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Research Article

Effectiveness of ReCOVery APP to Improve the Quality of Life of Long COVID Patients: A 6-Month Follow-Up Randomized Clinical Trial

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Purpose: This study aims to analyze the medium-term effectiveness of telerehabilitation in enhancing the quality of life for patients with Long COVID, using a mobile application (APP) called ReCOVery APP. The secondary purpose is to identify significant factors associated with an improvement in the quality of life and other secondary outcomes in this population.
Methods: A randomized clinical trial was carried out with two parallel groups involving a total of 100 patients with Long COVID. The first one (control group, $n = 48$) continued with their usual treatment (TAU), established by their primary care doctor. The second one (intervention group, $n = 52$), in addition to continuing with their TAU, attended three sessions based on motivational methodology and used the ReCOVery APP for 6 months. The primary outcome was quality of life.
Results: After 6 months, ReCOVery APP did not significantly improve the quality of life among Long COVID patients. Poor adherence to the APP was observed among the participants who tried it. Linear regression analyses revealed a significant relationship between the decrease in the number of symptoms and the improvement in mental health–related quality.
Conclusions: While this research contributes valuable insights into the potential of telerehabilitation for Long COVID patients, the lack of significant improvement in quality of life underscores the need for future large-scale studies. Such research should focus on identifying effective strategies to enhance adherence to digital interventions, such as increased professional support and personalized care approaches. Additionally, exploring the long-term effects of telerehabilitation could provide a more comprehensive understanding of its role in managing Long COVID.

Trial Registration: ISRCTN Registry identifier: ISRCTN91104012

Keywords: long COVID; mobile APP; quality of life; randomized clinical trial; telerehabilitation

1. Introduction

A pandemic of unprecedented magnitude has been unleashed by COVID-19, leaving widespread devastation in its wake. One of its enduring legacies is the plight of individuals experiencing debilitating symptoms months after infection since 2020 [1]. Termed Post COVID-19 Condition by the World Health Organization (WHO) in October 2021, this novel pathology encompasses persistent or worsening symptoms persisting three months post-infection, which defy classification under any other diagnosis, typical of probable or confirmed SARS-CoV-2 infection. Scientifically known as "Long COVID," this condition has afflicted approximately 145 million individuals worldwide within the first two years of the pandemic [2]. The prevalence among nonhospitalized COVID-19 patients is estimated between 10% and 30%, contrasting with 50%–70% among hospitalized patients [3].

Symptoms associated with Long COVID span multiple organ systems, including respiratory, cardiovascular, gastrointestinal, neurological, musculoskeletal, dermatological, visual, and olfactory [4]. This myriad of symptoms profoundly disrupts bodily functions and diminishes quality of life [5]. Comprehensive rehabilitation, involving multiple disciplines, is essential to address the diverse symptoms affecting these patients across various bodily systems [6].

The COVID-19 pandemic has accelerated the adoption of telemedicine, particularly telerehabilitation, which continues to gain widespread acceptance [7]. Telerehabilitation, proven effective even before the pandemic, not only offers therapeutic benefits but also enhances cost-effectiveness compared to traditional rehabilitation methods [8]. Consequently, it emerges as a viable alternative to support patients with chronic conditions such as Long COVID. Several studies highlight the significance of telerehabilitation programs in aiding recovery efforts for Long COVID patients, showing improvements in dyspnea, muscle strength, and overall functional capacity [9–13].

Owing to the increasing need of comprehensive care for patients experiencing Long COVID symptoms and the rising popularity of telerehabilitation, this research developed a mobile application (APP) named ReCOVery APP. This digital tool provides rehabilitation content aligned with clinical guidelines and evidence [14–18]. A randomized controlled trial (RCT) with two parallel groups was conducted to evaluate its short-term clinical effectiveness [19].

While the initial 3-month results provided valuable insights into the immediate impacts of the ReCOVery APP, understanding its medium-term effectiveness is equally critical. Chronic conditions like Long COVID may exhibit changes in symptoms and quality of life over extended periods, making longer follow-ups essential to capture sustained outcomes and potential delayed effects [20]. The decision to present the 6-month follow-up results in a separate manuscript was guided by the need to provide a detailed and focused analysis of these medium-term outcomes.

The 6-month data offer a comprehensive view of whether the initial benefits observed at 3 months are maintained, increased, or diminished over time. This extended observation period allows for a deeper exploration of adherence patterns, patient engagement, and broader impacts on physical and mental health [21]. Publishing these findings separately also enhances clarity and allows for a thorough examination without overwhelming the reader with data from both short- and medium-term analyses in one document.

Moreover, the 6-month follow-up results contribute significantly to the existing body of research on Long COVID by providing evidence on the sustainability and long-term benefits of telerehabilitation interventions. This informs future clinical guidelines and supports the development of similar digital health tools for managing chronic diseases.

Therefore, this study aims to further explore the medium-term effectiveness of telerehabilitation (ReCOVery APP) in enhancing the quality of life for individuals diagnosed with Long COVID over a 6-month period, compared to their usual treatment (TAU) administered in the context of primary health care (PHC). A secondary goal was to evaluate the evolution in the quality of life and other secondary outcomes of the study, and to determine associated factors.

