A Culturally Sensitive Mobile Application to Improve Self-Care in Patients with Type 2 Diabetes: A Design Thinking Methodology

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Abstract

Background: Mobile applications (apps) have demonstrated effectiveness in supporting self-care in patients with type 2 diabetes. However, the absence of cultural relevance in these apps may diminish user engagement, especially among specific ethnic groups. Portuguese Americans, a unique population with specific needs in diabetes management, appear to be an understudied group in this regard, with a lack of published research on culturally tailored diabetes apps designed for their unique needs and preferences.

Objective: This study aimed to develop a prototype app for Portuguese Americans with T2DM using the design thinking approach.

Methods: The development process was guided by the five-step design thinking methodology, a rigorous approach suggested by the Hasso-Plattner Institute of Design at Stanford University. Phase 1 of this study involved the first two steps: empathize and define. Phase 2, the focus of this paper, comprised the following two steps: ideate and prototype, during which the prototype DiaFriend app (Version 1) was designed and developed. Phase 3, the fifth step, test, entails the ongoing evaluation of the app.

Results: The DiaFriend app (Version 1), meticulously designed with insights from Portuguese Americans with type 2 diabetes residing in Massachusetts, comprises five features: blood glucose monitoring, weight tracking, carbohydrate tracking, exercise log, and medication reminder. The carbohydrate tracking feature was explicitly tailored to correspond to Portuguese food culture. This paper details the app's development, the creation of the frontend interface, and the challenges faced during the backend development, which further underscores the meticulousness and dedication in the ideate processing and beginning creation of the prototype.

Conclusions: The research team firmly believes that the DiaFriend app (Version 1), with its unique and crucial cultural sensitivity, has the potential to significantly improve self-care among Portuguese Americans with type 2 diabetes. This innovative approach sets the stage for a more culturally tailored and effective approach to diabetes management, underscoring the importance of cultural relevance in healthcare technology.

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Keywords: cultural sensitivity, design thinking, mobile application, self-care, self-management, type 2 diabetes

Introduction

The number of people with diabetes in adults aged 18 years or older in the United States (U.S.) reached 38.4 million, or 11.6% of all U.S. adults in 2021[1]. Between 2002 and 2018, the overall incidence of diabetes significantly increased, with approximately 16.8 million adults aged 18 years or older with diabetes visiting the emergency department, with 267,000 for hyperglycemic crisis (11.4 per 1,000 adults) and 202,000 for hypoglycemia (8.6 per 1,000 adults) [2].

Approximately 1.5 million people of Portuguese descent live in the U.S., with over 265,000 residing in Massachusetts, the second-highest concentration of Portuguese Americans [3]. Despite being one of the largest ethnic groups in Massachusetts and several other states, the health status, issues, and disparity among the Portuguese American population are not well-documented [4]. While the prevalence of diabetes among Portuguese Americans is not well documented, statistical data indicates a significantly higher prevalence of diabetes among numerous racial and ethnic minority populations in the U.S. relative to non-Hispanic White Americans [3]. The Portuguese Americans

represent a distinct ethnicity with unique cultural traditions, particularly dietary practices. Some aspects of these practices, such as the carbohydrate-rich, fatty, and sugary nature of many traditional Portuguese dishes, desserts, and pastries, may increase the risk of developing diabetes and pose challenges in improving self-care behaviors necessary for diabetes self-management.

Type 2 diabetes (T2DM) is a complex chronic condition that requires ongoing self-management strategies and self-care behavior modification, requiring patients to assume an active role in making daily decisions that impact their health and well-being. Effective diabetes management requires substantial lifestyle modifications with physical and psychological adaptation to maintain healthy behaviors. Mobile applications (apps) have provided effective self-management support for patients with T2DM, leading to enhanced glycemic control [5–8].

Mobile applications have the potential to facilitate improved T2DM self-care by providing patients with convenient access to monitoring and tracking features blood glucose level monitoring and carbohydrate counters) educational resources, and personalized support. However, many existing apps lack user-friendly interfaces and personalization of features, fail to accommodate diverse cultural perspectives, and do not offer tailored experiences tailored to individual needs and preferences [9–11]. Moreover, multi-step tasks, repetitive data-entering processes, and complicated system navigation are time-consuming and require technological skills. It could be burdensome and a significant obstacle for people with T2DM to adopt and integrate apps into their daily lives. To compound these challenges, those who are not technologically savvy could find apps as an obstacle to improving self-care behaviors and supporting self-management of T2DM [5,12–15]. In addition, social determinants of health, such as racial and ethnic background, limited health literacy levels, and socioeconomic disadvantages, could impede the adoption and utilization of diabetes self-management apps. Existing apps that lack personalization and cultural sensitivity may not support the unique needs and cultural contexts of Portuguese Americans with T2DM. This lack of tailored support can lead to reduced app engagement and diminished adherence to self-management.

While mobile apps have the potential to provide significant benefits for self-management, patients with T2DM may encounter various challenges that hinder their effective use of these tools. Therefore, a mobile app designed to support T2DM self-management should incorporate a user-friendly interface with features that are customized to cultural preferences, such as dietary intake, lifestyle, and support from family and healthcare providers [6,11]. Portuguese Americans with T2DM have distinct preferences that influence their behavior and expectations regarding technology; therefore, they require a user-centered app customized and sensitive to their culture.

