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PAR: Towards a Reference Architecture for Accessible Platforms in Respiratory Therapies

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Abstract: This article focuses on the Accessible Platform for Respiratory Therapies (PAR), designed according to the iPlus methodology with the application of usability and accessibility criteria, following the guidelines of WCAG 2.1. PAR aims to improve the quality of life for individuals with lung diseases by providing therapeutic education to patients in respiratory recovery. This approach aligns with Sustainable Development Goals 3, 4, and 10 and follows a user-centered design, facilitating access to treatments and techniques to enhance pulmonary function. Additionally, the platform promotes the education and training of professionals in respiratory therapies, reducing disparities in access to healthcare. Sustainability is strengthened by integrating telemedicine technologies, improving efficiency, and reducing costs. Implementing Web Content Accessibility Guidelines (WCAG) 2.1 ensures accessibility and usability for all individuals, including those with disabilities. The combination of WCAG 2.1 and the CSUQ questionnaire not only ensures accessibility but also contributes to sustainability and overall improvement of the user experience, even for individuals with cognitive disabilities.

Keywords: telerehabilitation; usable; accessible; respiratory rehabilitation; therapeutic education; sustainability; COVID-19; CSUQ

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1. Introduction

The COVID-19 pandemic [1] has underscored the importance of addressing respiratory diseases and the necessity for effective therapies to enhance the quality of life for affected individuals. In this context, chronic respiratory diseases have presented a significant challenge with a global impact across social, economic, and environmental dimensions. The World Health Organization (WHO) notes that between 2000 and 2019 [2], chronic respiratory diseases caused 4.1 million deaths globally, with a 37% decrease in mortality from these diseases during that period. This scenario highlights the relevance of implementing sustainable strategies to address these conditions, aligned with Sustainable Development Goals (SDGs) 3, 4, and 10, aiming to ensure a healthy life, promote inclusive and equitable education, and reduce inequalities while fostering social inclusion [3]. In this context, having an accessible platform for respiratory therapies can significantly contribute to the sustainability of healthcare by improving access to treatments and techniques to enhance lung function. It can also promote education and training for professionals in respiratory therapy, thereby reducing disparities in healthcare access.

Information and communication technologies (ICTs) are pivotal in addressing physical and functional recovery and facilitating social reintegration, mainly through pulmonary rehabilitation programs. In response to these challenges, telemedicine and telerehabilitation

(TR) have emerged as indispensable tools for delivering comprehensive respiratory care. These technologies bridge the gap between patients and healthcare providers, ensuring the safety and accessibility of healthcare services. In this context, telerehabilitation has become invaluable for providing remote healthcare services.

A team of professionals identified the need to design and implement a series of straightforward telerehabilitation exercises to improve physical conditions in individuals, particularly those with pulmonary respiratory diseases. In formulating our proposed solution, we adhered to a user-centered design (UCD) process, prioritizing users' needs throughout every design phase. Our methodology is grounded in the iPlus approach [4], initially devised for educational software, encompassing the virtual reality serious game for recreational therapy [4]. The iPlus methodology provides a unified approach seamlessly integrated with agile methods. It initiates problem definition and delineates intended learning outcomes, involving input from both experts and users to discern requirements. iPlus advocates for active and creative engagement from all stakeholders, emphasizing a participatory approach that ensures designers and users prioritize user requirements throughout the educational software design process. Consequently, the research team has devised a digital platform integrating therapeutic education exercises for respiratory rehabilitation to enhance the quality of life for individuals with respiratory diseases.

The developed educational telerehabilitation material will be accessible on a freely available platform. This resource is a valuable tool for professionals in education, rehabilitation, and healthcare, enabling them to integrate it into their intervention plans for respiratory rehabilitation. Furthermore, the platform can serve as both an assessment tool and an intervention instrument, allowing for tracking each patient's progress. Professionals can utilize these data to adapt and customize rehabilitation plans, select appropriate exercises, and enhance the development of physical processes such as respiration, motor skills, pain reduction, strength, and mobility. The exercises included in the educational platform, named "PAR", were meticulously designed by medical experts, ensuring that the workouts are simple and easy to perform. Additionally, the platform was intended to follow Universal Design for Learning (UDL) principles. UDL constitutes a framework striving to secure fair access to learning and equivalent chances for individuals, irrespective of their diverse needs and characteristics [5].

The purposeful structure of the platform guarantees its adaptability to various devices, including computers, tablets, and mobile phones. This strategic decision is influenced by the fact that numerous households in Ecuador face challenges in accessing computers. A research inquiry in public schools within the Sierra region of Ecuador revealed that just 33% of students had the opportunity to use computers. Similarly, the investigation highlighted that a minimal 11.9% of households in the northern highlands of Ecuador, where the students were situated, possessed a tablet [6].

The importance of our research-oriented product lies in its ability to address the unique requirements of our context. Initially designed for individuals with intellectual disabilities, the platform broadens its applicability to school children or older adults, aiming to improve physical functions such as breathing, motor skills, pain relief, strength, and mobility. By focusing on the specific needs of the target population and following universal design principles, the platform provides a comprehensive and effective solution to promote physical development and guarantee equal opportunities for everyone.

In addition to the outlined structure, this article aims to contribute to global health equity by exploring the implementation of our telerehabilitation solution in diverse socioeconomic contexts. It emphasizes accessibility for all, irrespective of geographical location or economic status. The discussion will extend to the long-term benefits of improved respiratory health, aligning with the journal's focus on health-related aspects of sustainability. Lastly, the educational component of the platform will be highlighted, demonstrating its role in promoting awareness of sustainable healthcare practices and contributing to the education of users on respiratory health and sustainable living.

This article is structured as follows. Section 2 presents a framework providing context on technology in respiratory diseases, accessibility and usability in sustainability, and our proposed solution to the problem. It also describes the design and implementation of the Accessible Platform for Respiratory Therapies (PAR). Section 3 offers the results of evaluating the platform's accessibility and usability. Finally, Sections 4 and 5 present the discussion and conclusions, respectively.

2. Materials and Methods

In this section, we delve into the critical components of developing and deploying the "PAR" educational telerehabilitation platform designed to address the specific needs of individuals with respiratory diseases. Our methodological framework draws on established approaches and standards to ensure a robust and user-centered platform.

For the conceptualization and design of our study, we employed the iPlus methodology, a participatory and user-centered approach proven effective in developing educational software and serious games. Embracing the principles of user-centered design (UCD) and Universal Design for Learning (UDL), we meticulously guided each phase of our study, from conceptualization to implementation. This strategy prioritized user needs and guaranteed the platform's accessibility to a diverse user base, irrespective of their abilities or characteristics. Furthermore, our adherence to the Web Content Accessibility Guidelines (WCAG 2.1) sets stringent standards, ensuring equitable access for all users. The implementation phase followed the agile SCRUM framework, a methodological choice aimed at efficient project management and iterative delivery of user-centric features. SCRUM facilitated seamless collaboration among team members and ensured the incremental enhancement of the platform with a focus on user satisfaction.

The PAR platform was evaluated following a rigorous and systematic approach to ensure the quality and accuracy of the results. The following measures were implemented to ensure the validity and reliability of the results:

Evaluation team: A team of rehabilitation and technology experts evaluated the PAR platform, using standardized methods and tools to ensure objectivity and consistency.

Evaluation criteria: Specific criteria were established to evaluate the effectiveness, usability, and accessibility of the PAR platform in line with WCAG 2.1.

Evaluation in different settings: The PAR platform was evaluated in various settings, including telemedicine rehabilitation and online healthcare, to ensure its functionality and accessibility in different contexts.

Data Analysis: Platform usage data, such as usage time, number of interactions, and identified errors or challenges, were collected and analyzed to identify areas for improvement and ensure the quality and accuracy of results.

In this section, we contextualize the current state of technology in pulmonary rehabilitation, addressing key aspects of accessibility, usability, and sustainability in healthcare platforms. Subsequently, we provide a detailed account of the conceptualization, design, and implementation phases of the "PAR" platform.

2.1. Background and Framework

2.1.1. Technology in Pulmonary Rehabilitation

Recent advancements in virtual healthcare technologies are reshaping the landscape of respiratory care, offering unprecedented opportunities for improved patient outcomes, enhanced access to healthcare, and reduced burdens on medical providers [7].

Integrating digital technology into healthcare, known as digital health, has transformed the healthcare sector through software programs, hardware systems, and associated support services. Digital health encompasses a range of technologies, including mobile health (mHealth), electronic medical records (EMRs), telehealth, electronic health records (EHRs), and telemedicine [8]. This digital shift addresses the growing demand for personalized healthcare and involves various stakeholders, such as physicians, patients,

app developers, researchers, distributors, and smart device manufacturers. Digital health plays a pivotal role in modern healthcare infrastructure [8].

The following overarching trends have indicated a pronounced inclination toward digital health.

- The utilization of digital communication technologies like computers, mobile phones, and tablets for healthcare delivery characterizes telehealth. The global telehealth market is projected to exceed USD 185 billion by 2026, reflecting a sustained growth trajectory. Telehealth is expected to persist, with estimates indicating that USD 250 billion of total U.S. healthcare spending could transition to virtual platforms in the post-pandemic years [9].
- The Internet of Things (IoT) refers to the expanding network of physical objects embedded with software, sensors, and other technologies that facilitate data exchange over the Internet. The Medical IoT sector in healthcare is rapidly evolving, employing wearable devices, monitors, and integrated applications to cater to healthcare needs. With artificial intelligence (AI) and machine learning technologies, Medical IoT enhances traditional medical devices, such as smart inhalers synchronized with mobile applications [9].

