MOBILE TOOL TO AID HEALTH BEHAVIOR CHOICES

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1. INTRODUCTION

The goal of this project is to develop and test a mobile application that will aid patients to make healthy behavioral choices. As obesity is one of the modifiable risk behavior factors for chronic diseases such as diabetes and heart diseases, the focus of this pilot study is on improving the self-efficacy and self-management activities for patients who are obese or are significantly overweight. Dietary choices have a significant impact on obesity. For patients at risk, it is important to identify and discuss both behavior and lifestyle modifications. These behaviors need to be tracked over time to ensure consistent patterns of change. In observational studies, a diet high in fruits and vegetables and low in saturated fats has been shown to reduce cardiovascular risk and cardiovascular events (Sotos-Prieto et al., 2015).

Food availability and access to high energy dense food has played a major role in the United States obesity epidemic. Accordingly, diet management applications, such as food journaling, e.g. myFitnessPal, and healthy recipes, e.g. Epicurious, for instance, have become increasingly popular. Furthermore, being informed of health risks is one of the major strategies for behavior change in health communication(Harle et al., 2008; Margolis et al., 2001). Accordingly, apps for calculating risks, e.g. Pan American Health Organization/World Health Organization (PAHO/WHO) CV Risk Calculator (Ordúñez and Tajer, 2015), have also gained attention to allow people to raise awareness about their long-term consequences. These applications, however, do not support people to make connections between their daily diet together with their outlook on long term consequences, that is, how their everyday eating patterns (e.g., behavior happening now) affect long-term health risks. Obese patients need increasingly specific, personalized strategies that can dynamically evolve as they encounter new challenges and needs over time. In any case, no systems are available to comprehensively support patients to understand personalized future consequences based on their dietary intakes.

Our proposed mobile app, mHeart, fills this gap by empowering patients to compare and make informed decisions that will affect their future health risks. Patients can use the app to set weekly goals and test what-if scenarios on how their diet intakes can influence future risks for heart disease. Through the seed funding provided by the MSU/Sparrow Center for Innovation and Research (CFIR), we have developed and tested the feasibility of our prototype mHeart system, which serves as a critical pilot work for future proposals to be submitted by our team. The feedback provided by patients who used the app have suggested that mHeart is an enjoyable, easy-to-use, and informative app. Analysis based on the diet information provided by the patients have also suggested that the median diet score for all mHeart users improves by more than 30% after 4 weeks of using the app compared to their initial diet score at the beginning of the study. The improvement in the diet score is as high as 45% for users who consistently use the app throughout the study.