The design thinking methodology, a user-centered approach that prioritizes cultural sensitivity, has recently gained popularity in mobile app development to enhance user engagement and improve self-management outcomes [6,16,17]. This methodology involves app users developing an application that better meets their needs and expectations. To date, there are no culturally tailored apps for diabetes self-management in Portuguese Americans with T2DM. This study aimed to develop a prototype app for Portuguese Americans with T2DM using the design thinking approach.

Methods

Study Design

The multidisciplinary research team comprised two nurse educators, an application development expert, and two graduate research assistants with mobile application development knowledge from the university's Computer and Information Sciences Department. The design thinking methodology developed by the Hasso-Plattner Institute of Design at Stanford University (Stanford D. School) [18] was used to develop the DiaFriend app (Version 1) for Portuguese

Americans with T2DM. Ethical approval for this study was obtained from the University Institutional Review Board (IRB Ref. No: 22.030)

This study consists of three phases that comprise five distinct steps of the Standford D. Schools design thinking methodology: *empathize, define, ideate, prototype, and test* [18–20]. Phase 1 of the app development in this study incorporated the first two steps of the design thinking methodology (step 1: *empathize* and step 2: *define*), in which 22 participants described the app's features and functions. The findings from Phase 1 informed the direction of Phase 2. Phase 2 comprised the following two steps (step 3: *ideate* and step 4: *prototype),* in which the prototype app was designed and developed. Phase 3 (step 5: *test)* will provide the app evaluation that is currently underway. This paper will describe Phase 2 of the prototype development, the DiaFriend app. The following section presents the app development process.

Results

The DiaFriend prototype app was developed using the design thinking methodology (step 3: ideate and step 4: prototype). During step 3 *(ideate),* the multidisciplinary research team met multiple times to brainstorm and discuss ideas for the DiaFriend app framework, programming language, features, and app functions. Due to the funding of this project coinciding with the COVID-19 pandemic, the research team's institution prohibited in-person interactions with study participants. As a result, the information gathered during the ideation phase about the app design originated exclusively from the research team members.

Flowcharts were utilized to illustrate the step-by-step process of navigating the app, which is the flow of the screens the user will interact with to perform specific tasks while using the application. Throughout the iterative design process, the flowcharts underwent multiple revisions. During this process, the research team acknowledged that no idea should be dismissed as inherently wrong and that not every idea represents the optimal solution. This approach fostered a creative and open-minded environment, encouraging the exploration of diverse possibilities. Upon the culmination of this iterative design phase, the team employed a consensus-driven approach to determine the optimal design framework explicitly tailored for Portuguese Americans with diabetes, our target user population.

Based on the participants' recommendations in Phase 1, the researchers prioritized and selected five essential features to be incorporated into the initial version of the DiaFriend app. These features include blood glucose monitoring, weight tracking, carbohydrate tracking, exercise logging, and medication reminders. For weight tracking, the basal metabolic index (BMI) was used. While more than five features were suggested, the research team first focused on implementing these five essential functionalities, intending to add more features in future iterations based on user feedback in the project's next phase (Phase 3).

Because the DiaFriend app does not require sensitive personal information, a login process involving a username and password was omitted. This design will reduce the burden on users by eliminating the need to create and memorize a password, thereby providing a more seamless and accessible user experience. Figure 1 illustrates the tree model of the final flowchart. The flowchart begins with the entry point to the app (home page screen) and ends with the exit point, where the user completes tasks of each function.