In this study, we adopted a purposive sampling approach, selecting platforms or tools widely recognized and representative of the current landscape in telerehabilitation and healthcare accessibility. The goal was to include platforms with diverse features, functionalities, and user interfaces to comprehensively understand the usability and accessibility considerations within the broader context. The decision to include ten platforms was based on balancing the need for an adequate sample size to draw meaningful conclusions and the practical constraints of resource availability and research scope. While a larger sample size might provide more statistical power, the complexity and depth of the analysis required for each platform necessitated a pragmatic approach. Furthermore, the platforms selected represent a cross-section of the major players in the field, encompassing variations in design philosophies, target user populations, and intended functionalities. This diverse selection enhances the reliability of our findings to a broader spectrum of telerehabilitation platforms.

Innovative technologies play a crucial role in providing effective healthcare solutions, for example:

- Health Care Originals: Offers a digital respiratory therapy platform catering to professional, research, and personal use, presenting portable solutions optimized for respiratory applications [10].
- MyNewLungs version 2023: An online pulmonary rehabilitation program, emphasizing highly effective remote intervention and showcasing positive outcomes such as improved pulmonary function and increased exercise tolerance [11].
- Rehab Guru: A trusted home exercise prescription platform, incorporating over 550 high-quality exercises, with telehealth features facilitating virtual consultations and digital exercise programs [12].
- Doctdot version 2020: A medical-grade respiratory disease diagnostic application 2023 version, leveraging AI for remote vital sign monitoring and providing rapid results through smartphone interaction [13].
- AI for COVID-19 Detection: Utilizes voice analysis, presenting a cost-effective and user-friendly approach more accurate than traditional tests [14].
- ReCOVery: Used to monitor and assess the recovery of patients who have experienced COVID-19, collecting data on symptoms, quality of life, and overall well-being [15].
- Rehab My Patient: A platform that delivers personalized and guided rehabilitation programs, facilitating physical recovery through customized exercises and care [16].
- FreePT: Provides physical therapy services remotely, allowing users to access personalized exercise routines and rehabilitation programs [17].
- Zoom version 5.11.11 and Microsoft Teams version 5.15.2: Widely used in the context of COVID-19 telerehabilitation, enabling remote sessions between healthcare pro-

fessionals and patients to assess, monitor, and guide recovery, providing access to healthcare services without the need for physical encounters [18].

The growing reliance on smartphones contributes to market dynamism, fostering innovative medical applications and enhancing chronic disease treatments. Digital health technologies stand as innovations and amplify the impact of other advancements by connecting patients with necessary services and cutting-edge therapies [19]. Telerehabilitation (TR) emerges as an innovative health strategy, leveraging ICT advances to improve healthcare access [20]. Research by [21,22] demonstrates the effectiveness of TR in addressing physical and mental health challenges, enhancing patient quality of life by overcoming obstacles like distance and strain on family members during face-to-face rehabilitation appointments.

This research endeavor is dedicated to enhancing the quality of life for patients through the implementation of an accessible digital platform for therapeutic education tailored to individuals with respiratory rehabilitation needs. The primary objective is to introduce the design of a telerehabilitation platform specifically crafted for respiratory rehabilitation in individuals recovering from respiratory or other diseases, employing a user-centered design approach. The digital platform, developed by the research team, incorporates therapeutic education exercises to foster respiratory rehabilitation. The study focuses on advancing pulmonary rehabilitation by creating a user-friendly digital platform for therapeutic education in respiratory rehabilitation. The platform's usability is systematically assessed through a proposed protocol and the Computer System Usability Questionnaire (CSUQ). By providing evidence-based insights, this research significantly contributes to the progression of telerehabilitation and telemedicine as integral components of respiratory care.

Furthermore, incorporating web accessibility aligns with the Sustainable Development Goals (SDGs), specifically contributing to SDG 3 by ensuring healthy lives and promoting well-being. SDG 4 is addressed by facilitating equal access to quality education, regardless of individual abilities. Additionally, SDG 10, focusing on reducing inequalities, is promoted by ensuring universal access to information and services. Web accessibility, in line with these SDGs, furthers the overarching goal of sustainable development by fostering inclusion and participation. This approach aims to create a more sustainable and equitable world where everyone enjoys equal access to the web.

2.1.2. Accessibility, Usability, and Sustainability in Modern Healthcare Platforms

Accessibility and usability play pivotal roles in healthcare platforms [23], where accessibility involves the platform's capacity to be utilized by all users, encompassing those with disabilities [24]. Simultaneously, usability, closely tied to sustainability, pertains to the platform's ability to operate efficiently and effectively without adverse impacts on the environment or society [25].

Ensuring the availability and functionality of healthcare platforms involves establishing a user-friendly atmosphere that accommodates individuals with diverse visual, hearing, motor, or cognitive abilities. Implementation strategies include incorporating alternative text for images, adding audio descriptions to videos, employing assistive technologies, and embracing interface designs that are both intuitive and user-friendly [26]. Incorporating accessibility and usability measures poses challenges, given the complexity and cost of implementation, often with decision-makers unaware of the associated benefits. Nevertheless, despite these challenges, both aspects are essential in the development and execution of enduring and effective healthcare platforms [27].

Efficient and effective operations exemplify sustainability in healthcare platforms without compromising environmental or societal well-being [28]. This entails adopting energy-saving technologies, digitizing processes to minimize paper usage, and considering recycled materials in operations [29].

Vital for individuals with disabilities to engage with healthcare platforms are assistive tools like screen readers and virtual keyboards. Adopting a user-centered strategy supports the development of user-friendly platforms that cater to the needs of all users, including

those with disabilities. Creative approaches, such as integrating virtual reality within hospital settings, contribute to an improved comprehension of treatments for patients with disabilities.

In terms of sustainability, healthcare organizations are adopting energy-saving technologies and digital processes to reduce environmental impact [3,28]. Investments in sustainability aim to minimize the organizations' ecological footprint. These trends emphasize the ongoing significance of accessibility and usability in developing healthcare sustainability platforms.

Web accessibility aligns with Sustainable Development Goals (SDGs), particularly SDG 3, ensuring healthy lives and well-being; SDG 4, promoting equal access to quality education; and SDG 10, reducing inequalities in information and services. Beyond specific SDGs, web accessibility contributes to the overarching goal of sustainable development by fostering inclusion and participation, envisioning a more equitable world with equal access to the web [3].

2.2. Conceptualization Using iPlus Methodology

In this subsection, we explore the development process comprehensively, focusing on the foundational stage of conceptualizing the "PAR" educational telerehabilitation platform. The subsequent design, implementation, and functionality phases are intricately interconnected with this conceptualization, forming the backbone of the platform's development journey.

The iPlus methodology, depicted in Figure 1, is applied for designing serious games [4]. This method encompasses a stage dedicated to confirming established requirements with the involvement of diverse specialists. The iPlus design methodology is adaptable and can be applied to formulate any educational game with seriousness, concurrently providing a unified design method compatible with additional agile techniques. With iPlus, professionals can collect and employ user narratives as input for any software methodology.

The application of the iPlus methodology is characterized by its participatory, adaptable, and user-centric design approach. It incorporates creative techniques that are universally accessible, merging elements of entertainment with the seriousness of the project. Additionally, experts from higher education institutions specializing in rehabilitation contributed valuable insights. An in-depth interview with a rehabilitation therapy expert was conducted to delineate the project's requirements precisely. Collaborative work was documented on a Padlet platform, encouraging active and collective participation. The generated ideas were meticulously scrutinized and categorized into functional and non-functional requirements. This process resulted in well-defined requirements that shaped the project's scope and facilitated visualizing use cases within the digital platform's interfaces. The iPlus methodology is evident in various projects, as documented in references such as [4]. In most of these developed projects, the methodology is oriented explicitly toward achieving Sustainable Development Goal 10 (SDG10), which aims to reduce inequality. This emphasis extends to education, social interaction, and health. Some of these requirements are presented in Table 1.

Table 1. Platform requirements.

Operational Prerequisites	Non-Operational Prerequisites
The system should enable users to register.	The system should function as a Progressive Web App (PWA) to maximize resource efficiency and enable offline utilization.
The system will integrate a dashboard designed to visually represent the user's rehabilitation progress in an instructive manner.	The system needs to furnish user-friendly error messages that convey helpful information.
The platform will enable users to reach audiovisual content as part of their self-rehabilitation process.	The design should be responsive, ensuring accurate presentation across various devices.
The system must document the physical condition before and after each exercise session to monitor rehabilitation advancements.	The system's interface design should incorporate colors corresponding to the tool's intended function.
The platform enables the generation of fresh exercises and rehabilitation schedules to assist in the patient's recovery journey.	The system's security necessitates ensuring user data are encrypted within the databases.
The system enables the customization of patient evaluation methods by configuring assessment metrics.	The platform should be available on the Internet at no charge.

