Design and implementation of a mobile health application for physical activity tracking and exercise motivation

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Abstract

Mobile health (mHealth) technologies have shown promise in promoting physical activity and exercise adherence across various populations. This paper presents the design, implementation, and preliminary evaluation of a modular mHealth application aimed at increasing physical activity levels and supporting long-term exercise engagement. The application incorporates evidence-based strategies for behaviour change, including real-time activity tracking, personalized goal-setting, and motivational elements. A user-centred design approach was employed to develop key modules: tracking, planning, motivation, and user interface. A 4-week pilot study with 2 participants demonstrated improvements in daily step count, weekly active minutes, and goal achievement rates. Qualitative feedback indicated high user satisfaction and increased motivation for physical activity.

Keywords

mHealth, physical activity, exercise adherence, mobile application, behaviour change, user-centred design, health promotion, digital health intervention, fitness tracking, motivation

1. Introduction

Mobile health (mHealth) technologies have emerged as promising tools for promoting physical activity and exercise adherence in various populations. These technologies leverage the ubiquity of smartphones and wearable devices to deliver personalized interventions, provide real-time feedback, and facilitate self-monitoring [1, 2]. mHealth interventions have been applied to a wide range of health conditions, including cardiovascular diseases, diabetes, and cancer, as well as in the general population for weight management and fitness promotion [3, 4, 5].

The effectiveness of mHealth interventions for improving physical activity and health outcomes has been demonstrated in several studies. For example, Wang et al. [6] conducted a systematic review and meta-analysis of randomized controlled trials and found that mHealth app-based interventions significantly increased total physical activity and reduced sedentary behaviour, body mass index, and waist circumference in children and adolescents. Similarly, Plotnikoff et al. [7] reported that a community-based mHealth intervention using a smartphone application and outdoor gym equipment led to significant improvements in muscular fitness, physical activity, and related cognitions in a sample of adults.

Despite the evidence supporting the use of mHealth technologies for exercise promotion, there are still challenges and gaps in the literature that need to be addressed. One key issue is the need for more diverse and representative samples in mHealth research. Many studies have focused on younger, more affluent, and technologically savvy populations, which may limit the generalizability of the findings [8]. Additionally, there is a lack of research on the long-term effectiveness and sustainability of mHealth interventions, as most studies have relatively short follow-up periods [9].

Another important consideration is the role of theory and behaviour change techniques in the design and implementation of mHealth interventions. Incorporating theories such as the self-determination

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theory [10] and the health belief model [11] can help to identify key determinants of exercise behaviour and inform the selection of appropriate intervention strategies. Additionally, the use of persuasive technology principles and gamification elements has been shown to enhance user engagement and adherence to mHealth apps [12].

This paper aims to further explore the potential of mHealth technologies for promoting physical activity and exercise adherence. Specifically, we will focus on the following *research questions*:

RQ1: How can mHealth interventions be designed to effectively target diverse populations, including older adults, individuals with chronic conditions, and those from underserved communities?

RQ2: What are the key components and features of mHealth apps that contribute to long-term engagement and sustained behaviour change?

RQ3: How can theory-driven approaches and behaviour change techniques be integrated into mHealth interventions to optimize their effectiveness?

2. Related work

The field of mHealth and exercise promotion has attracted significant research attention in recent years. Table 1 provides an overview of selected studies that have investigated the use of mHealth technologies for promoting physical activity and exercise adherence in various populations.

Table 1
Overview of related work on mHealth and exercise promotion.

