

Design and Simulation-Based Testing of a Mobile Application for Self-Care Management in Type 2 Diabetes Mellitus and Prediabetes

Annisa Ristya Rahmanti^{a,b}, Sensa Gudya Sauma Syahra^c, Anis Fuad^{a,c}, Hendri Kurniawan Prakosa^{c,d}, Candra^c, Wan Aisyah Baros^e, Khaterina Kristina Manurung^e, Dedy Revelino Siregar^e, Donni Hendrawan^e, Arif Budiman^e, Charleen Ika Jelita^e, Millean Rahman Hakim^{a,c}, and Guardian Yoki Sanjaya^{a,c,1}

^a*Faculty of Medicine, Public Health, and Nursing, Universitas Gadjah Mada, Yogyakarta, Indonesia*

^b*Faculty of Science and Technology, Middlesex University, London, United Kingdom*

^c*Center for Health Policy and Management, Universitas Gadjah Mada, Indonesia*

^d*Universitas Amikom Yogyakarta, Indonesia*

^e*BPJS Kesehatan (Social Security Agency on Health), Indonesia*

ORCID ID: Annisa Ristya Rahmanti <https://orcid.org/0000-0001-9478-6267>

Guardian Yoki Sanjaya <https://orcid.org/0000-0002-3444-4617>

Abstract. Mobile health applications are increasingly recognized as valuable tools for supporting self-care management among individuals with type 2 diabetes mellitus (T2DM) and prediabetes. This study explores the development and testing of NusaCare, a mobile app designed to assist patients through lifestyle tracking, education, and personalized interventions. Using a co-design approach, the process began with desk reviews and focus group discussions to gather initial insights. A pre-simulation phase followed, during which prototypes were tested and refined. The final prototype was evaluated in a simulation involving 61 participants, revealing that the challenges feature (70%) and food tracking (42.86%) were the most frequently used features. Post-intervention feedback highlighted the app's usability and its potential to enhance self-care behaviors. This study emphasizes the importance of engaging users in co-design processes to develop effective mobile health interventions for managing prediabetes and T2DM.

Keywords. Mobile health, self-care management, type 2 diabetes, prediabetes, co-design

1. Introduction

Type 2 diabetes mellitus (T2DM) and prediabetes are significant and escalating public health challenges globally. According to the International Diabetes Federation, approximately 537 million people worldwide were living with diabetes in 2021, with projections indicating a sharp rise in the next few decades [1]. In Indonesia, the

¹ Corresponding Author: Guardian Yoki Sanjaya. Email: gysanjaya@ugm.ac.id

prevalence of T2DM affects over 28.6 million individuals aged 20-79, marking a prevalence rate of 10.6% [1]. Similarly, prediabetes affects a substantial portion of the population, significantly increasing the risk of developing chronic complications.

This study presents NusaCare, a mobile application designed to enhance self-care management among individuals with T2DM and prediabetes. Utilizing a co-design approach, the development of NusaCare actively involves a broad spectrum of stakeholders, including patients, healthcare providers, and organizational professionals. Co-design is crucial for enhancing user engagement and acceptance, which are key to effective disease management and prevention. This approach ensures that the application is not only technically robust but also aligned with the clinical and practical needs of its users.

2. Methods

2.1. Study Design

This study adopted a co-design approach with rapid prototyping to develop and evaluate the Nusacare mobile application for managing prediabetes and T2DM. Utilizing the framework suggested by Sanders & Stappers [2], the study engaged stakeholders—including patients, healthcare providers, and organizational professionals at national, provincial, and district levels—in a series of design sessions using qualitative methods to ensure alignment with user insights and needs. The study protocol was approved by the Medical and Health Research Ethics Committee (MHREC) of the Faculty of Medicine, Public Health and Nursing at Universitas Gadjah Mada – Dr. Sardjito General Hospital, with approval number KE/FK/0940/EC/2024.

