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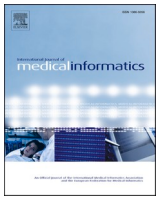

Usability of a mobile application for the clinical follow-up of patients with chronic obstructive pulmonary disease and home oxygen therapy

Anisbed Naranjo-Rojas [a,*], Luis Ángel Perula-de Torres [b], Freiser Eceomo Cruz-Mosquera [c], Guillermo Molina-Recio [d]

[a] Universidad Santiago de Cali. Cali, Colombia, Faculty of Health, Health and Education Research Group (GINEYSA). Biomedicine doctoral program, University of cordoba, Spain
[b] Multiprofessional Teaching Unit for Family and Community Healthcare in the Districts of Cordoba and Guadalquivir. Maimonides Biomedical Research Institute of Córdoba. (IMIBIC), Hospital Universitario Reina Sofía, University of Córdoba, Spain
[c] Universidad Santiago de Cali, Cali, Colombia, Faculty of Health, Integral Health Research Group (GISI)
[d] Nursing, Pharmacology and Physiotherapy Department. University of Cordoba. Lifestyles, Innovation and Health (GA-16). Maimonides Biomedical Research Institute of Cordoba (IMIBIC), Spain

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ABSTRACT

Background: Technological health tools (e-Health) may potentially facilitate the treatment of patients with chronic diseases through development of self-management and -care skills in patients and caregivers. However, these tools are usually marketed without prior analysis and without providing any context to final users, which frequently results in low adherence to their use.
Purpose: To determine the usability of and satisfaction toward a mobile app for the clinical monitoring of patients with chronic obstructive pulmonary disease (COPD) receiving oxygen therapy at home.
Methods: This was a participative-qualitative study focused on final users—with direct intervention by patients and professionals—consisting of three phases as follows: (i) medium-fidelity mockups design, (ii) development of a usability test for each user profile, and (iii) assessment of the satisfaction level regarding the usability of the mobile app. A sample was established and selected through non-probability convenience sampling and was divided into two groups as follows: healthcare professionals (n = 13) and patients (n = 7). Each participant received a smartphone with mockup designs. The "*think-aloud*" method was applied in the usability test. Participants were audio recorded and the anonymous transcriptions were analyzed, highlighting fragments about mockups characteristics and the usability test. The difficulty level of the tasks was assessed with a scale from 1 (very easy) to 5 (too difficult), and task non-completion was considered a critical mistake. The satisfaction level related to test usability was assessed with a 4-score Likert scale ranging from 4 (totally agree) to 1 (totally disagree).
Results: Regarding the difficulty level, >60% of professionals described most tasks as "very easy" and 70% of patients as "easy." No participant made critical mistakes and both groups reported a high satisfaction level regarding the usability variables. The patient and professionals group required 18 and 11 min to complete all tasks, respectively.
Conclusions: Participants described the app as intuitive and easy to use. The usability satisfaction results show a high level of satisfaction for both groups. This positive assessment and performance in user tests showed that the mobile application was able to be apprehended and used by participants in the circumstances of use in the usability tests. Usability evaluation through satisfaction surveys and qualitative data analysis allows for greater insight into the use of mobile applications in healthcare.

* Corresponding author at: Universidad Santiago de Cali. Cali, Colombia, Faculty of Health, Health and Education Research Group (GINEYSA). Biomedicine doctoral program, University of cordoba, Spain
E-mail address: anisbednaranjo24@gmail.com (A. Naranjo-Rojas).

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1. Introduction

Chronic obstructive pulmonary disease (COPD) is a disease that considerably damages the respiratory system, consequently affecting activities of daily living. Currently, COPD is considered the fourth leading cause of death worldwide, and is estimated to be the third by 2030 [1]. In Colombia, the Fundación Neumológica (Pneumological Foundation) conducted a national study on COPD prevalence and found that 9 in 100 individuals aged > 40 years had COPD. Moreover, prevalence in the main cities of the country were 8.5% in Bogotá, 13.5% in Medellín, and 8.5% in Cali [2,3].

