



## PAPER

# Software Design for Physical Rehabilitation in Patients with Musculoskeletal Injuries

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## ABSTRACT

Limited accessibility to rehabilitation services, especially in rural and marginalized areas, negatively impacts the recovery of patients with musculoskeletal injuries. This study presents the development of an application that seeks to overcome these barriers by offering personalized and digitally accessible programs. Using the design thinking (DT) methodology, five stages were implemented: 1) empathize, 2) define, 3) ideate, 4) prototype, and 5) test. During the empathize phase, the need for personalization, accessibility, and detailed visual tools was identified through patient-directed questionnaires. In the define phase, key features such as adaptable exercise plans, interactive tutorials, and progress monitoring were prioritized. In the ideate phase, proposals were devised focused on solving the identified problems. The final prototype of the application includes an intuitive interface with an interactive planner, progress graphs, and a reminder system to improve treatment integration. The results of the tests, conducted with 23 participants with musculoskeletal injuries undergoing various rehabilitation processes, indicate that functionality (37%), usability (37%), and effectiveness (26%) were the most highly valued aspects by users. In conclusion, this application represents an effective technological solution that can improve treatment adherence and transform physical rehabilitation, providing a replicable model for vulnerable populations.

## KEYWORDS

software design, physical rehabilitation, musculoskeletal injuries, patients, design thinking (DT)

## 1 INTRODUCTION

Globally, physical rehabilitation plays an important role in the recovery of patients with musculoskeletal injuries, such as fractures, sprains, and strains, affecting bones, muscles, tendons, and ligaments. According to the World Health Organization (WHO), approximately 2.4 billion people live with conditions that could benefit from rehabilitation. Since 1990, the demand for these services has increased by 63%, primarily due to an aging population and the rise in chronic diseases. However, more

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than 50% of people in low- and middle-income countries do not receive the necessary rehabilitation services, reflecting a significant gap in access to care [1].

In the Americas, the situation is also alarming. In 2019, the Pan American Health Organization (PAHO) estimated that approximately 366 million people (188 million women and 178 million men) could benefit from rehabilitation services, representing a 58% increase compared to 1990 [2]. This growth is slightly higher in women (61%) than in men (56%). In the Peruvian context, the situation is especially critical in rural areas and marginalized communities, where geographical and socioeconomic barriers hinder access to continuous treatment, delaying recovery and increasing the risk of long-term complications [3].

In this context, several studies have shown that technology plays a key role in the modernization of health services, including physical rehabilitation. Telemedicine and mobile applications have been successfully used to monitor and treat various conditions, facilitating access to care and improving therapeutic integration. The integration of multidisciplinary health teams, patient and family education, and the inclusion of physical activity routines have proven to be effective strategies for optimizing rehabilitation [4].

Although the growth of digital health solutions continues to increase, limitations in accessibility to physical rehabilitation programs persist, especially in communities with geographic and socioeconomic constraints. This lack of access can compromise patient recovery and generate additional costs for the healthcare system due to complications resulting from inadequate rehabilitation.

To address this problem, we propose the design of an application aimed at the physical rehabilitation of patients with mild or moderate musculoskeletal injuries, such as sprains, strains, or contractures, who have received a prior diagnosis from a professional. This application is designed to be used independently at home, although it can be complemented by expert follow-up with a professional if necessary. The aim is to offer an accessible and flexible solution that allows users to monitor their rehabilitation programs from any location, facilitating access to guided exercises, progress monitoring, and professional advice. Furthermore, the implementation of this technological tool could improve treatment integration and optimize rehabilitation outcomes.

This study aims to design a technological solution that facilitates remote physical rehabilitation, providing patients with musculoskeletal injuries with an accessible and personalized option. This application aims to overcome geographical and socioeconomic barriers, allowing patients to follow exercise programs tailored to their needs and efficiently influence their recovery.

Within this framework, this study is guided by key questions that allow us to understand the effectiveness of the methodological and technological approach used. First, it considers how the design thinking (DT) methodology can contribute to the design of an effective application geared toward real user needs. It also seeks to identify the most valued features in a personalized remote rehabilitation environment. Finally, it explores the challenges and limitations that arise when implementing a digital solution in real-life physical recovery contexts.

This study is structured into five sections. Section 1 introduces the issue of limited accessibility to rehabilitation services for patients with musculoskeletal injuries, establishing the objective of developing an app to improve access to physical rehabilitation. Section 2 presents a literature review of health technologies and user-centered design approaches. Section 3 details the methodology used, based on design thinking, with an emphasis on the phases of empathizing, defining, ideating, prototyping,

and testing. Section 4 presents the results obtained from the prototype, highlighting user feedback on its adaptability and key functionalities. Finally, Section 5 offers conclusions, discussing the app's impact on improving access to rehabilitation and its potential as a replicable model.

## 2 LITERATURE REVIEW

The purpose of this review is to examine recent advances in digital technologies applied to musculoskeletal rehabilitation, with an emphasis on personalized solutions for telerehabilitation. Although multiple applications and studies focused on remote rehabilitation exist, there remains a gap in the design of user-oriented tools that incorporate functionality, usability, and adaptability to improve therapeutic continuity. In this context, it is necessary to explore the variety of approaches aimed at closing this gap by creating technological solutions focused on patient perception.