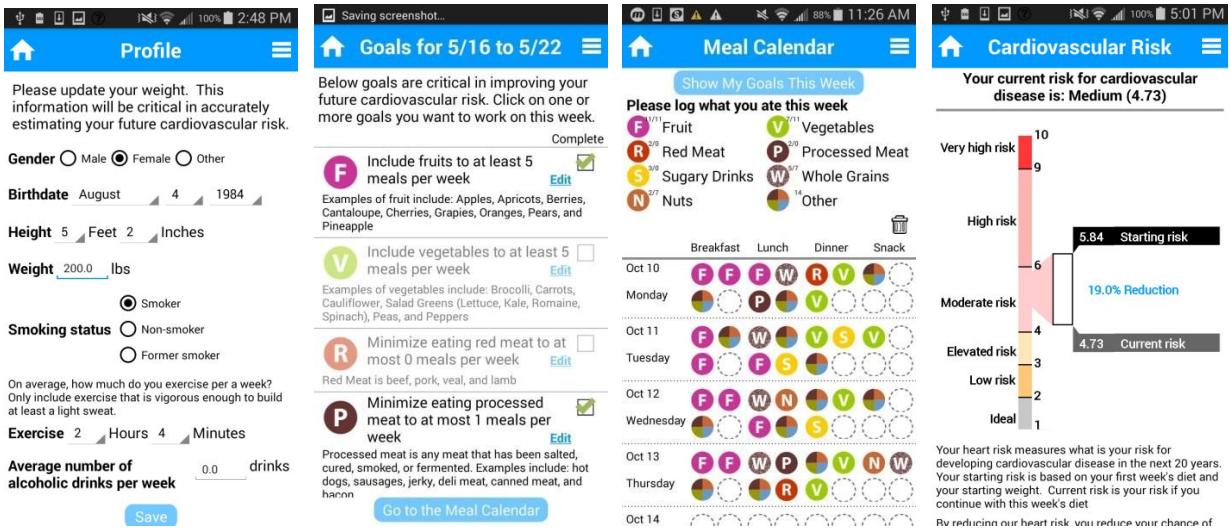
2. THE mHEART APP

Hundreds of mobile apps relate directly or indirectly to heart disease have been developed (Chow et al., 2016; Martínez-Pérez et al., 2013). These apps focus on improving one of the factors for heart disease risk, such as smoking cessation, exercise or weight loss. However, these apps do not show how the behavior change affects their outcomes to preventing heart disease (Azar et al., 2013; Boulos et al., 2014; Chow et al., 2016; DiFilippo et al., 2015; Eyles et al., 2014; Martínez-Pérez et al., 2013; Piette et al., 2015; Urrea et al., 2015). Apps related to heart disease focus on secondary prevention, when the user has already developed cardiovascular disease (Gandhi et al., 2017; Park et al., 2016). These apps include heart rate monitors, blood pressure tracking, and electrocardiogram (ECG) education for heart monitoring (Martínez-Pérez et al., 2013).

The mHeart app was developed under the Android platform. The app enables users to keep track of their diet intakes, the goals they have set, and their risk for heart disease. A screenshot of the different functionalities provided by the app is shown in Figure 1. First-time users are initially directed to the *Profile* screen to provide their demographic and other useful information for calculating their risk for cardiovascular diseases, including smoking status, exercise level, and weekly alcohol intake. Users can then log their daily diet intake in the *Meal Calendar* (Figure 1c). The *Meal Calendar* allows users to enter up to 4 food items per meal for breakfast, lunch, dinner, and snack. Users can provide the food information in two ways. First, they can drag a food category icon, e.g. Fruit, to one of the meal slots. This adds one serving of that category to that meal. Second, users can tap an icon within the calendar (for a specific day and specific meal) to see a popup. This popup allows users to increase the number of servings and add the name of the food they consumed.

The mHeart app suggests users to reduce their risk with guided diet goals which users can modify as they see fit, as shown in Figure 1(b). Users can select the food categories they want to actively work on or deactivate a goal. If one of the goals for unhealthy categories is active, users will be notified on the *Meal Calendar* if they exceed the total number of servings the goal said they should not exceed. The Goals screen also includes a checkbox that shows the status of whether the user has met the goal for the given week.

The selection of the categories of food provided in the *Meal Calendar* and *Goals* were those that had a direct impact to the risks for heart disease, per the risk model developed by Chiuve et al. (Chiuve et al., 2014). This model considers multiple factors that contribute to the risk for heart disease, which includes the person's diet. The factor that considers the contribution of the diet is called the *Diet Score.* A higher diet score leads to a lower risk of heart disease. The *Meal Calendar* also includes the Other category to log foods not included in the provided categories. On the *Goals* screen, the default number of servings suggested for *healthy categories*–fruits, vegetables, whole grains, and nuts–is the minimum needed to reduce risk suggested by the model. *Unhealthy categories*–red meat, processed meat, and sugary drinks–were those suggested as 0 servings per week by the risk model, thus the goal is by default set to 0 for these categories. The user is prompted every week to set goals.



(a) Profile (b) Goal (c) Meal Calendar (d) Risk Calculation

Figure 1: Screenshots of the mHeart App

A novel feature of the app is that it allows users to determine their heart disease risk in real-time based on their meal plan recorded for the given week. The *Cardiovascular Risk* screen, displayed in Figure 1d, calculates changes in their risk of developing heart disease for two weeks, the week when they started using the app and the current week. The risk value is normalized to a range between 1 and 10. This choice is based on feedback from our focus groups. A risk score *R* displayed in mHeart can be interpreted as the person is (*R*-1)/2 times more likely to develop heart disease than someone who is normal weight and living a healthy lifestyle. For example, a person with a displayed risk score of 9 would be four times more likely to develop heart disease than an individual with a healthy lifestyle (Chiuve et al., 2014). The ideal risk for an individual, as displayed on mHeart, is between 1 and 2.

3. METHOD

The mHeart app was designed through a series of focus groups conducted between December 2015 and February 2016 to assess the feasibility, acceptability, and efficacy of the app. In total, 13 participants were recruited from the Sparrow weight management clinic for our focus group study. The goal of the focus group is to solicit feedback on how the mobile app should be designed. Specifically, members of the focus group were asked questions about their current use of mobile phones, their diet management practices, as well as their opinion on the app design. The participants were presented with multiple screenshots of the mHeart app interface and were asked what they thought was the purpose for each app function, how they would use it, and what they liked or disliked about the app. The comments and suggestions provided by the focus groups were then used to improve the design of mHeart.