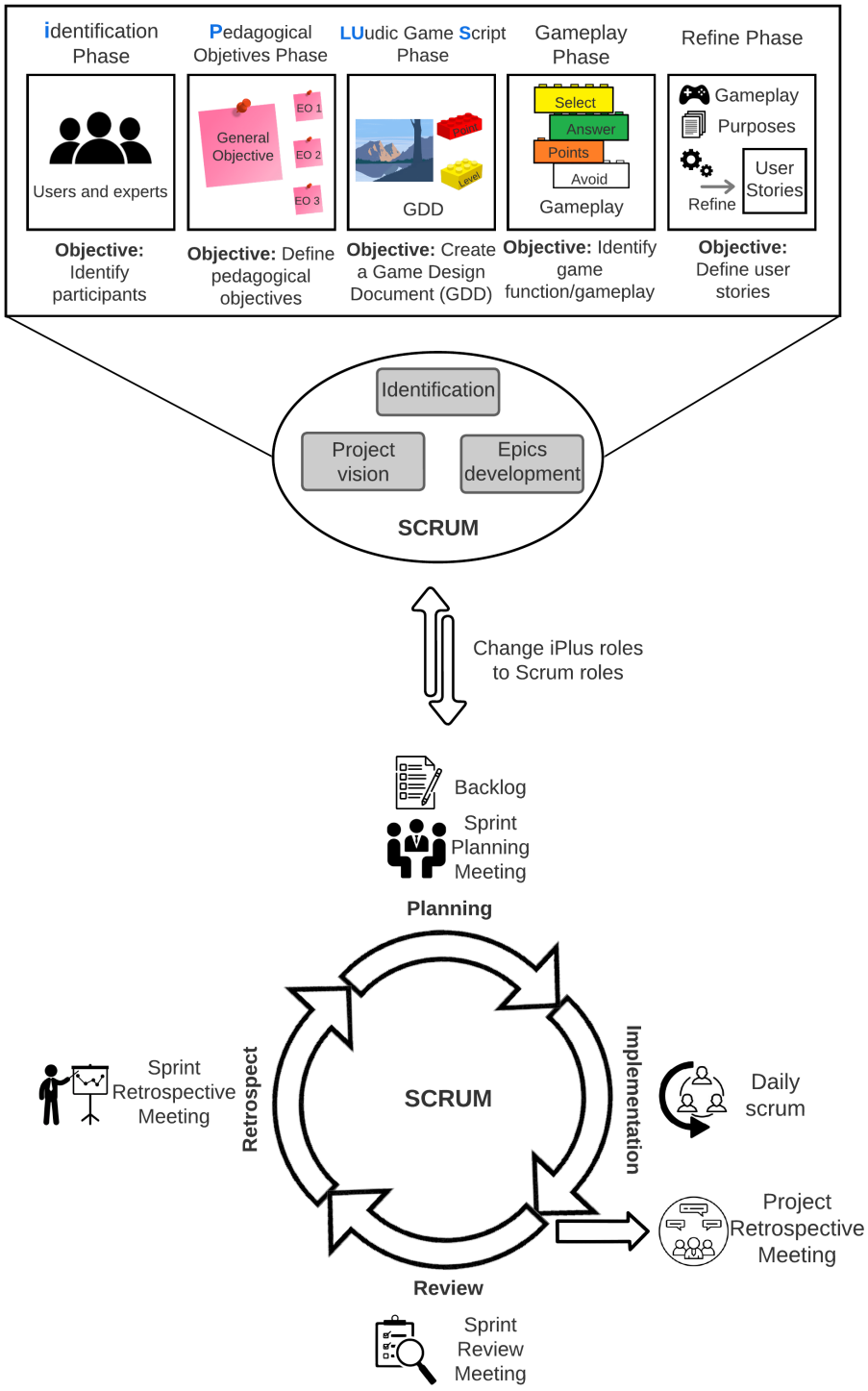


Figure 1. iPlus–Scrum integration.

2.3. Design and Implementation of the PAR Platform

The structural planning of the PAR system (Accessible Platform for Respiratory Rehabilitation) relies on a data framework outlining the configuration and interconnections among different data types housed within the platform. As depicted in Figure 2, a segment of the system's data structure is illustrated, encompassing tables that oversee details about

organizations, patients, medical professionals, assessments, exercises, and various components. Every table has essential fields to house the data in the associated database. The presented data model excerpt delineates the interrelation among users (patients, medical professionals, and students) affiliated with an organization. This organization manages the users and will submit rehabilitation plans. Additionally, rehabilitation plans group exercises and evaluations, storing data on the patient's physical state and progress.

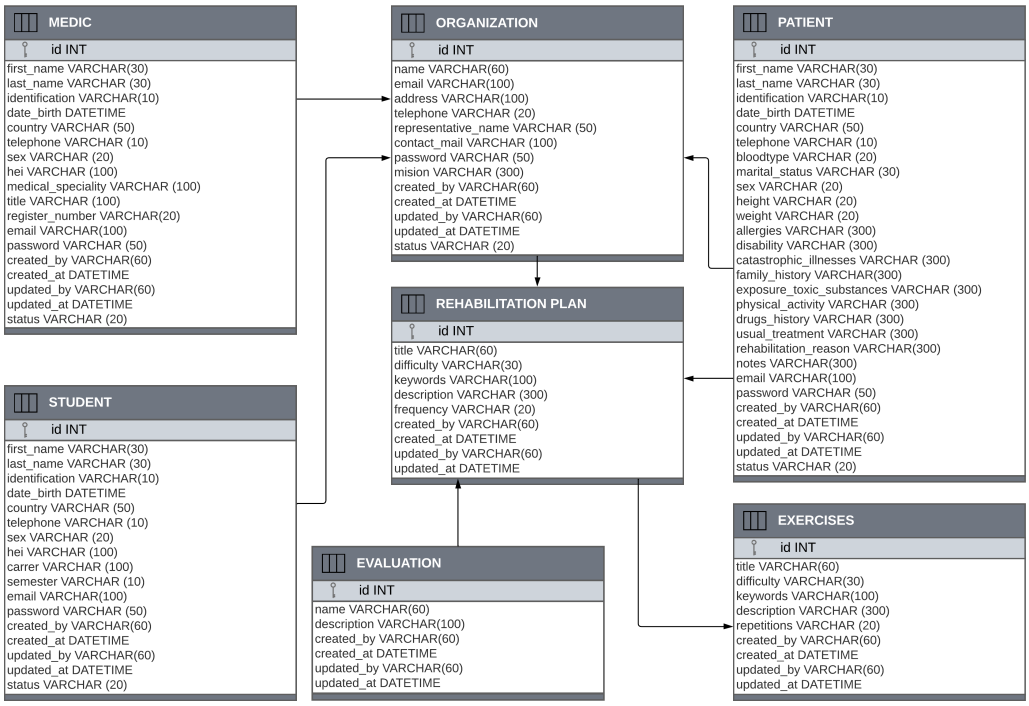


Figure 2. Data model extract.

The navigation framework delineates the pathways for user engagement with the platform. As depicted in Figure 3, the proposed navigation model for the PAR platform is categorized by distinct colors, corresponding to the actions users can execute based on their designated roles. Illustrated in Figure 3, the visual representation of the navigation model demonstrates that an unregistered user can access a limited set of platform functionalities. Conversely, a registered patient can view their profile and generate progress reports. A medical specialist is empowered to devise rehabilitation and exercise plans and oversee the patients assigned to them throughout rehabilitation. Administrative personnel within an organization can administer their users (patients and medical specialists), configure the assessment metrics for rehabilitation plans, and review reports on the progress of their organization's users. Ultimately, platform administrators can manage organizations and access platform configurations.

The design of user interfaces plays a pivotal role in defining user–system interactions. In this instance, we aim to maintain straightforward and effective interfaces that align with the users' goals. The design of these interfaces is aligned with the requisites delineated during the collaborative and user-centered development process.

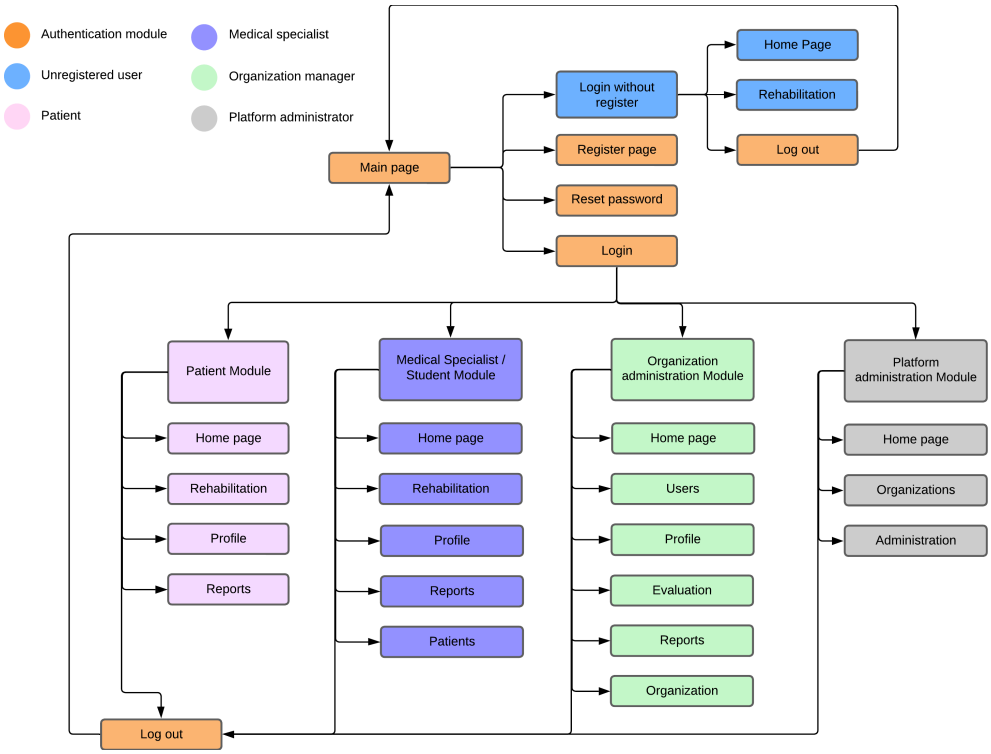


Figure 3. Navigation model of the platform.