2. Methodology

2.1. Study Design. This research is an open-label RCT performed with two parallel groups of Long COVID patients experiencing persistent symptoms for at least 12 weeks. The control group have continued to receive their TAU established by their general practitioner (GP) of PHC. The intervention group was also given their TAU and additionally access to ReCOVery APP as an adjuvant treatment in the form of telerehabilitation, besides receiving three motivational sessions aimed at maximizing adherence to the APP.

Baseline evaluations and the start of the intervention occurred in March and April 2022, the follow-up evaluation between June and July 2022 [19], and the final evaluation in October 2022.

This investigation was conducted in Aragon (northeast of Spain). This study complies with the guidelines prescribed by the Consolidated Standards of Reporting Trials (CONSORT) checklist (Supporting information). Additionally, the original protocol article of this investigation was published [22] and a preprint has previously been published [23].

2.2. Development and Evaluation of the APP. Before designing the APP, a qualitative research was conducted through individual interviews and focus groups with Long COVID patients [24]. This study identified key themes such as persistent symptoms, expressed needs, and potential treatments. Subsequently, existing scientific evidence on health recommendations and rehabilitation for Long COVID patients was gathered [14–18]. Thus, a human-centered design was chosen [25], aiming to address problems and needs by understanding the users, in this case, Long COVID patients.

A native APP was created using Java language and the Android Studio platform, chosen over a hybrid approach to leverage the device tools such as notifications. All content was tailored and personalized according to patient's individual needs and characteristics, as outlined in available guidelines. Details regarding the content and bibliographic references of ReCOVery APP were documented in the protocol article of this RCT [19, 22]. ReCOVery APP comprised six main modules (diet; sleep hygiene; physical exercises; breathing exercises; cognitive exercises; participation in the community), which are described in more detail in the Supporting information.

2.3. Data Privacy and Installation Process. To protect patient privacy and data security, ReCOVery APP was not made available on public platforms such as Play Store. Instead, the APP was directly installed on patients' mobile devices by the research team during the initial session. This approach ensured that data collected through the app was stored securely and used exclusively for research purposes. Since the data was not transmitted to or stored by third-party services like Google, we were able to maintain strict control over the information, thereby respecting patient privacy and adhering to data protection regulations.

2.4. Sample Size. The sample size was determined based on calculations outlined in the protocol article of this RCT study [22]. Initially, the minimum required sample size of 78 subjects was calculated using parameters derived from the Spanish study by Dalbosco-Salas et al. [26], which utilized a longitudinal design and a similar intervention in a PHC setting. Given the absence of specific studies on Long COVID patients evaluating such interventions via clinical trials, the pre–post score difference of the SF-36 instrument was utilized, assuming the highest possible standard deviation (SD) and a minimum expected difference of 19.3 points. The study accepted a risk of 0.05 and aimed for a power of 95% in a two-sided test, with a maximum dropout rate of 10%.

Due to significant interest from potential participants, the researchers decided to increase the sample size by approximately 28%. Thus, the final sample included 100 participants.

2.5. Recruitment of Participants. The assessed population were patients with Long COVID condition, aged 18 or older, infected for 12 weeks or more, and with a positive diagnostic test for COVID-19. Exclusion criteria were rigorously defined to ensure the integrity of the study. Patients with a positive COVID-19 test within the past 12 weeks, those participating in another clinical trial within the last six months, and individuals who were pregnant or lactating were excluded. Moreover, individuals with severe uncontrolled illnesses (such as decompensated health failure, severe Chronic Obstructive Pulmonary Disease, advanced-stage cancer, or uncontrolled autoimmune diseases), a significant risk of suicide (as determined by their GP based on clinical history and professional judgment), ongoing structured psychotherapeutic or rehabilitative treatment, or any comorbidities that could significantly interfere with study outcomes (e.g., severe neurological disorders, significant cognitive impairment, or acute psychiatric conditions) were also excluded.

Patients meeting the inclusion criteria were recruited from consultations of GPs of PHC. Additionally, interested patients from the "Long COVID Aragón" association were referred to their GP to determine eligibility. Recruitment took place consecutively from January to March 2022.

2.6. Randomization, Assignment, and Blinding of Study Groups. The individual randomization process was carried out using an alphabetical list of participants and computer-generated blind sequence, under the monitoring of an independent, blinded investigator. Because of the nature of the intervention, patients were aware of the group to which they belonged, but they were instructed not to disclose their assignment to third parties.

2.7. Intervention. As previously stated, participants in the intervention group not only continued with their TAU but also had access to ReCOVery APP. Furthermore, at the outset of the intervention, this group attended three sessions focused on motivational methodology, APP utilization, and reinforcement of personal constructs (health literacy, self-efficacy, and personal activation) related to their disease. All sessions were performed in person, following the guidelines outlined by Miller and Rollnick [27].

The first two sessions were conducted individually by a clinical psychologist, during which the APP was installed and any questions regarding its use were addressed. Since the APP was only available for Android devices, those in the intervention group who owned Apple devices were provided with an Android phone for the duration of the intervention to ensure equal access to the ReCOVery APP. Technical support was also provided as needed to ensure usability.

