Fall 8-2019

EVALUATION OF FOOD JOURNAL APPLICATION VALIDITY IN COMPARISON WITH DHQ III

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BA, University of Texas Rio Grande Valley, 2016

Presented to the Faculty of The University of Texas

School of Public Health

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF PUBLIC HEALTH

THE UNIVERSITY OF TEXAS

SCHOOL OF PUBLIC HEALTH

Houston, Texas

August 2019

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ABSTRACT

As chronic conditions associated with the high prevalence of obesity/overweight in the United States continue to rise, research focusing on nutrition has grown in recent years. The gold standard for collecting detailed nutritional information on individuals is food journals, mostly via pen and paper. Alternatively, smartphone food journal applications have become more popular and widely accessible in recent years. These applications allow the user to quickly make meal entries, often taking advantage of the application's food and servings database.

This study compared the results of the third iteration of the Diet History Questionnaire (DHQ III) with a dietary journal data collected from participants using the FatSecret and MyFitnessPal mobile applications. Estimated calories, carbohydrates, fats, proteins, sodium, and sugars consumed on average daily were first calculated from data

derived via the two mobile applications and the DHQ III. Intraclass correlations (ICC) were used to determine the level of association between data derived from the two applications and DHQ III. In addition, the two applications were compared to determine similarities between queried meals.

Pearson correlations between 0.65 - 0.80 and ICC between 0.68 – 0.80 were found between the nutritional components derived from the mobile applications and the DHQ III, although only eight participants completed the entirety of the study. Significant variability was found between the nutritional data of both food journal applications. This along with numerous obstacles regarding the application technologies, such as lack of Application Processing Interfaces (APIs) per food journal application, must be considered before considering applying them to a standardized medical workflow.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

BACKGROUND

Literature Review

As depicted in Flegal et al.'s study, which used data from the National Health and Nutrition Examination Survey (NHANES), there has been an ongoing increase in the prevalence of obesity in the United States (2010). A more recent study by Freedman et. al. (2016) also analyzed NHANES data, concluding an increase in both obesity (body mass index ≥ 30 kg/m^2) and severe obesity (body mass index ≥ 40 kg/m^2) amongst adults between 2007 and 2016. These increases in body mass do not come without consequences, as depicted in Determinants and Consequences of Obesity: "Among key findings are the effects of excess weight, even in normal BMI ranges, on the risk of chronic disease morbidity and mortality, the importance of limiting weight gain, and dietary, lifestyle, and genetic determinants of obesity, as well as gene–environment interactions," (Hruby et. al., 2016, p. 1656). Dietary lifestyle and measuring one's food consumption are shown to be important in terms of preventative healthcare measures for obesity and associated chronic diseases.

In Principles of Nutritional Assessment (Gibson, 2005), examples of food consumption and eating habit measurement tools include: the twenty-four-hour recall method, estimated food records, weighted food records, dietary history, and food frequency questionnaires (2005, p. 41) (Figure 1). The 24-hour recall method involves participants recording their intake of food from the past 24 hours in a standardized format (Gibson, 2005, p. 41). Such procedures work best when repeated on multiple days and can be used to track seasonal dietary habits. This method relies on the memory and accurate estimations of the participant in terms of proportions consumed. Similarly, estimated food records involve participants journaling all foods and beverages for an extended period of time (Gibson, 2005, p. 44). Portions, ingredients, and brand names are noted in these records. Weighed food records require extensive journaling of all foods consumed by the participant, which is the most precise method available to estimate the usual food and nutrient intakes of individuals (Gibson, 2005, p. 45). Weights, descriptions, and brand ingredients must be recorded, demanding much cooperation and dedication from both participant and nutritionist. Results are still subject to the influence of a participant changing eating habits due to being observed. The dietary history method consists of an interview and 24-hour dietary recall, a food frequency questionnaire, and a three-day dietary recall (Gibson, 2005, p. 45). There is no universal standard to this method, and many studies following this method, spanning well over a month. Dietary histories have been noted as a very labor-intensive method with some interviews taking up to two hours per participant. Food frequency questionnaires (FFQ) consists of a standardized questionnaire involving the eating habits of the participant (Gibson, 2005, p. 46). Specific questions vary between questionnaires with most taking between 15 to 30 minutes to complete. This makes

Nutritional Assessment Methods

- 24-Hour Recall Method
- Estimated Food Records
- Weighted Food Records
- Dietary History
- Food Frequency Questionnaires

Figure 1: Methods of Nutritional Assessment: detailed in Principles of Nutritional Assessment (Gibson, 2005).

the questionnaires more convenient to both the participant and the nutritionist as little to no supervision is required.

Weighed food records are the most precise method, while FFQs are the least burdensome in terms of time and effort on the part of the nutritionist and participant. NHANES uses both 24-hour recalls and a food frequency questionnaire for the gathering of data (U.S. Department of Health and Human Services, 2018). Other common food frequency questionnaires include the Block (Block et. al., 1986), Willett (Willett et. al., 1985), and National Cancer Institute Food Frequency Questionnaire (Dietary History Questionnaire, 2018). The National Cancer Institute Food Frequency Questionnaire is also referred to as the Dietary History Questionnaire (DHQ) and has undergone three iterations. The utility of the DHQ was examined in the Eating at America's Table study. Beginning August of 1997, the Eating at America's Table study (Subar, et. al., 2001) called 12,615 telephone numbers to recruit participants for their cohort. A total of 1,640 willing participants, ages 20-70, were enrolled. Four nonconsecutive 24-hour recalls were administered three months apart via telephone during different seasons of one calendar year. In order to determine the validity of the Block, Willet, and Dietary History Questionnaires, the participants were randomly divided into two groups; one to take the Block questionnaire along with the DHQ, and one to take the Willet questionnaire along with the DHQ. Descriptive statistics regarding demographics, response rates, and median nutritional intakes were presented. Twenty-six nutrients were common among the three questionnaires, so correlations were assessed among these nutrients. The study concluded that the DHQ performed the best overall in terms of correlation to the 24-hour recall when compared to the Block and Willet questionnaires (Subar et. al., 2001).