2.4. Functionality of the PAR Platform

In summary, the platform's design specifies the system's subsystems. Figure 4 presents the login page of the PAR platform. It is composed of two modules:

- The utilization of the authentication module is reserved for users who have completed the registration process, enabling monitoring of their engagement with both the platform and rehabilitation exercises. This module is intricately divided into four segments: the platform administration module, the organization administration module, the medical specialist module, and the registered patient module.
- The login without registration module provides entry to rehabilitation exercises for users without registering or authentication with the platform. Notably, interactions of users who opt for this method will not be documented in the system.

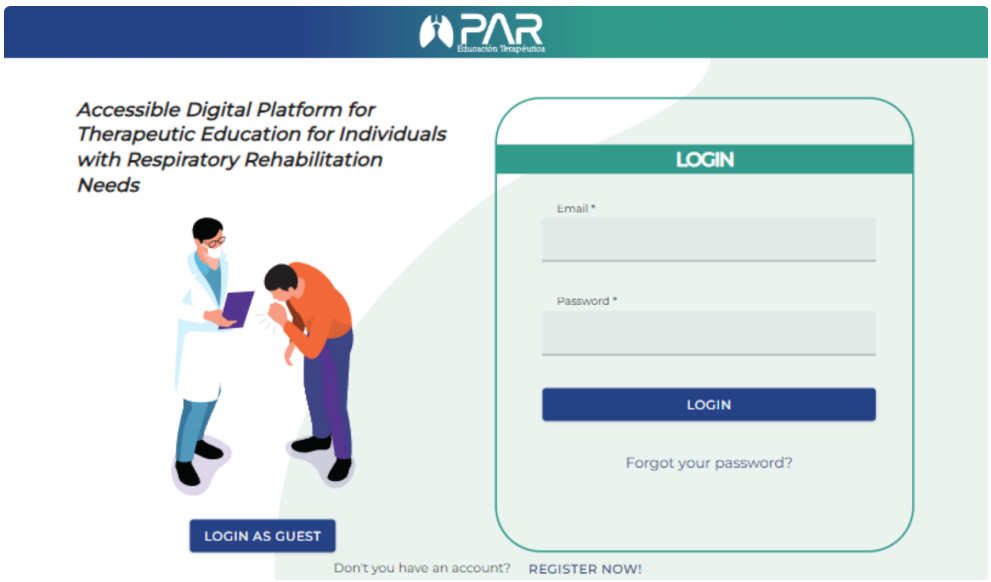


Figure 4. Platform login.

The platform provides free and open access to asynchronous telerehabilitation sessions for all users with respiratory disease. It facilitates user registration through a straightforward and intuitive process involving completing forms. These forms encompass entering personal information, granting consent for managing personal data, and specifying the particular aftermath the user is undergoing. Once registered, the user can access all the exercises on the platform, including comprehensive rehabilitation plans, as shown in Figure 5a. Upon selecting an exercise, the user can actively engage by following a video demonstration, providing clear guidance on the proper execution of the activity. Furthermore, a detailed description of the exercise can be read in Figure 5b. A thorough evaluation, shown in Figure 5c, post-exercise, enables the platform to systematically document the patient's progress and gain insights into their well-being throughout the telerehabilitation session. The feedback obtained from these evaluations serves as a valuable record, contributing to a holistic understanding of the patient's journey and overall improvement during the telerehabilitation process.

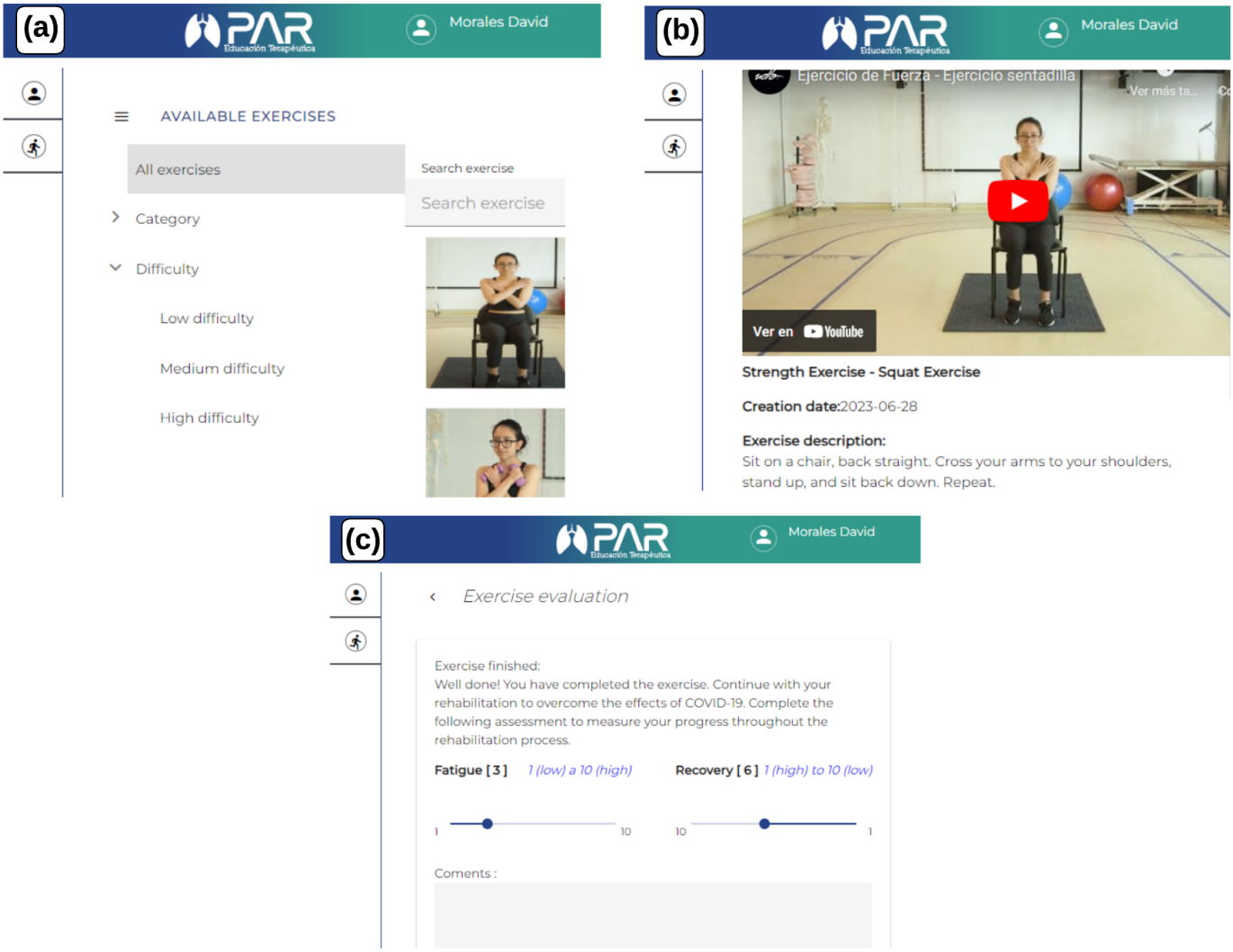


Figure 5. Telerehabilitation exercises.

In conclusion, developing and deploying the "PAR" educational telerehabilitation platform represents a comprehensive and user-centric approach to addressing the specific needs of individuals with pulmonary diseases. The conceptualization phase, guided by the iPlus methodology, laid the foundation for a platform designed to contribute to Sustainable

Development Goal 10 (SDG10), which aims to reduce inequality, particularly in education, social interaction, and health. The design and implementation phases were meticulously executed, incorporating an accessible and inclusive data model, navigation model, and user interface design to ensure usability for a diverse user base. The education and training of professionals in respiratory therapies were accomplished by integrating educational modules within the platform. This functionality is intended for use by medical experts, allowing them to upload their rehabilitation plans and students, who can utilize it to learn about respiratory rehabilitation. The iPlus methodology, emphasizing participatory design, facilitated the creation of training materials that are accessible and user-friendly. This ensures that healthcare professionals can effectively employ and integrate telerehabilitation into their practices.