The third session was developed in a group format, with 8–10 participants, and was led by two clinical psychologists. The sessions were held over three consecutive weeks, ensuring that all participants completed them within the same time frame.

2.8. Adverse Events and Follow-Up of the Intervention. Before initiating the intervention, the research team identified the following potential adverse events: COVID-19 reinfection, hospitalization, use of emergency medical services, surgical interventions, or any other circumstance that could impact the intervention progress. Participants were given a telephone number as so they could contact and report adverse events at any time during the study. No adverse events other than those mentioned were notified during the intervention.

Despite the remote and "uncontrolled" nature of the intervention, two follow-up calls were conducted at 6 weeks and 18 weeks from the start of the intervention. During these calls, information regarding potential adverse events was requested.

2.9. Measures and Outcomes. Three measurements were assessed throughout the research: baseline evaluation (T0), a follow-up evaluation at 12 weeks from the beginning (T1) and a final evaluation at 24 weeks from the start of the intervention (T2). All the evaluations were conducted face-to-face and individually at a healthcare center over two consecutive weeks. Two blinded researchers with previous experience in similar research studies performed the evaluations.

The measured outcomes and assessment tools used in this study are shown in Figure 1 and are described in more detail in the protocol article of this RCT [22].

The primary outcome was quality of life, which was evaluated using the Short Form-36 Health Survey Questionnaire (SF-36) [28]. This tool assesses eight dimensions of health: vitality, physical functioning, bodily pain, general health perceptions, physical role functioning, emotional role functioning, social role functioning, and emotional well-being. These dimensions are categorized into two main components: physical health and mental health. Responses are rated on Likert scales ranging from one to three points, depending on the item, and each of the eight scales is scored from 0 to 100. Scores above or below 50 indicate better or worse health status, respectively. In this study, the Cronbach's alpha coefficient obtained for the SF-36 was 0.84.

Permission to use Montreal Cognitive Assessment (MoCA) and Patient Activation Measure (PAM) in this research were granted by their developers.

2.10. Statistical Analysis. Statistical analyses were elaborated using IBM SPSS Statistics version 22.0.0.0 and Microsoft Excel software. Parametric statistics were employed since, in large samples, statistical tests tend to approximate normality even if the data distribution is not normal [29].

Initially, a descriptive analysis of the sample was conducted, calculating frequencies and percentages for qualitative variables and mean and SD for quantitative variables. Next, a bivariate analysis was performed, comparing baseline measurements and their differences at 3 months and 6 months. Chi-square test was used for qualitative variables, and Student's *t*-test was employed for quantitative ones.

To analyze the effectiveness of ReCOVery APP, a per-protocol analysis was performed. This involved comparing baseline (T0), 3-months (T1), 6-months (T2), and six-months-baseline differences between both groups using Student's *t*-test.

To address the second objective, it was examined whether there had been significant advances in the entire sample over the 6-month period, irrespective of their allocation group. Post-intervention/baseline (T2-T0) comparisons were performed using Student's *t*-test for the related samples across the 10 selected scales and the number of symptoms.

Finally, to analyze the variables associated with significant or trend improvement in the primary outcome, a linear regression model was developed for progress in physical and mental health–related quality of life (SF36 physical health and SF36 mental health respectively) assessed as dependent variables. The assignment group, the sociodemographic variables of sex and age, the number of symptoms, three of the most prevalent comorbidities (cardiovascular and circulatory issues, musculoskeletal issues, and psychiatric disorders), some clinical variables (cognitive state, emotional state, physical functioning, and sleep disorders), and three personal constructs (GSES-12, PAM and HLS-EUQ16) of all the participants who completed the study were included as independent variables, since evidence shows that they can influence quality of life. Linear regression was employed since the model residuals exhibited a finite mean, constant variance, and normal distribution. Additionally, to validate the results, a bootstrapping analysis was conducted using 2000 samples.

3. Results

Initially, a total of 182 people were assessed to determine their eligibility (Figure 2). Among them, 72 (39.56%) were excluded for not meeting the inclusion criteria and 10 (5.49%) declined to participate. Finally, 100 people were randomly allocated to the investigation, with 52 allocated to the intervention group and 48 to the control group. During the evaluation conducted after six months, 20 individuals were discarded (8 were reinfected by COVID-19 and 12 declined to continue participating), resulting in 80 individuals being evaluated.

The general characteristics of the recruited patients are presented in Table 1, along with a comparison by assigned group based on the variables collected at baseline. The descriptive analysis at baseline included a total of 100 participants (80 women and 20 men). The standard profile corresponded to a woman with a mean age of 48.28 years (SD: 9.26), holding secondary or university education and with active employment or TWD. Regarding comorbidities, the analysis revealed that the most prevalent conditions among participants included cardiovascular and circulatory issues (48.0%), musculoskeletal issues (43.0%), and psychiatric disorders (34.0%). Participants presented an average of 16.47 (SD: 5.99) persistent symptoms and showed a low quality of life (both physical and mental), as indicated by the SF-36 results. This was accompanied by limited physical functioning (as reflected in the sit-to-stand test), cognitive impairment (MoCA), elevated levels of anxious-depressive symptoms (HADS), and insomnia (ISI). In terms of personal constructs, participants proved acceptable levels of self-efficacy (GSES-12), high activation and self-management (PAM), but low levels of health literacy (HLS-EUQ16). Regarding the comparison by assigned group, this analysis subsequently revealed no significant differences between both groups (intervention and control).