Deviating from phone surveys, modern day smart phone devices, and mobile applications are widely available and have grown in use throughout the United States. Jacob Poushter, in reviewing the Spring 2015 Global Attitudes survey, noted that 72 percent of adults reported owning a smartphone with 89 percent of them using the internet occasionally. As expected, "millennials (those ages 18 to 34) are much more likely to be internet and smartphone users compared with those ages 35 and older" (Poushter, 2016, p. 6). Poushter also stated that the survey depicted similar trends throughout every developed nation and developing nations are following suit. Health related smart phone applications are becoming more common as well. In a 2015 national survey of 1604 mobile users throughout the United States, 58.23% of those surveyed stated that they had previously downloaded a health-related mobile application. Of the downloaded applications, fitness and nutrition related applications were the most common (Krebs & Duncan, 2015). Of those using such applications, cost was a significant concern, but there was trust in the accuracy and the data generated by such applications (Krebs & Duncan, 2015).

In 2013, an article was published reporting results for usage of mobile food journal applications for self-monitoring during a weight loss program for adults (Turner-McGrievy et. al., 2013). The study found lower caloric intake for participants tracking diet through electronic devices in comparison to those using a paper food journal (Turner-McGrievy et. al., 2013). However, Cordeiro et. al. suggested inaccuracies in some application's food database and stated that users reported that looking up a food and serving per each meal on the application required too much effort to continue as a regular habit (Cordeiro et. al., 2015).

Cordeiro, Bales, Cherry, and Fogarty conducted a later field study using a newly designed food journal application named DECAF. This application did not count calories but required an image to be taken by the user to reflect their meal (Cordeiro, Bales, Cherry, & Fogarty, 2015). Taking a similar approach in terms of image-based food journaling, Meyers et. al. developed *Im2Calories*, an application in development using machine learning to identify food items and portion sizes. The application then takes the identified food and creates the nutritional profile from a database to calculate total calories per meal. This project is still in production but has achieved moderate success in being able to accurately identify foods and their nutritional content in its prototype phase (Meyers et. al., 2015).

Used in previously cited studies such as Turner-McGrievy et. al., the FatSecret mobile application is free to use on both Android and Apple based mobile devices. It also has a free to use application program interface (API), which has made it appealing to other researchers seeking to create software based on FatSecret's technology (Hariadi, Khotimah, & Wiyono 2015). Another food journal application that is widely popular is MyFitnessPal. Below is a description of the app by Teixeira et al, (2018) :

> MyFitnessPal (MFP) is a free smartphone and computer application that offers self-monitoring of food intake, physical activity and anthropometric measures. MFP was considered the favorite application from many others at the same category by sports dietitians who used applications in nutritional care. Qualitatively, MFP achieved ninth position when evaluated along with 28 similar applications in a ranking that assessed

criteria such as accountability, scientific coverage, technology features and usability. (Teixeira et. al., 2018, p. 219).

Tiexeira et al.'s article focused on validating MyFitnessPal food records by comparing them with paper food records. They concluded that the MyFitnessPal underestimates some nutrients but has good relative reliability in terms of caloric estimates. However, careful use was recommended due to database gaps (Teixeira et. al., 2018).

Public Health Significance

A food journal involves a participant consistently recording their dietary intake on a daily basis along with their portion sizes. With the added variety of foods and brands in the market today, this task proves more difficult each year. Dietary questionnaires require participants to recall their dietary habits over an extended period of time and specify supplemental vitamin intake which the survey uses to adjust its estimated nutritional intake on. Using modern food journal applications has the benefit of adding the accessibility of a smartphone device with well-structured foundation of pre-established nutritional databases. This may assist future nutritional studies as well as current clinics seeking to keep track of an individual's nutritional intake.

Aims and Hypothesis

The first aim of this study was to evaluate correlations between the estimated average daily intake of specified nutrients produced by the DHQ III and the average daily intake of specified nutrients derived from data collected via the FatSecret and MyFitnessPal mobile applications. Assuming the application sampled directly from participants' dietary histories, we hypothesized that the food journal mobile applications' data would show similarity with that of the DHQ III results. The second aim of this study was to evaluate correlations of the two food journal application databases. We hypothesized that these nutrients would be highly correlated between databases.

METHODS

Overview

This study sought to compare the results of the third iteration of the Diet History Questionnaire (DHQ III), with a sample of dietary journal data collected from participants using the MyFitnessPal and/or FatSecret mobile food journal application. Volunteer participants were recruited online via social media platforms such as Facebook, Reddit forums, MyFitnessPal forums, and FatSecret member groups following the guidelines and regulations of each respective site. Participants who agreed to participate in this study were requested to take a Qualtrics survey, disclosing demographic information and an email address to be contacted after the study regarding a raffle which was offered as incentive for participation. Qualtrics data were hosted by University of Texas Health Science Center (UTHealth) servers. The Qualtrics survey linked to a web application made for this study, which functioned to synchronize data from a participant's food journal application account with their consent. This deidentified information was stored on a remote secured server by the hosting service Python Anywhere (https://www.pythonanywhere.com/). A second link redirected participants from the web application to the DHQ III website hosted by the National Cancer Institute on their servers. At the end of the study, all data from three separate repositories were aggregated into one dataset to be stored on UTHealth servers.