3. Results

3.1. Accessibility Evaluation

Individuals with disabilities or functional limitations may face substantial barriers while accessing online information and services, hindering their participation in and benefit from respiratory therapeutic education [30]. Hence, it is imperative to design and assess accessible digital platforms that cater to the diverse needs of this user group. In this study, the evaluation focused on ten web pages of the platform, encompassing patient management and rehabilitation functionalities. These pages covered features such as:

- Patient Features: Involving patient profile management and reporting.
- Rehabilitation Features: Including the rehabilitation plan and tracking of therapeutic programs.

A modified version of WCAG-EM 1.0 and the Web Content Accessibility Guidelines (WCAG) 2.1 were employed for this assessment. The approach integrated the WAVE (Web Accessibility Evaluation tool), previously utilized by the authors, and a manual review [30]. The objective was to achieve the AA level of accessibility, as defined by accessibility experts. This evaluation method comprises nine distinct phases, illustrated in Figure 6, and explained as follows:

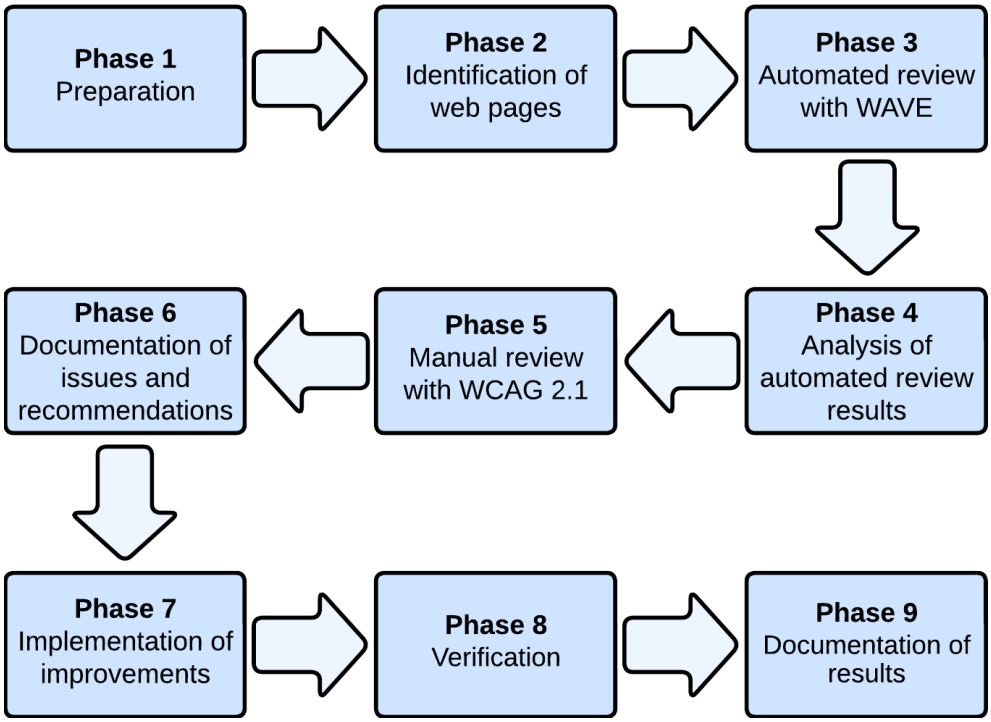


Figure 6. Combined approach to accessibility assessment.

1. Preparation: In this initial phase, criteria based on WCAG 2.1 are established, and accessibility goals for the evaluation are defined. Web accessibility experts specializing in respiratory therapy conduct a comprehensive assessment focusing on evaluating compliance with web accessibility standards and identifying potential barriers.
2. Identification of web pages: Patient web pages, shown in Table 2, crucial for providing therapeutic education and support for individuals with respiratory needs, are selected for accessibility evaluation. These pages are strategically chosen to represent diverse aspects of the platform, covering patient management, rehabilitation plans, educational resources, and interactive features.

Table 2. Platform web pages from the patient's perspective.

ID	Web Page	Description
W01	Home	The patient menu main page displays the options menu, providing quick access to different functionalities and relevant sections.
W02	Profile	The patient's profile is defined and configured, including personal information and relevant medical data.
W03	Report	This page contains reports allowing us to generate and access reports on the patient's progress and performance in respiratory therapies.
W04	Plans	Available exercise plans show the different respiratory therapy exercise plans available for patients to select and follow according to their needs and abilities.
W05	PatientPlan	Patient Assigned Exercises display the specific exercises assigned to the patient as part of the personalized respiratory therapy plan.
W06	Difficulty	Difficulty selecting an exercise includes considering potential challenges or difficulties the patient may face in selecting an exercise, such as clarity of instructions or understanding of breathing techniques.
W07	Category	The respiratory therapy exercise plan category contains the plans according to the specific therapeutic category or approach, facilitating appropriate search and selection.
W08	Exercise1	Active Cycling Breathing Technique Exercise one contains a specific activity designed to improve respiratory function and strengthen respiratory muscles.
W09	Exercise2	Exercise with active cycle two breathing technique includes another specific activity to improve lung capacity and respiratory endurance.
W10	Evaluation	Evaluation of the patient's assigned exercise plan contains a review and evaluation of the assigned exercise plan to monitor progress and adapt therapies as needed.

3. Automated review with WAVE: The WAVE tool conducts an automated review of the selected web pages [31]. This tool adeptly identifies potential accessibility issues such as missing tags, improper heading structures, or color contrast problems, as shown in Figure 7. WAVE is instrumental in scanning the pages and pinpointing potential accessibility barriers that could hinder users with disabilities.
4. Analysis of automated review results: Results obtained through the automated WAVE review undergo a meticulous analysis. Potential accessibility issues are scrutinized, ranked, and prioritized based on severity and their impact on the overall user experience. This analysis provides insights into specific areas requiring improvement to enhance the platform's accessibility.

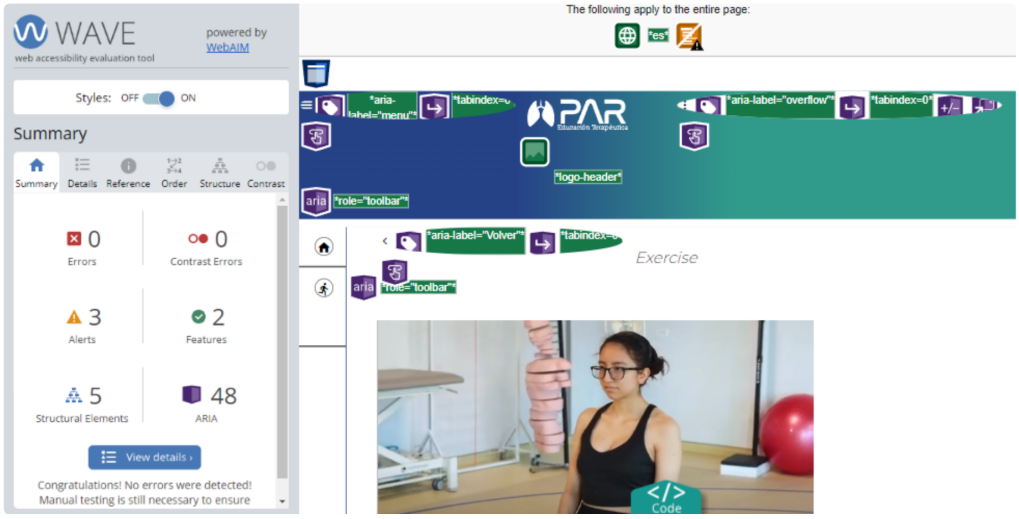


Figure 7. Errors detected with WAVE on one of the selected pages.

5. Manual review with WCAG 2.1: During this phase, web accessibility experts conduct a detailed manual review of the selected web pages. The examination covers various aspects, including providing alternative text for images to ensure accessibility for visually impaired users, assessing keyboard navigation, and verifying compatibility with screen readers. The manual review identifies accessibility gaps and recommends enhancing the platform's compliance with WCAG 2.1.
6. Documentation of issues and recommendations: All identified accessibility issues and corresponding recommendations from automated and manual reviews are meticulously documented. Each issue is detailed, including its nature, location, and potential impact on user accessibility.
7. Implementation of improvements: Necessary modifications are made to the patient web pages to address identified accessibility issues and align with the standards set by WCAG 2.1. This phase focuses on implementing recommended improvements to resolve accessibility problems detected in the platform's patient web pages.
8. Verification: A final verification ensures the implemented improvements effectively resolve the accessibility issues identified in the previous phases. This verification process aims to validate that the platform attains the AA level of accessibility, meeting the standards established by WCAG 2.1.
9. Documentation of results: The results of the accessibility evaluation, comprising identified issues, implemented improvements, and any other relevant findings, are documented for future reference and monitoring [32].

Significant progress has been observed in resolving serious and contrast errors, which were not identified during the automatic evaluation. Additionally, the platform has achieved a compliance level of 95.1% in alerts, 93.6% in characteristics, and 93.4% in structural elements, as illustrated in Figure 8.

The selection of accessibility standards and guidelines implemented in digital health platforms significantly influences the enduring nature of web accessibility within the healthcare domain. These standards' ongoing development and upkeep are essential to guarantee that individuals with disabilities maintain fair and impartial access to health-related information and services on the Internet.