When analyzing the usage of ReCOVery APP in the intervention group, the range of usage over 6-month period varied from 10.95 min to 5764.81 min. On average, participants utilized the APP for 839.65 min (SD: 1118.48) during this period. However, only seven participants (13.4%) in the intervention group demonstrated significant usage of the APP. Approximately 62% of the participants used the APP during the first 3 months, but not afterward, contributing to the observed low adherence in the medium term.

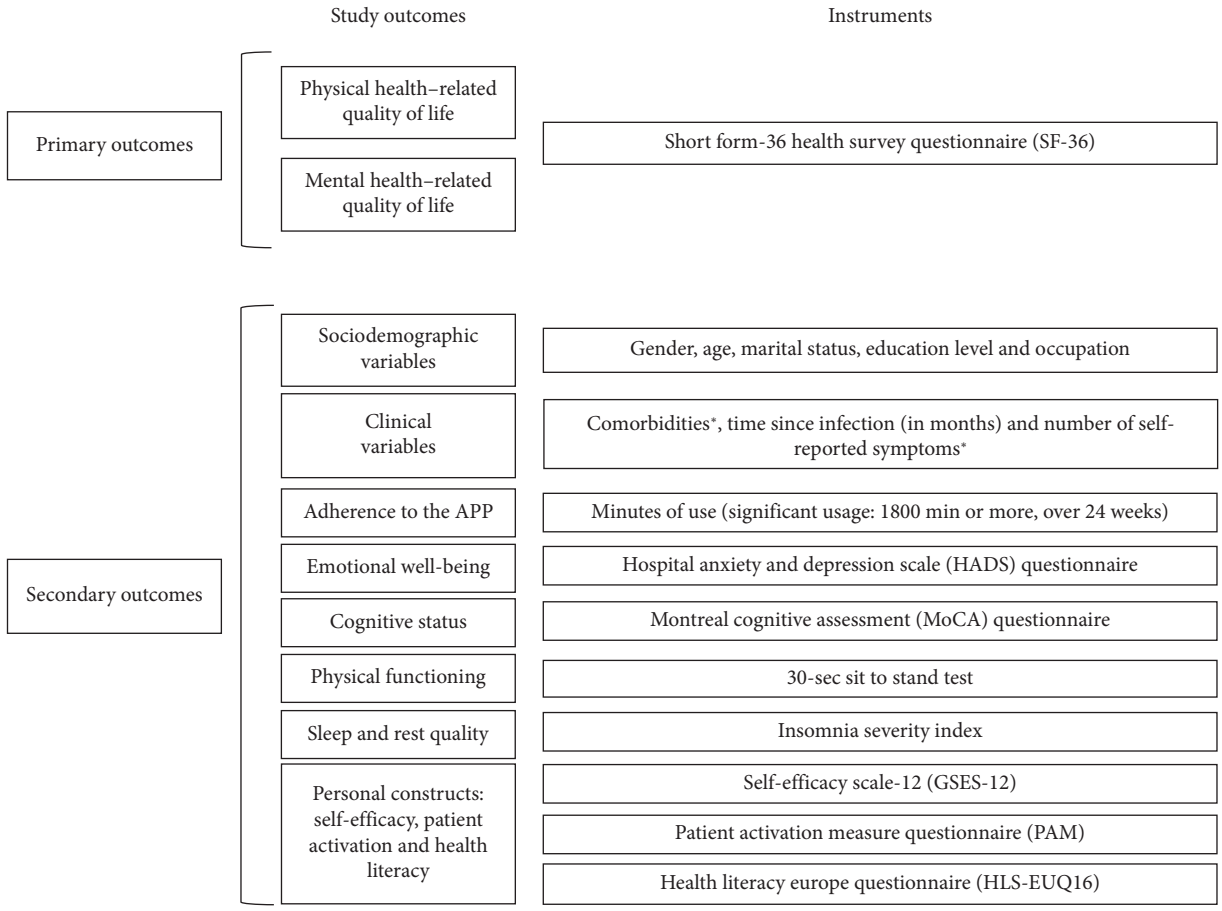

Figure 1: Study outcomes and assessment instruments. *A comprehensive list of assessed comorbidities and symptoms is provided as supporting information.

Table 2 presents a comparison between both groups (intervention and control group), using data obtained from three different measurements spanning from the beginning to the end of the intervention. As shown, no significant differences favoring the intervention group were identified between the end (T2) and the beginning of the intervention (T0) in any clinical variable. However, the SF-36 Physical Health variable did show statistically significant differences between the intervention and control groups at three months (p: 0.020; CI: −15.63, −1.36) and six months (p: 0.045; CI: −18.49, −0.20), with better levels of physical health for the control group. Compared to it, the intervention group improved to a greater extent from the beginning of the project (T2–T0) in the following variables: mental health–related quality of life, cognitive status, emotional well-being, activation, and health literacy.