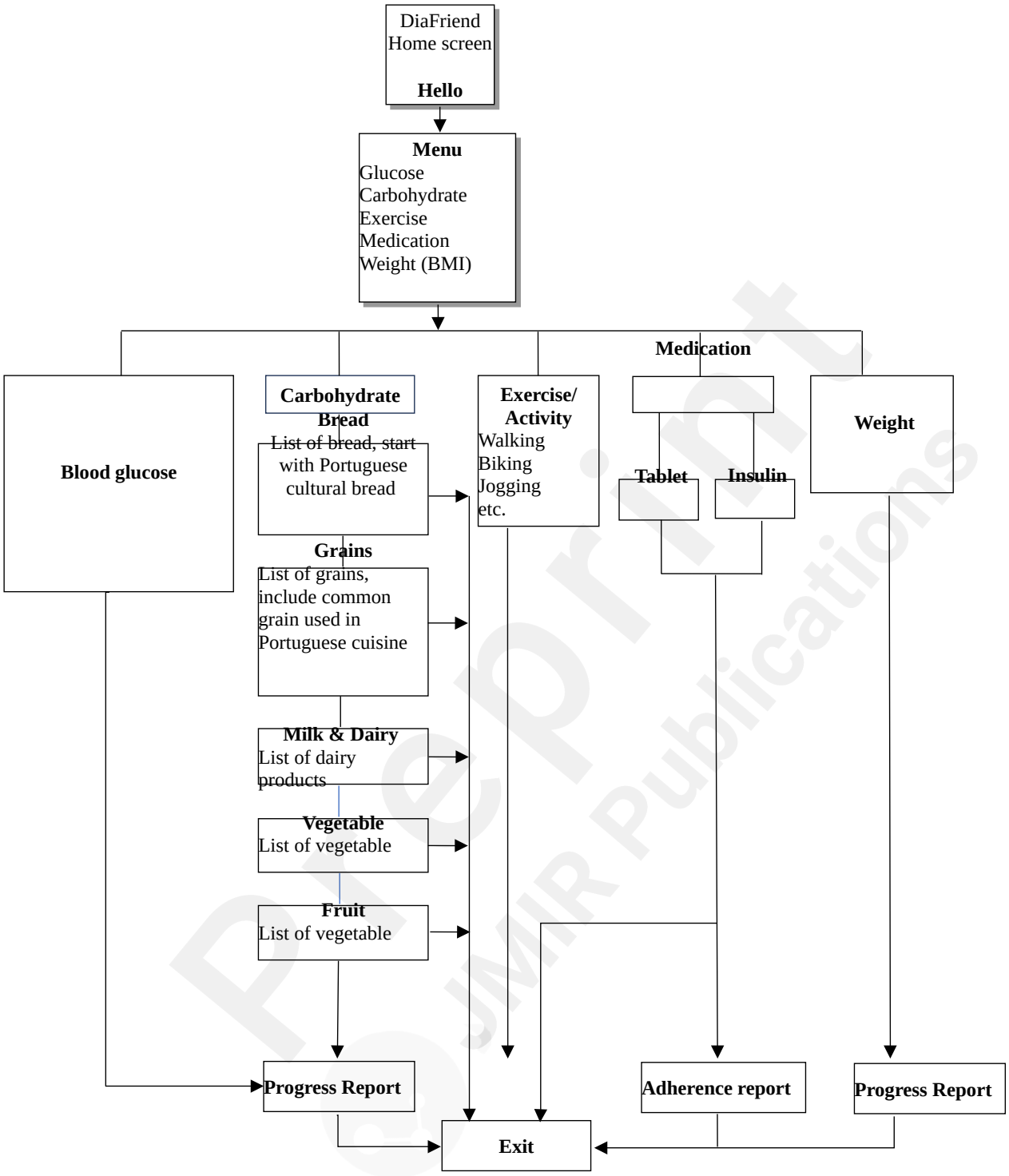

Figure 1 DiaFriend app flowchart

In step 4 (*prototype)*, the prototype app development stage, the five features (blood glucose monitoring, weight tracking, carbohydrate tracking, exercise logging, and medication reminders) were built into the app. Flutter Software, a single codebase version 2.2, was used to build the DiaFriend prototype application; therefore, the application can run on both Android and iOS smartphones. In adherence to intellectual property rights, the research team designed and created the app logo and graphic symbols for each feature (Figure 2).

The glucose monitoring feature, which included a customizable list of testing times, enabled

users to select the times recommended by their physicians and track their blood sugar levels in real time. As suggested in Phase 1 of the study, the input can be presented as a comprehensive list of all the results in numerical format or as a visual graph (Figure 3).

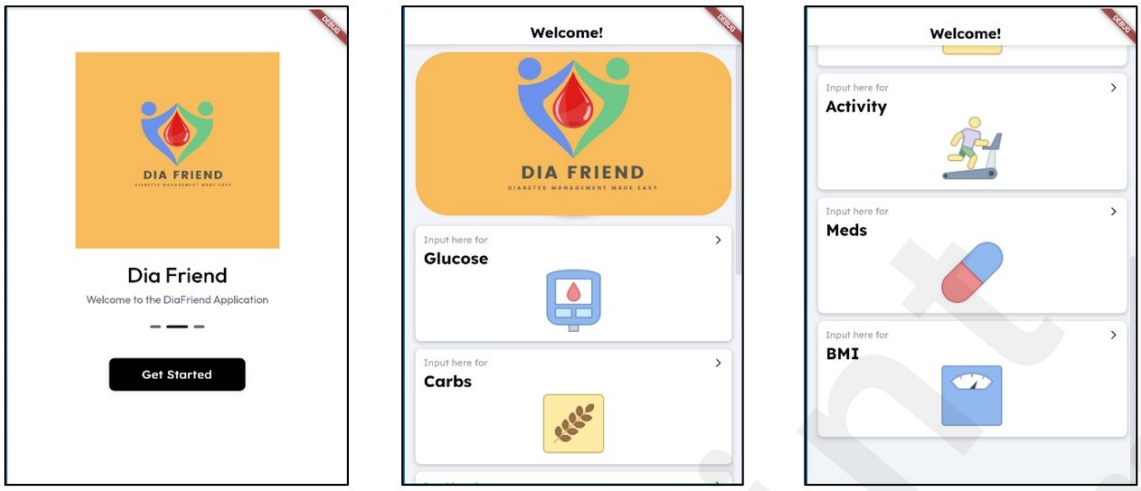

Figure 2 Home screen and feature screen.