The impact of the COVID-19 pandemic on musculoskeletal rehabilitation has been widely analyzed. The study [5] analyzes how social distancing measures affected access to these services, driving the adoption of telerehabilitation as a viable alternative. However, limitations were identified, such as the lack of physical contact, which hinders manual therapies. Complementarily, [6] evaluated the TelePainFree platform, which combines biomechanical taping (BMT) with therapeutic exercises, showing improvements in pain reduction and functionality, although highlighting the need for greater technological reliability. Likewise, [7] examined the role of emerging technologies such as wearable devices, the internet, and virtual reality (VR) in home-based rehabilitation, demonstrating their positive impact on patients' motor recovery and physical capacity. These studies highlight the potential of telerehabilitation as an effective tool to improve access and therapeutic outcomes, particularly in contexts of health restrictions and geographical difficulties.

On the other hand, several investigations have explored the use of technology in musculoskeletal rehabilitation. On the one hand, [8] analyzes how artificial intelligence (AI) can improve the personalization of exercise therapies, overcoming the limitations of conventional mobile applications. Through the evaluation of physiotherapists and feedback from patients, it was determined that AI is efficient in the creation of safe exercise plans, although the need to complement this technology with face-to-face physiotherapy is highlighted. On the other hand, [9] focuses on the impact of spinal cord injuries and the integration of BMT with telemedicine on the Go platform. PainFree. Results show high system acceptance and improvements in functionality and pain, although challenges related to platform reliability persist. Similarly, [10] analyzed the effectiveness of telerehabilitation in the treatment of non-specific low back pain, comparing a mobile app-based program with conventional outpatient physical therapy. Results showed that telerehabilitation offers therapeutic outcomes comparable to in-person treatments, highlighting its potential to expand access to care in geographically limited regions. These studies underscore the growing role of technology in rehabilitation, highlighting both its benefits and the remaining challenges in terms of usability and reliability.

Rehabilitation technology has shown significant advances in various areas. In this case, [11] proposes an AI-based application for the detection and classification of musculoskeletal pressure ulcers in the elderly, using YOLOv4 and smartphone cameras. With an overall accuracy of 63.2% and high specificity, the results highlight the viability of mobile health (mHealth) applications in geriatric care settings.

Furthermore, [12] compares the use of surface and intramuscular EMG to estimate joint torques in assistive devices, evaluating their reliability in healthy subjects and patients with incomplete spinal cord injury. The results indicate that both methods present a similar correlation in torque estimation, with implanted sensors proving to be a viable option for exoskeleton control. Along the same lines, [13] examines the effectiveness of a six-month telehealth program designed to improve cardiorespiratory fitness in people with spinal cord injury. Through individual telephone counseling and adapted modules from the Diabetes Prevention Program, the study showed improvements in physical activity and indicators such as  $VO_2$ , as well as benefits in quality of life, pain, and depression. These studies reflect the impact of technology on rehabilitation and patient well-being, highlighting both its applicability and the need to optimize its implementation.

In addition to advances in rehabilitation and telehealth, initiatives to improve accessibility to physical activity in populations with specific needs have been explored. In this regard, [14] analyzes the usability of an inclusive mHealth fitness application for people with physical disabilities (PWD), evaluating its effectiveness, efficiency, and perceived satisfaction. Through a usability study complemented by interviews, researchers identified that 96% of the tasks were completed successfully and that overall satisfaction was positive; however, accessibility barriers exist. The study highlights that only 45.8% of PWD find applications appropriate to their needs, which underscores the urgency of developing more accessible and adapted tools. In conclusion, although the evaluated application shows great potential, it is considered crucial to optimize its design to encourage participation in physical activity among this population.

In summary, these studies demonstrate significant progress in the inclusion of technologies in rehabilitation but also reveal limitations in terms of customization, reliability, and user-centeredness. Few studies incorporate methodologies with end users, which limits their implementation and effectiveness in real-life settings. This work seeks to contribute in this direction by suggesting a telerehabilitation tool developed using the DT methodology, focused on filling this gap from an inclusive and functional perspective.

### 3 METHODOLOGY

The app was developed using the DT methodology, an approach focused on innovation and user experience, with the goal of designing a technological solution that provides personalized exercise programs for patients with musculoskeletal conditions. This methodology consists of five phases: 1) empathize, 2) define, 3) ideate, 4) prototype, and 5) test, which allows for an iterative process that meets the needs of patients and healthcare professionals.

#### 3.1 Design thinking

Design thinking is an innovation methodology that prioritizes user needs to develop technological solutions that optimize their experience. Its approach is based on a deep understanding of user problems, using structured processes that foster team collaboration and creativity in the search for solutions. This method is recognized by innovation companies and designers for its ability to generate products

that effectively meet user expectations by integrating their needs into every stage of the process [15].

Furthermore, DT is not only oriented towards the creation of technological solutions but also towards the continuous improvement of the product through collaborative tools that allow the adaptation and improvement of the identified solutions [16]. The process structure in its five phases provides a flexible framework for the constant refinement of the design, as illustrated in Figure 1.