Statistical analysis via Python and SPSS was used to determine the level of correlation between estimated average daily consumption of nutrients as suggested by the average calculated from data derived via the food journal application and the average outputted as a result of the DHQ III. This study structure relates to the Eating at America's Table study with the exception that 24-hour recalls were used as the gold standard for candidate methods to be compared to. However, 24-hour recalls spanning one year were not achievable due to the project duration and available resources, so data acquired was treated as 24-hour recalls, repeated 24-hour recalls, or an estimated food record (Subar et. al., 2001).

FatSecret Food Journal Application

FatSecret is a free to use open source application for both food and exercise journaling. Their food database is open to the public and much of its information is data created and edited by users of the application. However, food and beverage companies are encouraged to post the details of their food's nutritional information. Each food item in the database contains data regarding protein, calories, saturated fat, sodium, vitamin C, cholesterol, fiber, carbohydrates, calcium, potassium, sugar, monosaturated fat, polyunsaturated fat, vitamin A and iron. Each food and serving also has its own unique identification, which can be referenced to the database at any time. This particular feature provides means to ensure the accuracy of a food journal (FatSecret Platform, 2018).

MyFitnessPal Food Journal Application

The MyFitnesPal application is a popular application for food and exercise journaling. It is available via all mobile platforms as well as on PC via web application. The food database of MyFitnessPal is not open sourced and is almost entirely composed of the user's entries. The nutrition profile of each food item is limited to calories, fats, carbohydrates, proteins, and sugars. (Evans, 2017)

Dietary History Questionnaire III

The original Dietary History Questionnaire (DHQ) was released in 2001 and was solely paper based. Today, the DHQ III is available both online and through paper, and offers one of the few free to use online versions. There is a Spanish version of the DHQ and Canadian version both in English and French. The DHQ III is associated with a unique food database for each respective version of the questionnaire (Csizmadi, 2016). Variables calculated by the DHQ III include those contained in the FatSecret database, totaling 219 variables. These variables include supplements, but for the purposes of this study, supplements were excluded from the DHQ III. The DHQ III was administered to all volunteers for the study. The average estimated time to complete a full length DHQ III is approximately an hour (Dietary History Questionnaire, 2018)

Study Design

This study uses cross-sectional retrospective survey data from the modified Dietary History Questionnaire III (DHQ III) and averaged data of previous serial food journal entries from the FatSecret and MyFitnessPal mobile applications. Figure 2 shows a flow diagram of the entire study, from recruitment, to data collection and extraction.

The target population of the DHQ III were inhabitants of the United States. Participants were linked to a Qualtrics survey, which following the provision of informed consent, directed volunteers to a custom-made web application where participants were able to synchronize their food journal library and be redirected to take the modified DHQ III. The respective deidentified data collected were stored in the SQL database of the web application and the DHQ III database. Once data collection was complete, these two datasets were compiled for statistical analysis.

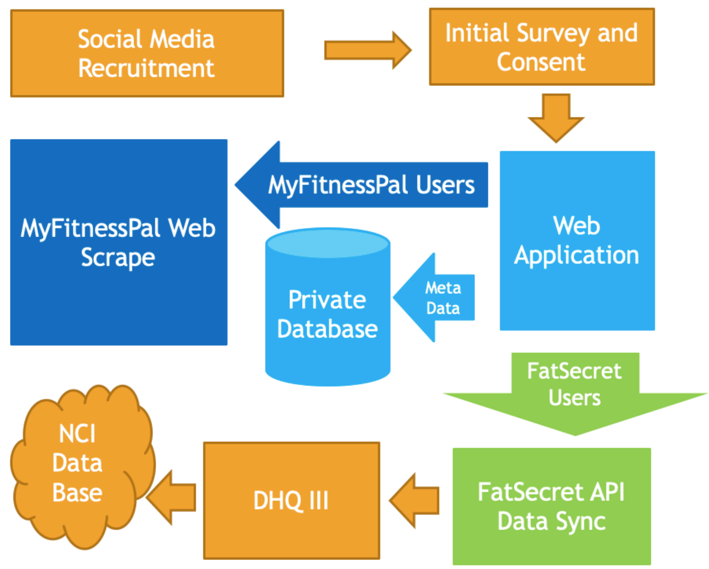

Figure 2: Flowchart depicting dataflow and user traffic from Qualtrics survey to the DHQ III survey.

Participant Recruitment and Consent

All recruitment of volunteer participants was done online via social media platforms such as Facebook, Reddit forums, and FatSecret member groups. The terms and agreements of each respective website were reviewed to ensure that recruitment methods were not in violation of said terms and agreements. Moderators of each forum were notified, and permission requested so that recruitment would not be viewed as spam (Gelinas et. al., 2017; Temple et. al., 2012).