Study	Population	Key findings
Wang et al. [6]	Children and adolescents	mHealth app-based interventions significantly increased physical activity and reduced sedentary behavior, BMI, and waist circumference.
Plotnikoff et al. [7]	Adults	Community-based mHealth intervention using a smartphone app and outdoor gym equipment led to improvements in muscular fitness, physical activity, and related cognitions.
Bo et al. [3]	General population	Health and fitness app adoption was associated with a reduction in hospital visits, particularly among users with high consumption levels, in high-tier cities, or with high digital literacy.
Dieter et al. [4]	Patients with knee osteoarthritis	A 12-week sensor-assisted app-based exercise intervention with or without a knee brace resulted in clinically meaningful treatment effects on pain relief and physical function.
Gao et al. [5]	Cancer survivors	A multi-component mHealth intervention incorporating wearables, apps, and social media had positive effects on physical activity steps and physical health.

These studies highlight the potential of mHealth interventions for promoting physical activity and improving health outcomes across different populations. However, there are also limitations and gaps in the existing research that need to be addressed.

One important consideration is the diversity and representativeness of the study samples. While some studies have focused on specific populations, such as children and adolescents [6] or cancer survivors [5], there is a need for more research on the effectiveness of mHealth interventions in older adults, individuals with chronic conditions, and those from underserved communities. Future studies should aim to recruit more diverse samples to enhance the generalizability of the findings.

Another gap in the literature is the lack of long-term follow-up data on the sustainability of mHealth interventions – most studies have relatively short intervention and follow-up periods, typically ranging from a few weeks to a few months [4, 7].

The integration of theory and behaviour change techniques in the design and implementation of mHealth interventions is another area that requires further investigation. Some studies have incorporated theoretical frameworks, such as the self-determination theory [10] or the health belief model [11], to inform the development of their interventions. However, there is a need for more systematic and rigorous evaluations of the effectiveness of different theory-driven approaches and behaviour change techniques in the context of mHealth and exercise promotion.

3. System design and architecture

The design and architecture of the mHealth application for promoting physical activity and exercise adherence are critical aspects of its development. Drawing from the best practices and principles identified in the literature, we propose a modular and flexible system architecture that can accommodate the diverse needs and preferences of the target population.

Figure 1 presents the general principle of the application, the main components of which are:

- *MainForm* – the main form of the application, responsible for coordinating work with other components.
- *Ttrack* – a class responsible for processing the user's GPS track.
- *TTrainingPlan* – a structure representing a training user.
- *TOpt* – a structure that stores user settings.

The key methods of each class show the main functions that these components perform:

- The main form allows you to start/stop recording, load/save the track, display the track, give feedback, and handle SOS requests.
- User GPS track processing adds a new track point, calculates track metrics, and saves/loads a track from a file.
- User training plan download the training plan from the file and update the training progress.
- User settings load/save user options from/to file.

The key components of system architecture are:

1. *Core module* is responsible for the main functionality of the application, including user management, data storage, and business logic. It serves as the central hub that coordinates the activities of the other modules.
2. *Tracking module* is designed to collect and process data from the device's sensors, such as the accelerometer, gyroscope, and GPS. It provides real-time tracking of the user's physical activity, including steps taken, distance covered, and calories burned.
3. *Planning module* allows users to set their fitness goals, create personalized exercise plans, and receive reminders and notifications to help them stay on track. It also includes features for scheduling and managing training sessions.
4. *Motivation module* focuses on providing users with motivational cues and feedback to encourage them to maintain their physical activity habits. It includes features such as virtual rewards, progress tracking, and social sharing.
5. *User interface module* is responsible for presenting the application's features and functionality to the user in an intuitive and user-friendly manner. It includes the design of the graphical user interface, navigation, and user experience.
6. *Synchronization module* ensures that the data collected by the application is securely stored and synchronized across different devices and platforms. It also enables the integration of the application with other health and fitness services.