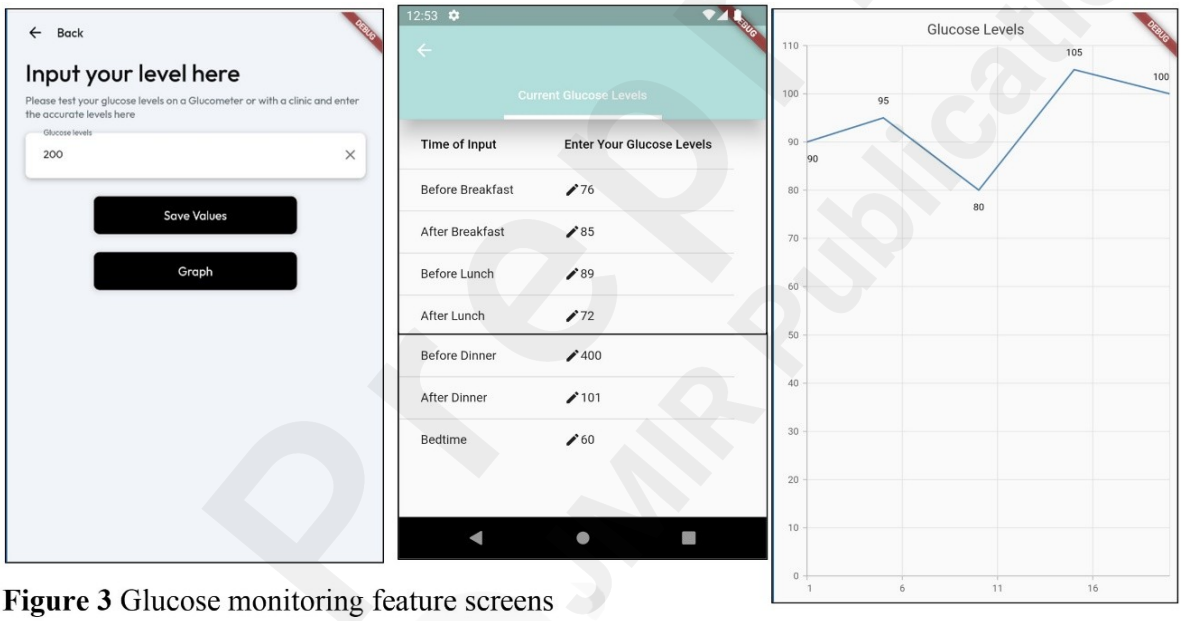

Figure 3 Glucose monitoring feature screens

The carbohydrate tracking feature included food databases tailored to Portuguese food culture, incorporating Portuguese American cultural dietary choices such as various types of Portuguese bread, beans, sausages, pastries, and desserts. The database provided nutritional information (e.g., calories, carbohydrates, etc.) for each food item, enabling users to make informed decisions about their dietary intake. To enhance the user experience and make food selection more accessible, the app displayed pictures alongside the food names, offering visual cues that facilitate quicker recognition and choice compared to a text-only list (Figure 4). Moreover, fresh and dried figs, which are not commonly used in American cuisine but are staples in Portuguese dishes, were added to the food database to make it easier for users to track their calorie intake. The DiaFriend app incorporates various images to enhance user experience and engagement. However, due to copyright restrictions, the images used in the app cannot be reproduced or displayed in this paper.

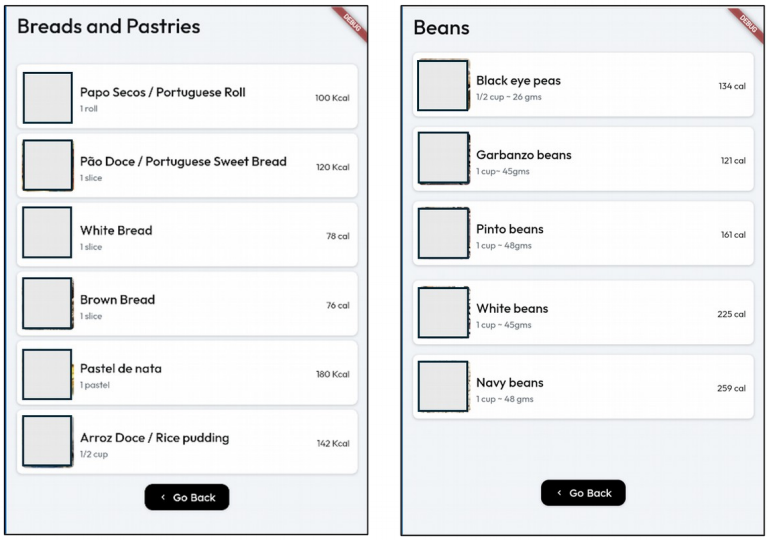

Figure 4 Food choice

For the exercise feature, walking was prominently featured on the exercise screen because most participants interviewed in Phase 1 indicated that walking was their primary form of exercise. The research team intended to create a visually appealing and easily recognizable image design that displayed estimated calorie expenditure per mile, enabling users to make informed choices.

At this stage, the medication tracking feature permitted users to input their medication name, dosage, and time and establish reminder times. To enhance usability, the researchers plan to incorporate a pre-populated list of diabetes medications, allowing patients to select their medications without the need for manual input.