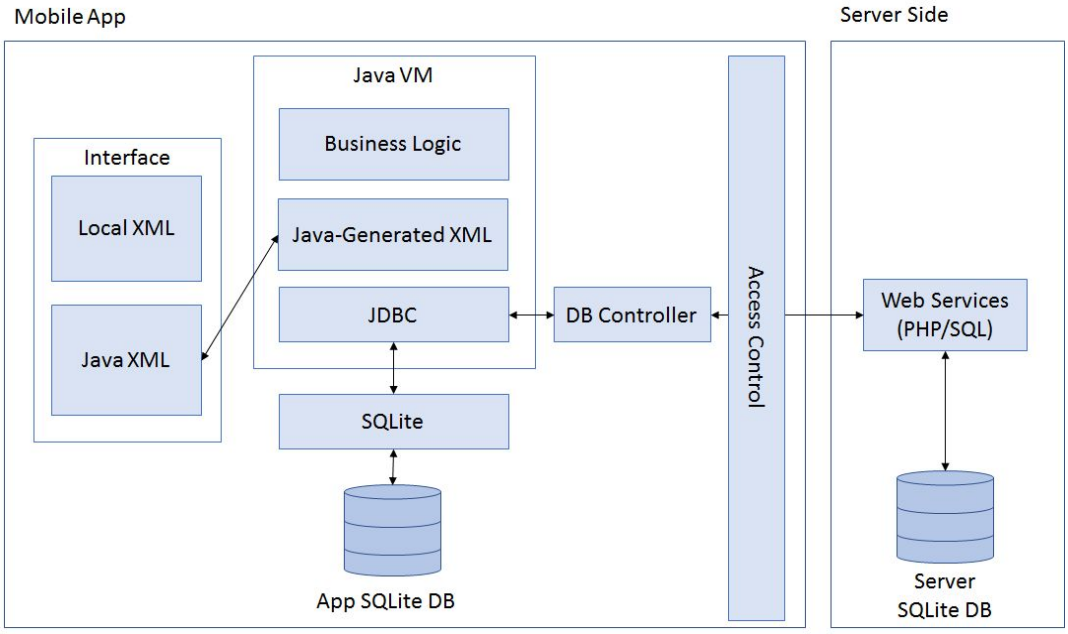


Figure 2: System architecture for mHeart design.

Figure 2 shows a schematic diagram illustrating the system architecture of mHeart. The mobile app was developed in XML and Java using Android Studio. In addition to rendering the graphical user interface, the system tracks the mobile app usage (when the app was opened, what food items were

logged, which goals were set, etc.) and records the information in a database. Since the smartphone may not always be connected to the Internet, the usage data is initially stored on the local SQLite database. The DBController module will automatically push the data to the centralized database server when the phone is detected to be online. To preserve their anonymity, the users were assigned randomized IDs when recording their information into the database. A schema diagram summarizing the structure of the data tables and their relationships is shown in Figure 3.

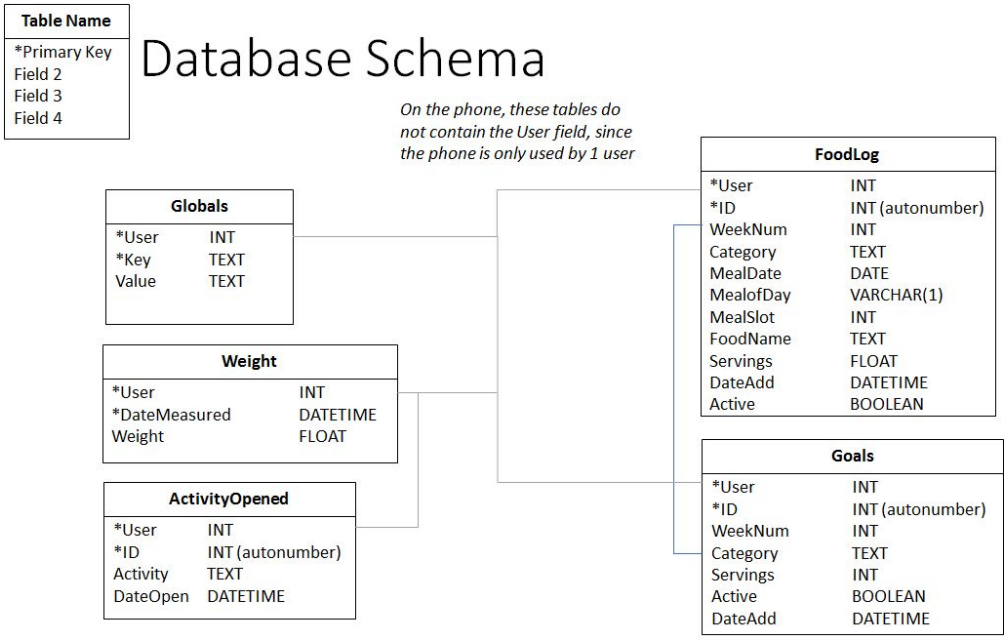


Figure 3: Database schema for storing the mobile app usage data.