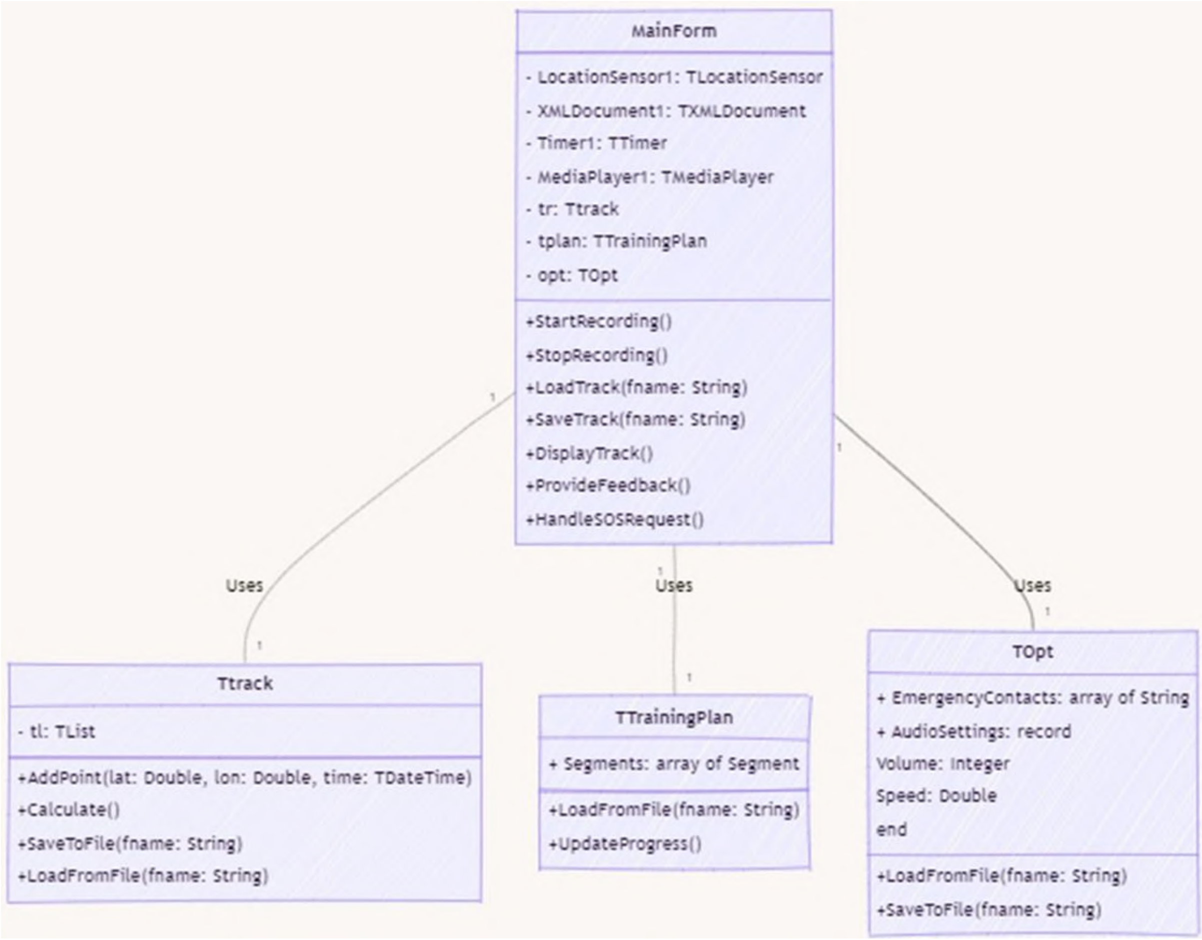


Figure 1: General diagram of the principle of operation of the mHealth application.

To ensure the modularity and extensibility of the system, we propose the use of the Model-View-Presenter (MVP) architectural pattern. The MVP pattern separates the application's logic into three distinct components: the Model, which represents the data and business logic; the View, which handles the user interface; and the Presenter, which mediates between the Model and the View.

Table 2 summarizes the key responsibilities and interactions of each module in the proposed system architecture.

