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ORIGINAL ARTICLE

Creation, Validation, and Use of Photo-Based Smartphone Application for Dietary Fiber Counting Among University Students

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The main aim of this study was to develop a smartphone application specializing in assessing dietary fiber intake of university students. The validity of the application was tested among 45 volunteers, their daily intake was recorded for 3 days using the Daily Fiber application, and intakes were compared with a 3-day food record matched to the same days. The mean intake of dietary fiber using the 3-day food record and our application was 10.08 ± 4.48 and 10.21 ± 4.64 g/d, respectively ($P < .01$). Overall, Daily Fiber is a promising tool for assessing dietary fiber intake among undergraduates. **Key words:** *application*, *dietary fiber*, *nutritional assessment*, *smartphone*, *undergraduates*

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This manuscript has been read and approved by all the authors, and the requirements for authorship as stated earlier in this document have been met. Each author believes that the manuscript represents honest work and has never been published or is under consideration for publication elsewhere.

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DIETARY fiber includes the edible parts of plants and analogous carbohydrates that resist digestion and absorption in the small intestine and undergo complete or partial fermentation in the colon.[1] Dietary fiber has been categorized into soluble fiber (eg, mucilages, pectins, and gums) and insoluble fiber (eg, lignin, cellulose, and hemicellulose).[2]

Dietary fiber is normally found in fruits, vegetables, nuts, and cereals. The composition and quantity of fiber vary from food to food.[3] The existing recommendations for dietary fiber intake are based on several factors,

including life stage, sex, and energy requirements, and the general recommendation for adequate intake (AI) is considered to be 14 g per 1000 calories per day.[4] Dietary fiber is essential in maintaining a healthy diet.[2] Adequate fiber intake can decrease the risk of developing several diseases, including stroke, hypertension, coronary heart disease, and diabetes. In addition, a generous fiber intake can reduce serum lipid levels, regulate blood glucose concentrations, may promote better immune function, and assist in weight loss.[5]

Because of the difficulty in measuring daily dietary intake, dietary assessment remains the standard for researchers.[6,7] The constraints of assessing dietary intake have been well documented and vary according to the selected method.[7] Scientists usually apply traditional methods to assess dietary intake: the 24-hour recall, food frequency questionnaire, and 3-day food diary.[8] Scientists can confront several obstacles when determining which method is superior.[8] Challenges include participant literacy and memory, participant burden, readiness, and motivation to precisely document diet. Furthermore, the time needed to record and analyze diet information and, subsequently, the availability of resources to properly analyze dietary recalls should be considered before conducting research. Therefore, new methods and approaches must be developed to assist researchers, participants, and nutritionists.

Evidence of the acceptability, suitability, and tendency to utilize smartphone applications (apps) for dietary assessments is increasing.[8] In Palestine, the rates of smartphone ownership are increasing.[9] A research study conducted by the Ministry of Telecommunication and Information Technology noted that by the end of 2019, smartphone holders in Palestine were 4.2 million compared with 2.6 million at the end of 2010, showing an increase of 63%.[9] Therefore, verifying whether smartphone apps can enhance the quality of assessing dietary fiber intake is possible.

Because smartphones are portable and socially acceptable, an app-based food diary may be more suitable and more likely to be completed at a meal than a paper-based diary, thus minimizing the inaccuracy of recalling dietary intake when documenting it later.[10] Furthermore, utilizing these devices can minimize costs and errors associated with entering data.[11]

Alfawaz et al[12] conducted a study in Saudi Arabia and found inconsistency between consumption and knowledge of dietary fiber. The study also observed an inverse relationship between consuming dietary fiber and health problems.[12] The Palestinian National Health and Nutrition Survey also found that the average daily intake of dietary fiber, which was 20 g, was below the recommended levels, which are between 25 and 30 g/d across all age groups.[13] According to the same study, the authors found that college students between 18 and 24 years of age consumed less fiber than the recommended amounts.[13] The results of this previous Palestinian study[13] were consistent with those of García-Meseguer et al,[14] who found that the consumption of fiber among university students was below AI in Spain, Tunisia, and the United States.

Therefore, there is a need for nutrition education to increase awareness about the benefits of dietary fiber and improve its consumption. The aim of this study was to develop a validated smartphone app to help university students assess their dietary fiber intake.