2.2. NusaCare App

NusaCare is an Android-based mobile application operates on an Ubuntu Server 24.04, designed for scalability and real-time data handling. The app employs a modular architecture, with separate containers for different functionalities like user management and notifications, leveraging Firebase Cloud Notifications for timely alerts. Available on the Google Play Store, the app includes features such as:

- **User Profile Management:** Users can set up profiles that allow for the personalization of content based on health conditions, such as customized dietary suggestions and tailored educational contents.
- **Lifestyle Tracking:** Tools for tracking blood glucose, Rockport test results, and anthropometric measurements as well as logging vital signs and food tracking.
- **Medication Reminders:** Notifications for medication intake to help ensure adherence to prescribed treatment plans.
- **Educational Resources:** Reliable tips and educational resources on managing diabetes to assist users in better understanding and managing their condition.
- **Engagement and Motivation:** A gamified challenges feature, integrated with a points system, encourages healthy behaviors and enhance user interaction.
- **Self-Monitoring Visualization Dashboard:** Interactive graphs for tracking vital signs, calorie intake, activity levels, and anthropometric data.

NusaCare includes a dashboard designed for healthcare providers to monitor and manage patient care effectively. The dashboard is designed to support two distinct user roles, such as:

- **Healthcare Facilities Users:** Access patient-specific data such as demographics, health screening results, and clinical metrics within their facility.
- **District Health Office Users:** View aggregated data from multiple facilities to analyze public health trends and assess regional diabetes care effectiveness.

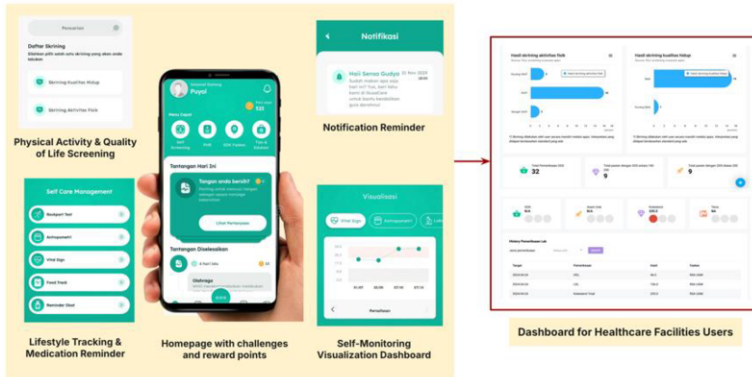


Figure 1. User interface of NusaCare application and healthcare facilities visualization dashboard

2.3. Data Collection and Development

The development of the NusaCare app followed a structured and multi-phase process to address user needs and clinical requirements:

- **Pre-Design Phase:** Insights were gathered through desk reviews and Focus Group Discussions (FGDs) with 33 participants to understand user needs and define necessary features for managing diabetes and prediabetes effectively.
- **Pre-Simulation Phase:** Early prototypes were tested internally by three experts (an internist, a health promotion specialist, and a registered dietitian) and six enumerators with nursing or nutrition background. Feedback on usability and functionality was incorporated through iterative refinements.
- **Simulation Testing:** The refined prototype was tested over five-month intervention by 61 participants (44 diagnosed with T2DM and 17 prediabetes) to evaluate the app's effectiveness in real-world scenarios.
- **Post-Simulation:** Additional FGDs with 19 users were conducted to collect feedback on user experience and suggestions for further improvements.

3. Result

The study consisted of four phases, including six FGDs during pre-simulation and post-simulation involving stakeholders at national and district levels, and patients.

- **Pre-design phase finding**
Initial findings from the desk review and FGDs highlighted the need for features like screening features, health reminders, and a self-monitoring dashboard to

track health measurement trends. Additional features included dietary monitoring, fitness tests such as the Rockport test, gamified educational materials and medication reminders. A visualization dashboard for health authorities was also developed to track public health metrics.