Table 3 presents the evolution of the entire sample, encompassing both the control and intervention groups, in the different quality of life and health constructs analyzed after a 6-month follow-up period. On average, participants demonstrated significant improvements in physical and mental health–related quality of life, as well as reductions in the number of persistent symptoms, and enhancements in cognitive status, physical functioning, and levels of depression and anxiety ($p < 0.001$).

Table 4 shows the regression models concerning enhancements in the primary outcome (quality of life) for the entire sample. In the first model, improvement in physical health–related quality of life (T2-T0) was included as dependent variable. The independent variables were: sociodemographic variables (gender and age), the assignment group, the number of symptoms, three of the most prevalent comorbidities (cardiovascular and circulatory issues, musculoskeletal issues, and psychiatric disorders), and the 6-month evaluation scores of the secondary clinical variables of cognitive status, emotional state, sleep disorders, and personal constructs (self-efficacy, health activation, and health literacy). Although the model was not significant, the results would show a trend of how increases in physical health–related quality of life could be predicted by experiencing a lower number of symptoms ($b = -0.723$; $p < 0.05$). The relationship between health activation and improvement in physical health–related quality of life would also reveal a certain tendency towards significance ($b = 0.777$; $p = 0.51$).

In the second model, improvement in mental health–related quality of life (T2-T0) was included as dependent variable. Sociodemographic variables (gender and age), the assignment group, the number of symptoms, three of the most prevalent comorbidities (cardiovascular

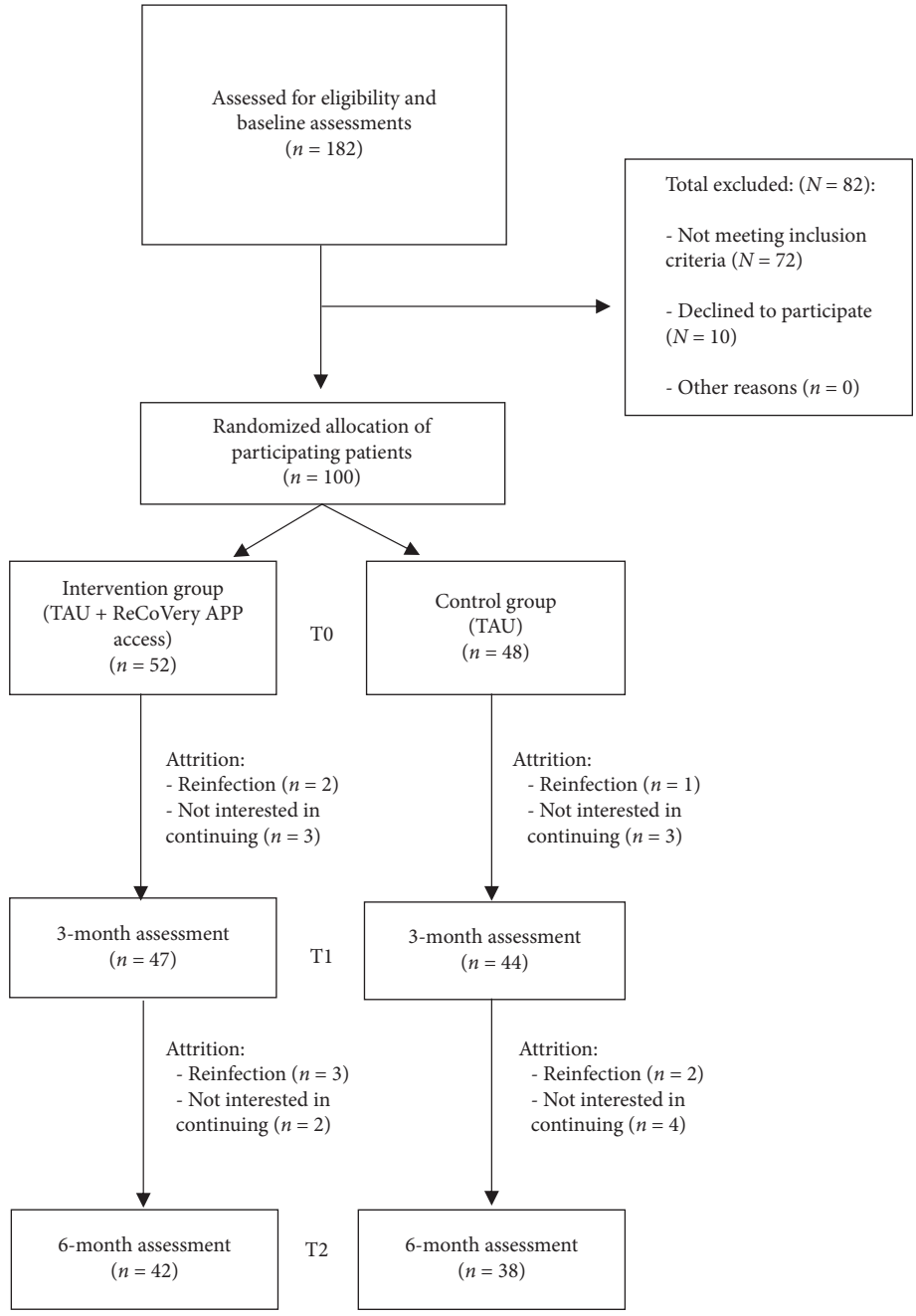

Figure 2: Flowchart of the study.