Below is a sample of a post used for recruitment of participants for this study on a forum. This example was approved by the UTHealth Institutional Review Board:

> Hello, I am a senior graduate student from the University of Texas Health Science Center working on a thesis project that will be looking to compare how well food journaling applications estimate people's nutritional intake when compared to more standard food questionnaires. In particular we are looking for current users of the FatSecret app.
>
> We are currently looking for willing participants to share some of their food journal data from the FatSecret app or MyFitnessPal app along with taking the Diet History Questionnaire III, a standard food frequency questionnaire by the National Cancer Institute. The results of this questionnaire will be yours to keep. The total process should take between 30 – 45 minutes and to compensate for your time, we will be holding a raffle for five $20-dollar Amazon gift cards at the end of the study.
>
> Your privacy is very important to us and any information acquired during this study will only be used for the purposes of this study. If you are interested, please click below to read more about the study and complete a consent form to begin participation. Thank you for your contribution.

All participants were informed of the purpose of this study and which data was to be collected first via recruitment in forums and then in the participant consent form via Qualtrics survey. By agreeing to the consent form, the participant confirmed that they were over the age of 18 and in good health. The consent form specified the participant's ability to withdraw from the study at any time by not completing it. If there were data missing for a participant, it was assumed that the participant withdrew from the study and all their respective data were deleted from the data set.

Data Storage and Security Measures

There were no perceived safety concerns to well-being of any participant in this study. All data collection was done at the time and place of the participants choosing with no supervision on behalf of the researchers. Once the study was complete, all emails were removed from the dataset and a single de-identified dataset with all remaining variables was stored on UTHealth servers for possible future revisions. The surveys of this study were able to be done on any platform including desktop and mobile devices.

In order to ensure the security of any personal data collected from participants, all data collected were divided into three servers. The participants began by completing a Qualtrics survey and consenting to participate in the study. The survey requested the email and demographics of the participant. These data were contained in the Qualtrics servers, which were preapproved for collection of PHI data through the UTHealth. Following this survey, the participant was redirected to a web application created for the purposes of this study. This application was hosted in Python Anywhere (https://www.pythonanywhere.com/) and functioned to synchronize data from the participant's FatSecret food journal to the web application's Structured Query Language (SQL) database. The database also stores the participant's randomized identification number from the Qualtrics survey. After syncing the food journal, the web application redirects the participant to the DHQ III website with a customized URL. This customized URL is also stored in the SQL database hosted by Python Anywhere. Python Anywhere is a Python web application hosting service paid for by the research team. The data is private and owned by the web application owner. To add extra security, the DHQ III URLs identification numbers were encrypted. The last part involves the participant taking the DHQ III on the official website hosted by the National Cancer Institute (https://www.dhq3.org/). These are hosted on their private servers and all information is anonymized and encrypted.

Study Sample

Figure 3 describes the number of participants at each of the data collection phases. From the initial recruitment, a total of ninety-two people clicked on the Qualtrics link and sixty-three consented to begin the survey. Thirty completed the final open-ended question on the survey, nine synchronized their food journal data to our database, and eight went on to complete the full DHQ III. The final number of participants used for the study was eight. Participants ranged in age from seventeen to fifty-three.

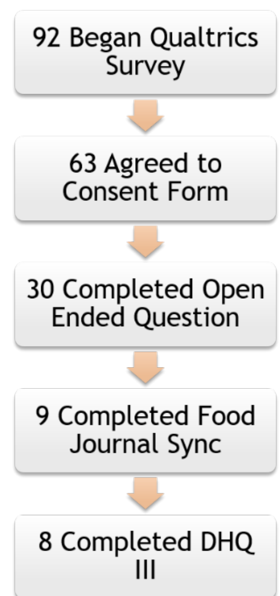

Figure 3: Flowchart of participants through each data collection phase.

As seen in *Table 1*, two of the participants were female and six were male. There were two users of the MyFitnessPal app and six users of the FatSecret app. The individual with the smallest amount of entries had 37 while the person with the largest amount of entries is 266 in total.

Table 1: Overview of final participants used for study.

Participant	***Age***	***Days Journaled***	***Food Journal Application***
1	17	37	FatSecret
2	50	39	FatSecret
4	53	85	FatSecret
5	50	41	FatSecret
6	27	266	MyFitnessPal
7	22	92	MyFitnessPal
8	24	45	FatSecret
9	24	86	FatSecret

Data Extraction Methods Using API and Web Application Design

The web application used to collect data from the FatSecret food journal application was built using a Django web framework for Python (Django Version 2.1.4). Data are accessed from the FatSecret Rest API via a Python library publicly available via GitHub (Walexnelson, 2017).

The FatSecret API is free to use for basic services; however, students, start-ups, and non-profit organizations are allowed to use the "premier API" with the permission of the FatSecret developer team. The API allows a local profile to be created and the FatSecret's food database to be queried (The FatSecret Platform API, 2018). Both of these provided ample data for creating useful applications, but for the purpose of this project, the 3-Legged Open Authorization (OAuth) process was used. A 3-Legged OAuth is a relatively simple authentication system that acts as a mediator between two applications and a user (Janetzko, 2017). In this case, it consists of the user, the web application, and FatSecret's user database. When a user accesses the web application and requests to sync their FatSecret food journal data with the web application's database, the web application opens a tab in a browser to an authentication page. Here the user needs to log into their FatSecret account and verify that they wish to give access to the web application. By using the 3-Legged OAuth process, the web application does not deal with the login credentials provided by the user. This limits the security risk handled by the web application of the data collected from the FatSecret profiles.

In this study, once the user provided permission, the application then had full access to the user's complete food journal history.Specified start and end dates for data collection were chosen by the investigator. An API call requested all nutritional data for day one, so the application ran a loop, making an API call for each day in a specified range. Once a call was made, a list of meals with the participants' respective foods and nutritional data were created. If there was no information for that date, an empty list was outputted. These journal entries were then packaged into a python dictionary, similar to a JavaScript Object Notation (JSON) object. Once all days were been called upon, the program was complete, and all data were exported to a private database in JSON format from the web application. The database formatting for the backend of the application is interchangeable for the preference of the developer. The current program outputs a JSON formatted data object for the user journal. This data is suitable for storage in both SQL and non-SQL databases.