METHODS

App development

The development process consisted of 3 stages: stage 1 included preparing a comprehensive list of foods; stage 2 included selecting pictures and writing a brief introduction about dietary fiber; and stage 3 involved creating the app to test its validity.

Stage 1

The first stage involved preparing a comprehensive list of foods containing dietary fiber, including most traditional and

nontraditional foods consumed by the Palestinian population. The list was prepared on the basis of 3 reliable sources: the Food Composition Book,[15] Food Composition Tables for Kingdom Bahrain,[16] and Food Data Central.[17] Next, the selected food items were entered into a spreadsheet (Microsoft Excel 2016) to calculate the serving size of the representative foods.[18] Then, a focus group discussion was conducted with 5 experts in the field of nutrition. The discussion was divided into 2 sessions: the first session optimized the food lists, and the second session classified them into subgroups.

Stage 2

During the second stage, pictures of representative foods taken from the Palestinian Food Atlas project[19] and were added to the app. The amount of fiber in each food item based upon weight was also determined.

Then, a brief presentation about dietary fiber, its sources, benefits, and current recommendations was incorporated. Ten questions were inserted into the app to assess consumer knowledge and awareness of dietary fiber.

Finally, the programmer developed the app using an Android platform with a local compressed database (SQL-lite)[20] and used a Firebase database to store the collected data for use in the app. Two information technologists and 3 nutritionists assessed the app's content validity.

Stage 3

During the third stage, the app was trialed. Criterion validity for the app was performed. After obtaining approval, volunteers were e-mailed links to download the Daily Fiber app from either Google Play or the Apple App Store, as well as demonstration videos on how to use the app to enter their dietary intake. Volunteers were asked to record all food and beverages consumed for 3 successive days. Volunteers received daily e-mails and/or text prompts to encourage them to log their intake during the study period. The volunteers also completed a 3-day food record (3DFR). Sociodemographic data, including age, sex, income status, and area of residence, were also collected.

3-Day food record

All volunteers were provided with a hard-copy, single-page 3DFR to document their diet. They were asked to estimate and document the details of all the main meals and snacks they consumed, including the methods used in cooking, the size of the meal, and any add-ons (such as dressings, herbs, spices, and jam). When eating meals outside the home (eg, in restaurants), students were required to document the restaurant's name and the meals eaten. All 3DFRs were coded to maintain confidentiality.

Nutrient analyses

All foods recorded in the 3DFR were reviewed and converted into grams by a trained researcher. The 3-day average nutrient intake for each participant was computed using NutriSurvey software 2007 for dietary fiber (g).[21] As no updated nutritional database has been collected for some Arabic foods, the US Department of Agriculture (USDA) nutrient database[17] was used as a standard to estimate nutrient content, in addition to local and regional food composition databases.[15,16] On the basis of recipes, ingredients were measured to the nearest 1 g for edible portions of the foods. Thereafter, the food items were cooked, and the final meal was measured. The dietary fiber composition of the end product was computed and standardized to the food portion (small, medium, and large) using weight in grams or household measurements (cup, spoon, small bowl, and scoop) for each portion. Finally, data were exported to SPSS version 23 for statistical analysis.[22]

Food records from the Daily Fiber app were also exported precisely, as they were entered by the volunteers (app participants). A trained researcher reviewed each food record for missing items and exported the data for analysis. Nutritional assessments and recommendations were sent to the participants by

the research dietitian after the reports were corrected and reviewed.

Participants

Participants were undergraduates randomly selected from Palestine Polytechnic University, Hebron City, Palestine, between February and April 2020. The eligibility criteria were as follows: (1) enrolled as a student at Palestine Polytechnic University; (2) ownership of an Android smartphone. The exclusion criteria included undergraduates who were not enrolled as students at Palestine Polytechnic University; students who had had recent surgery, suffered from chronic diseases (eg, gastrointestinal diseases), followed a low-fiber diet due to medical problems, and/or did not want to participate in the research or did not confirm their participation. The study protocol was approved by the Deanship of the Scientific Research Ethics Committee of Palestine Polytechnic University.

Ethical standards disclosure

This study was conducted according to the guidelines of the Declaration of Helsinki, and all procedures involving the research study participants were approved by the institutional review board ethical committee at An-Najah National University. Written informed consent was obtained from all participants.