We applied various techniques to analyze the data collected from the mobile app. First, a time series was created to summarize the daily or weekly app usage frequencies for each user. The time series was normalized and then clustered using the k-means clustering algorithm (Dubes and Jain, 1988). The clustering allows us to identify groups of users who share similar usage patterns. In addition, the clustering can also be used to detect outliers, i.e., users whose app usage behavior differ significantly from other users. We also analyze changes in the diet scores of users in each cluster. Although reducing the risk for heart disease among users is one of the goals of this research, given the short duration of the study and the fact that the risk for heart disease depends on other factors besides diet intakes (e.g., hours/week of exercise, smoking status, and alcohol consumption), we assess the effectiveness of mHeart in terms of improvement in the diet score of the users instead of changes in their risk for heart disease. To do this, a weekly diet score was computed for each user based on the data recorded from the Meal Calendar. We monitored the changes in the diet score of the users in each cluster over time. Our hypothesis is that users who consistently used the app will show improvement in their weekly diet score, suggesting that the app is helping them to make healthier dietary choices.

Finally, at the end of the study, the participants were interviewed to gather feedback about their experience using the mobile app.

4. RESULTS

We initially recruited 102 patients who agreed to participate in the study. The participants were required to visit the Sparrow weight management clinic to measure their weight, blood pressure, and fasting blood sugar. Unfortunately, many of the participants did not respond to our subsequent emails and phone calls. At the end, only 32 participants had completed all the tasks required for this study. The average age of the participants was 58 years old. 17 of the patients were diabetic and the rest were not. 1 participant is currently a smoker, 12 were former smokers, while the remaining 19 never smokes. The study took place over a 7-week duration. The participants were required to use the app for the first 5 weeks. At Week 0, the participants were asked to log their diet information only to establish a baseline of their normal diet. They were not required to set goals during Week 0. In Weeks 5 and 6, the participants were given the option to continue using the app.

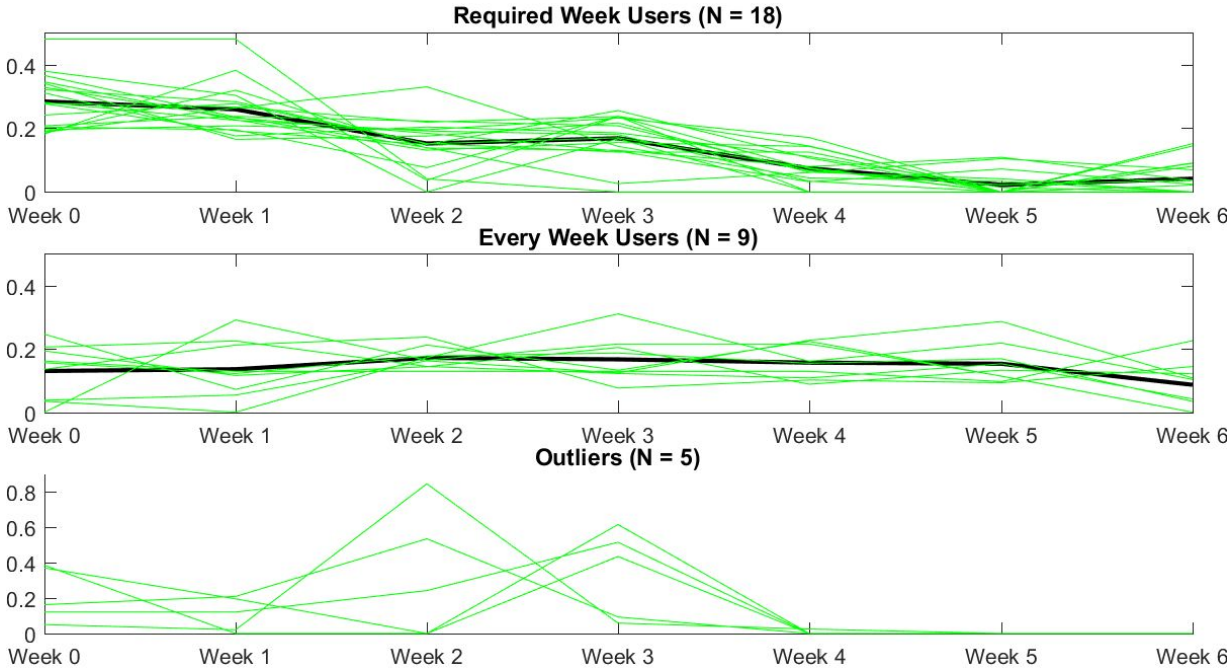


Figure 4: Normalized frequency of app usage by week. Excluding the outliers, two clusters were found: (1) Required Week Users, who stopped using the app when they were no longer required to use it and (2) Every Week Users, who continuously used the app throughout the study.