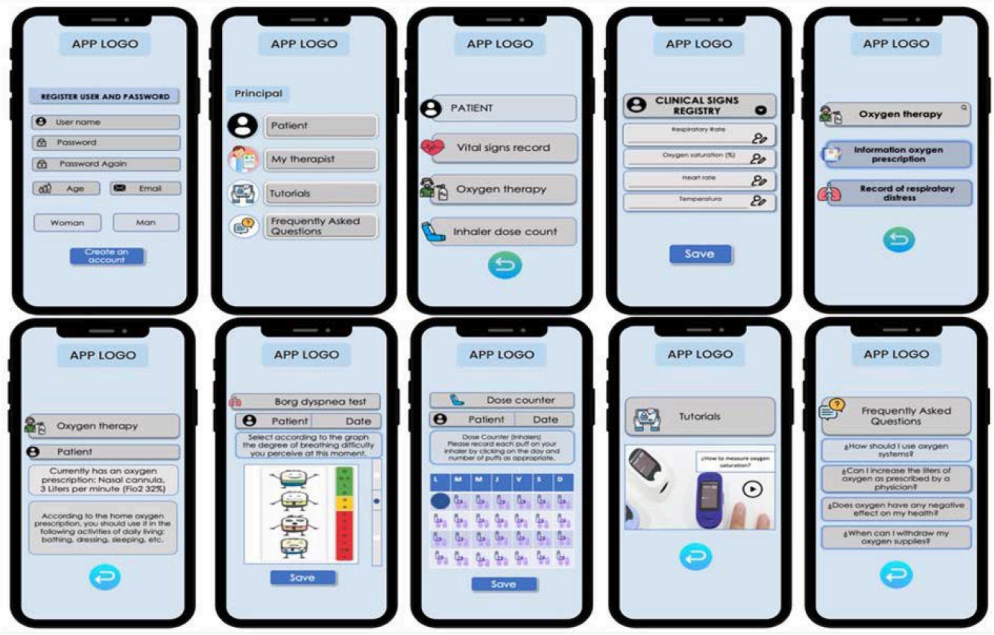
One of the main therapies is home oxygen therapy, which alleviates the symptoms of dyspnea and increases patients' life expectancy, especially among those managed through domiciliary care [3]. In Colombia, approximately 3,176 COPD patients have been prescribed home oxygen therapy in the first phase of treatment thus far [3]. In this type of therapy, it is important to ensure that the conditions of the medical prescription are being met [4]. In this sense, technological health tools (e-Health) [5,6] can potentially help in the treatment of patients with chronic diseases as they facilitate the development of self-management and self-care skills in patients and caregivers, thereby increasing their knowledge, activity, and autonomy. Moreover, they help healthcare professionals guide their patients in the development of skills and the management of chronic diseases [7]. Some studies [8,9,10] have suggested that the application of e-Health strategies decreases the incidence of complications, exacerbations, and even rehospitalizations, and develops self-management skills among patients and caregivers [11,12,13]. Furthermore, such strategies could be beneficial for healthcare professionals as they provide healthcare institutions with a safe, reliable, and cost-effective follow-up method [4,14]. e-Health tools are usually marketed without prior review and without providing any context to final users, which frequently leads to low adherence to the use of these tools and decreases the efficacy of these therapeutic strategies [15,16]. Therefore, mobile health apps should be designed through a methodology focused on final users [14,16]. Through this strategy, users' needs can be identified and reflected in functions and ease of deployment based on the final users' perceptions and expectations [14]. In addition, the usability of these tools needs to be assessed before their implementation. Usability is defined as "a software's ability to be understood and used by a final user under specific circumstances" [15]. According to some studies, users typically spend < 30 s learning how to use an app before choosing other options or just not using the app any more [16,17]. User tests intend to assess mobile app usability based on the performance of specific tasks. Some tests are conducted on prototype designs, and assess satisfaction through surveys [18,19,20,21] that collect users' opinions. In this sense, it seems evident that assessing the usability of a mobile app for the clinical monitoring of COPD patients under home oxygen therapy may be a convenient and necessary strategy for the design and development of an app aiming at achieving high adherence to their use. For the reasons above, this study was conducted on patients and professionals with the purpose of determining the usability of and satisfaction towards a mobile app for the clinical follow-up of COPD patients prescribed with home oxygen therapy.

2. Materials and methods

This study is part of a project for the performance of a controlled, randomized, and non-pharmacological clinical trial [3] to assess the efficacy of a mobile app in the clinical monitoring of patients under home oxygen therapy by following a methodology focused on final users (the study is registered in ClinicalTrials.gov: NCT04820790). Before this research, the authors conducted a study [22] with the purpose of identifying final users' expectations and needs regarding the content of the app, through end-user centred methodology. During this prior stage, two user profiles were created, one for healthcare professionals and the other for patients and caregivers. Based on this research, data architecture and organization were defined according to users' profiles and interests. This research contributes to the design of the app and is focused on assessing its usability through a participative-qualitative design, with direct intervention by patients and professionals. The investigation is divided into three phases as follows: (i) medium-fidelity mockups design for each user profile, which included the main functions of the mobile app, (ii) development of a usability test for each user profile, and (iii) assessment of the satisfaction level regarding the usability of the mobile app. The study was conducted in the city of Cali, Colombia. A non-probabilistic and convenience sample was selected, which consisted of two groups—i.e., one including health professionals with respiratory therapists and/or physical therapists (n = 13) and the other including patients (n = 7) of the domiciliary healthcare provider Todomed. Usability studies normally include small groups. For example, Nielsen et al. [23] suggest that five users were able to identify 85% of usability issues, especially when they are part of a homogeneous group. Other authors have used similar sample sizes as that used in our research (n = 20) [23,24]. For the recruitment of participants, the following inclusion criteria were applied to the group of professionals: (i) subjects aged 18 years and older; (ii) respiratory therapists and/or physiotherapists linked to a home care company; (iii) experience in home care of more than six months; and as an exclusion criterion, professionals with experience in managing patients with home oxygen for less than six months. The inclusion criteria for the group of patients were: (i) subjects aged 18 years and older; (ii) patients with a medical prescription for home oxygen use of more than one year; (iii) individuals who have a caregiver, and (iv) who gave informed consent to participate in the study and to record the audio of the sessions. The exclusion criterion was that patients were on mechanical ventilation.

