	1331.0	176.3
	Urine	2437.1	57	1135.2	150.4

and 2533.5 mg of sodium respectively. While those who do not prefer less salty food consume 3262 mg of sodium. Moreover. A significant relationship was found between reducing salt intake and the sodium intake values obtained from the FFQ screener ($p<0.05$). Participants who never sought to reduce salt intake had a mean sodium intake of 3217.4 mg, whereas those who did so had a sodium intake mean of 2593.8 mg. No other significant relationship was found between salt intake practice and sodium intake values, as shown in Table 7.

Discussion

This study successfully validated a FFQ screener for sodium intake among a representative sample of 18–40-year-old Palestinian adults from the West Bank. The appropriate sample size was obtained to the research data and conduct the needed statistical analysis. Up to date, this is the first study in Palestine to develop and validate a FFQ screener for sodium consumption among Palestinians.

FFQ screener development

The nine food groups in the FFQ screener were created using the serving size and sodium concentration of items in the primary groups, chosen from the typical Palestinian diet for their high sodium content. Some items, like tomato paste and flour chips, have relatively low salt content but are widely consumed. In contrast, others like "Mussakhan" are consumed less frequently but have significant sodium content. The screener examines all aspects of food items, taking into account the salt pinches added after cooking. The first step in this study was to determine which foods will be included on the sodium screener. A specific sodium content was set as the lowest threshold, assuming the chosen items are consumed frequently and regularly. Similar results were found in other studies [19, 25]. The next step was determining the average serving size for each item. The source for determining serving size varied in the literature ; this research used the Palestinian Atlas, while another study estimated the average serving size by analyzing and comparing repeated 24-hour recall data [25]. The third step in this phase involved determining the sodium calculation method for each item. This study took into account the

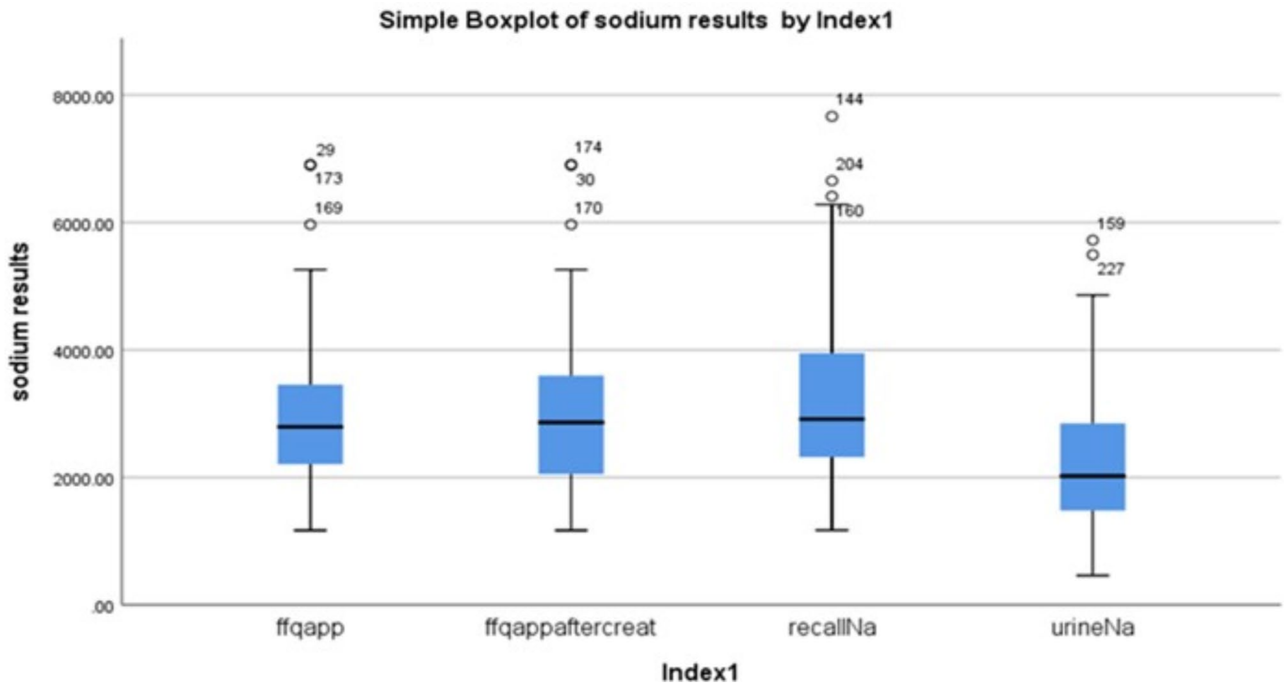

Fig. 3 Boxplot for FFQ screener, recall and urine sodium results

Table 7 Relationship between salt intake practice and sodium intake from FFQ screener