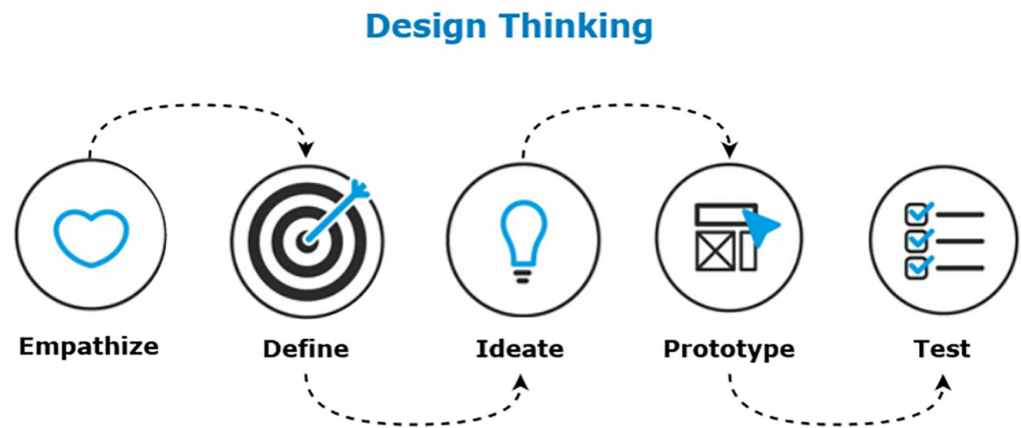


Fig. 1. DT methodology

### 3.2 Execution methodology

1. *Advantages:* Among the advantages of the DT methodology are its ability to foster creativity, continuous replication, and early validation of ideas, which reduces the risk of developing non-functional products. Furthermore, its flexible structure allows the solution to be modified at each stage based on user feedback.
2. *Disadvantages:* Among the disadvantages of DT is the need for significant time and resources to effectively complete all its phases. Furthermore, its replicable nature can generate constant changes that make strict development planning difficult.
3. *Comparisons:* Compared to methodologies such as Scrum or Mobile-D, DT focuses more on a detailed understanding of the user experience before implementation, while Scrum prioritizes rapid delivery of functionality through sprints, and Mobile-D seeks to develop its product through rapid cycles. Despite these differences, DT has proven to be a methodology that can enhance product development by balancing creativity with efficient execution.
4. *Limitation of the methodological approach:* Although DT has proven useful in creating user-oriented solutions, especially in general health and wellness contexts, it is recognized that its use in physical rehabilitation processes requires greater methodological rigor and specialized clinical validation. In this context, this study is presented as an initial phase of user-centered design, which can be used as a reference for future implementations that include proven clinical protocols. In this sense, it is highlighted that the DT methodology allowed for the collection of real user needs and the proposal of functional solutions. However, it does not replace regulated clinical processes but rather complements them from an innovation approach oriented toward the patient experience.

### 3.3 Phases of the methodology

1. *Empathize*: In this first phase, we sought to understand the needs and challenges of patients with musculoskeletal injuries who undergo rehabilitation at home [17]. To this end, structured questionnaires were administered to a sample of 23 participants, selected through purposive sampling, who were in various rehabilitation programs for musculoskeletal injuries (sprains, strains, and contractures), which had been previously identified by specialists. All participants were in the initial phase of treatment and performed rehabilitation exercises from their homes, with various scenarios; some with moderate injuries had remote professional supervision, and users with mild injuries received general instructions. The information collected made it possible to identify patterns of user needs, as well as key aspects for the design of functional and personalized software.
2. *Define*: This phase consists of synthesizing the data obtained from the previous stage to identify the central problem to be solved [18] [19]. The responses to the questionnaires were analyzed to detect the main difficulties faced by patients in their rehabilitation. From this analysis, the key functionalities that the application must include to guarantee safe and effective exercises are defined.
3. *Ideate*: This phase involves generating and evaluating different innovative proposals to design a functional, engaging, and motivating application for patients [20]. Based on the needs identified in the previous phase, we seek to explore technological, educational, and emotional support solutions. Ideas will be selected based on their feasibility and impact on the user experience.
4. *Prototype*: This prototyping phase seeks to develop tangible representations of the application to validate concepts before final implementation [21] [22]. Prototypes were designed that integrate personalized exercise plans, interactive tutorials with visual guides, a library of educational resources, and a reminder system to improve integration into treatment and optimize rehabilitation outcomes.
5. *Test*: In this final phase, the prototypes were evaluated through usability testing with the 23 participants already defined. Each user interacted with the system during simulated exercise sessions, where feedback on the usability and effectiveness of the software was obtained [23] [24]. Aspects such as the functionality of the exercise plans, the clarity of the tutorials, and the usefulness of the educational resources were analyzed. The aim is to verify the effectiveness of the reminder system, making adjustments according to the needs and preferences of the patients to ensure an optimal rehabilitation experience.

### 3.4 Tools for design

For the design of the web application focused on the rehabilitation of musculoskeletal injuries, various tools were used that guarantee efficient integration between technologies [32], providing an accessible and easy-to-use interface for patients.

*Figma*: It is a graphic editing and prototyping tool used to design user interfaces and web pages. Its cloud-based operation allows real-time collaboration, facilitating access from any browser without the need for installation [25].

*Power Apps*: It is a Microsoft platform that enables rapid development of custom applications for mobile and web devices. Its graphical interface simplifies connection to various data sources, such as Microsoft 365, SQL Server, and SharePoint,

without requiring advanced programming knowledge [26]. In addition, its ability to integrate with local servers optimizes business processes and workflows [27].