mHeart is designed to act as an intervention to help users modify their diet and reduce their heart disease risk. To assess its effectiveness, we first analyzed the general usage of the app. We found many participants used the app consistently each day of the week and throughout the study. The normalized frequency of mHeart use by the participants across each week of the study is shown in Figure 4. Based on the clustering results, we found 84% of the participants used the app regularly throughout the first 5 weeks of the study. More than one-fourth of them continued using the app after Week 4 even though they are not required to do so. Among the participants who stopped using the app after the first four weeks, the primary reason they gave was because they were already using another diet tracking app, such as myFitnessPal, and did not like logging their diet information into two separate apps on two different phones (since mHeart is only available on Android devices and had to be installed on a borrowed phone for participants who use iPhone as their primary phone). These participants noted that they would have continued to use mHeart if it was available on iPhone.

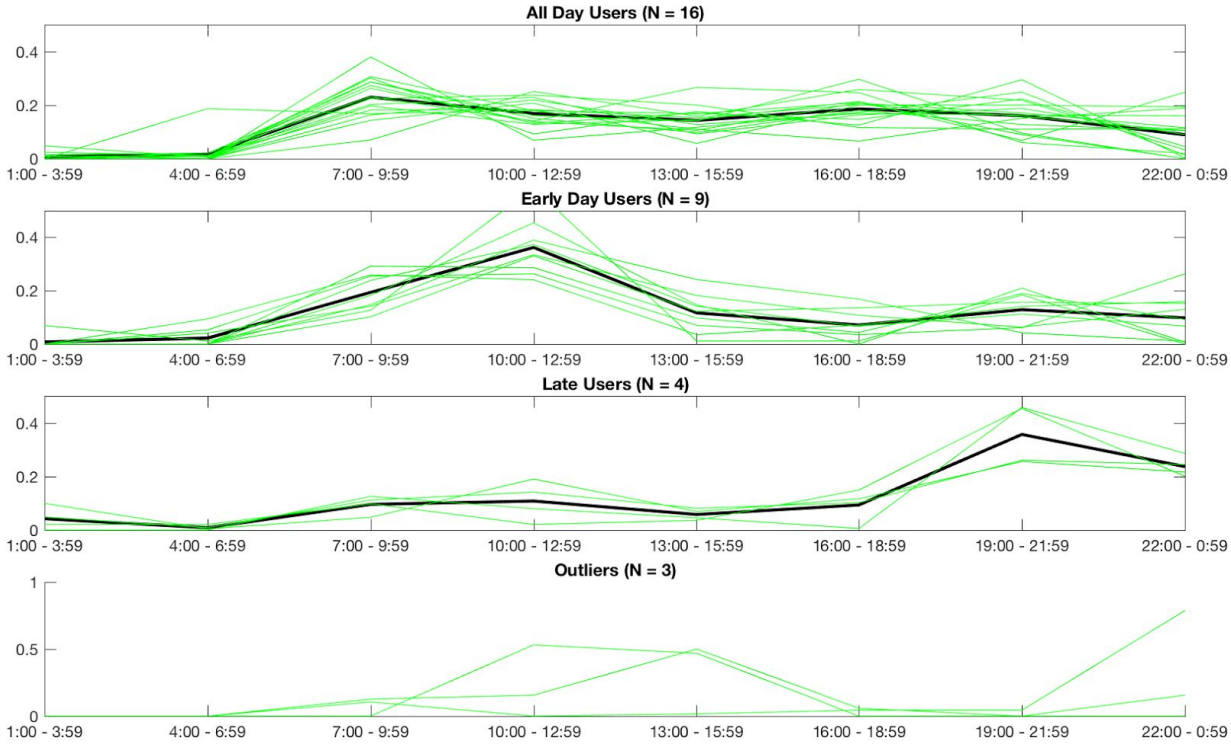


Figure 5: Normalized Frequency of App Usage by Time of Day. Excluding the outliers, three clusters of usage were found. Early day users use the app primarily in the morning and early afternoon. All day users use the app consistently throughout the day. Late users used the app mostly at the end of the day.