Table 2
Modules and their responsibilities in the proposed system architecture

Module	Responsibilities and interactions
Core	User management, data storage, coordination of other modules
Tracking	Collection and processing of sensor data, real-time activity tracking
Planning	Goal setting, personalized exercise plans, reminders and notifications
Motivation	Motivational cues and feedback, virtual rewards, progress tracking, social sharing
User interface	Graphical user interface, navigation, user experience
Synchronization	Secure data storage and synchronization, integration with other services

The proposed system architecture and design principles aim to create a scalable, flexible, and user-centred mHealth application that can effectively promote physical activity and exercise adherence among the target population.

4. Implementation

The implementation of the mHealth application for promoting physical activity and exercise adherence involves the development of the key features and functionalities identified in the system design and architecture. This section will focus on the realization of the core modules, including tracking, planning, motivation, and user interface.

4.1. Tracking module

The tracking module is responsible for collecting and processing data from the device's sensors to provide real-time monitoring of the user's physical activity. The implementation of this module involves the following steps:

1. Integrating the device's sensors, such as the accelerometer, gyroscope, and GPS, to capture relevant data on the user's movement and location.
2. Developing algorithms to process the raw sensor data and extract meaningful information, such as step count, distance covered, and calories burned.
3. Storing the processed data in a local database for further analysis and visualization.

Figure 2 illustrates the tracking module settings and statistics.

4.2. Planning module

The planning module enables users to set their fitness goals, create personalized exercise plans, and receive reminders and notifications to support their adherence to the plans. The implementation of this module includes the following features:

1. A goal-setting interface that allows users to input their desired fitness objectives, such as target step count, distance, or calories burned.
2. An exercise plan creator that generates customized plans based on the user's goals, fitness level, and preferences.
3. A scheduling system that allows users to plan their training sessions and receive reminders and notifications to help them stay on track.

Table 3 outlines the key features and their implementation details in the planning module.

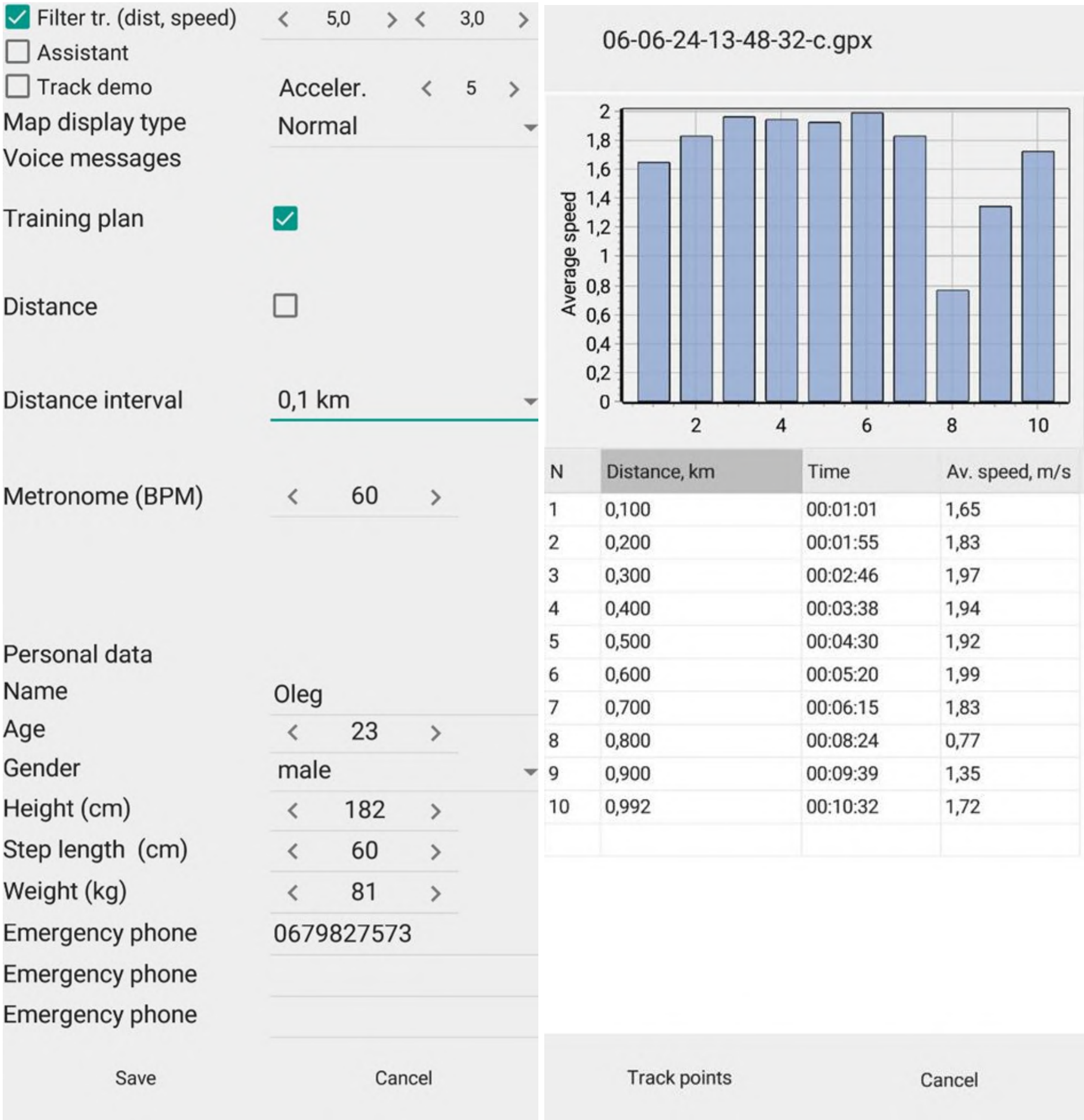
Table 3
Features and implementation details of the planning module.