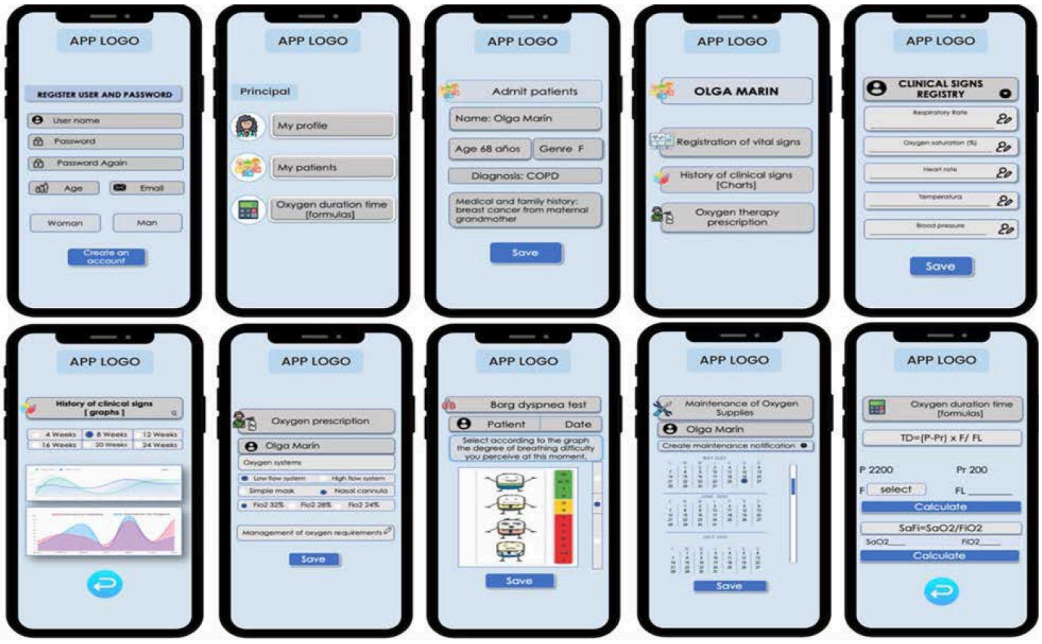
The primary caregiver of each patient accompanied the researchers during the home visit. The researchers provided each participant with a smartphone equipped with interactive and functional mockup designs. Participants could scroll through and select each section appropriate to the tasks assigned in the user tests. Fig. 1 shows the content and distribution of information on each screen. The usability tests consisted of executing a list of tasks, with scenarios of use cases of the mobile application (10 tasks for each group of participants) (Table 1). During the test, if the participant made a pause for more than 30 s, the researcher would ask *"What are you looking at?"* or *"What are you trying to do?"* if necessary. The tasks were analyzed to assess the difficulty level, execution time, and success percentage. The researchers analysed the test tasks, assessing the degree of difficulty, execution time and success rate. In addition, they recorded it as a "successful task" if participants had completed their task on the first attempt while counting the number of errors after two, three or more shots. On the other hand, if the individual did not complete the task, it was recorded as a "critical mistake". The following scale was used to measure task difficulty: 1 = very easy, 2 = easy, 3 = moderately easy, 4 = difficult, and 5 = very difficult. In order to assess satisfaction towards app usability, a survey was designed based on previously validated questionnaires [25,26,27,28], and adjusted to the purpose of this study. These adaptations were minor, and although translated into Spanish, the changes were minor in content. Prior research [29,30] on the design of questionnaires on satisfaction towards app usability highlight the importance of basing design on the context in which the app will be used [30]. The survey had 9 questions for therapists and 10 for patients (Table 2). Satisfaction towards ease of deployment, navigation and utility for self-management, monitoring, and decision-making activities associated with home oxygen patients was assessed. Responses were measured with a 4-score Likert scale ranging from 4 (totally agree) to 1 (totally disagree). To determine the satisfaction level, 1 point was granted to the questions in which participants totally or moderately agreed and 0 points to the ones in which they moderately or totally disagreed. Cut-off points for the satisfaction level were obtained by measuring quartiles. In the patients group, satisfaction was considered low if it was in quartile 1 (1–3 points), moderate if it was in quartiles 2 and 3 (4–8

a. Patient profile



Oxygen therapy: in this section, the patient will be able to visualize the medical prescription for home oxygen, evaluate the degree of respiratory difficulty using the Borg dyspnea scale and know the estimated time duration of oxygen supply.

b. Professional profile



Oxygen therapy: professionals will be able to record changes in the oxygen prescription required by patients and record the assessment of the degree of respiratory distress. With the recording of clinical data, the professional will analyze the clinical status of patients and make decisions about their treatment with home management.

Fig. 1. Usability tests mockups.

Table 1
Tasks conducted by participants in usability tests.