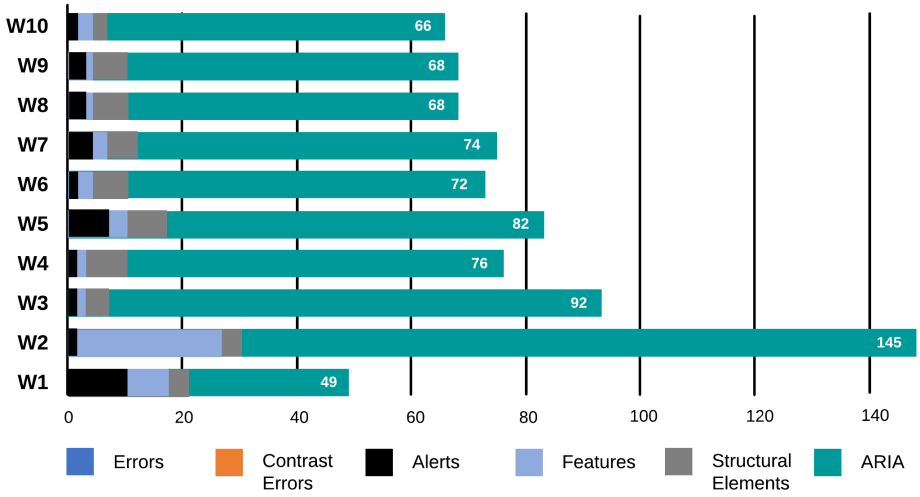


Figure 8. Results detected with WAVE.

3.2. Usability Evaluation

This section provides an overview of the usability evaluation process for the "PAR Therapeutic Education" web platform for individuals with respiratory diseases. The results obtained from this evaluation contribute to improving the quality of life for individuals by identifying and addressing usability issues.

The evaluation process followed the usability evaluation protocol proposed by [33], as depicted in Figure 9. This protocol was complemented by the inquiry method outlined by [34,35] and included the Computer System Usability Questionnaire (CSUQ).

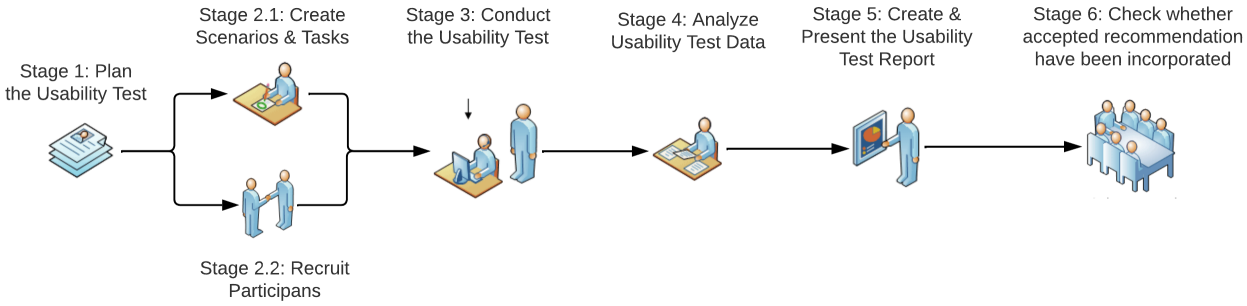


Figure 9. Usability protocol.

The usability evaluation process is as follows:

1. Test Planification: In this phase, we prepared the necessary materials and documentation for each user. Objectives were defined to guide the usability test, including using the CSUQ questionnaire to assess the "PAR" web platform and understanding patient users' responses and satisfaction levels. Documentation, including a consent letter and instructional guide outlining the platform's description and task details, was provided to users.
2. Participant Identification: During this stage, individuals are selected for the usability assessments of the application. Following Nielsen's recommendations, a group of up to five individuals conducting multiple brief tests is deemed satisfactory for identifying approximately 85% of usability issues. The participant group must be homogeneous to evaluate the application [36] effectively. The assessment involved 58 users, divided into two groups of 29 users each, categorized as patients with a history of pulmonary diseases, aged between 23 and 28 years old.
3. Evaluation Execution: This phase began with providing general instructions on how the usability evaluation would be conducted and delivering the necessary documentation or links to each user. Users were then tasked with performing specific actions, as

detailed in Table 3. Following the tasks, participants completed a usability survey containing 16 questions rated on a scale from 1 to 7, with higher scores indicating greater satisfaction. The survey was based on the Computer System Usability Questionnaire (CSUQ) by Lewis [34].

Table 3. Tasks and subtasks of usability evaluation.

Tasks and Subtasks	
T1. Register as a patient on the platform	• Enter first name. • Enter last name. • Enter identification. • Enter date of birth. • Enter email address. • Enter a password. • Select user type. • Confirm consent. • Enter medical history.
T2. Log in to the platform	• Enter email address. • Enter password.
T3. Explore rehabilitation exercises through workout plans	• Access the Rehabilitation menu. • Click on workout plans. • Select a workout plan. • Click on difficulty and review plans categorized as advanced, low, and basic. • Click on the category and review the muscular and respiratory options.
T4. Follow a low-difficulty training exercise	• Click on a video from the workout plans or free training based on your need. • Repeat what you see in the exercise video.
T5. Evaluate an exercise when it has been completed	• Click on the completed exercise. • Click and move the fatigue line according to your progress level, considering 1 (lower) to 10 (higher). • Click and move the recovery line according to your progress level, considering 1 (higher) to 10 (lower). • Click on Finish. • Check if the message "Exercise completed for the day" appeared.
T6. Disconnect from the platform	• Click on the user with your name. • Click on Log Out.

4. Analysis of Test Data: In this stage, the obtained values are analyzed and presented through the inquiry method of the CSUQ usability surveys [35]. The values ranged from 1 (Strongly Agree) to 7 (Strongly Disagree), including the "Not Applicable" (N/A) option; lower values were interpreted as indicators of higher satisfaction. To calculate the usability acceptance percentage, a correspondence between *CSUQ* and SUS values was established to transform the CSUQ scale values from 1 to 7 into a 0-to-100-point scale that matched the SUS scale for interpretation. Equation (1) presents the formula for this transformation.

$$CSUQ = 100 - \left(\left(\left(\frac{\sum_{n=1}^{16} CSUQ_n}{16} \right) - 1 \right) \times \left(\frac{100}{6} \right) \right) \quad (1)$$

Obtaining an equivalent score to that of the SUS from a CSUQ score involves subtracting one from the mean of the 16 individual CSUQ questions and multiplying that value by 100/6 to extend it to a 0-to-100-point scale. Then, this value is subtracted from 100 to reverse the scale [35]. The transformation was carried out to utilize the SUS scale [37], presented in Figure 10, which allows us to compare adjective ratings and acceptability scores about the obtained SUS score. As we can observe in the SUS scale [38], it assigns the label "Acceptable" when the evaluation score is above 70, "Not Acceptable" when the value is below 50, and "Marginal" when it falls between 50 and 70. The average of the usability test results is 72.56%, which falls within the "Acceptable" range according to the SUS scale; see Figure 10.

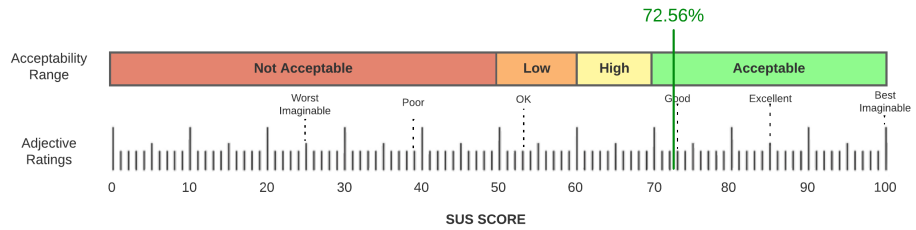
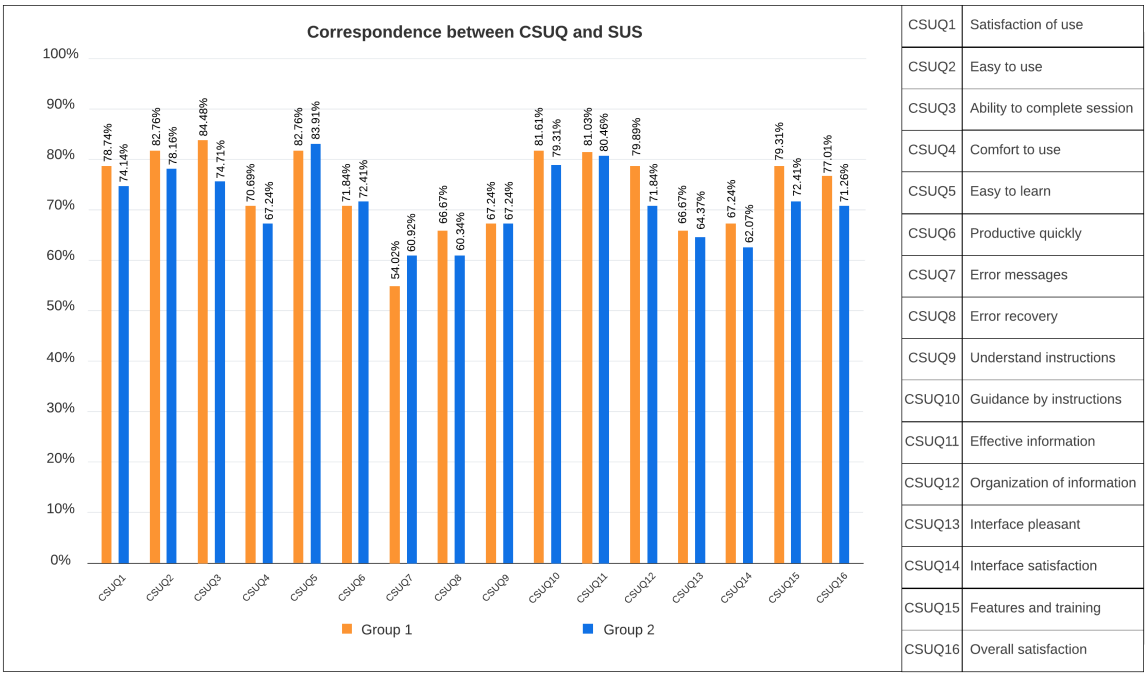


Figure 10. Usability test results.