• **Pre-simulation findings**

Testing with experts and enumerators focused on refining the app's interface and functionalities. The discussions highlighted the need for distinct intervention features tailored to prediabetic and diabetic users, guided by the behaviour change wheel (BCW) framework and specific notification formats to maintain user engagement and effective self-management [3].

• **Simulation phase findings**

During the five-month intervention, 61 participants used the app, with challenges (70%) and food tracking (42.86%) being the most frequently used features. Diabetic participants engaged more with challenges (61.22%) and lifestyle tracking feature like Rockport test (62.50%), food tracking (60%), and lab result monitoring (58.62%) compared to prediabetic users. User feedback led to targeted enhancements such as improved error correction capabilities and more accurate portion size options in the food tracking feature, as well as expanded food item variety. Further details on feedback-driven refinements are summarized in Table 1.

Table 1. Summary of technical issues and solution status

Issues	Status
Daily challenges error (no answer choices available)	<i>Solved</i>
Missing in some food items, incorrect portion sizes and typos	<i>Solved</i>
<i>Food Track</i> entries could not be edited if mistakes were made by users	<i>Solved</i>
Rockport test history not saved	<i>Solved</i>
Screening results not displayed	<i>Solved</i>
Anthropometry feature could not accept decimal numbers	<i>Solved</i>
Medication reminder data not saved (blank page appeared)	<i>Solved</i>
NusaCare app error, all features are disabled	<i>Solved</i>
Users suggested adding other lab tests (e.g., Uric Acid)	<i>Solved</i>

• **Post-simulation findings**

Participants reported improved management of T2DM and prediabetes. Specifically, 12 T2DM participants showed a reduction in HbA1C, and 10 reported decreases in glucose levels, with improvements in physical activity and quality of life reported by 23 participants. Among prediabetic participants, five people reported reductions in HbA1C and six observed decreased glucose levels, along with enhancements in diet and physical activity. Participants also demonstrated higher compliance with diabetes management protocols, incorporating Prolanis, a chronic disease management program launched by the social health insurance agency (BPJS Kesehatan) in primary healthcare facilities to prevent complications, into their routines [4]. However, challenges such as managing diet during social events, and technical issues like bugs and data instability were also reported. Despite these issues, the app showed significant potential in supporting self-management for T2DM and prediabetes. To enhance NusaCare integration with existing systems, we explored several potential integration scenarios with Mobile JKN, a national platform for mobile personal health records. Proposed integration scenarios include embedding

NusaCare as a plugin, merging its architecture with Mobile JKN, or linking specific key data points for improved data management.

4. Discussion

NusaCare demonstrates the potential of mobile health applications to enhance self-care management for T2DM and prediabetes. Its co-design approach is aligned with current digital health trends, which emphasize integrating user feedback and adaptive learning systems to improve the functionality and acceptance of health technologies [5]. While clinical outcomes were not quantitatively assessed in this phase, the app provided benefits in raising awareness and facilitated real-time monitoring for better management decisions through its visualization dashboard, which does not commonly exist in typical mobile apps [6]. However, challenges included technical issues like app bugs and data loss and the need for system integration to reduce healthcare provider's workload. Despite these challenges, the app was well-received due to its user-friendly interface and effectiveness in promoting healthier lifestyle choices, similar to findings from other studies that underscore the importance of user engagement in mobile health outcomes [6]. Future work will focus on evaluating clinical outcomes and leveraging AI-driven features, such as predictive analytics for blood glucose levels and nutritional recommendations based on individual health profiles, to enhance user experience.

5. Conclusion

The development and evaluation of NusaCare through rapid prototyping and use case simulations have provided pivotal insights into the creation of user-centered digital health tools. While further enhancements are necessary to realize measurable clinical outcomes, this study highlights the critical role of iterative design and comprehensive stakeholder involvement in the development of effective mobile health interventions. Moving forward, the NusaCare initiative will continue to refine its features, aiming to exceed the evolving expectations of its user base and the broader healthcare community.

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