Question		*n*	%	Sodium intake mean (mg\day)	*P* value
Do you add salt to food after cooking	Yes	26	32.9	2985.1	0.486
	Sometimes	26	32.9	3170.4	
	No	27	34.2	2770.3	
Do you like salt	Saltier	17	21.5	3290.2	0.383
	No difference	47	59.5	2942.6	
	Less salty	15	19.0	2707.2	
Do you usually read food label	Yes	10	12.7	3319.5	0.092
	Sometimes	25	31.6	2547.9	
	No	44	55.7	3135.1	
Do you generally prefer less salty foods	Yes	10	12.7	2724.4	0.042*
	Sometimes	24	30.4	2533.5	
	No	45	57.0	3262.0	
Have you ever reduced salt intake	Yes	31	39.2	2593.8	0.024*
	No	48	60.8	3217.4	

frequency of food items consumption. The FFQ screener calculates sodium intake based on various frequencies (daily, weekly, monthly, or annually). Other studies used different categories and frequency factors to determine daily intake [19, 25].

Pilot study and reliability

The second phase of this study was assessing reliability, which involved a pilot study with participants who completed the questionnaire twice after a specific time frame. this pilot study included healthy participants of various ages without any diseases that affect sodium levels. Other studies had different participant characteristics, including hypertensive and normotensive individuals [19, 25].

Before data collection, it was necessary to confirm the questionnaire's reliability. According to van Teijlingen et al. (2019) a pilot study provides a warning if the project's steps are correct, as well as a warning of any potential failure. Furthermore, it aids in data adjustment [34]. In a study to validate technology-assisted FFQ screener for elementary and middle school children, a pilot study was conducted for 55 children to modify graphics, food groupings, portion sizes, and food items, if necessary, prior to using it with children [35]. In our study, the pilot was used to assess the usability of the questionnaire, the consistency of the results between the test and the retest, the difficulty of the questions for the participants, the clarity of the images, and the comprehension of the quantities. In a pilot study by Pritchard et al. (2010) that was conducted to validate a FFQ for assessing Calcium, Vitamin D, and Vitamin K intake. In conjunction with a 5-day dietary record, 15 women completed the FFQ. Due to participants' awareness of the significance of the research, it was found that the participants overestimated their nutrient intakes. In addition, the number of items was relatively high, 161 items, and this prompted the researchers to expand and subdivide the population and design a questionnaire that includes food items that are consistent with the participants' cultural, socioeconomic, and geographic dietary [36].

Correlation between sodium intake using FFQ screener and 24-h urine sodium results

In this study, there was a significant correlation between sodium intake values from the FFQ screener and the 24-hour urine samples. This contradicts the findings of Fadhillah et al. (2015) who reported that the correlation between 24-hour urine and their FFQ was not statistically significant. This might be due to their smaller sample (29 participants), and the fact that they have converted spot urine to 24-hour urine using the Tanka equation before calculating the correlation [37]. In a study on 430 participants, Kamiliah et al. (2012) evaluated the correlation between spot urine and 24 h urine collection with a FFQ and observed a moderate relationship between them [38]. which confirms that the 24-hour urine sodium measurement is the gold standard. Other studies also used 24-hour urine as the gold standard for assessing sodium intake [37]. In Gallani (2020) study, it was found that sodium intake values from a FFQ were significantly and strongly connected to the 24-hour urine collection, with a correlation coefficient of 0.30, which is moderately significant; however, they have reported that the FFQ often underestimates the total intake by 2.3 g [39]. Comparing multiple days 24-hour recall to 24-hour urine collection, it was determined that 24-hour urine collection is the most precise and accurate method for measuring sodium intake, although it is a laboratory technique [24]. It is crucial to include the table salt and processed foods inside the FFQ. I Otherwise, FFQ sodium intake values will be 30% lower than the 24-hour urine collection's results [40]. Processed foods and table salt were included in our FFQ screener to insure the accuracy of data.

Correlation between FFQ screener and the 3DR sodium results

3DR was used as the gold standard in this study to assess sodium consumption as in previous studies [19, 23]. A moderate to strong correlation between the FFQ screener and the 3DR sodium intake values. In a research where a FFQ was established for cardiac patients and was compared to 3DR, one of the days was a weekend, just as our study. There was a significant relationship between sodium values obtained from the FFQ and the 3DR, the association between them was acceptable to moderate when table salt was included and poor when table salt was omitted [40]. A study reported that sodium intake data were enhanced by the addition of a 24-hour recall to a FFQ, and they improved more when the recall period was longer than 24 h. The 24-hour recall is regarded as unbiased, whereas the FFQ cannot be used alone in studies. Even though it is challenging to complete 4–6 days 24-hour recalls with the FFQ, it is the most accurate and reliable method for producing reliable results [41]. Del Pino et al. (2011) developed a FFQ screener for children ages from 6 to 10 years old to check energy and nutrients intake, including sodium. it was determined that the FFQ and the 24-hour recall values were significantly correlated. Which confirmed the significance of using the multiple days 24-hour recall for FFQ validation [42]. Some studies favored the 3-day records over recalls. However, this technique might be laborious for the participant and may cause them to alter their diet during the study as Gallani et al. (2020) reported [39].