5. Results Phase: Figure 11 displays the average analysis results for each question, along with their corresponding CSUQ and SUS scores obtained from the usability evaluation of the "PAR" platform. The data from both groups were analyzed, and it was concluded that most survey questions achieved over 70% acceptance with a standard deviation of 0.298, indicating consistency in responses between the two groups. The highest scores were recorded for "CSUQ5—Easy to learn", "CSUQ11—Effective information", and "CSUQ2—Easy to Use". The questions with the lowest acceptance rates were "CSUQ7—Error messages" and "CSUQ8—Error recovery", scoring 55.3% and 60.9% on average, respectively [32].



CSUQ1	Satisfaction of use
CSUQ2	Easy to use
CSUQ3	Ability to complete session
CSUQ4	Comfort to use
CSUQ5	Easy to learn
CSUQ6	Productive quickly
CSUQ7	Error messages
CSUQ8	Error recovery
CSUQ9	Understand instructions
CSUQ10	Guidance by instructions
CSUQ11	Effective information
CSUQ12	Organization of information
CSUQ13	Interface pleasant
CSUQ14	Interface satisfaction
CSUQ15	Features and training
CSUQ16	Overall satisfaction

Figure 11. Usability evaluation results per question.

6. Conclusions: The usability evaluation of both groups resulted in an average score of 72.56%, placing it within the "Acceptable" range on the SUS scale, as illustrated in Figure 10. The outcomes of the inquiries suggest that participants found the "PAR" educational platform to be a usable system.

Incorporating web accessibility considerations into the usability evaluation aligns with the principles of the Sustainable Development Goals (SDGs). Specifically, SDG 3 prioritizes achieving healthy lives and well-being, representing a fundamental aspect of sustainable development. Correspondingly, SDG 4, focusing on quality education, underscores the importance of ensuring equal access to information and educational resources, irrespective of individual abilities. Furthermore, SDG 10 centers on reducing inequalities by promoting equal access to information and services for all. The integration of web accessibility, as emphasized in the usability evaluation, actively contributes to the overarching goal of sustainable development. By fostering inclusion and participation through accessible digital platforms, it plays a crucial role in creating a more sustainable, equitable, and interconnected global environment. The integration of the iPlus methodology is transparent, ensuring a user-centered design approach. Treatment access is facilitated through the platform's user-friendly interface, allowing individuals to navigate and engage with respiratory therapies more efficiently. This approach aims to overcome barriers related to complex interfaces, contributing to broader accessibility.

4. Discussion

In post-COVID-19 care, the creation of the Accessible Platform for Respiratory Therapies (PAR) stands as a significant leap forward. By employing the iPlus methodology and adopting a user-centered approach, the platform ensures usability and active stakeholder participation throughout its design process. Recent breakthroughs in virtual healthcare technologies, especially digital health, have revolutionized respiratory care and healthcare infrastructure. The PAR platform substantially contributes to telerehabilitation, offering evidence-based insights and underscoring the importance of user inclusivity and effective physical development. The integration of universal design principles guarantees widespread accessibility, and meticulous evaluations of accessibility and usability adhere to standards, ensuring a platform that caters to diverse users. Furthermore, the study underscores the long-term economic benefits of investing in accessibility measures. It illustrates how improved accessibility not only leads to increased patient retention but also dismantles traditional barriers in healthcare, such as the necessity for patients to travel to a specific location for treatment, thereby saving both time and money, which is particularly crucial for underprivileged populations. The societal implications emphasize the dedication to establishing an inclusive society, ensuring equal access to healthcare information and services for all individuals, regardless of their abilities.

The World Health Organization (WHO) notes that between 2000 and 2019 [2], chronic respiratory diseases caused 4.1 million deaths globally, with a 37% decrease in mortality from these diseases during that period. This scenario highlights the relevance of implementing sustainable strategies to address these conditions, aligned with Sustainable Development Goals (SDGs) 3, 4, and 10, aiming to ensure a healthy life, promote inclusive and equitable education, and reduce inequalities while fostering social inclusion [3].

Telemedicine and telerehabilitation (TR) have emerged as crucial tools for post-COVID-19 care. Our proposed platform, the Accessible Platform for Respiratory Therapies (PAR), is designed to address the respiratory rehabilitation needs of individuals who have suffered from COVID-19. The user-centered design (UCD) process, particularly the iPlus methodology, guided our approach, ensuring a focus on usability. Recent advancements in virtual healthcare technologies, encompassing digital health, have transformed respiratory care and healthcare infrastructure [7,8]. Integrating digital technology into healthcare offers opportunities for improved patient outcomes and enhanced access to healthcare [8,19].

During the realization of this investigation, the work team found some advantages, especially in the telerehabilitation field focused on respiratory rehabilitation.

Telerehabilitation platforms play a crucial role in delivering synchronous and asynchronous support to ambulatory patients, and our research significantly contributes to the advancement of this field. The PAR platform, crafted with the Universal Design for Learning (UDL) principles, is pivotal in promoting inclusive and effective physical development. Implementing the iPlus methodology and a user-centric approach ensures enhanced usability, providing a positive experience for users.

Moreover, the platform offers free and open access to telerehabilitation sessions tailored to the specific needs of individuals with COVID-19 sequelae, ensuring inclusivity. Rigorous evaluations of accessibility and usability, conducted following modified WCAG-EM 1.0 and WCAG 2.1 standards and usability evaluation protocols, confirm the platform's commitment to inclusivity.

4.1. Web Content Accessibility Guidelines (WCAG) 2.1 Applied in PAR for People with Disabilities

Web Content Accessibility Guidelines (WCAG) 2.1 play a critical role in our Accessible Respiratory Therapies (PAR) platform, ensuring accessibility and usability for all people, including those with disabilities. These guidelines provide recognized international standards to make web content more accessible to a wide range of users, regardless of their abilities and disabilities.

Perception: WCAG 2.1 addresses perceptual accessibility, ensuring that information and user interface components are presented clearly and perceptibly. This standard benefits people with visual disabilities by requiring, for example, that visual information be available in text, facilitating comprehension through screen readers.

Operability: The guidelines improve the operability of the platform, allowing it to be navigable and operable through various input devices, such as keyboards and touch devices. This standard benefits people with motor disabilities by providing flexible interaction options.

Comprehension: Cognitive accessibility is addressed through the clear presentation of information and the logical organization of content. These guidelines benefit people with cognitive disabilities by making the platform easier to understand and navigate.

Robustness: The creation of robust web content compatible with various assistive technologies is promoted, ensuring that the platform is accessible to people who use adaptive technologies, such as screen readers or alternative input devices.

The benefits highlighted in our study, endorsing investments in accessibility measures for long-term gains, underscore the platform's potential to increase patient retention and break down traditional healthcare barriers. Furthermore, the dedication to creating a more inclusive society, providing equal access to healthcare information and services irrespective of abilities, stands out as a significant social advantage.

While the accessibility and usability evaluation of the platform posed a challenge, it was completed by assessing two user groups from the same target population. However, the assessments have limitations in the study results, particularly in gauging internal consistency and result variability. In future endeavors, a more comprehensive evaluation of the platform's usability and accessibility will be pursued, incorporating tests with multiple user groups to ensure robust usability. The acknowledgment of the long-term significance of investments in telemedicine is accompanied by challenges in fully quantifying the economic and social benefits over time, particularly in developing countries. Additionally, given the rapid advancement of virtual health technology, there may be a need for frequent updates to the platform to maintain its relevance and effectiveness over the long term.

The PAR platform is a crucial advancement in post-COVID-19 care and respiratory therapy, offering a user-friendly digital space for respiratory rehabilitation education. Our thorough usability assessment, using the protocol and CSUQ, enhances our understanding of telerehabilitation usability and guides future research.

The fusion of technology, healthcare, and education holds immense promise. Future research should explore the potential of Technology-Enhanced Healthcare and Education (TEHE), leveraging Information and Communication Technologies (ICTs) for innovative solu-

tions. Exploring the nexus of therapeutic education, telerehabilitation, and broader educational frameworks opens avenues for comprehensive patient care and skill development.