The current stage of the diabetes prototype app's development includes a functional frontend interface that incorporates the five selected features. The frontend user interface was established during the initial development of the DiaFriend app; however, improvement was still necessary to ensure consistency in feature nomenclature and component design. The backend infrastructure and application programming interface (API) still need to be developed to ensure full functionality and data management. Due to the specialized nature of backend development, the research team acknowledges the need for collaboration with experts in this field to complete the prototype. Future steps will involve partnering with experienced backend developers to design and implement the necessary backend components, such as databases, server-side logic, and communication interfaces between the frontend and backend.

Discussion

Mobile apps can effectively support self-care practices among individuals with type 2 diabetes. However, many apps lack cultural relevance, which may negatively impact user engagement, particularly within specific ethnic populations. Portuguese Americans, for instance, seem to be an underrepresented group in this context. Employing steps 3 and 4 (*ideate and prototype*) of the designed thinking methodology, the research team developed the DiaFriend app, a culturally sensitive app that supports Portuguese Americans with T2DM.

The DiaFriend app incorporates five core features: blood glucose monitoring, weight tracking, carbohydrate tracking, exercise logging, and medication reminders. As a diabetes self-care app, these features are essential for supporting effective diabetes self-management [11,15,21,22]. While existing apps that help patients with diabetes manage their blood sugar, carbohydrate intake, and exercise are often built as separate, standalone applications, requiring patients to use multiple apps to track each aspect of their progress, the DiaFriend app integrates all these features into a single, user-friendly platform. Therefore, streamlining the self-care monitoring behaviors necessary

for diabetes self-management into a single app should enhance user engagement and adherence [23].

T2DM is a chronic disease that requires lifelong self-care behavior modification, including dietary changes and regular exercise, often influenced by an individual's cultural background and ethnicity. Previous studies have indicated the need for culturally sensitive and personalized apps to support self-care for specific cultural and ethnic populations [6]. Culturally tailored apps are likely to increase users' motivation to engage in behaviors, such as caloric restriction, healthy eating, and physical activity, be perceived as personally relevant, and lead to a greater likelihood of behavior change [24]. Moreover, a dietary tracking feature should incorporate culturally relevant food databases in features with visual aids to facilitate effective monitoring of calorie intake [10]. Therefore, the carbohydrate tracking feature of the DiaFriend app, which incorporates Portuguese American cultural dietary choices and food images alongside the food names, is one of the significant strengths of the app.

The DiaFriend app provides a carbohydrate tracking feature tailored to Portuguese food culture to ensure cultural sensitivity. Portuguese American cuisine has its specialty dishes, such as a soup made by soaking country bread in a broth, some stew containing tripe, beans, linguiça sausages, cured ham, chicken, and vegetables, and typical desserts and confections, such as flan (a baked custard topped with a caramelized sugar sauce) and pastel de nata (Portuguese custard tarts), which may be served as dessert or used as icing on a cake [25]. Therefore, the food database in the DiaFriend app includes Portuguese American cultural dietary choices from which users can select the food they consume.

Previous studies indicate that a more user-friendly app is desirable; users expect less effort in learning, tracking data, and understanding the app [13]. Easy to use is one of the characteristics of diabetes self-care app characteristics that affect patient intention to use and engage with the app, especially for participants with limited exposure to technology [9,11–13]. Many diabetes apps are too confusing, complex, and stressful to set up and use. [10]. In contrast, apps tailored to individual technological skill levels are perceived as easy to use and associated with engagement and successful usability [9]. When designing the DiaFriend app, the research team adhered to the characteristics of an easy-to-use app described by Portuguese Americans with T2DM. The user interface screens were simple and easy to navigate, and a login process involving a username and password was bypassed. The app displays large picture icons and a sizable font size that provides easy visualization. This simplicity characteristic of the app should reduce time constraints and be less burdensome to Portuguese Americans who may not be familiar with the technology. In addition, the DiaFriend app is a user-centered design that considers the preferences and habits of the target population. Based on insights gathered from Phase 1 interviews, walking was identified as the primary form of physical activity among most participants.

Limitations

While the researchers successfully developed a user-centered, culturally sensitive prototype app, the current version of the DiaFriend app has several limitations due to funding and development time constraints. First, advanced functions such as real-time feedback and notifications based on users' inputs have not been incorporated into this iteration of the app. These features could provide timely reminders to users. Timely prompts can encourage regular blood sugar monitoring, consistent carbohydrate and exercise tracking, and improved medication adherence.

Second, the app's backend infrastructure, which requires expert development skills, has not been fully developed. This limitation hinders the app's ability to store, process, and analyze user data securely and efficiently. Therefore, future versions of the DiaFriend app should prioritize the development of these critical backend components and integrate real-time feedback and notification features to offer a more comprehensive and user-centric diabetes self-care tool.

Third, as the research team members are not Portuguese speakers, the current version of the DiaFriend app is available only in English. This language barrier may limit the app's accessibility and usability for Portuguese American users who prefer their native language. Previous studies highlight the need for culturally tailored apps for non-English speakers to enhance healthy eating, promote exercise, and weight control [24]. Future versions of the DiaFriend app should be translated appropriately into Portuguese to address this limitation.