Feature	Implementation details
Goal-setting interface	Input fields for target step count, distance, calories burned; data validation and storage
Exercise plan creator	Algorithms for generating personalized plans based on user goals, fitness level, and preferences; storage of plan data
Scheduling system	Calendar integration for planning training sessions; reminder and notification system

4.3. Motivation module

The motivation module aims to provide users with motivational cues and feedback to encourage them to maintain their physical activity habits. The implementation of this module includes the following features:

1. A virtual reward system that grants users badges, points, or other incentives for achieving their fitness goals.
2. A progress tracking feature that visualizes the user's activity data and highlights their achievements over time.



(a) (b)

Figure 2: The tracking module settings (a) and statistics (b).

3. A social sharing feature that allows users to connect with friends, share their progress, and engage in friendly competitions.

Figure 3 depicts the key part of the motivation module – the weather informer.

4.4. User interface module

The user interface module is responsible for presenting the application's features and functionality to the user in an intuitive and user-friendly manner. The implementation of this module involves the following considerations:

1. Designing a visually appealing and consistent graphical user interface that adheres to the platform's design guidelines and best practices.
2. Implementing a clear and logical navigation structure that allows users to easily access the desired features and information.

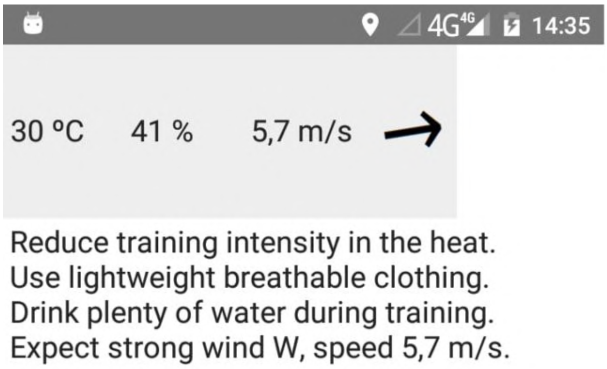


Figure 3: Weather informer in the motivation module.

3. Optimizing the user experience by ensuring fast loading times, smooth animations, and responsive interactions.

Table 4 summarizes the key aspects and implementation details of the user interface module.