It is important that the participants use the app throughout the day to log their diet information as they will more likely remember what they ate compared to those who logged their diet irregularly. The clustering results shown in Figure 5 suggest that half of the participants used the app consistently throughout the day while 28% of them used the app mostly in the late morning and early afternoon, which is typically around lunch time. Four participants used the app only in the late evening. Users who only used the app at the end of the day may have forgotten details about what they ate, e.g., amount consumed, and would also be limited in the amount of intervention a health app can provide.

To determine whether participants are improving their diet, we examine the diet score from the risk model. If the diet score increases, then the risk for heart diease will decrease. We found that participants increased their diet score from Week 0 to Week 3, shown in Figure 6. The median, designated by the red line, increased from 1.424 to 2.1397. In Week 4, the median diet score decreased slightly, possibly as a result of participants logging less food, but it remained higher than the Week 0 diet score. In fact, the change in median diet score from Week 0 to Week 4 is more than 30%.

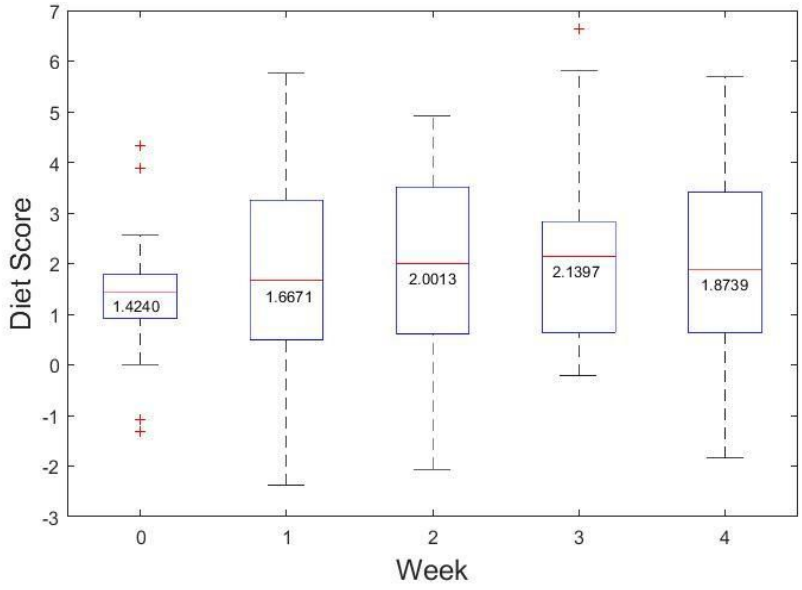


Figure 6: Diet score of users for each week of the study. Participants are increasing their diet score, i.e. reducing their heart disease risk, from Week 1 to Week 3 of the study.