Finally, the research team recognized the significance of user collaboration with designers throughout every stage of app development to ensure that the app effectively fulfills their needs. However, the COVID-19 pandemic posed challenges, limiting the ability to conduct face-to-face research with participants. Due to institutional guidelines, the research team was not permitted in-person contact with study participants. Thus, the information about the app design derived during the ideate step was solely from the research team, which had experience caring for patients with T2DM who have limited health literacy and technological skills. Moreover, specialists such as clinical diabetes educators and endocrinologists were not included in the design and development. Thus, some valuable user and expert perspectives might have been overlooked.

DiaFriend app Version 1, which is the result of Phase 2 of this study, will be used to revise and develop the DiaFriend app Version 2. To address the limitations and enhance the functionality and usability of the DiaFriend app, the research team plans to recruit Portuguese American patients with T2DM to be involved in the remaining stages of frontend development and backend creation. Furthermore, the team plans to collaborate with a multidisciplinary healthcare team and experienced backend developers. This collaboration will focus on designing necessary personalized features, such as real-time feedback and notifications based on the users' inputs, and completing the backend functionality, including data computing, analysis, and storage, before progressing to the app testing step, step 5 of the design thinking methodology.

Conclusions

As a result of Phase 2 of this study, the prototype DiaFriend app for Portuguese Americans with T2DM was developed. Two steps in the design thinking methodology (step 3, *ideate, and step 4 prototype)* were used to ensure the user-friendliness and cultural sensitivity characteristics of the app. The DiaFriend app Version 1 comprises five features: blood glucose monitoring, weight tracking, carbohydrate tracking, exercise log, and medication reminder. The carbohydrate tracking feature was explicitly tailored to correspond to Portuguese food culture. This feature includes food databases tailored to Portuguese food culture and dietary choices. The app features displayed large picture icons and a sizable font size that provides easy visualization, and the data entry steps are easy to navigate, which should reduce time constraints and be less burdensome to Portuguese Americans who may not be familiar with the technology. Incorporating these characteristics into the app's design, the DiaFriend app should promote app engagement and adherence to self-management among Portuguese Americans with type 2 diabetes. The findings for this phase will serve as the basis for updating and refining the DiaFriend app, leading to the development of Version 2. The usability of the app will be tested in Phase 3 of this study, which employs the final step of the design thinking methodology: step 5, *test*.

Acknowledgments

The authors would like to acknowledge 22 participants in this study for giving valuable insight into the development and testing of the application in phase 1. Their feedback and perspectives have been instrumental in shaping and improving the app to better meet user needs and preferences.

Conflicts of Interest

The authors declared no potential conflicts of interest in respect of the research, authorship, and/or publication of this article.

Abbreviations

apps: applications
DiaFriend app: DiaFriend application
T2DM: type 2 diabetes

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Supplementary Files

Figures

Flow chart.