*Power Automate:* This is a Microsoft tool that allows you to automate business processes through workflows, reducing the need for manual tasks. In this study, it will be used to manage notifications, appointment reminders, and data synchronization, ensuring accurate and continuous updating of rehabilitation treatment information [28].

*Power BI:* It is a data analysis tool that transforms large volumes of information into interactive reports and visual dashboards. Its ability to connect to multiple data sources facilitates real-time analysis, optimizing decision-making and monitoring rehabilitation treatments through intuitive graphics [29] [30].

*Dataverse:* A cloud storage platform that allows you to manage and synchronize data across various applications. Its integration with Power Apps and Power Automate facilitates secure, real-time access to patient information, ensuring that rehabilitation treatments are constantly updated [27].

*AI Builder:* This is a Microsoft tool that offers AI capabilities without requiring advanced programming knowledge. Its integration with Power Apps and Power Automate allows for the automation of processes such as treatment classification or the prediction of patterns in patient behavior, improving personalization and precision in rehabilitation [31].

## 4 RESULTS

This section presents the results obtained from the implementation of the DT methodology, addressing the main challenges faced by patients in their physical rehabilitation process. The developed solution consists of an application designed to optimize the rehabilitation experience for people with musculoskeletal injuries. The results include the integration of key features, such as personalized exercise plans, educational resources, and interactive guides. In addition, a usability analysis was conducted, allowing for user feedback and facilitating continuous improvements to the application. This approach seeks to ensure that the developed solution effectively responds to patients' needs, promoting connection to rehabilitation programs and optimizing the recovery process.

### 4.1 Results of the empathize phase

To obtain results from the first stage of design thinking, a questionnaire was designed to identify users' needs and problems. This instrument was validated by experts in the field and included four questions (Q1 to Q4), detailed in Table 1. The first three were multiple-choice questions to facilitate the identification of patterns in the responses, while the last was open-ended, allowing participants to freely express their opinions and suggestions.

The questionnaire was sent to a representative sample of 23 people with musculoskeletal injuries, whose information served as a basis for better understanding their experiences during the rehabilitation process. This data was essential for guiding the subsequent phases of the methodology and ensuring that the app design addressed the real needs of users.

**Table 1.** Questions

ID	Questions
P1	How would you adapt a rehabilitation program for different skill levels or physical conditions?
P2	What types of resources do you consider important for patients to better understand the exercises?
P3	What type of information about your rehabilitation would you like to see in progress reports?
P4	What features do you consider necessary in an app to ensure that the exercises are performed correctly?

## 4.2 Results of the define phase

In the second phase of the methodology, the responses to the questionnaire administered to 23 people with musculoskeletal injuries, detailed in Table 2, were analyzed to identify key needs for the design of the proposed solution. Each of the questions identified in the first phase (Q1 to Q4) is addressed in this phase (Q1 to Q4). These questions address a key aspect for identifying the specific needs and problems of users, which are fundamental to the design of the proposed solution.

**Table 2.** Responses

ID	Answers
P1	Adapt exercises according to the patient's initial assessment (32.4%) Offer options for each exercise (easy, intermediate, advanced) (8.2%) Adjust exercises according to the patient's progress (16.2%) Perform exercises with videos or guides that explain the use of support for each level (27%) Adjust the duration and frequency of exercises according to the patient's ability (16.2%)
P2	Show how to do each exercise step by step (31.2%) Explain each exercise with clear and simple text (12.5%) Provide images that show the correct posture (27.1%) Include tips to avoid injuries during exercises (12.5%) Reminders to stay consistent with exercises (16.7%)
P3	Average number of repetitions performed per exercise (12.2%) Percentage of compliance with the rehabilitation plan (36.6%) Number of sessions completed in the week/month (29.3%) Cumulative progress in terms of exercises completed (21.9%)
P4	Inclusion of videos and detailed guides per exercise (19.5%) Exercise finder according to personal injuries (18.8%) Exercise programming according to the user's free days (5.3%) Identification of current level and capacity (2.9%) Online advice with trained staff (11.9%) Ease of user interface (21.7%) Reminders with images or microvideos (2.6%) Accessibility of exercises (17.3%)

1. *Q1*: This question, related to the adaptation of rehabilitation programs, shows that 32.4% of participants prioritized personalizing exercises based on the patient's initial assessment, while 27% highlighted the importance of videos and explanatory guides. Other options, such as adapting the duration and frequency of exercises (16.2%) and progressive adjustment based on patient progress (16.2%), were also relevant, although less frequently selected. These results reflect the need for a flexible, multimedia approach to improving rehabilitation.

2. Q2: This question focuses on the most effective resources for understanding the resources. It highlighted that 31.2% of respondents prioritized step-by-step demonstrations, while 27.1% emphasized the importance of proper posture. Similarly, 16.7% valued reminders as a support for exercise consistency. These results reinforce the need for graphic and multimedia resources within the app, as well as reminder systems to encourage treatment adherence.
3. Q3: This question shows that 36.6% of respondents considered it essential to know the percentage of rehabilitation plan adherence. Other metrics mentioned were the number of sessions completed (29.3%) and cumulative progress in terms of exercises performed (21.9%). These results indicate that users prefer general and cumulative indicators that clearly and reflect their progress, motivationally.
4. Q4: This question revealed the importance of a personalized, visually clear, and accessible app, with special attention to the needs of patients with specific injuries. The inclusion of detailed videos, the ability to adjust exercises based on the user's progress, and injury-based personalization were valued. The need for scheduling flexibility and constant feedback through reminders or real-time monitoring was also emphasized. These results highlight the importance of offering an adaptable, user-centered rehabilitation experience.