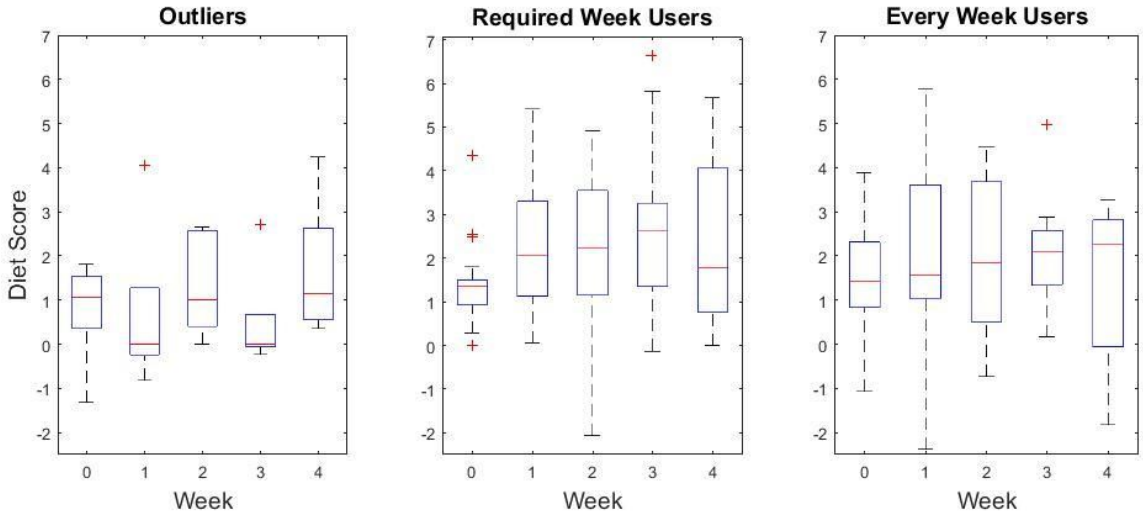
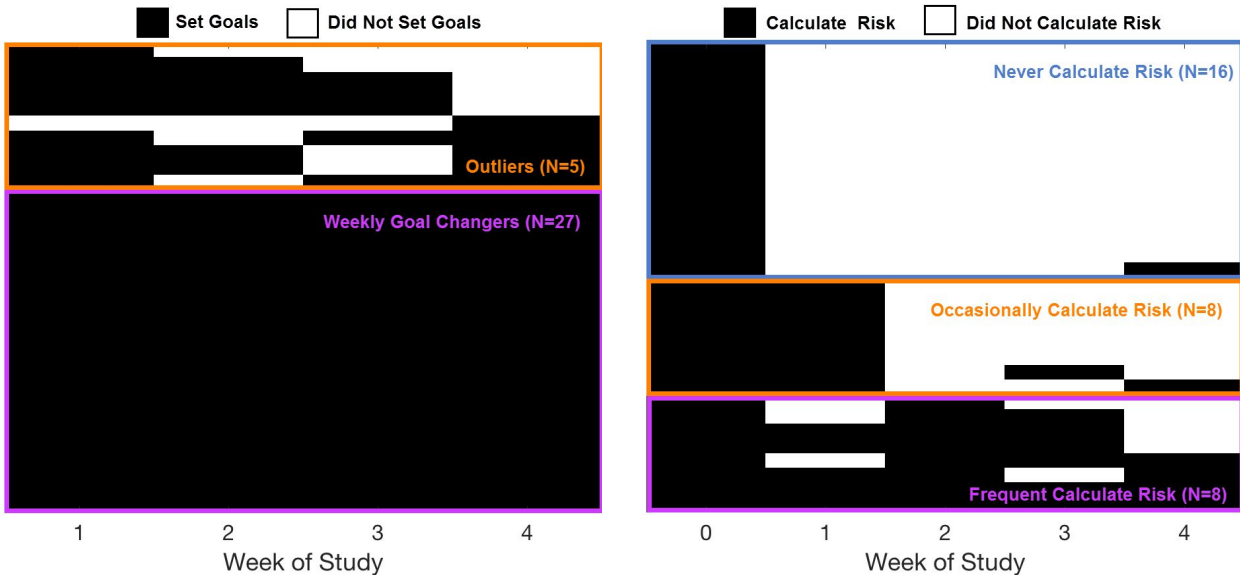


Figure 7: Diet score of users for each week based on their usage across the study. Participants who used the app only during the required weeks increase their diet score during those required weeks. Participants who used the app consistently every week of the study increased their diet score every week.



(a) Goal Setting

(b) Risk Calculating

Figure 8: Weekly usage of the Goals and Risk screens. Black indicates user set or modified a goal or visited the Risk screen to calculate their heart disease risk. 84% of the participants set or modified goals every week of the study. 25% of the participants calculated their risk frequently.

We also found that participants' overall usage of the app affects their diet score. As shown in Figure 7, participants who used the app consistently (denoted as the cluster of "Every Week Users") increased their diet score from Week 0 to Week 4. Participants who used the app during the required weeks improved their median diet score through Week 3, but had a decreased diet score in Week 4. Despite the decrease, their Week 4 diet score was still higher than their starting diet score in Week 0.

Next, we analyze how participants used the goal setting and the risk calculation screens. Figure 8a shows that 84% of the participants set their goals every week. In contrast, Figure 8b shows that only 25% of the participants checked their risk for heart disease frequently. Furthermore, 50% of the participants did not check their risk after the first week of the study. The participants responded that they either forgot they could check their heart disease risk or they were not interested in heart disease. For example, one participant explained "*I didn't know it was in there*" while another mentioned that "*If I had heart trouble, it would be a good visual. I don't have any problems.*" Nevertheless, participants who checked their risk regularly generally appreciated the information, though they did not always like the outcome. One described the experience with the risk calculation screen as "*I liked that, but it was kinda scary*." Other participants expressed concern their risk was too high, "*Starting out with a risk like at 58 and you want me to get down to like 3?*".

Analyzing the diet scores of participants based on whether they set goals every week, we found that participants who set their goals regularly increased their median diet score from Week 0 to Week 3, as evidenced in Figure 9. In Week 4, we saw a slightly lower median diet score than Week 3 but remains higher than the median diet score for Week 0. Participants who did not set goals every week, i.e. outliers, had no significant increasing trend in their diet scores.