MyFitnessPal has no open sourced API for accessing a user's information. However, developers have worked around this by creating a third-party alternative which web scrapes data from a user's profile while logged in. This does not include a 3-legged O-Auth so it does provide less security. However, the web application used for this project does not store the user's login information in any format to prevent any security concerns. All other data

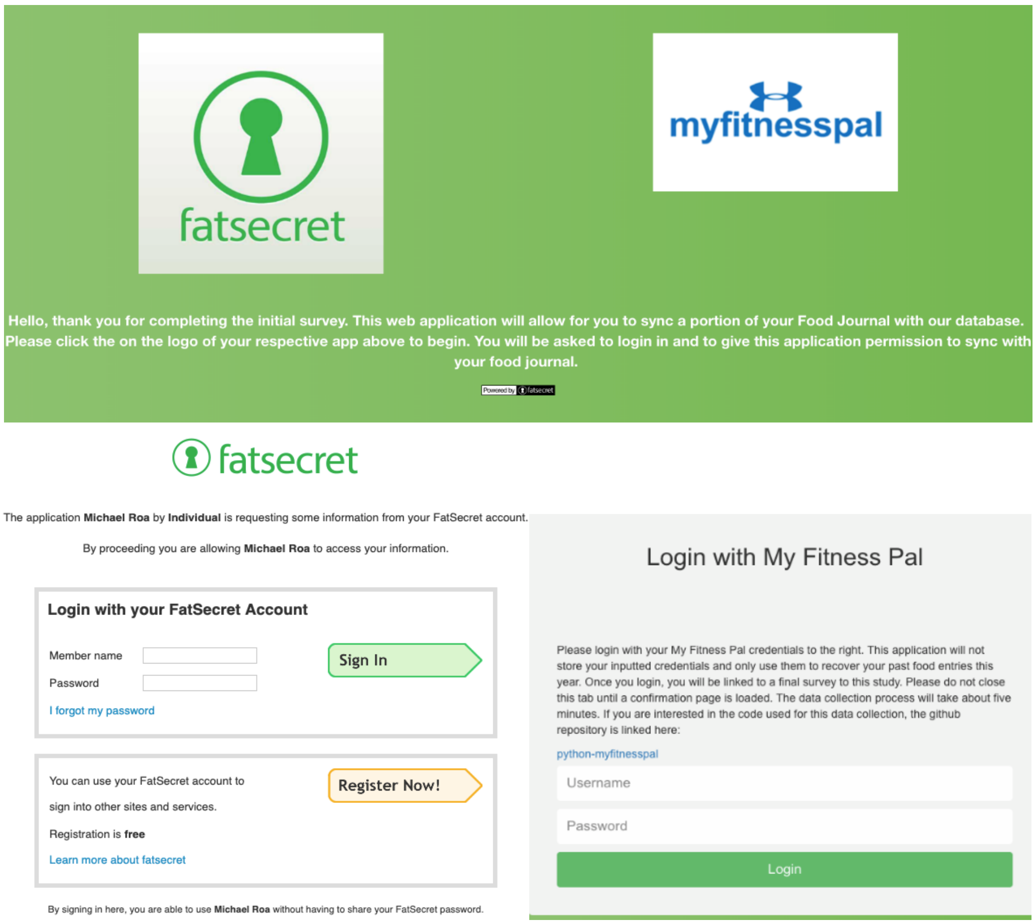

Figure 4: Screenshots of the web application used for the study: first page linked to the initial Qualtrics consent survey

formatting and processing then occurs in a similar way as data collected via the FatSecret API with the exception that by default, a maximum of one year of data is collected from the MyFitnessPal users.

Statistical Analysis

For this study, the similarity between the averages of the food journal application daily entries were compared to DHQ III estimates using Pearson's correlation coefficient analysis using Python Scipy library and a two-way mixed, average measures, absolute agreement intraclass correlation (ICC) analysis *(Figure 5)* using SPSS software (Fleiss & Cohen 1973). Deviations of food journal entries from assumed normal caloric intakes were also investigated as to whether these deviations negatively influenced the correlation of each dietary component with their DHQ III estimates. To test this, new Pearson correlations were calculated between new averages for each individual after a certain set of entries were excluded due to certain conditions. These conditions included being below two standard deviations, one standard deviation, 100 calories, 200 calories, 300 calories, and 500 calories.

$$\frac{MS_R - MS_E}{MS_R + \frac{MS_C - MS_E}{n}}$$

Figure 5: Equation for a two-way mixed, average measures, absolute agreement ICC: MS_R = mean square for rows; MS_E = mean square error; MS_C = mean square for columns

RESULTS

Validity of Food Journal Mobile Application in Comparison with DHQ III

An aspect worth noting is how variable some of the caloric intakes are with some reporting intakes of less than 500 calories per day as shown in *Figure 6*. The average caloric intake for adult males with a moderate activity level is between 2000 and 3000 calories daily to maintain current weight. The average caloric intake for the two male participants seemed well within range. Normally, adult females with moderate activity levels average between 1500 and 2500 calories consumed daily (Trumbo, Schlicker, Yates, & Poos, 2002). Most of the female participants fell within this range. However, participant 4 and 5 averaged well below the 1500 level with participant 4 averaging right below the 1000 level. This brought