### 4.3 Results of the ideate phase

During the ideation phase, the team generated various proposals to address the problems identified in the previous phase, taking into account the results of the questionnaire. Based on these ideas, the key functionalities for the application were defined, ensuring that the exercises were performed correctly and that the user experience was optimal. These functionalities are presented in Table 3.

**Table 3.** Features

Features	Description
Search for Exercises	Find exercises based on a patient's injury or condition, tailored to their rehabilitation needs.
Personalized Exercise Plans	Create specific exercise plans based on each patient's needs and abilities.
Feedback	Users can provide feedback on exercises to improve the experience and effectiveness.
Step-by-step tutorials	Includes detailed guides (text, images, or videos) for proper execution of the exercises.
Progress Monitoring	View progress with charts and statistics on exercise completion.
Exercise Programming	Allows you to schedule and receive reminders about exercise days and times to stay consistent.

### 4.4 Results of the prototype phase

The prototype app for the rehabilitation of patients with musculoskeletal injuries has been designed to offer an intuitive and efficient experience.

Figure 2 shows the app's cover page, which includes the company logo to reflect the project's identity and mission, providing a professional first impression. It also shows the user login for account creation, where they must enter their personal information to ensure a secure and personalized registration.

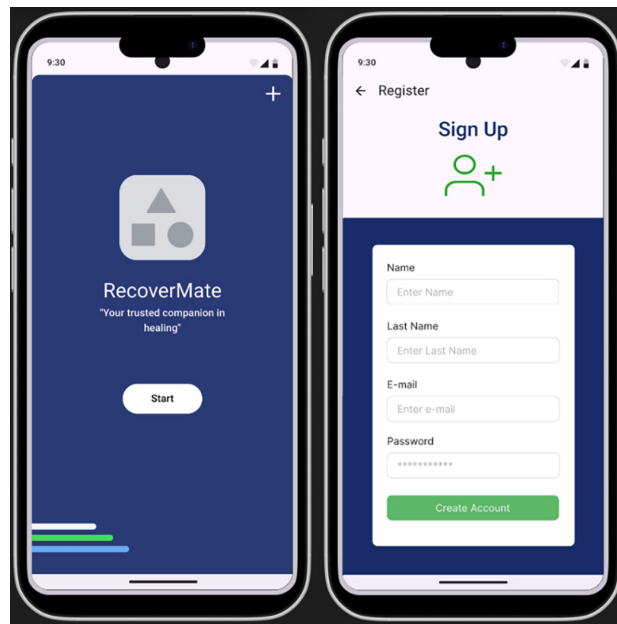


Fig. 2. Presentation interface and registration interface

Figure 3 shows the login interface, where users can securely access their account with their email and password. Before that, the home interface is displayed, welcoming the user with shortcuts to the main sections.



Fig. 3. Login interface and home interface

Figure 4 shows the exercise search, where users can enter their injury or physical condition to find specific exercises. This interface includes a search engine and a list of suggested exercises with details such as sets, repetitions, and illustrative thumbnails. The user profile is also shown, allowing users to manage their personal information, such as profile picture, name, age, email, and phone number, ensuring a personalized and up-to-date experience.



Fig. 4. Exercise finder and user profile interface

Figure 5 shows the workout plan interface, where users can manage their personalized routine. In this interface, they can modify exercises, view details, rate exercises, and access features such as progress monitoring, session scheduling, and adding new exercises to the plan. Additionally, the workout scheduling interface allows users to schedule their workouts on a calendar, assigning specific days and times based on their needs.

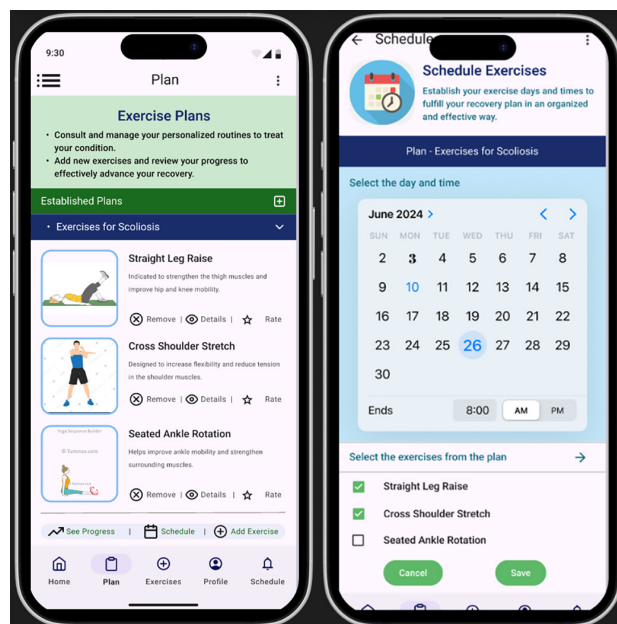


Fig. 5. Exercise plan and programming interface

Figure 6 shows the calendar interface, which allows you to view scheduled activities. Days with assigned exercises are highlighted on the calendar, and selecting them displays a list of scheduled exercises along with the option to mark them

as completed. If the user misses an exercise, the system records it as pending, providing accurate progress tracking. Additionally, the exercise details interface offers a visual guide with tutorial videos, descriptions, illustrative images of each step, and options to rate and add the exercise to the plan.