Task No.	Usability test for the healthcare professional profile	Usability test for the patient profile
1	Create account.	Create account.
2	Log in.	Log in and enter name, ID, age, sex, and contact number.
3	Register a new patient. Name: Olga Marín; age: 68; sex: F; medical diagnosis: COPD; relevant family history: maternal grandmother diagnosed with breast cancer (save the information).	Enter the following clinical signs: RR higher than 25 breaths per minute, saturation lower than 80%, HR 60–100 per minute, temperature 36 °C–37 °C.
4	Enter the following: Olga Marín, RR 25 breaths/min, oxygen saturation > 80%, HR 60–100 heartbeats/minute, capillary filling > 2 s, temperature 36 °C–37 °C (save the information).	Visualize the oxygen prescribed by your physician or therapist.
5	Supposing that clinical data has been recorded over the last eight weeks, visualize the graphs showing trends in clinical signs (go back).	Visualize use data on home oxygen therapy.
6	Enter the oxygen system that your patient is using (supposing that he/she needs a low flow oxygen system, nose cannula, 32% Fio2) (save the information).	Enter the level of breathing difficulty, supposing that it is "moderately breathless (a)."
7	Enter an assessment on the breathing difficulty of Olga Marín, supposing that she reports feeling "moderately breathless" according to Borg's scale (save the information).	Supposing that there is a formulated nebulizer scheme (Atrovent), enter three puffs administered on Monday, Wednesday, and Friday (one each day) in the dose counter.
8	Identify the section on oxygen maintenance and schedule a notification for oxygen concentrator maintenance on May 26, 2022 (confirm the notification and save the information).	Identify your therapist assigned (a) by the domiciliary healthcare program, supposing that she is Daliana López, and enter the domiciliary visit that took place on June 12, 2022.
9	Locate the formulas section to identify the duration time of the oxygen cylinder (go back to home page).	Watch the tutorial (video) which explains how to measure oxygen saturation with the pulse oximeter.
10	How would you change your password?	Look at the section "Frequently asked questions" to read about home oxygen use.

points), and high if it was in quartile 4 (9–10 points). In the professionals group, satisfaction was considered low if it was in quartile 1 (1–3 points), moderate if it was in quartiles 2 and 3 (4–7 points), and high if it was in quartile 4 (8–9 points).

In addition, audio recordings were made, and we used a stopwatch to record the time spent by each participant in the usability tests. The recordings were transcribed verbatim without identifying the participants. The "Think-aloud" method [30,31,32] was applied, which consists of asking the participant to mention aloud while simultaneously performing the tasks, thoughts, opinions, perceptions of difficulty or ease, and observations related to decision-making and errors. Qualitative methods such as this allow detailed identification of usability issues that need to be addressed [33]. The anonymous transcriptions were analyzed, highlighting those parts about the characteristics of mockups and usability tests that were associated with the study goals. The researcher attended next to each participant, monitoring and visualising every gesture and behaviour during the tests. Finally, the researcher summoned the health professionals to *Todomed's* facilities while the patients were visited at home. The patient's main caregiver accompanied the researchers during the visit, which lasted approximately 45 min. Quantitative data obtained through the surveys were analysed using the statistical package SPSS, version 22, and GraphPad Prism. The researchers used no software for the qualitative analysis of the information obtained during the usability testing.

Table 2
App usability satisfaction survey.

Questions for professionals	Questions for patients
1. The App is easy to use	1. The App is easy to use
2. The organisation of the mobile application's content is consistent and allows for easy and intuitive monitoring.	2. The content of the App is easy to understand
3. According to the clinical signs recorded, the graphs are easy to interpret.	3. The App makes it easy to recall oxygen prescription information at home
4. The mobile application helps to be more effective in clinically monitoring home oxygen patients.	4. Clinical data records are easy to complete in the App
5. The mobile application is helpful in decision-making in the clinical monitoring of home oxygen patients.	5. The App's "frequently asked questions" allow an easy understanding of the use of home oxygen equipment and supplies
6. Would you recommend the use of the mobile application?	6. App videos are helpful
7. It is easy to remember to use the mobile application	7. Would you recommend the use of the mobile App?
8. The actions performed in the mobile application are easy to execute.	8. The App allows one to feel safe when the responsible professional is not at home
9. There are no errors in the information presented in the mobile application.	9. The actions performed in the mobile App are easy to execute
	10. The content presented in the mobile App is excessive

Note: The original questions were written in Spanish. This table shows the translation of the questions for an easier understanding of the survey.

3. Results

Two data collection groups were formed, which consisted of healthcare professionals (n = 13) and patients (n = 7). The professionals were mostly respiratory therapists (85%), female, with a median age of 41 years (interquartile range of 9 years), and with more than 3 years of experience in home care in 54.0% of cases. Patients were mostly male (4/7), and had received home oxygen therapy for 1–3 years (71%).

Table 3
Sociodemographic characteristics of participants.

Health care professionals			Patients		
Variable	n	Percent (%)	Variable	n	Percent (%)
Gender			**Gender**		
Male	1	8	Male	4	57
Female	12	92	Female	3	43
Profession			**Education level**		
Respiratory Therapist	11	85	Elementary	4	57
Physiotherapist	2	15	High School	3	43
Time of experience in home care			**Time in the program with oxygen therapy**		
<1 year	4	31	1–3 years	5	71
1–3 years	2	15	>3 years	2	29
> 3 years	7	54			
Experience with home oxygen therapy					
Yes	13	100			
No	0	0			
	Median	IQR		Median	IQR
Age	41	9	**Age**	56	25

IQR: Interquartile range.

Detailed information on participants' sociodemographic and clinical characteristics can be found in Table 3.