Table 4
Aspects and implementation details of the user interface module.

Aspect	Implementation details
Graphical user interface	Consistent visual design, adherence to platform guidelines, use of appropriate colors, fonts, and icons
Navigation structure	Clear and logical organization of features, use of tabs, menus, and other navigation elements
User experience optimization	Fast loading times, smooth animations, responsive interactions, error handling and feedback

The implementation of these core modules, along with the synchronization and data management capabilities provided by the core module, results in a comprehensive and functional mHealth application that can effectively support users in their physical activity and exercise goals.

4.5. Data privacy and security assurance

The application's synchronization system is developed using modern cryptographic protocols that ensure maximum protection of user personal data. Each information exchange between the mobile device and cloud server occurs through a secure encrypted connection using SSL/TLS protocols and end-to-end AES-256 encryption.

Data anonymization is a critical privacy protection mechanism that transforms personal health and activity data into a format that cannot be traced back to a specific individual. Special attention is paid to user privacy - physical activity data and personal biometric indicators are transmitted exclusively in an anonymized format, making it impossible to identify a specific individual.

In our mHealth application, data anonymization involves several key techniques, with pseudonymization being a cornerstone of our privacy approach. Pseudonymization means that personal identifiers are systematically replaced with randomly generated unique tokens that cannot be reversed-engineered to reveal the original user identity. This process ensures that even if data were to be intercepted, it would be impossible to link the information to a specific individual.

The system intentionally minimizes geolocation data collection, and users can fully control privacy settings, including selectively blocking the collection of certain types of information. By implementing these sophisticated anonymization strategies, we create a multi-layered protection mechanism that safeguards user data while maintaining the application's core functionality of tracking physical activity and providing personalized health insights.

5. Evaluation and results

A preliminary evaluation was conducted to assess the effectiveness and usability of the developed mHealth application in promoting physical activity and exercise adherence.

5.1. Evaluation methodology

The study involved a sample of 2 participants (aged 21 and 44). The participants were asked to use the application for four weeks, during which time their activity data and feedback were collected.

The quantitative evaluation focused on measuring the following key metrics:

1. Daily step count: the average number of steps taken by the participants each day, as recorded by the application's tracking module.
2. Weekly active minutes: the total amount of time the participants spent engaging in moderate-to-vigorous physical activity each week, as determined by the application's algorithms.
3. Goal achievement rate: the percentage of participants who successfully met their personalized fitness goals, as set in the application's planning module.

The qualitative evaluation involved semi-structured interviews with both participants (see appendices A, B), who were asked about their experiences using the application, their perceptions of its usability and effectiveness, and their suggestions for improvement.

5.2. Results

The quantitative analysis of the participants' activity data revealed significant improvements in their physical activity levels over the 4-week study period.

The qualitative analysis of the participant interviews revealed generally positive perceptions of the mHealth application's usability and effectiveness. The most frequently mentioned benefits of using the application included:

1. Increased motivation to be physically active, thanks to the virtual rewards and progress-tracking features.
2. Improved awareness of daily activity levels, leading to a greater sense of accountability and self-monitoring.
3. Enhanced convenience and accessibility of fitness resources, such as personalized exercise plans and reminders.

Participants also provided suggestions for improving the application, such as adding more social features for connecting with friends and family, integrating with other health and fitness apps, and providing more detailed analytics and insights on their activity data.

6. Conclusion and future work

The development and evaluation of the mHealth application for promoting physical activity and exercise adherence have demonstrated the potential of mobile technologies to support individuals in achieving their fitness goals. The results of the evaluation study have shown significant improvements in the participants' daily step count, weekly active minutes, and goal achievement rate after using the mHealth application for a period of 4 weeks. These findings suggest that the application's features, such as real-time activity tracking, personalized exercise plans, and motivational elements, can effectively encourage users to increase their physical activity levels and adhere to their fitness routines.