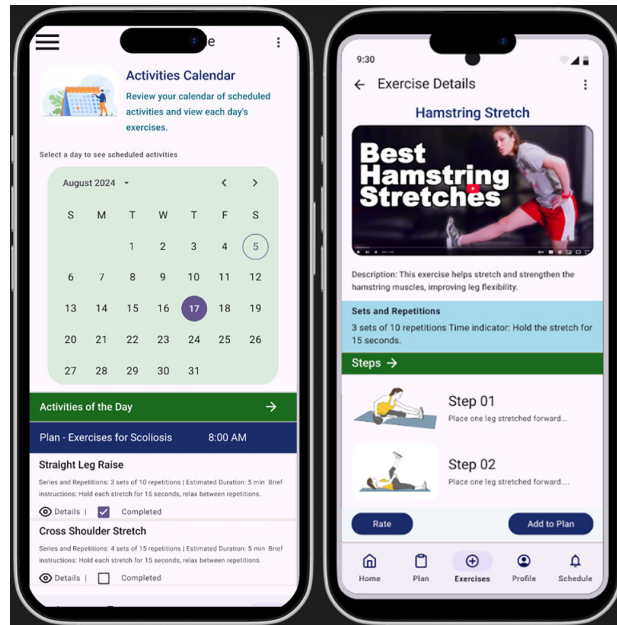


Fig. 6. Agenda and exercise details interface

Figure 7 shows the progress interface, where users can monitor their progress through percentage graphs that reflect their adherence to their exercise plan. It also includes a detailed breakdown of the number of completed and pending sessions. Additionally, an exercise rating interface is displayed, allowing users to rate each exercise using a star system (from 1 to 5), indicate whether it met their expectations, and leave comments or suggestions for future improvements.

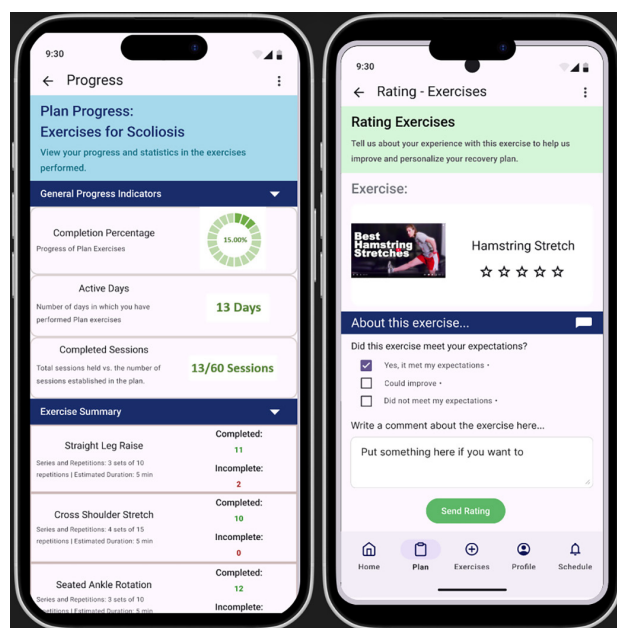


Fig. 7. Progress and exercise grading interface

Figure 8 shows the web version of the RecoveryMate app, highlighting its home page with the app name and slogan, accompanied by a registration button that guides users through creating an account. The navigation menu includes access to the platform's main sections, such as home, workout plans, and calendar. Additionally, the page highlights the app's benefits and goals, seeking to convert visitors into active users. Additional information and relevant links are provided in the footer to facilitate navigation.