3.1. Think-aloud method and participants' perceptions during task performance

The think-aloud method was essential in determining whether the app was intuitive, since participants described their experience with the difficulties and their perceptions while completing the tasks. By transcribing the audio recordings through this method, the authors could extract fragments expressed by the participants, which allowed the analysis and identification of improvements in the design or organisation of the App's content, with which the use of the mobile application by the end users is expected. In the Professionals group (8/13), difficulty was perceived in the task where they had to visualize, through graphs, the behavior of clinical signs per week. Five of thirteen professionals suggested that the app allows them to visualize the information differently (pie charts or bar graphs) according to their preferences. to visualize the information in different ways (pie charts or bar graphs) according to their preferences. Moreover, information should also be displayed by month (3/13). Finally, 2 of 13 professionals described the importance of having a button that would lead them back to each patient's home page. Regarding the patients (5/7), most stated that, even though entering the clinical signs was not complex, the app should let them enter the value of each vital sign instead of selecting a default range. They also suggested that, in order to exit a section of the app, instead of pressing the left arrow button, they should press an "X" in order to close the current window and automatically go to the home page of the app (3/7). Furthermore, four de 7 patients said that the oxygen prescription would be better visualized as a reminder and highlighted the importance of fluent information exchange between professionals and patients. 11 of 13 professionals described the test as "easy" and the pictures as "understandable," while patients (5/7) said that "the mobile app is useful for vital sign self-monitoring," (7/7) "the app is nicely organized," "the test was simple," (7/7) and "data on home oxygen use can be easily remembered" (6/7). All participants also stated that the simple design of the mockups allowed them to conduct the test without prior training and to become familiar with the case scenarios presented. Table 4 shows detailed information on participants' comments.

Table 4
Participants' comments collected through the think-aloud method and difficulties identified in the tasks.

Participants	Participants' comments	Task difficulties
Healthcare professionals [PS]	"Well… I don't know, when creating an account, I only saw 'user' or 'password', but when looking at the full screen I could see 'forgot your password?' or 'need an account?', so I knew I had to select 'need an account'" [PS4].	The participant had concerns when creating an account, but solved them quickly.
	"If it is a new patient… Here you can see previously created patients, so I would look for the option 'create a patient', but I can't see it, I guess this icon lets me create a new patient……." [PS2].	The participant looks for a written option to create a patient.
	"When I saw the graphs, I thought that they could be presented in different ways, such as pie charts or bar graphs, according to the therapist's preferences… I don't know, it seems interesting… I wasn't sure whether only one way of interpreting the information was the correct choice" [PS13].	The participant looks for an option that downloads different ways of visualizing graphs.
	"Clinical sign visualization is fine, but… I didn't know what to do, I get confused when graphs only show weeks, I would like to see months…" [PS10].	The participant wants to visualize clinical signs by month and not by week.
	"When creating an oxygen maintenance notification, I don't think a confirmation is necessary, I get confused if I have to confirm it again… I believe only one confirmation is enough…" [PS8].	The participant hesitates when confirming the creation of the maintenance notification, but is able to complete the task.
Patients [PC]	"I don't know…if I create an account, I will receive a confirmation email… I thought that my name and ID were enough to log in, but first I need to create an account" [PC5].	The participant hesitated when creating an account but was able to complete the task.
	"When saving the information of each section, in order to go back…although the arrow lets me go back, I thought an "X" would appear in order to close the window and go back" [PC6].	Too many steps to go back.
	"I think I can enter my clinical signs by clicking on the picture that says 'medical records'…. … I don't know if I just have to select values or write the exact data" [PC2].	The participant was looking for an option to write vital signs.

3.2. Difficulty level for participants when performing the tasks during the usability tests

When determining the difficulty level in performing the tasks in the usability tests, we observed that, in the healthcare professionals group, activities associated with creating an account, creating a username and a password, entering the oxygen system, creating a maintenance notification for oxygen supply, and changing password were assessed as "very easy" by >60% of participants (Table 5a). Conversely, no task was described as "difficult or too difficult." In the Patients group, tasks associated with creating an account, creating a username and a password, visualizing oxygen therapy data, and identifying the assigned therapist were described as "easy" by more than 70% of participants. As in the Professionals group, no participant described the tasks as "difficult or too difficult" (Table 5b).

3.3. Tasks completed successfully by participants in usability tests

In the group of professionals of the ten usability test tasks, six tasks were "successful", i.e., performed on the first attempt: entering clinical signs, describing the oxygen therapy systems, entering the Borg's scale, creating a notification for oxygen maintenance, entering the duration of the oxygen cylinder, and changing password. Success percentages of 46% and 69%, respectively (Table 6a), were observed for the tasks "create an account" and "create a username and a password." Out of the participants, 46% made one to two mistakes, and 16% made three mistakes in the test. The professionals mentioned that the errors were related to the lack of confidence and training to interpret the clinical signs graphs in their day-to-day work. In addition, they stated that presenting the information simply and easily to understand would optimise time in the decision-making and suggested that the visualisation of the vital signs report should be observed by month. Finally, they were hesitant to create an account.

Conversely, in the group of patients, all participants successfully

Table 5
Difficulty level for participants when performing the tasks.

a. Professionals

Task	Very easy n (%)	Easy n (%)	Modernly Easy n (%)	Difficult n (%)	Very difficult n (%)
T1. Create an account	8(62)	4(30)	1(8)	0(0)	0(0)
T2. Log in	8(62)	5(38)	0(0)	0(0)	0(0)
T3. Patient data record	7(54)	6(46)	0(0)	0(0)	0(0)
T4. Registration of clinical signs	6(46)	6(46)	1(8)	0(0)	0(0)
T5. Graphic display	5 (38.5)	5 (38.5)	3(23)	0(0)	0(0)
T6. Registration Oxygen systems	8(62)	4(30)	1(8)	0(0)	0(0)
T7. Registration Borg scale	7(54)	5(38)	1(8)	0(0)	0(0)
T8. Oxygen maintenance notification	8(62)	5(38)	0(0)	0(0)	0(0)
T9. Oxygen cylinder duration record	6(46)	4(30)	3(23)	0(0)	0(0)
T10. Password change.	9(69)	4(30)	0(0)	0(0)	0(0)