and circulatory issues, musculoskeletal issues, and psychiatric disorders), and the 6-month evaluation scores of the secondary clinical outcomes of cognitive status, physical functioning, sleep disorders, and personal constructs (self-efficacy, health activation, and health literacy) were entered as independent variables. This model, which was found to be significant, revealed that a lower number of symptoms predicted a greater improvement in mental health–related quality of life ($b = -0.956$; $p < 0.05$). In this case, a trend relationship was also observed between evolution in mental health–related quality of life and better scores in another personal construct—health literacy ($b = -0.673$; $p = 0.059$).

4. Discussion

For the scientific community, understanding the etiology of Long COVID is proving to be much more complex than in the case of COVID-19 [30] and—despite recent evidence—there are still many unknowns surrounding the disease [20]. In the last 2 years, several medical guidelines have been published focusing on the diagnosis and management of Long COVID [14, 17, 18]. However, these guidelines lack potentially useful rehabilitation interventions, which is understandable given the paucity of RCTs conducted in this patient group. In the same vein, official sources highlight the need for interventions based on

Table 1: Description of sociodemographic and clinical variables of the total sample and comparison by assigned group.

Variables	Total sample *N* (%)/mean (ED) *N* = 100	Intervention gr. *N* (%)/mean (ED) *N* = 52	Control gr. *N* (%)/mean (ED) *N* = 48	*p*-value
Gender (%)				
Men	20 (20.0%)	8 (15.4%)	12 (25.0%)	0.230
Women	80 (80.0%)	44 (84.5%)	36 (75.0%)	
Age	48.28 (9.26)	48.25 (10.36)	48.31 (8.01)	0.973
Self-perceived age	58.10 (14.69)	59.69 (15.02)	56.38 (14.27)	0.261
Marital status (%)				
Married or in a relationship	70 (70.0%)	35 (67.3%)	35 (72.9%)	0.541
Single, separated, widowed	30 (30.0%)	17 (32.7%)	13 (27.1%)	
Educational level (%)				
Without studies or primary studies	9 (9.0%)	5 (9.6%)	4 (8.3%)	0.823
Secondary or university studies	91 (91.0%)	47 (90.3%)	44 (91.7%)	
Occupation (%)				
Employed	46 (46.0%)	20 (38.5%)	26 (54.2%)	0.350
Unemployed	5 (5.0%)	4 (7.7%)	1 (2.1%)	
TWD	37 (37.0%)	21 (40.4%)	16 (33.3%)	
Retired	9 (9.0%)	6 (11.5%)	3 (6.3%)	
Others	3 (3.0%)	1 (1.9%)	2 (4.2%)	
Comorbidities (%)				
Respiratory diseases	14 (14.0%)	8 (15.4%)	6 (12.5%)	0.678
Cardiovascular and circulatory issues	48 (48.0%)	23 (44.2%)	25 (52.1%)	0.432
Musculoskeletal issues	43 (43.0%)	22 (42.3%)	21 (43.8%)	0.884
Metabolic and endocrine issues	15 (15.0%)	6 (11.5%)	9 (18.8%)	0.313
Gastrointestinal issues	23 (23.0%)	11 (21.2%)	12 (25.0%)	0.648
Neurological issues	20 (20.0%)	12 (23.1%)	8 (16.7%)	0.423
Vision and hearing problems	32 (32.0%)	17 (32.7%)	15 (31.3%)	0.877
Psychiatric disorders	34 (34.0%)	15 (28.8%)	19 (39.6%)	0.257
Allergies	35 (35.0%)	21 (40.4%)	14 (29.2%)	0.240
Other comorbidities	30 (30.0%)	16 (30.8%)	14 (29.2%)	0.861
Time since the contagion (months)	16.12 (6.34)	15.75 (6.56)	16.52 (6.14)	0.547
Number of persistent symptoms*	16.47 (5.99)	17.50 (5.29)	15.35 (6.55)	0.076
SF-36				
SF-36 physical health	32.19 (16.61)	29.06 (13.67)	35.58 (18.86)	0.053
SF-36 mental health	34.77 (19.31)	32.64 (17.98)	37.09 (20.59)	0.251
MoCA	23.64 (3.85)	23.48 (4.20)	23.81 (3.46)	0.669
Sit-to-stand test	10.37 (3.49)	9.87 (3.77)	10.92 (3.10)	0.134
HADS	17.61 (8.31)	17.86 (7.98)	17.33 (8.74)	0.751
ISI	11.34 (6.58)	11.13 (7.21)	11.56 (5.89)	0.745
GSES-12	44.66 (7.51)	44.57 (6.49)	44.75 (8.55)	0.910
PAM	39.82 (6.16)	38.92 (7.24)	40.79 (4.61)	0.125
HLS-EUQ16	32.10 (7.03)	32.94 (7.84)	31.18 (5.98)	0.214