Statistical analysis

Variables were graphically assessed for normality of distribution using the Kolmogorov-Smirnov test.[23] The total dietary fiber and energy intake was calculated, and the means were determined for each participant on the 3 study days. The Wilcoxon signed-rank test was conducted to compare the 3 days of data from each method. Bland-Altman plots[24] were constructed to assess the agreement between the Daily Fiber app and 3DFRs for mean dietary fiber intake. The correlation between the Daily Fiber app and 3DFRs was assessed using Pearson's correlation. Descriptive statistics were calculated for the sociodemographic variables. SPSS Statistics version 23 (IBM Corporation, Armonk, New York) was used to conduct all statistical analyses, and $P < .05$ values were considered statistically significant.

RESULTS

Application development

The app took 6 months to build, including creating databases, developing the design with an information technologist, and validating the app. The development process involved the fields of nutrition, dietetics, and information technology. In total, 120 food items were included in the app: vegetables (26 items), fruits (25 items), grains and legumes (8 items), main meals (22 items), nuts (10 items), bread (5 items), juices (9 items), appetizers (9 items), and desserts (5 items) (see Supplemental Digital Content File 1, available at: http://links.lww.com/TIN/A57). The names and proportions of each food item were also recorded.

The app provided the correct data for the user from the database, and the calculations were precise (eg, calculating the fiber content in 2 apples). The first screen users see when they download the app includes 3 buttons. A small summary of dietary fiber was displayed by pressing the first button. By pressing on the second button, "calculating fiber," at the beginning, the users have to specify their gender (male/female); then, the users must press the verification button to proceed to the next section where the users can enter their behaviors (their food consumption) and review or edit information they have recorded. Details about reference guidelines are then shown on a "targets" screen. A new section consisting of 10 questions designed to determine the users' knowledge about dietary fiber was displayed by pressing the third button.

Participants' characteristics

In total, 48 undergraduates from Palestine Polytechnic University were recruited for this

study. Of these, 3 withdrew from the study for personal reasons, leaving a final sample size of 45 volunteers. There were 20 women and 25 men, with a combined mean age of 20.5 ± 1.1 years (range, 19-23 years). The recruited volunteers belonged to 4 different colleges: College of Engineering, College of Applied Sciences, and College of Information Technology and Computer Engineering. About half of male undergraduates (48%) reported being smokers, whereas all females reported being nonsmokers.

Criterion validity of the Daily Fiber app

A summary of Pearson's correlation and the Wilcoxon signed-rank test results is presented in the Table. There were no significant differences in fiber density between the 3DFR and Daily Fiber app ($P = .229$). A significant correlation was observed between the 2 methods ($P < .01$) (Table).

Bland-Altman plots were constructed for dietary fiber intake (Figure). Bland-Altman plots comparing mean intakes versus the difference between Daily Fiber app and 3DFR methods for dietary fiber intake indicated that most values were within the acceptable limits of agreement (LOA). There was also no apparent proportional bias, indicating that the differences between the 2 methods occurred randomly throughout the intake range.

DISCUSSION

A new smartphone app was created to promote dietary fiber intake among undergraduates at Palestinian Polytechnic University. The app's validity was proven, as indicated by the significant association between daily fiber intake and 3DFRs. Moreover, Bland-Altman plots confirmed acceptable agreement with no systematic bias.

A small number of public health scientists have reported the development of smartphone apps for single-nutrient modification. Hughes et al[25] developed an app for maintaining energy balance, Lee et al[26] developed a weight control game, and other researchers have developed a mobile app to promote lifestyle modifications among patients with type 2 diabetes mellitus.[27]

In general, smartphone apps have the potential to improve and enhance population health owing to their prevalent and growing utilization, dynamic technological improvements, capacity to download new versions, utilize available features, and minimize intervention delivery costs.[28]

Bland-Altman plots suggested an acceptable level of agreement between the Daily Fiber app and 3DFRs at a range of intakes, with most of the data plots falling within 1.96 SD of the mean (narrow LOA). This confirms that the Daily Fiber app is promising for precisely estimating dietary fiber intake at an individual level. Our finding of narrow LOA parallels former studies by Timon and colleagues.[29] Moreover, a former study with young females showed that smartphone and computer food records were as precise as traditional methods for assessing dietary intake and were more favorable than traditional methods.[30]

Our findings are consistent with a previous study conducted in Canada by Ji et al,[31] which found that the Keenoa app was a valid tool for measuring the daily intake of some nutrients,

Table. Differences in Fiber Density Intakes Recorded by the 3-Day Food Record and the Daily Fiber App

Nutrient	3-d Food Record, Mean (SD)	Daily Fiber App, Mean (SD)	Correlation Coefficient *I*	Difference, Mean (SD)	LOA[a]		*P*[b]
					Lower	Upper	
Fiber, g/d	10.08 (4.48)	10.21 (4.64)	0.989[c]	−0.12 (0.69)	−1.47	1.23	.229

Abbreviations: LOA, limits of agreement; SD, standard deviation.