b. Patients

Task	Very easy n (%)	Easy n (%)	Modernly Easy n (%)	Difficult n (%)	Very difficult n (%)
T1. Create an account	2(29)	5 (71)	0(0)	0(0)	0(0)
T2. Login (username and password)	1(14)	6 (86)	0(0)	0(0)	0(0)
T3. Registration of clinical signs	1(14)	4 (57)	2(29)	0(0)	0(0)
T4. Oxygen prescription display	3(43)	4 (57)	0(0)	0(0)	0(0)
T5. Home oxygen use visualization	6(86)	1 (14)	0(0)	0(0)	0(0)
T6. Register degree of dyspnea	1(14)	5 (71)	1(14)	0(0)	0(0)
T7. Inhalotherapy registry	3(43)	4 (57)	0(0)	0(0)	0(0)
T8. Assigned therapist identification	2(29)	5 (71)	0(0)	0(0)	0(0)
T9. Tutorial visualizations	3(43)	3 (43)	1(14)	0(0)	0(0)
T10. Frequently "asked questions" display	4(57)	3 (43)	0(0)	0(0)	0(0)

completed the tasks of creating an account, entering the nebulizer doses, and visualizing the "frequently asked questions." Out of these patients, 57% made one to two mistakes and 43% made three mistakes on the test (Table 6b). Mistakes in the patient group were related to unfamiliarity with scrolling through the screens, preferring to have a button that would take them directly back to the main screen.

None of the participants in the two groups made critical mistakes.

3.4. Satisfaction level towards the usability of the mobile app

Regarding satisfaction towards the app, all healthcare professionals answered 3 of the 9 questions as "totally agree." Regarding the question about the ease of graph interpretation, 6 out of 13 professionals said they moderately agreed (Fig. 2a). After adding up all the participant's responses to the application's rating, the final score was 9/9 possible points for 100% of the people. In the patient group, one of the ten

Table 6
Successful completion of the tasks by participants.

a. Professionals

Task	Yes		No	
	Frequency	%	Frequency	%
T1 Create an account	6	46	7	54
T2 Log in	9	69	4	31
T3 Patient data record	11	85	2	15
T4 Registration of clinical signs	13	100	0	0
T5 Graphic display	12	92	1	8
T6 Registration Oxygen systems	13	100	0	0
T7 Registration Borg scale	13	100	0	0
T8 Oxygen maintenance notification	13	100	0	0
T9 Oxygen cylinder duration record	13	100	0	0
T10 Password change	13	100	0	0

b. Patients

Completed task	Yes		No	
	Frequency	%	Frequency	%
T1 Create an account	5	71	2	29
T2 Login (username and password)	7	100	0	0
T3 Registration of clinical signs	3	43	4	57
T4 Oxygen prescription display	3	43	4	57
T5 Home oxygen use visualization	5	71	2	29
T6 Register degree of dyspnea	6	86	1	14
T7 Inhalotherapy registry	7	100	0	0
T8 Assigned therapist identification	6	86	1	14
T9 Tutorial visualizations	5	71	2	29
T10 Frequently "asked questions" display	7	100	0	0

questions with the answer "totally agree" was selected by all participants. On the other hand, in the group of health professionals, in 5 of the ten tasks, 6 participants reported "strongly agree" (Fig. 2b). Similarly, in the Patients group, when adding the points awarded to each question, we observed that 86% of participants granted 10 points to the app and 14% granted 9 points, so a high level of satisfaction was obtained (Fig. 2b). In conclusion, both groups reported a high satisfaction level regarding the usability variables of the app.

App: mobile application.

Finally, we observed that the time required to complete all tasks was 18 RI:5 min, for the patients group and 11 RI: 8 min for the professionals group.

4. Discussion

The main findings obtained from this research are that the degree of satisfaction with the usability tests in both groups was high and that none of the participants made critical errors.

Furthermore, professionals and patients reported that the app could help develop self-management skills and clinical monitoring in-home care. In addition, the usability tests allowed us to identify improvements in the design of the mobile application.

4.1. Socio-technical approaches and human factors considerations for improving the usability of healthcare technology

There are different socio-technical approaches to improving the usability of healthcare technologies. Some address user characteristics, task complexity, healthcare technical aspects, and patient health status changes. These approaches include the technology component. However, these approaches do not help identify usability issues. In the research conducted by Sittig DF et al. [34], they propose a socio-technical model to study the design, development, use and implementation of health information technology, which integrates eight dimensions: (i) computer hardware and software infrastructure, (ii) clinical content, (iii) human–computer interface relationship, (iv) people, (v) workflow and communication, (vi) organizational policies and

Fig. 2. Satisfaction towards app usability.

procedures, (vii) rules, regulations and external pressures, and (viii) system measurement and monitoring. In this model, these mustn't be taken as "sequential steps". On the contrary, they should be related and interact with each other. These authors have highlighted that examining software, content, and user interfaces separately makes it challenging to grasp the entirety of healthcare technology, resulting in difficulties. In this sense, it is common to find poorly organized content and an interface that is difficult to interpret [34]. In other words, the usability of software will not only depend on direct failures of the technology, but also on how the content and user interface are organized. In line with these authors, we have observed that by designing a mobile application with intuitive user interfaces and contextualized content for home care, participants expressed positive opinions about using the application's features, which generated a high degree of satisfaction.