Note: The comprehensive list of assessed symptoms is provided as supporting information. Chi-square test for the variables gender, marital status, educational level and occupation, and Student's *t*-test for the rest of the variables. SF-36, short form-36 health survey questionnaire; SF-36 physical health = physical function + physical role + bodily pain + general health; SF-36 mental health = vitality + social function + emotional role + mental health; GSES-12: self-efficacy scale-12; PAM: Patient Activation Measure questionnaire; HLS-EUQ16: Health Literacy Europe questionnaire.

Abbreviations: HADS = hospital anxiety and depression scale, ISI = insomnia severity index, MoCA = Montreal Cognitive Assessment, TWD = temporary work disability.

*A total of 30 symptoms were included.

a personalized care plan, from a multidisciplinary perspective [31]. In this context, and since Long COVID patients have experienced a reduction in their quality of life, functional capacities, and well-being [19], ReCOVery has been designed, an APP with a multidisciplinary rehabilitative approach, focused on improving the quality of life of patients with Long COVID.

4.1. Effectiveness of the ReCOVery APP on Quality of Life in Long COVID Patients. The results of this study concluded that ReCOVery APP was not significantly effective in improving the primary outcome of quality of life of patients with Long COVID who used it over a 6-month period. From 2021 onwards, the first research on telerehabilitation and digital health in Long COVID emerged,

Table 2: Outcome data at baseline, 3- and 6-month follow-up, and their comparting by assigned groups.

Outcomes	Intervention group* *N* (%) mean (SD)	Control group** *N* (%) mean (SD)	Significance *p*-value (CI)
Primary outcomes			
SF-36 physical health			
Baseline (T0)	29.06 (13.67)	35.58 (18.86)	0.053 (–13.12; 0.07)
3 months (T1)	33.80 (12.19)	42.30 (20.31)	**0.020 (–15.63; –1.36)**
6 months (T2)	32.53 (18.11)	41.88 (22.40)	**0.045 (–18.49; –0.20)**
T2-T0	5.33 (14.03)	7.50 (17.37)	0.541 (–9.16; 4.84)
SF-36 mental health			
Baseline (T0)	32.64 (17.98)	37.09 (20.59)	0.254 (–12.16; 3.24)
3 months (T1)	37.35 (20.01)	40.29 (19.59)	0.491 (–10.96; 5.30)
6 months (T2)	44.45 (24.07)	48.57 (24.30)	0.449 (–14.90; 6.66)
T2-T0	14.48 (19.85)	11.87 (19.92)	0.559 (–6.25; 11.48)
Secondary outcomes			
Number of persistent symptoms			
Baseline (T0)	17.50 (5.29)	15.35 (6.55)	0.076 (–0.23; 4.52)
3 months (T1)	16.48 (4.65)	14.00 (6.64)	0.102 (–0.47; 5.17)
6 months (T2)	13.61 (6.25)	11.97 (7.04)	0.272 (–1.31; 4.60)
T2-T0	–3.92 (5.47)	–4.02 (5.11)	0.935 (–2.26; 2.45)
MoCA			
Baseline (T0)	23.48 (4.20)	23.81 (3.46)	0.669 (–1.86; 1.20)
3 months (T1)	24.13 (4.45)	24.14 (3.84)	0.874 (–1.88; 1.60)
6 months (T2)	25.56 (3.01)	25.39 (3.52)	0.822 (–1.28; 1.60)
T2-T0	2.41 (3.49)	1.28 (2.34)	0.097 (–0.20; 2.46)
Sit-to-stand test			
Baseline (T0)	9.87 (3.77)	10.92 (3.10)	0.134 (–2.43; 0.32)
3 months (T1)	10.65 (3.66)	11.28 (3.89)	0.463 (–2.22; 1.02)
6 months (T2)	11.00 (4.05)	12.60 (4.77)	0.119 (–3.62; 0.42)
T2-T0	1.31 (2.70)	1.74 (4.26)	0.600 (–2.03; 1.18)
HADS			
Baseline (T0)	17.86 (7.98)	17.33 (8.74)	0.751 (–2.78; 3.85)
3 months (T1)	17.20 (8.72)	16.00 (9.95)	0.471 (–2.42; 5.19)
6 months (T2)	16.90 (8.62)	15.42 (9.18)	0.458 (–2.48; 5.44)
T2-T0	–2.14 (4.68)	–1.97 (5.11)	0.878 (–2.35; 2.01)
ISI			
Baseline (T0)	11.13 (7.21)	11.56 (5.89)	0.745 (–3.03; 2.17)
3 months (T1)	10.50 (5.53)	10.33 (5.94)	0.646 (–1.84; 2.95)
6 months (T2)	13.69 (7.47)	11.18 (7.23)	0.132 (–0.77; 5.78)
T2-T0	1.52 (6.38)	–0.68 (5.20)	0.096 (–0.40; 4.81)
GSES-12			
Baseline (T0)	44.57 (6.49)	44.75 (8.55)	0.910 (–3.21; 2.86)
3 months (T1)	43.31 (9.10)	44.92 (8.69)	0.449 (–5.05; 2.25)
6 months (T2)	43.14 (8.48)	43.74 (8.21)	0.752 (–4.31; 3.12)
T2-T0	–0.71 (6.28)	0.21 (6.62)	0.524 (–3.79; 1.95)
PAM			
Baseline (T0)	38.92 (7.24)	40.79 (4.61)	0.125 (–4.26; 0.52)
3 months (T1)	40.24 (6.90)	39.92 (5.72)	0.816 (–2.39; 3.02)
6 months (T2)	40.17 (6.17)	40.79 (4.76)	0.618 (–3.09; 1.85)
T2-T0	1.59 (7.53)	–0.26 (4.66)	0.194 (–0.96; 4.68)
HLS-EUQ16			
Baseline (T0)	32.94 (7.84)	31.18 (5.98)	0.214 (–1.03; 4.54)
3 months (T1)	32.00 (7.35)	30.32 (7.16)	0.291 (–1.46; 4.81)
6 months (T2)	32.79 (8.24)	30.00 (6.34)	0.097 (–0.51; 6.08)
T2-T0	–0.69 (6.01)	–0.34 (5.78)	0.793 (–2.98; 2.28)