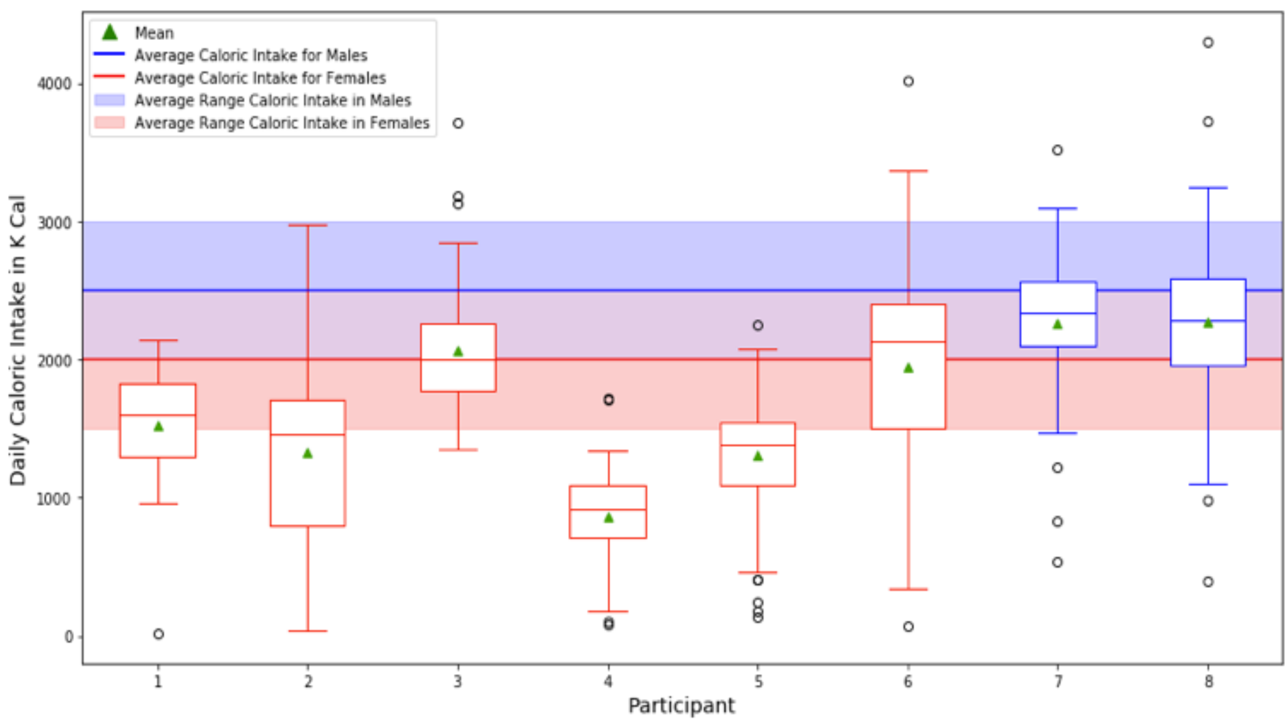

Figure 6: Box-Cox Plot of participants' caloric intakes.
(Mean intake is depicted by green triangle, median intake is depicted by green line, gender is depicted by a red color for female and blue color for male. Blue and red shading depicts male and female average caloric intake respectively.)

into question whether their nutritional documentation was accurate or not. Perhaps they contained incomplete journal entries. This can also be said for food journal entries from other participants, which appear to be abnormally low: lower than two times the standard deviation or below five hundred calories. It is reasonable to assume that if these are incomplete entries, and if so, should these outliers be disregarded? Having DHQ estimates similar to the low average caloric intake for participants 4 and 5 as shown in *Figure 7* suggests these entries are valid. On the other hand, some participants with higher caloric averages did not compare as well with the DHQIII estimated average. Table 2 shows the descriptive statistics of each nutrient for all gathered food journal data from the eight participants of this study.

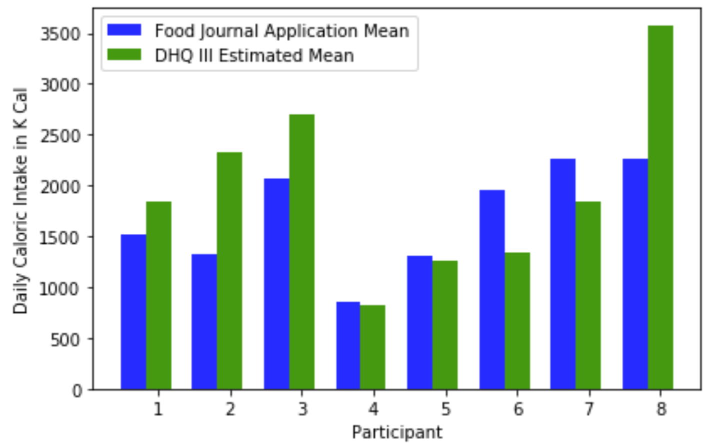

Figure 7: Bar chart comparing food journal entry averages with the DHQIII estimated averages.

Table 2: Descriptive statistics for sampled food journal entries.