Validation of software

The importance of technology comes from its ability to produce results quickly and cheaply. Using technology for diet assessment is also essential for improving the accuracy of data, reliability, and precision. Additionally, the presence of qualified interviewers is not necessary for a comprehensive interview, and computerized assessment can save a great deal of time in data coding because data are immediately saved, which facilitates research and helps to simplify the self-tracking process, thereby increasing compliance and the validity of self-reported food and energy intake [43]. Software is one of the most significant types of technology used to monitor diet. Before it is released in its final form, it undergoes several stages of verification and validation, beginning with the requirements definition phase, which tests the adequacy, correctness, completeness, and consistency of the requirements. Then entering the design and construction phases, which consist of the general design, structural codes, and testing. Finally, operation and maintenance must be matched with the level of redevelopment [44].

In a study by Phyllis J. Stumbo (2013) examined digital methods for increasing food record accuracy,. they discussed the evolution of technology and the emergence of mobile phones with cameras and wireless devices, which make it simple to capture photographs or videos to clarify the type of food and portion size. The automated self-administered 24-h (ASA24) dietary recall is one of the accurate methods that uses food images to help report the type and quantity of foods consumed. It is a web-based, 24-hour dietary recall system that is accessible from anywhere with an internet connection. ASA24 is an application that utilizes a three-panel food entry screen, with two panels to browse for foods in a database and one panel to access serving size and record amount consumed. This confirmed that the precision of newer technologies has the potential to propel dietary assessment to the next level [22].

Sodium intake practice Vs. FFQ screener results

No significant relationship was found between the adding salt after cooking and the sodium intake obtained from the FFQ screener. Similarly, a study conducted in China, did not find a significant relationship between adding salt to food after cooking and a FFQ sodium intake values [45] In our study, participants who like salty food had higher average sodium consumption compared to those who do not like them. However, the difference was not statistically significant. On the other hand, preferring less salty foods was significantly related to lower sodium intake. A study in 2015 demonstrated a significant positive correlation between salt taste threshold and urinary excretion of sodium [46]. Another study reported that the correlation between diet sodium intake and salty taste preference was significant [47].

No significant relationship was found between reading the nutrition label and sodium intake among this study's participants. However, Frequent users of nutrition labels consumed 92.79 mg less sodium per day, according to a U.S. study, but this varied significantly by age, gender, and socioeconomic status [48]. Moreover, trying to reduce salt intake was significantly related to lower sodium intake. A systematic review and meta-analysis study concluded that behavioral changes are effective in reducing salt intake by more than 1 g per day [49].

Conclusion

This study had successfully developed and validated a FFQ screener for sodium intake among a representative sample of Palestinian adults. Using the serving size and levels of sodium of each of the 41 items in the nine primary categories, the FFQ screener comprised nine groups. The sodium intake values obtained from the FFQ screener and the 24-hour urine collection and the 3DR were significantly correlated. In addition, the study found a significant relationship between lower sodium intake and preferring less salty foods and trying to reduce salt intake.

Further research is needed to evaluate dietary sodium practices across various age and regions groups. Comprehensive cross-sectional research is necessary to evaluate the factors that impact sodium intake. Additionally, further research is imperative to establish the correlation between sodium intake and health outcomes across various age cohorts. Educational program are needed to increase the awareness on the health impacts of high sodium intake in the Palestinian community.

Limitations

The study's sample size was limited due to a relatively low engagement rate, as a significant proportion of individuals declined to provide a 24-hour urine sample. Furthermore, the study was geographically restricted to specific regions.

Abbreviations

FFQ	Food frequency questionnaire
WHO	World health organization
USDA	United state department of Agriculture
3DR	3 days diet recall
ASA24	Automated self-administered 24-hour

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Author contributions

Manal Badrasawi: Principle investigator, suggested the idea and drafted the problem statement, data evaluation, Supervise the analysis, reviewing and editing. Radwan Qasrawi and Lubna Kharraz: optimize the methodology, data validation, reviewing and editing supervise the data collection. Razan Awad: draft the proposal, apply for ethics, collect the data, primary analysis, Reem Abu Al Wafa, contributed in the data analysis and manuscript writing. All authors read and approved the final manuscript.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study protocol was approved by The study protocol was approved by the Institutional Review Board at An-Najah National University (Ref: Bse July, 2022/28). Permissions and approval to conduct the study were obtained from the Palestinian Ministry of Health and the An-Najah National University. Written and verbal informed consent was obtained from all subjects prior to data collection. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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