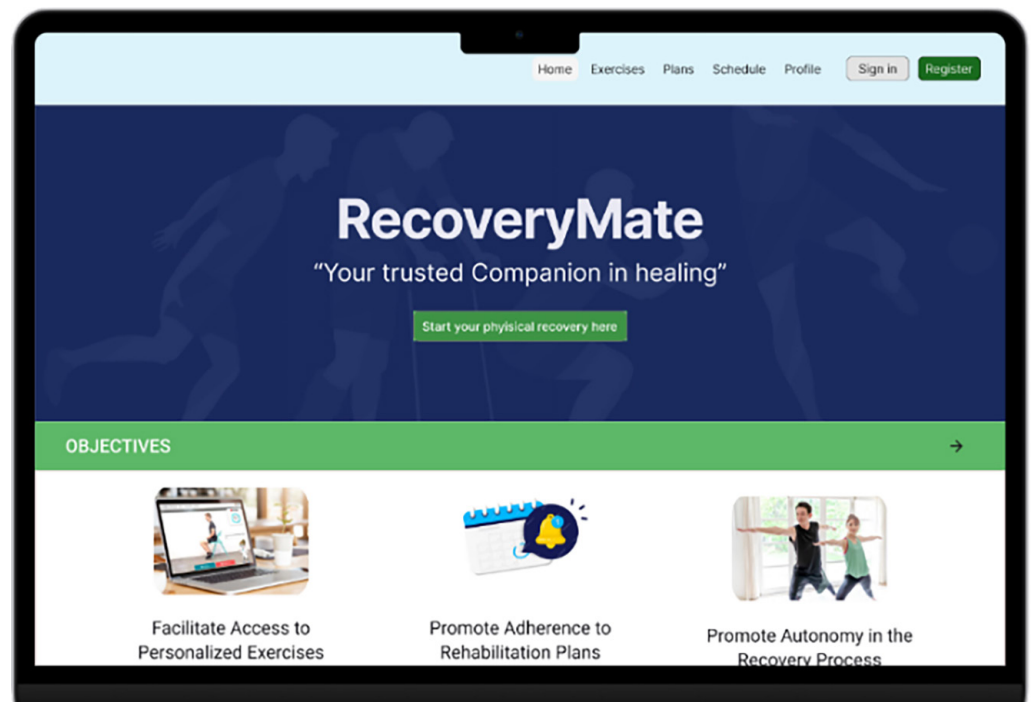


Fig. 8. Home web interface

#### 4.5 Results of the test phase

During the testing phase, three key aspects of the software were evaluated: 1) functionality, 2) usability, and 3) effectiveness. These tests were conducted with 23 participants, all of whom were patients with various musculoskeletal injuries undergoing rehabilitation. These tests identified key aspects that influence the user experience and identified opportunities for improvement to properly optimize the final implementation.

For the evaluation, a test format was designed that included three main activities. First, users were given the opportunity to explore the application independently without prior instructions, with the aim of detecting problems in navigation and interaction with the interface. They were then asked to complete specific tasks, such as registering, searching for an exercise, adding it to their plan, scheduling it in their calendar, and marking it as completed, which facilitated the analysis of the efficiency and clarity of the processes within the platform. Finally, a satisfaction questionnaire was administered to collect opinions on aspects such as ease of use, clarity of information, fluidity of navigation, and visual design. Figure 9 shows the values obtained in the tests.

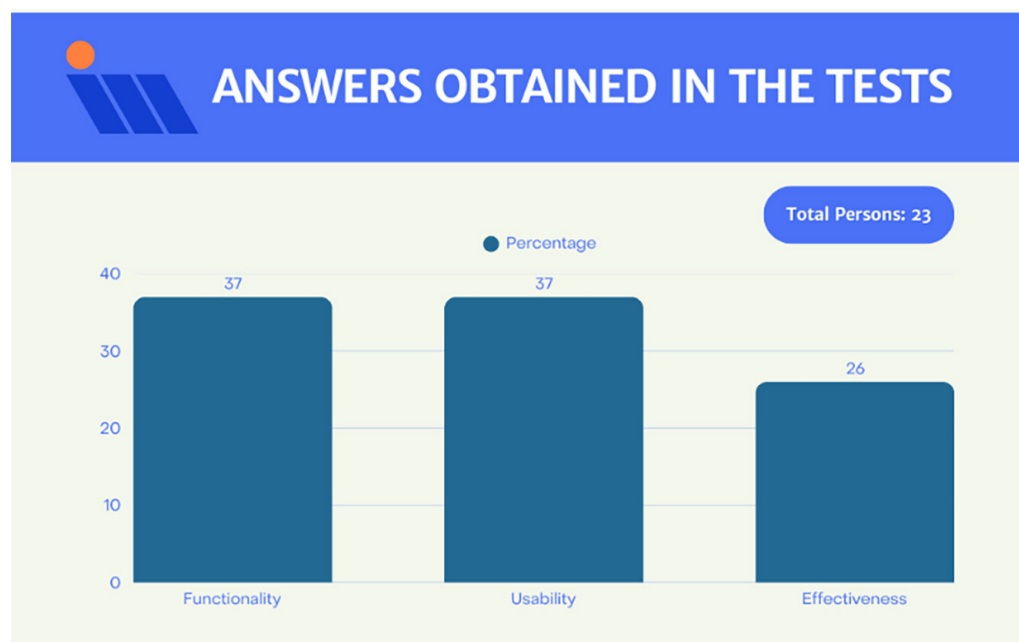


Fig. 9. Responses obtained

The results show that 37% of participants highly valued the app's ability to adapt to their individual needs in terms of functionality, highlighting the importance of allowing personalized adjustments to exercise plans based on rehabilitation progress. Furthermore, 37% of users highlighted the usefulness of the visual guides in terms of usability, noting that the explanatory images and videos were essential for understanding and correctly performing the exercises, underscoring the need to strengthen these resources within the platform. Meanwhile, 26% of participants indicated that reminders and notifications significantly contributed to maintaining rehabilitation consistency. This is related to the perceived effectiveness of the software in promoting treatment adherence, although it is not considered a direct clinical measure of therapeutic outcomes.

Based on feedback from participants, several improvements to the app were proposed. First, we expanded the customization of exercise plans to allow users to dynamically adjust their routine based on their progress and specific needs. Second, we proposed improvements to the visual guides, incorporating more detailed explanatory images and videos to enhance the understanding of each exercise. Finally, to strengthen the reminder system, we are considering offering more flexible options so that each user can configure the frequency, format, and type of notification that best suits their recovery process.