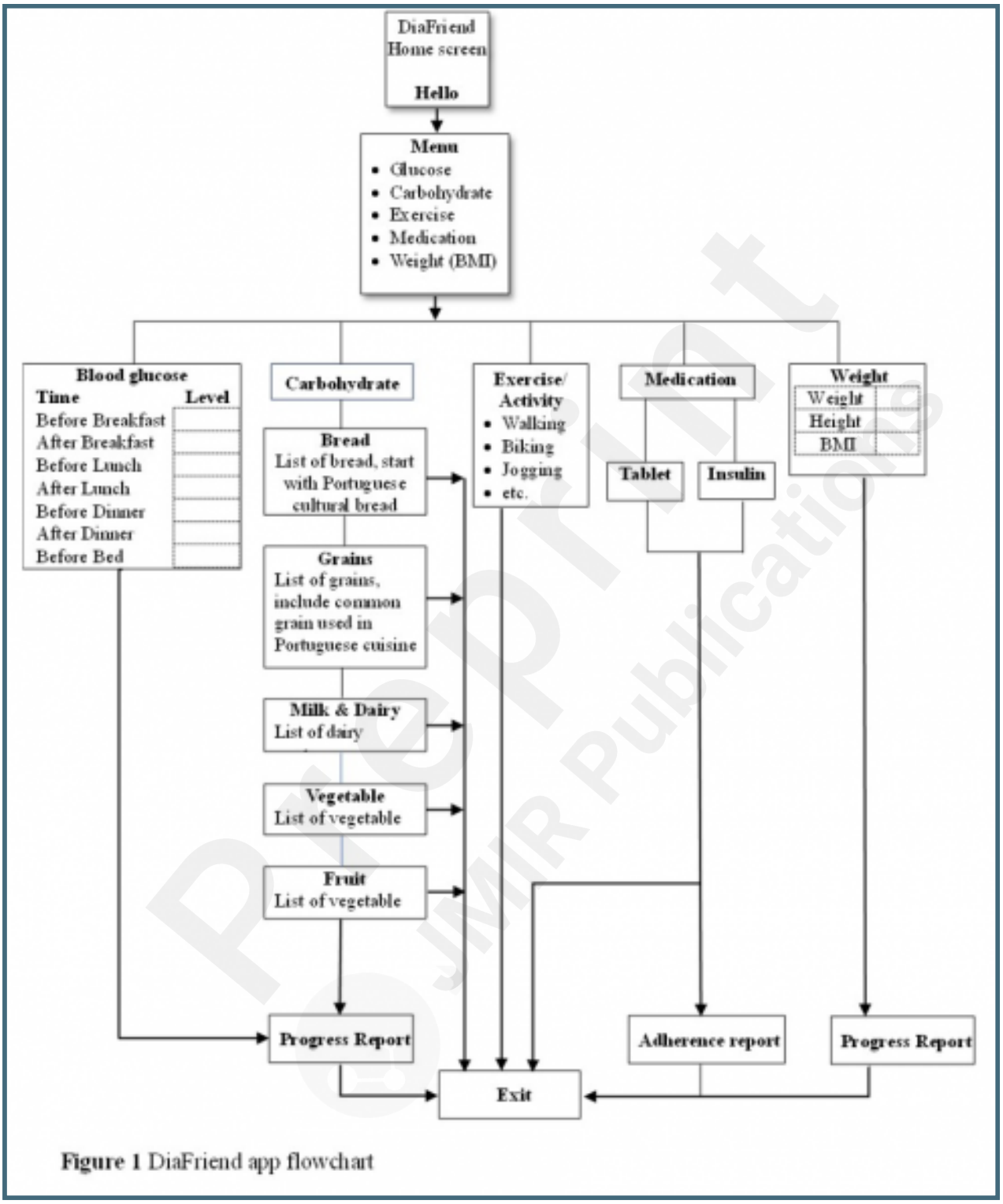

Figure 1 DiaFriend app flowchart

Home screen and feature screens.

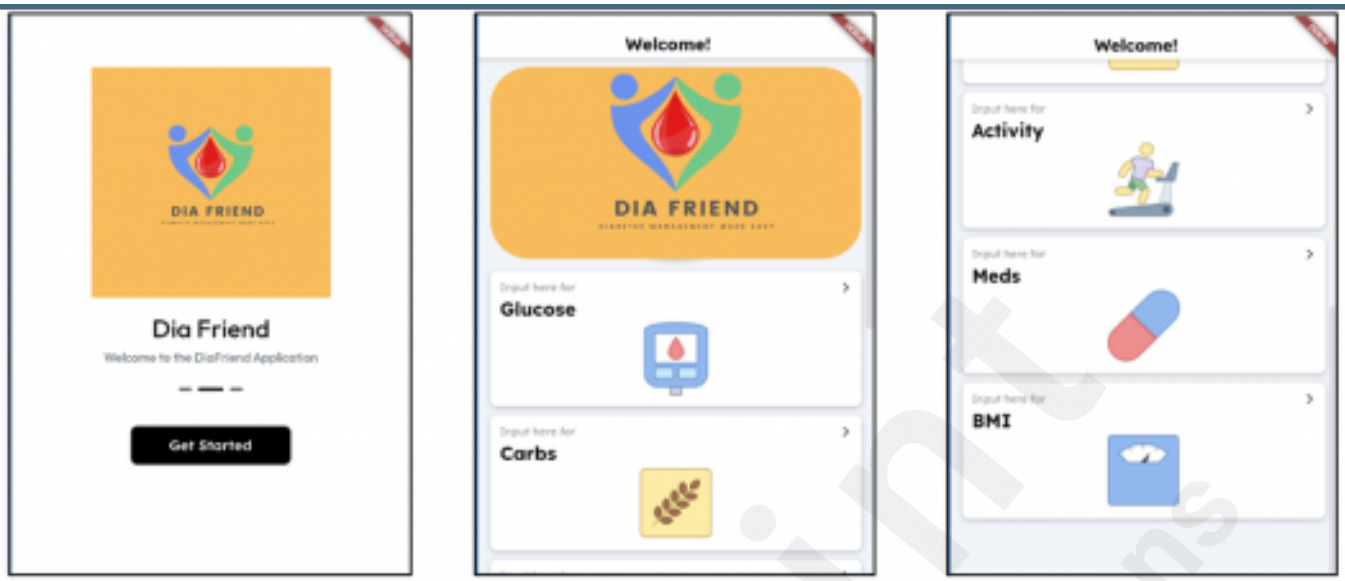

Figure 2 Home screen and feature screen.

Blood glucose monitoring feature screen.