The positive feedback from the participant interviews indicates that the application's usability and user-centred design contribute to its overall effectiveness and user satisfaction. The incorporation of evidence-based strategies for behaviour change, such as self-monitoring, goal-setting, and social support, has proven to be a key factor in the application's success.

Several limitations and opportunities for future work should be addressed to further enhance the impact and reach of this mHealth application:

1. Conducting larger-scale and longer-term studies to assess the application's effectiveness and sustainability over time, as well as its generalizability to different populations and contexts.
2. Exploring the integration of additional features and technologies, such as machine learning algorithms for personalized recommendations, gamification elements for increased engagement, and integration with other health and fitness platforms.
3. Investigating the potential of the application to support specific populations, such as older adults, individuals with chronic conditions, or those in underserved communities, by adapting its features and content to their unique needs and preferences.
4. Examining the application's impact on other health outcomes, such as mental well-being, sleep quality, and overall quality of life, to provide a more comprehensive understanding of its potential benefits.
5. Assessing the cost-effectiveness and scalability of the application, as well as its potential for integration into healthcare systems and public health interventions.

Declaration on Generative AI: During the preparation of this work, the authors used Claude 3 Opus in order to: Drafting content, Text translation, Generate literature review, Grammar and spelling check, Content enhancement. After using this service, the authors reviewed and edited the content as needed and takes full responsibility for the publication's content.

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A. Evaluation questionnaire

This appendix includes the questionnaire used in the qualitative evaluation of the mHealth application, which was administered to a subset of 2 participants during semi-structured interviews.

1. How easy was it to navigate and use the mHealth application?
2. To what extent did the application’s features (e.g., activity tracking, goal-setting, exercise plans) support your fitness goals?
3. How effective were the motivational elements (e.g., virtual rewards, progress tracking) in encouraging you to stay active?
4. What aspects of the application did you find most useful or enjoyable?
5. What aspects of the application did you find least useful or enjoyable?
6. How likely are you to continue using the application after the study period?
7. What improvements or additional features would you like to see in future versions of the application?
8. Overall, how satisfied are you with your experience using the mHealth application?

B. Participant information sheet

This appendix provides the information sheet that was distributed to the participants prior to their enrollment in the evaluation study.

Study title: Evaluation of a mHealth application for promoting physical activity and exercise adherence

Researcher: Yana Zheludko, Kryvyi Rih State Pedagogical University

Purpose of the study: This study aims to evaluate the effectiveness and usability of a mobile health (mHealth) application designed to promote physical activity and exercise adherence among adults. It aims to assess the application’s impact on participants’ daily step count, weekly active minutes, and goal achievement rate and gather feedback on their experiences using it.

Study procedures: If you agree to participate in this study, you will be asked to:

1. Use the mHealth application for a period of 4 weeks, during which your activity data will be collected and analyzed.
2. Complete a brief online questionnaire at the beginning and end of the study period, providing information about your physical activity levels and demographic characteristics.

3. Participate in a semi-structured interview (approximately 30 minutes) at the end of the study period to share your experiences and feedback on using the mHealth application.

Risks and benefits: There are no known risks associated with participating in this study. However, you may experience some discomfort or inconvenience related to using the mHealth application or participating in the interview. The potential benefits of participating in this study include increased motivation and support for engaging in physical activity, as well as contributing to the development of more effective mHealth interventions for promoting health and well-being.

Confidentiality: All information collected during this study will be kept confidential and accessible only to the research team. Your personal information will be coded and stored separately from your activity data and interview responses. The results of this study may be published in academic journals or presented at conferences, but your identity will not be revealed.

Voluntary participation: Your participation in this study is entirely voluntary. You may refuse to participate or withdraw from the study at any time without penalty or loss of benefits to which you are otherwise entitled.

Contact Information: If you have any questions or concerns about this study, please contact the researcher, Yana Zheludko, at yanazeludko16@gmail.com or phone +380XX-XXX-XX-XX[1].

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