One of the dimensions proposed in the socio-technical model developed by Sittig et al. [34] is the "People" dimension, which represents the human beings involved in designing, implementing, and using health technology. The authors expressed that the people involved in the technology implementation process must have the knowledge and skills to develop these technologies. Furthermore, they insist that patients and their caregivers are becoming increasingly frequent users of new technologies, especially in the home monitoring and control environment. For these reasons, they express their concern that patients may not have the skills and abilities to manage health technology. In this same sense, some authors [35,36,37,38] have highlighted that the technologies used at home present challenges for older patients concerning interface design problems, negatively affecting their performance and perceiving them as useless. In contrast to this research, the group of patients expressed that, although they did not have ample experience managing mobile applications when performing usability tests, they felt that the app was intuitive. Furthermore, its organisation allowed straightforward interpretation to perform the tasks presented.

Concerning human factors considerations in implementing health technologies, some studies [36,39] describe how systematised medical prescribing can be taken as additional work. However, health professionals also recognise how recording clinical data through technology can be beneficial to perform their job better. As in the present study, the group of professionals expressed that, in-home care programs, the recording of clinical signs and medical prescriptions is currently done through physical reports, so when performing the usability tests and weighing the opportunity of integrating the mobile application into their work, they recognised that it would imply additional time for the management of the tool. In addition, they mentioned that it could be of great help in making decisions regarding managing patients with chronic diseases.

In the implementation of technological tools in health, some benefits related to communication have also been described. For example, Georgiou et al. [40] mention that, through electronic systems, more professionals can access patient information easily and quickly. In the present study, the professionals highlighted that the mobile application would allow them accessible and fluid communication.

4.2. Acceptability of technology in chronically ill older adults in-home care

Predicting technology use is beneficial in identifying the success or failure of a technology tool. [41,42]. Different technology acceptance models exist for foretelling this adoption and adherence to use. However, these have been used in young, healthy populations and non-healthcare settings. For example, Calvin et al. [43] present a model on technology acceptance in patients with early-stage disease (ESDP) considering factors associated with older adult populations. The authors mention that patients will be willing to use the technologies if they are motivated, if they perceive it as useful and if they are satisfied with the recommendations given by the professionals. In contrast to this research, the group of patients expressed an intention to use the mobile application, especially in tasks related to recognising their clinical status and the possibility of close communication with professionals.

Another essential aspect to consider for technology acceptance in chronically ill patients in-home care, according to Calvin et al. [43], is the perceived visual functional status and capacity of the upper extremities. These impaired functions make them less likely to accept and use technology [43]. In this research, the patients suggested that the information on the screens should be timely, accompanied by images and little text, which will improve the app's visualisation. In addition, they expressed feeling comfortable manipulating the cell phone.

Besides, Knox et al. [44] designed a mobile app for COPD patients, applied the technology acceptance model (TAM) and addressed two issues: usability and perceived ease of use. Participants in this study suggested that the app should have a dashboard that would benefit long-term data interpretation. Similarly, in our research, the group of professionals indicated that these could be represented in easy-to-interpret graphs for presenting the behaviour of clinical data according to one selected period. On the other hand, the group of patients suggested that information on clinical signs should be provided in notifications indicating basic behaviour according to clinical status. Another important point addressed by Knox et al. [44] was that having patients report clinical information in the app would help in their treatment. As in our research, patients agreed that filling out clinical information and sharing it with professionals would help them make decisions promptly, which could suggest a greater intention to use the mobile application.

Increasingly, COPD patients in-home care are being encouraged to develop self-management skills for their symptoms [43,45], that have led to an increase in technology-based strategies. Technological tools in health care provide benefits that allow these patients to learn about information in the self-management of their disease. However, these benefits could only be effective if this technology is used and accepted [46]. Thus, the usability tests in the present investigation revealed a high degree of satisfaction of the participants in the performance of the tasks, suggesting that the mobile application could be accepted.

4.3. Recommendations for mobile application design based on usability testing

The usability study by Tao et al. [47] describes that the "go to data history page" task was among the most complex for older adults. The authors mention that the design of the button directed to the data review section was probably not consistent with the other navigation buttons. Another possible explanation is that this task required more steps to complete. This result is consistent with this research since the patient group suggested including a single button that would allow them to decrease the steps to return to the main screen of the mobile application. Another point, in joint with the research conducted by Tao et al. [47], is related to the graphical representation of the clinical information. Patients suggested that it should be easy to interpret and recommended that graphs with clinical sign information be presented simply and intuitively.

Furthermore, our work used text and emoticons so that patients could record the assessment of the degree of respiratory distress. The group of patients positively valued having this type of design, which is consistent with the research of Tao et al. [47], who mention that using emoticons allowed older adults to evaluate their health status.

The features frequently used in the design of mobile applications are little applied in technological tools for COPD patients, although they have special conditions due to their health status [45]. The research conducted by Davies et al. [45] showed that the designs should have significant tactile elements to facilitate scrolling and comprehension. The particularities of the users (age, education and knowledge of technology) must also be considered. As in our study, patients recommended minimizing the steps for scrolling from one screen to another. In addition, they valued the tutorial section for providing reliable and understandable information.