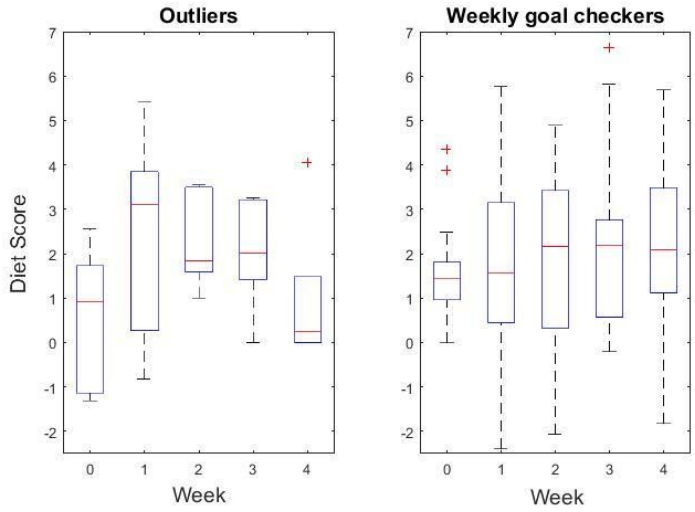


Figure 9: Diet score of users for each week based on their goal setting activity. Participants who set goals every week increased their diet score from Week 0 to Week 3.

5. DISCUSSION

From the feedback received at the end of the study, we surmise that mHeart was an enjoyable and informative app. Among the responses provided by the participants regarding the food logging part of the app include "*I was surprised how easy it was. A couple of times I got a little too happy with it*". "*I like the click and drag thing. That was kind of... Made it easier although sometimes it didn't seem to recognize that I was trying to pull something*". Participants also expressed they liked the clean display that visualized their diet each week. "*The thing I really likes about his app was the quick visual that I could get from a day and then also a week. I found it really helpful as a visual learner*". One participant mentioned visualizing their diet helped them improve their diet. "*And honestly structuring it, like you start out the week being Monday, you cruise along to Friday and see that you haven't had any fruits and vegetables, so then you eat smarter on Saturday and Sunday when you would normally go off track*".

Most participants used the app consistently throughout the main portion of the study. Although many users stopped using the app after the main portion of the study, their feedback suggests it was less due to qualities of the app and more to do with logistics of using the app as a temporary, prototype solution. Several participants were primarily iPhone users who found it challenging to juggle two phones. If mHeart was available for iPhone, they said they would continue to use it. The second external factor was several participants were required by their doctor to use another health app, myFitnessPal, to track their diet and they disliked logging their diet in two apps . With numerous diet apps available, an app focused on reduction of risk of heart disease that can interface with other apps to gather diet information would motivate users to use that app. Users would be alleviated from the hassle of logging their diet twice, and instead can open the app and get the information they need to reduce their risk.

6. CONCLUSIONS

In this study, we design a mobile app called mHeart to promote diet change and a healthier lifestyle among patients who are overweight or obese. We analyzed how the participants used the app and the

effect of the app usage on the diet score of the participants. The preliminary results based on a sample of 32 participants looked promising, demonstrating the potential of mHeart to improve the diet scores of the participants. The results of this pilot study also provide important insights into the appropriate features and design of a mobile app that can effectively help participants to reduce their risk for heart disease.

The primary barriers to implementing this study were participant recruitment and scheduling. The majority of participants who signed up for the study could not be reached using their provided contact information. Several of them indicated they did not want to participate because the app was not developed for their iPhone and participation in the study would require them to carry two phones. Participants also withdrew from the study due to unavailability during the meeting times. Participants would have their fasting weight, blood pressure, and blood sugar measured at the beginning of the study and at the end of the required weeks of the study. Based on the availability of project personnel, these meetings occurred on Tuesday mornings. Participants who could not meet at these times were not able to participate in the study.

Our next steps are threefold. First, we plan to expand this study to recruit more participants. To fund this effort, we plan to write an NIH proposal in June Cycle in collaboration with Dr Jina Huh to help evaluate mHeart in other regions (such as San Diego). This effort will assist us to determine whether the findings from our pilot study can be generalized to a broader population. Second, we plan to deploy the app in a study for a longer duration. Habits take more time to develop than the duration of this study. In particular, trends are more likely to emerge in a longer study. Finally, we plan to improve the design of mHeart to enhance user experience based on the feedback provided by the participants of our pilot study.

7. ACKNOWLEDGMENT

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