With these improvements, the RecoveryMate app is constantly being optimized to offer a more accessible, functional, and tailored experience for rehabilitation patients, ensuring that each user can continue their treatment effectively and without technological difficulties.

## 5 DISCUSSION

During project development, several limitations were identified that influenced the scope and implementation of the results. One of the main limitations was the absence of long-term clinical studies that would allow for accurately measuring

the app's effectiveness in the rehabilitation process. Furthermore, the lack of integration with real-time monitoring devices limited the ability to adapt exercise programs to individual user progress. Furthermore, interaction analysis systems, such as heat maps, were not included, which would have been useful for identifying the most frequently used sections of the app and optimizing the user experience. These limitations highlight the need to adopt broader approaches, incorporate advanced tools, and conduct longitudinal studies in future projects to improve both development and outcomes.

Despite these limitations, this study offers a significant contribution to the field of remote digital rehabilitation, especially by implementing a user-centered methodological approach through the use of DT. This approach not only guided the technical development of the prototype but also facilitated the identification of specific requirements from the patient perspective, which constitutes a shift from proposals originating solely from clinical or technical criteria. In this way, the use of DT expands the traditional healthcare technology design paradigm by prioritizing empathy, creation, and early validation of solutions. This provides a solid foundation for seeking to improve treatments from a patient-centered perspective.

In line with the recommendations of the World Confederation for Physical Therapy (WCPT), which emphasize the use of remote therapies to promote patient autonomy in various aspects [5] [34], this application proposed an exercise details interface that combines tutorial videos, descriptions, and detailed steps, elements that are considered to improve user self-efficacy. These strategies are reinforced by the findings of [6], which indicate that the clarity and accessibility of content are decisive in following digital treatments.

In contrast to traditional methodologies based on exercise protocols and home treatments [7] [33], this proposal expands existing strategies by integrating dynamic personalization technology, such as a smart exercise finder based on injury type, which represents a significant advance in treatment adaptation. Furthermore, the implementation of an exercise rating system allows for direct feedback, favoring continuous improvement of the system, as highlighted in research evaluating the effectiveness and satisfaction of similar applications [14].

From an originality perspective, although the developed prototype is a technical implementation, its value lies in the combination of multiple elements into a user-focused solution, using DT as the central axis. This perspective allowed for structuring the application's development and generating relevant knowledge about the real needs of users in remote rehabilitation processes. By identifying specific patient needs early on, the potential of DT to structure patient-centered technological solutions was evident. This methodological approach, still underexplored in similar studies, positions this study as a significant contribution to the combined aspects of technology, healthcare, and user-oriented design.

Finally, it is important to recognize the risks associated with the use of software in medical contexts, especially when guiding physical exercises for patients undergoing rehabilitation. Incorrect implementation resulting from misunderstood instructions could compromise the user's health. In this sense, the need for more rigorous regulatory responsibility when developing technologies applied to health becomes evident. Because the software involves the planning and monitoring of therapeutic exercises, it may be classified as Software as a Medical Device (SaMD), which would require compliance with international standards such as IEC 62304, which regulates the life cycle of medical software, and ISO 14971, which regulates risks. These are considered good practice frameworks for user-centered design for health technologies established by entities such as the World Health Organization. Furthermore, to

strengthen its potential for integration into institutional health contexts, it is recommended to explore its interoperability with health information systems or electronic medical records, which will allow for more coordinated and secure monitoring of the treatments under consideration. In this regard, it is essential to include clinical validation and ethical certification processes to ensure that the solution is not only practical and applicable but also safe and reliable for implementation in different rehabilitation contexts.

## 6 CONCLUSIONS

This project achieved its primary objective of designing an app for the physical rehabilitation of patients with musculoskeletal injuries, providing a personalized and intuitive experience. The use of the DT methodology allowed for a deep understanding of patients' real needs, the identification of critical points to consider in the remote rehabilitation process, and the development of functional solutions through continuous interaction with users. Each stage of this methodology was crucial to developing a user-centered proposal.

Regarding the first research question, it was found that DT significantly contributes to the design of technological solutions by helping to understand and identify the patient's problem. In the Empathize and Define phases, specific difficulties in exercise adherence and the need for clear instructions were identified. Subsequently, in the Ideate phase, key features such as exercise search, the exercise plan, and visually supported exercise details were prioritized. The prototype phase, meanwhile, provided a preview of the considered solution, which was validated in the final Test phase, confirming its usefulness in terms of user perception in real-life rehabilitation contexts. Regarding the second question, the results show that users value adaptability, the clarity of visual guides, and reminders as fundamental tools for increasing rehabilitation adherence. These features were designed with their preferences and difficulties in mind, highlighting the importance of considering their opinions during the software development process. Regarding the third question, during prototype testing, opportunities for improvement were identified, such as the need for greater customization of notifications or the integration of real-time tools. These limitations open up new avenues for improvement for future versions of the app.

Finally, future studies recommend integrating technologies such as motion sensors to assess exercise accuracy in real time, using advanced analytics such as heat maps to optimize the user experience, and conducting longitudinal studies in diverse populations to validate the app's effectiveness and scalability. The incorporation of these elements will improve the personalization and effectiveness of the rehabilitation process, ensuring a greater impact on patient recovery.

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