[a]Lower and upper LOA (mean difference ±1.96 SD).

[b]*P* value is the significance level between 2 methods using the Wilcoxon signed-rank test.

[c]$P \leq .05$.

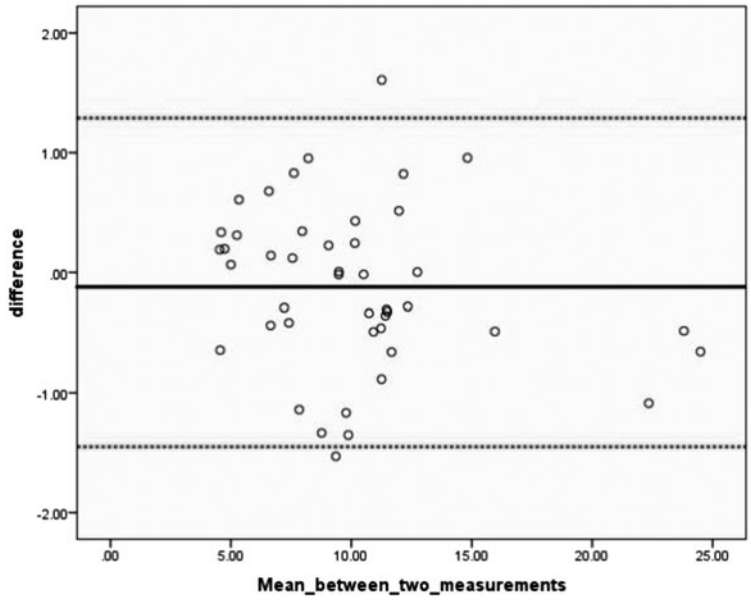

Figure. The Bland-Altman plot showing mean difference ("3-day food record" – "Daily Fiber app," solid line) versus mean intakes [("3-day food record" + "Daily Fiber app")/2] between the Daily Fiber app records and 3-day food record dietary fiber intake, and 2 SDs of the difference (limits of agreement, dotted lines). The solid line represents the mean difference of fiber intake −0.12 g/d, and the dotted lines represent the 95% limits of agreement for fiber intake (1.23 g/d, −1.47 g/d) (95% CI, −1.45 to 1.21).

including dietary fiber, when compared with a 3DFR.

Strength and limitations

There are a few limitations of the current study that should be recognized. First, volunteers may not be representative of all undergraduates at Palestinian universities. Second, a previous study confirmed that 3 days might be insufficient for assessing the intake of dietary fiber[32]; thus, more days of recording may have been needed. Finally, as there are no published Palestinian food composition tables, foreign databases were used to determine the dietary fiber content of foods. The current study also has many strengths. First, to the best of our knowledge, this study is the first of its kind in an Arab country. Second, undergraduates were able to download the Daily Fiber app on their own smartphones from an Android platform, in comparison with former studies where participants were asked to utilize a provided "study" apparatus.[33,34]

Future directions

Additional research is necessary to test the use of the Daily Fiber app in other population categories, including older adults, those with lower educational or literacy levels, and patients, to increase their dietary fiber intake. Further studies are needed to understand which aspects of technology are especially beneficial for promoting the precision of dietary assessment. Moreover, future research is warranted to determine whether participants want to use the app.

CONCLUSION

Improving diet quality among university students can play a major role in optimizing health status and preventing chronic diseases. Photo-based dietary assessment

methods provide an opportunity to improve the assessment of dietary intake and help students increase their daily fiber consumption. However, these modern methods require sufficient evaluation in different populations and environments to guarantee precise measurement of food intake. The smartphone app Daily Fiber is a valid tool for assessing dietary fiber intake in university students. The app could be used by nutritionists in clinics, primary health care centers, and hospitals to improve fiber intake of patients. Further research is needed to confirm the app's validity in various populations.

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