Regarding creating an account to log into the mobile application by healthcare professionals, our results are consistent with the study by Nabi et al. [48], who also highlighted that most of the participants could perform the registration and creation of a user account efficiently. Likewise, Davies et al. [45] mention in their findings the importance of creating a new account with simple steps and passwords with a maximum of four digits to remember easily. Regarding the task of creating an account to use the app in the tests for healthcare professionals, the findings of this research are consistent with those of the study conducted by Nabi et al. [48], who also highlighted that most participants were able to register in the app and create a user account without difficulty. Likewise, participants in this study, especially the patients, reported feeling comfortable when performing the test. The study conducted by Henshall et al. [49] yielded similar results to those of

our study, since participants also highlighted the importance of making changes in the self-registration of clinical data, such as being able to introduce the exact value of the clinical sign instead of a default range, because it could increase the usability of the app.

Unlike our research, Choemprayong et al. [50] reported that participants were not comfortable when writing information on the app, and stated that the size of the mobile screen was quite small when compared with the size of their hands, and that they preferred selecting the clinical value instead of writing it. Moreover, this research is consistent with the one conducted by Storm et al. [51] in the sense that patients also suggested that notifications and alerts would be a useful option to increase the use of the mobile app, especially for the self-monitoring of their health. In our study, the Professionals group highlighted the simple design of the mockups, especially because they did not need prior training before completing the test. Based on our prior work [22], the structure and content of the app were developed with a user-centered methodology, which probably accounts for participants' acceptance. Previous studies [52,53,54] also reported that one of the most valued aspects was the simple design of the apps, which enabled participants to complete the test without prior instructions. Previous research [55,56,57] highlights the importance of allowing data exchange between professionals and patients, which is consistent with the findings of our study.

It is essential to highlight that qualitative methodologies such as the "Think-aloud" method [31,32] through participant feedback identified minor changes in the design of the content and organisation of the mobile application. Our results demonstrate that this method can identify important areas for improving the use of the App. The high degree of satisfaction and no critical mistakes (not completing tasks), as expressed by patients and professionals, indicates that an end-user-centred design from the early stages [22] led to a simple presentation of the architecture of the screens. In addition, participants expressed that the distribution of the sections or sections of the App was intuitive; therefore, they did not need prior instructions to complete the tasks. Another relevant aspect that our research highlights concerning the high degree of satisfaction on the part of the participants is the presentation of use cases adapted to the needs that may arise in the home care setting. In these settings, tasks related to monitoring, medical prescription and simulated self-management activities are widespread. Healthcare professionals' assistance through a mobile application that allows interaction and communication between patient and professional was a factor valued positively by patients.

Finally, the usability study allowed for the identification of improvements proposed by participants, especially regarding the registration and visualization of clinical signs. These changes will be adjusted by remodeling that section of the prototype and showing the option of writing clinical data. In the Professionals profile, clinical data will be shown in graphs based on the professionals' preferences. The patients profile will show each vital sign next to a picture with a text explaining how to measure that sign. Similarly, prior research [58,59] also considered patients' recommendations, and changed the app to free space on the screens in order to make the registration of self-monitoring journals more comfortable and include pictures with little text.

5. Study limitations

The sample size was 20 participants; however, this size is desirable for this type of methodology. As it was mentioned before [23], considerable percentages of usability issues were identified with small populations. Other authors have used similar sample sizes in studies with designs similar to the ones of our study [49,50,51]. The findings of this investigation are consistent with the ones of other studies assessing the usability of health technological tools. However, results cannot be generalized to all the health fields because one of the main features of this app is the clinical monitoring of patients diagnosed with COPD and home oxygen therapy in the Colombian health context. The stopwatch method was also supplemented by audio recordings, the viewing of a research team member during the interaction, and participant satisfaction and difficulty rating surveys. Although the stopwatch method on its own may not be very reliable, we consider that, by assessing the difficulty of the tests by the participants, as well as the fact that the tasks were completed or not, we believe that it was a complementary tool that also provided information on the usability of the mobile application.

5.1. Future work

Further research will focus on the design and development of the mobile app. Subsequently, a non-pharmacological clinical trial will be conducted [3] for 6 months (ClinicalTrials.gov: NCT04820790), where COPD patients under home oxygen therapy will be remotely monitored and the effects of the app on their clinical status and self-management skills will be assessed. It is essential to highlight that developing the mobile application is intended for a wider use of health technology within home care institutions, generating benefits in the clinical monitoring of patients with chronic diseases. In addition, it is planned to include in the mobile application educational activities and control of prescription inhaled drugs. It is expected to become a connecting tool between professionals, patients, caregivers and home care providers, thus optimizing the patient's experience in the home environment.

6. Conclusions

Participants described the app as intuitive and easy to use. The usability satisfaction results show a high level of satisfaction for both groups. We should highlight that professionals and patients suggested minor changes to increase the usability of the app. It is also worth mentioning that the mistakes made during the tests were not critical. This positive assessment and the performance in the user tests lead us to conclude that the mobile application was able to be understood and used by the participants under the circumstances of use in the usability tests. The evaluation of usability through satisfaction surveys and the analysis of qualitative data allows a better understanding of the use of mobile applications in health. Furthermore, the development of App designs and usability tests consider the context of use and particularities of patients, such as age, education and functionality conditions according to the health status of patients with chronic diseases such as COPD. This approach has proven to be a valuable strategy to ensure the usability of technological tools in health.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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