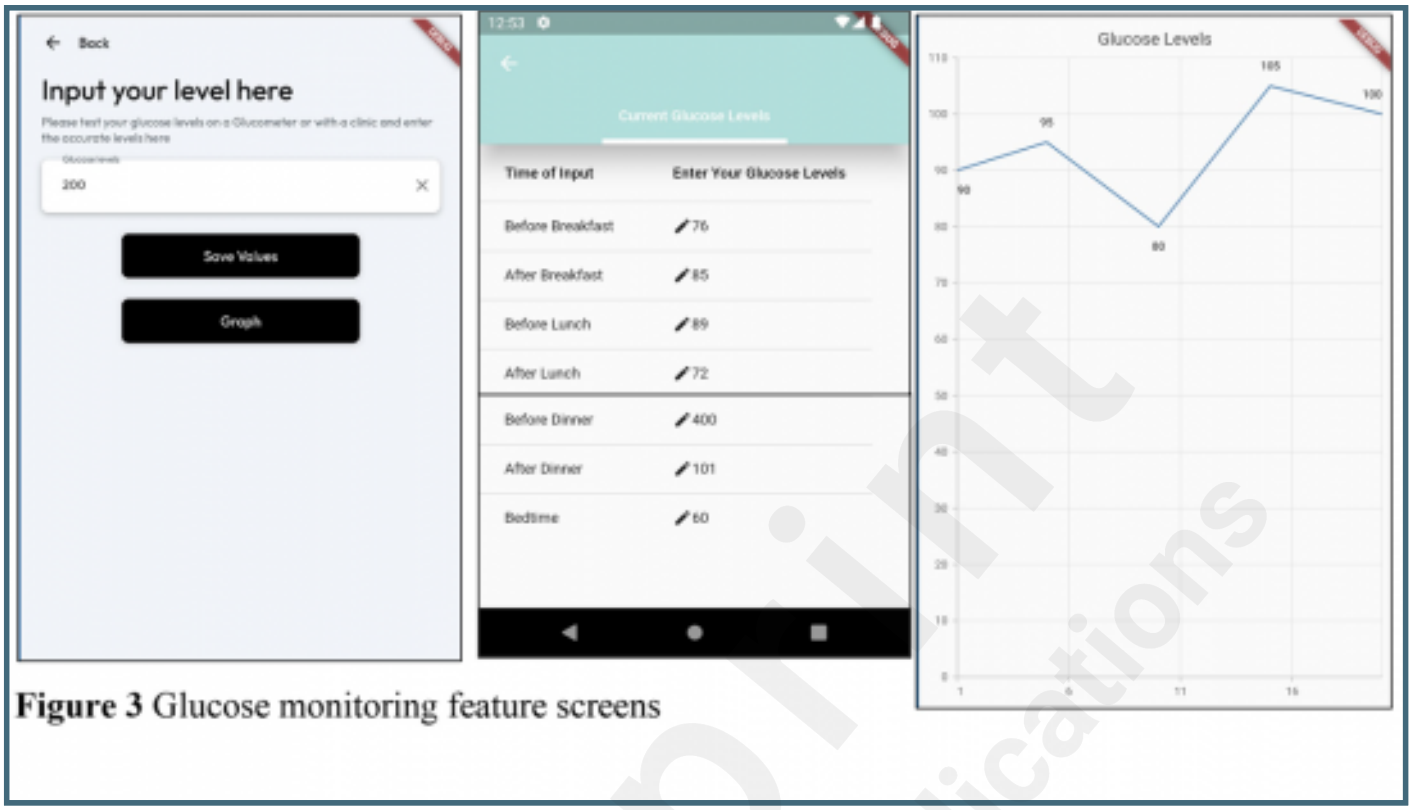

Figure 3 Glucose monitoring feature screens

Food choice screen.

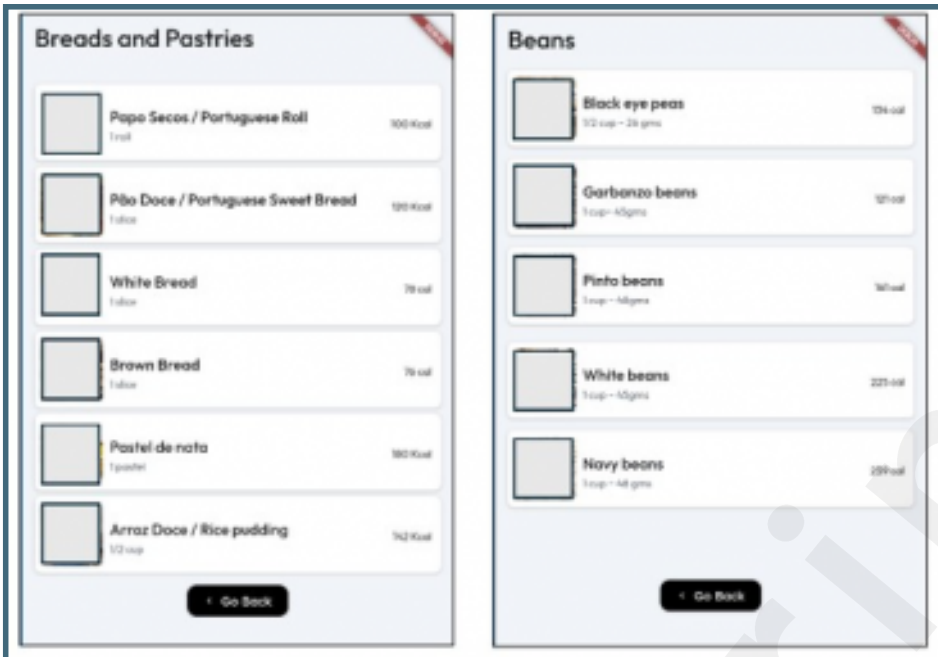

Figure 4 Food choice