	Calories (kcal)	***Carbohydrates (grams)***	***Fats (grams)***	***Proteins (grams)***	***Sodium (milligrams)***	***Sugars (grams)***
Count of Entries	691	691	691	691	567	515
Mean	1653.829	143.640	78.945	91.596	2586.436	44.099
Standard Deviation	668.904	96.294	36.408	37.184	1538.896	37.310
Min	16	0	0.1	0	0	0
25%	1248.5	63.535	54	69	1437.5	14
50%	1594	127	75.82	92	2401	34
75%	2110.5	215.37	100.52	115.595	3312.5	64
Max	4304	484.56	237.94	245.86	9507	210.13

Pearson Correlations of the six nutritional values between the food journal application and DHQ III estimates revealed significant correlation for fats, proteins, and sodium. Pearson correlation coefficients ranged from 0.652-0.807 as shown in *Table 3.* Moderate ICCs were found for all nutrients ranging from 0.686-0.802 as shown in *Table 3.* All nutrients were shown to have a moderate to strong Pearson's correlation and a moderate intraclass correlation. All nutrients except calories resulted in a significant p-value for intraclass correlation.

Table 3: Pearson and intraclass correlations between DHQIII and food journals.

Nutrient	*Pearson's Correlation*	*Pearson's P Value*	*Intraclass Correlation Coefficient*	*Intraclass Correlation P Value*
Calories	0.652	0.080	0.717	0.056
Carbohydrates	0.686	0.060	0.802	0.021
Fat	0.782	0.021	0.782	0.035
Protein	0.777	0.023	0.758	0.040
Sodium	0.807	0.015	0.761	0.017
Sugars	0.672	0.068	0.686	0.028

Adjusting for Deviations from Normal Food Journal

The finding of lower correlation for calories is one similar to the Eating at America's Table Study, however, it was thought that some journal entries used may have been inaccurate or incomplete. To examine this, daily food journal entries were deleted depending on the parameters depicted in *Table 4* along with the new adjusted correlation values. Correlations were also made for data sets where journal entries were excluded if calories summed were below one or two standard deviation of the individual's average caloric consumption. Correlations were also made excluding journal entries with a caloric intake value of less than 100, 200, 300, 400, and 500. Every possible adjustment made failed to increase the average correlation of all nutrients compared while there were some increases in individual nutrition correlations. As shown in *Table 4,* no adjustments made to food journal entries used were able to significantly improve the

Pearson correlation between estimated nutritional averages. Still, for future analysis involving self-reported food journal entries, there must be methods devised to recognize incomplete journal entries.

Table 4: Correlations for adjusted food journals with adjusted daily entries.

No Modification		Exclude 1 SD Below		Exclude 2 SD Below		Exclude below 100 Calories	
Nutrient	**Correlation**	**Nutrient**	**Correlation**	**Nutrient**	**Correlation**	**Nutrient**	**Correlation**
Calories	0.6516	Calories	0.6485	Calories	0.6160	Calories	0.6535
Carbohydrates	0.6857	Carbohydrates	0.6882	Carbohydrates	0.6812	Carbohydrates	0.6845
Fat	0.7818 *	Fat	0.7431 *	Fat	0.7737 *	Fat	0.7708 *
Protein	0.7772 *	Protein	0.8024 *	Protein	0.7647 *	Protein	0.7910 *
Sodium	0.8068 *	Sodium	0.7801 *	Sodium	0.8149 *	Sodium	0.8195 *
Sugars	0.6717	Sugars	0.6714	Sugars	0.6592	Sugars	0.6728
Mean Correlation	0.7291	**Mean Correlation**	0.6694	**Mean Correlation**	0.6521	**Mean Correlation**	0.6703

Exclude below 200 Calories		Exclude below 300 Calories		Exclude below 400 Calories		Exclude below 500 Calories	
Nutrient	**Correlation**	**Nutrient**	**Correlation**	**Nutrient**	**Correlation**	**Nutrient**	**Correlation**
Calories	0.6652	Calories	0.6708	Calories	0.6531	Calories	0.6588
Carbohydrates	0.6855	Carbohydrates	0.6855	Carbohydrates	0.6837	Carbohydrates	0.6827
Fat	0.7722 *	Fat	0.7708 *	Fat	0.7613 *	Fat	0.7537 *
Protein	0.8049 *	Protein	0.8114 *	Protein	0.8065 *	Protein	0.8180 *
Sodium	0.8248 *	Sodium	0.8325 *	Sodium	0.8352 *	Sodium	0.8535 *
Sugars	0.6741	Sugars	0.6732	Sugars	0.6857	Sugars	0.6883
Mean Correlation	0.6749	**Mean Correlation**	0.6765	**Mean Correlation**	0.6742	**Mean Correlation**	0.6766

** Significant correlation between the nutrient estimation of the DHQIII and the average of the food journals.*

Comparison of the Two Food Journal Application Databases

Variation between food journal databases might also influence the reliability of nutritional elements. This was investigated by conducting independent searches for 4,428 meal names, which appeared in the participants food journal entrie in both food journal databasess. In the FatSecret database, 4204 of these meals were found while 4196 were found in the MyFitnessPal database. FatSecret notably had more data in terms of micronutrients in comparison to MyFitnessPal. After the initial search of these foods was retrieved from both FatSecret and MyFitnessPal's nutritional databases, correlation were calculated (*Figure 8*). The initial correlation (rho = 0.295) was extremely low and further investigation into the retrieved food profiles revealed a significant difference between default serving sizes. For example, the default serving size for tortilla chips for FatSecret was ten chips while the default for MyFitnessPal was the entire bag. Because of this, a new correlation was calculated, dropping any meal whose caloric estimate in one database's record

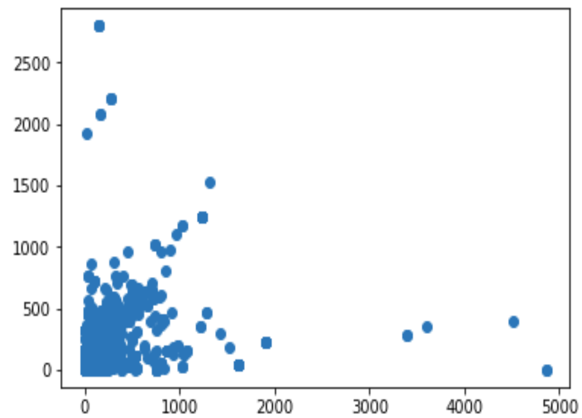

Figure 8: Scatter plot of calories from queried foods' in FatSecret and MyFitnessPal databases.