While recognizing the potential necessity for initial investments in accessibility measures, this study contends that the long-term economic impact justifies these expenditures. Improved accessibility, as emphasized, extends the user base, augments patient retention, and ultimately leads to economic benefits for healthcare organizations [39]. The societal implications of accessibility underscored in this research contribute to creating a more inclusive society, ensuring equal access to healthcare information and services for all individuals, irrespective of abilities [39]. This study lays a robust foundation for future inquiries, inviting researchers to explore the dynamic role of technology in healthcare and education. The overarching goal is to innovate boldly, forging connections that redefine post-pandemic care and introduce new dimensions to learning and rehabilitation.

4.2. Errors Corrected in the PAR Platform According to WCAG 2.1

During the evaluation of the PAR platform, the following specific errors were identified and corrected by WCAG 2.1:

Incompatibility with devices and browsers: The PAR platform had to be compatible with various devices and browsers, resulting in accessibility issues for some users.

Lack of proper labels: The PAR platform was not fully WCAG 2.1-compliant in terms of labels, which made it difficult for some users to understand the structure and function of the platform.

Visual perception problems: The PAR platform did not provide sufficient contrast between the text and the background, making reading the information challenging for some vision-impaired users.

During the implementation of the PAR platform, the following challenges were faced in customizing rehabilitation plans for each patient:

Adaptability of rehabilitation plans: The PAR platform had to adapt to each patient's needs, which required precise and flexible customization of rehabilitation plans.

Incorporation of user feedback: The PAR platform had to be able to collect and analyze user feedback to adjust and improve rehabilitation plans continually.

Collaboration between health professionals and technology developers: Collaboration between the platform development team and health professionals was essential to ensure that each patient's rehabilitation plans were appropriate and personalized.

Scalability and sustainability: The PAR platform had to scale and adapt to the growing demand of patients who needed access to the platform and rehabilitation services.

4.3. Criticality and Limitations in the PAR Platform

The ethical–legal issues related to protecting the privacy of the data subject on the PAR platform include responsibility for any damage caused by the programmer.

These issues are critical due to the need to protect users' personal and medical information and have limitations in terms of the complexity of ensuring privacy in digital environments and the potential for programmers to make errors that could result in harm.

Protecting the privacy of data subjects on the "PAR" platform raises essential ethical and legal challenges, especially regarding liability for any harm caused by the programmer. The collection and processing of medical and personal data requires a high level of protection to ensure the confidentiality and integrity of the information. The criticality of these issues lies in the need to safeguard the privacy and security of patient data and the importance of complying with data protection regulations and standards, such as data privacy and security laws. Various measures have been implemented to protect data privacy on the PAR platform, such as using strong passwords, two-factor authentication, keeping software updated, and using antivirus programs to prevent cyberattacks.

The study in [40] addresses the growing importance of cybersecurity in assistive robots, particularly in physical therapy. The research focuses on assessing physical therapists' awareness of cybersecurity issues related to human–robot interactions. Through

an electronic questionnaire, the study explores aspects such as the use of robots in physiotherapy, the level of training in cybersecurity and robotics, the self-assessment of insiders on cybersecurity in different scenarios, experiences with cyberattacks, and suggestions for improvement.

The authors of [41] argue that despite the potential of digital platforms, challenges exist, including gaps in health information systems, slow adoption of electronic medical records, digital literacy issues, high device costs, and concerns about data privacy. The authors emphasize the need to address these challenges, warn against over-reliance on such systems, and call for clear legal frameworks to guide patients' decision making.

Additionally, encryption of collected data was considered to protect against unauthorized access and to comply with privacy and data protection laws and regulations.

Privacy in the digital environment covers many aspects, from protecting online identity to controlling personal information. Protecting devices that access digital platforms, such as computers, smartphones, and tablets, is essential to ensure data security.

In addition, companies must have comprehensive systems to process, collect, and protect personal data, analyze private data securely, and control it by anonymizing personal information.

Citizen awareness and education, cybersecurity, laws and regulations, and accountability are critical approaches to addressing ethical and privacy challenges in the Big Data and artificial intelligence era.

Importantly, these measures have limitations regarding the complexity of ensuring privacy in digital environments and the possibility of programmers making errors that could result in harm. Therefore, it is essential to continue working on the development of new measures and technologies to protect data privacy on digital platforms.

4.4. Sustainability of the PAR Platform

User sustainability on our platform, PAR, is ensured through several key strategies:

User-centered design: PAR has been developed with a user-centered design approach, where users' needs, preferences, and capabilities are taken into account at every stage of development. This case ensures that the platform is intuitive, easy to use, and aligns with the expectations of those who interact with it.

Education and Training: PAR focuses on providing therapeutic education to patients and emphasizes the education and training of healthcare professionals involved in respiratory therapies. This dual approach contributes to the platform's sustainability by empowering patients and professionals, ensuring continued and effective use of the platform.

Telemedicine Integration: Integrating telemedicine technologies improves the efficiency and accessibility of respiratory therapies. By enabling remote interaction and monitoring, PAR reduces the need for frequent in-person visits, making it more sustainable for users, especially those facing challenges traveling to healthcare facilities.

Technological robustness: PAR is designed to be robust and adaptable to evolving technologies. Regular updates and improvements are part of the platform's sustainability strategy, ensuring that it remains compatible with the latest devices, operating systems, and technological advances. This adaptability improves the longevity and relevance of PAR users.

Cost-effectiveness: The integration of telemedicine technologies not only improves accessibility but also contributes to cost reduction. Users can reduce associated costs such as transportation and time off work by minimizing the need for physical visits. This cost-effectiveness improves the sustainability of PAR, making it an economically viable option for both healthcare providers and patients.

5. Conclusions

The development and evaluation of our digital platform, the Accessible Platform for Respiratory Therapies (PAR), signifies a significant stride in meeting the escalating demand for remote rehabilitation services, particularly in respiratory diseases. Guided by a robust

user-centered design approach involving collaboration with rehabilitation therapy experts and educational institutions, the platform prioritizes usability and inclusivity.

The usability evaluation, employing the protocol proposed by Abhay Rautela and the Computer System Usability Questionnaire (CSUQ), engaged a cohort of 58 participants in simulated patient roles. The CSUQ facilitated the collection of feedback on user satisfaction and overall platform usability. These findings, crucial for refining the platform, underscore the importance of prioritizing user experience in telerehabilitation initiatives.

This study significantly contributes to the evolution of telerehabilitation and telemedicine, offering insights that empower healthcare providers to deliver high-quality, patient-centric care remotely. As we grapple with the persistent challenges arising from the COVID-19 pandemic, the usability-driven solutions presented in this research hold promise for enhancing patient lives and optimizing healthcare services. The integration of accessibility principles from the project's inception aligns with our commitment to fostering equal opportunities for individuals with respiratory therapy needs.

The obtained results furnish essential insights into the usability aspects integral to a web platform for telerehabilitation. These insights are crucial for guiding healthcare professionals in adapting their practices to a remote rehabilitation modality, enhancing patient autonomy and overall quality of life. By mitigating barriers related to distance, time, and costs, such platforms are transformative tools in providing post-pandemic healthcare.

In conclusion, the PAR platform is a testament to telerehabilitation's potential in reshaping post-COVID-19 healthcare. As we chart the future of remote rehabilitation, it is evident that the fusion of user-centered design, usability assessments, and accessibility considerations is imperative for creating impactful, inclusive, and patient-focused digital healthcare solutions. Furthermore, web accessibility is positioned as a cornerstone for sustainability by aligning with the Sustainable Development Goals (SDGs). SDG 3 emphasizes healthy lives and well-being, crucial for sustainable development. SDG 4, associated with delivering high-quality education, guarantees impartial access irrespective of capabilities. SDG 10, focused on diminishing disparities, strives for uniform access to information and services. Beyond these SDGs, the accessibility of the web contributes to the overarching objective of sustainable development by fostering inclusivity and engagement. This presents the prospect of establishing a more sustainable and just world where everyone can access online resources equally.

Looking forward, we heed the suggestions for future research to broaden the scope of literature reviews. This entails addressing usability, accessibility, and sustainability by incorporating diverse user groups, encompassing different disabilities and health conditions. Additionally, expanding assessments to include more platforms and integrating emerging technologies in healthcare can be valuable avenues for research regarding accessibility and sustainability in digital health. This comprehensive approach ensures a nuanced understanding and practical application of these principles, paving the way for further advancements in the field. Finally, to advance toward the future of respiratory health through this platform, we are improving the lives of affected individuals and forging a path toward a more inclusive, sustainable, and globally aligned healthcare. This comprehensive approach addresses current needs and lays the groundwork for a healthier, fairer, and more accessible future for all, in line with the global goals we all aspire to achieve.

For future research, we will carefully evaluate the feasibility of incorporating more advanced statistical methods using tests such as ANOVA, Kruskal–Wallis, or regression, allowing for a more profound interpretation of our findings. We are committed to strengthening the robustness of our results and contributing to continued advancement in accessible respiratory therapies. Our goal is to provide a solid foundation for future studies that can benefit from more detailed statistical approaches, thereby improving the quality and applicability of research in this critical health area.

In future work, we will incorporate a comparative study of applications similar to our PAR platform with associated clinical results. This addition will offer a broader perspective on the potential impact of such platforms and contribute to a more robust and

complete understanding of their therapeutic benefits in various respiratory pathologies. By drawing parallels with existing applications and their respective clinical outcomes, we will emphasize the importance of our proposed platform and its potential positive implications for patients with various lung conditions.

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