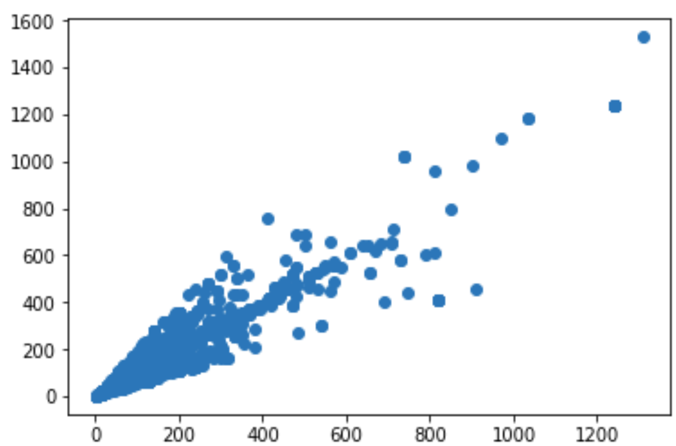

Figure 9: Scatter plot of calories from queried foods in FatSecret and MyFitnessPal post adjustment for serving size.

was twice that of the other database's record *(Figure 9).* This is an arbitrary method but was used as there were no other options to ensure equal serving sizes due to access constraints of MyFitnessPal's database. Web scrapping was used to access these data due to a lack of a MyFitnessPal API which did not allow for changing the default serving size to a query. All missing nutritional values were defaulted into zero for calculations.

In order to compare the variability between these two databases, a correlation was run for each nutritional value. Initial correlations (*Table 5*) were extremely low and further investigation revealed that the difference in correlation was likely due to a large difference in serving sizes between the two applications. Some default serving sizes differed as much as a thousand-fold. The correlations were recalculated, with each food item whose caloric difference was greater than two-fold was dropped. The new correlation still depicted considerable variability between databases despite adjusting for different serving sizes.

Table 5: Original vs new correlations (adjusting for serving size) between food journal databases for meal entries.

Nutrient	*Original Correlation*	*Adjusted Correlation*
Vitamin A	0.825	0.888
Fiber	0.726	0.894
Vitamin C	0.725	0.866
Iron	0.609	0.730
Cholesterol	0.575	0.895
Protein	0.538	0.908
Calcium	0.502	0.387
Carbohydrate	0.412	0.938
Sugar	0.392	0.825
Total Fat	0.331	0.947
Calories	0.295	0.957
Saturated Fat	0.236	0.835
Sodium	0.196	0.781

DISCUSSION

Analysis of similarities between the DHQIII and both food journal applications have shown a moderate correlation between each of the variables and several significant p values despite the small sample size. However, it would be beneficial to have a larger sample size to draw firmer conclusions. Gathering data and performing analysis for this study has revealed limitations that come with analyzing nutritional data in this manner. Most of these are the result of technicalities of gathering nutritional data from the applications. An application that does not provide an open sourced API is particularly difficult to work with because customized scripts must be written in order to data mine both the individual's data as well as the application's nutritional database. There is no foundation built for seamless data retrieval with any application, so a platform must be developed to retrieve data from a user's account. This leads to the need to set up data repositories and web application structures.

Additionally, while using different food journal applications may increase the number of users in a sample population, the nutritional data may become inconsistent when comparing between applications, as they did in this analysis. Each application is slightly different in their methods of updating and creating their nutritional data libraries. Finally, another of the largest hurdles comes in the user's data logging. For example, a user might be more likely to log their meals daily when trying a new diet in order to lose weight. This diet may only reflect a small period of their year but is the most logged in the application. Perhaps individuals make simple errors when entering portion sizes, stopped logging for a period of time, or didn't complete their log for the day. These are all factors that can hamper how well a food journal application reflects an individual's real nutritional intake. In order to bring this approach into a more research oriented and practical clinical use, these barriers must be overcome.

Future studies must keep these limitations in mind. Assuming that such food journal applications would be viable resources for integration into an individual's healthcare data, a method to confirm the validity of each food journal entry should be established. It is also reasonable to think that height and weight on each participant would be useful. In particular this could be used to calculate an individual's basal metabolic rate, or what should be their tailored caloric intake. Finally, it would be optimal to keep data collection to one food journal application in order to avoid differences between data resources. Of the food journal applications analyzed, FatSecret appears to have the most data for micronutrients and does not rely as heavily on user reported nutritional data as MyFitnessPal does.

This study supports the assumption that food journal applications are able to produce a reasonably accurate estimated average of a user's nutritional intake. Despite a small sample size, there were significant correlations of several dietary components between the food journals and the DHQ III. Future studies are warranted to provide further confirmation, optimally in comparison to a 24-hour recall assessment to further validate the use of these food journal applications. Future integration of food journal applications into clinical medical workflow will rely heavily on overcoming hurdles set in place by current food journal applications' technological infrastructure, as well as the classification of incomplete daily journal entries by the user.

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