Note: Significant differences ($p \leq 0.05$) are highlighted in bold. SF-36: short form-36 health survey questionnaire; GSES-12: self-efficacy scale-12; PAM: Patient Activation Measure questionnaire; HLS-EUQ16: Health Literacy Europe questionnaire.

Abbreviations: HADS = hospital anxiety and depression scale, ISI = insomnia severity index, MoCA = Montreal Cognitive Assessment.

*Intervention group had 52 participants in T0, 47 participants in T1, and 42 participants in T2.

**Control group had 48 participants in T0, 44 participants in T1, and 38 participants in T2.

Table 3: Evolution of the entire study sample (control and intervention groups) from baseline to follow-up at 6 months.

Outcomes	T2-T0 $N = 80$ Mean (SD)	T0 $N = 80$ Mean (SD)	T2 $N = 80$ Mean (SD)	p-value	Confidence interval 95%	
					Inf.	Sup.
Primary outcomes						
SF-36 physical health	6.36 (15.64)	30.61 (14.40)	36.97 (20.68)	**< 0.001**	−9.847	−2.883
SF-36 mental health	13.24 (19.80)	33.16 (18.35)	46.40 (24.12)	**< 0.001**	−17.652	−8.836
Secondary Outcomes						
No of persistent symptoms	−3.97 (5.27)	16.81 (6.08)	12.83 (6.65)	**< 0.001**	2.801	5.148
MoCA	1.88 (3.04)	23.59 (3.94)	25.48 (3.24)	**< 0.001**	−2.563	−1.215
Si-to-stand test	1.51 (3.49)	10.22 (3.60)	11.74 (4.45)	**< 0.001**	−2.311	−0.715
HADS	−2.06 (4.86)	18.26 (8.31)	16.20 (8.87)	**< 0.001**	0.980	3.144
ISI	0.47 (5.92)	12.02 (6.40)	12.05 (7.42)	0.475	−1.792	0.842
GSES-12	−0.27 (6.42)	43.70 (7.92)	43.43 (8.30)	0.703	−1.154	1.705
PAM	0.71 (6.36)	39.75 (6.32)	31.46 (5.52)	0.320	−2.129	0.704
HLS-EUQ16	−0.52 (5.87)	31.98 (7.29)	31.46 (7.49)	0.426	−0.781	1.831

Note: Significant differences ($p \leq 0.05$) are highlighted in bold. SF-36: short form-36 health survey questionnaire; GSES-12: Self-efficacy Scale-12; PAM: Patient Activation Measure questionnaire; HLS-EUQ16: Health Literacy Europe questionnaire.
Abbreviations: HADS = hospital anxiety and depression scale, ISI = insomnia severity index, MoCA = Montreal Cognitive Assessment.

Table 4: Linear regression model in relation to the improvements of physical health–related quality of life and mental health–related quality of life.

	Coefficient	p-value	Confidence interval 95%		Collinearity statistics	
					Tolerance	VIF
SF-36 physical health improvement (T2-T0)						
Number of symptoms (T2)	−0.654	**0.05**	−1.310	0.001	0.576	1.736
PAM (T2)	0.765	0.061	−0.035	1.564	0.561	1.781
R2			0.259			
R2adj			0.114			
p value			0.065			
SF-36 mental health improvement (T2-T0)						
Number of symptoms (T2)	−0.956	**0.017**	−1.735	−0.177	0.576	1.736
HLS-EUQ16 (T2)	−0.673	0.059	−1.374	0.028	0.562	1.780
R2			0.347			
R2adj			0.219			
p-value			0.004			

Note: Significant differences ($p \leq 0.05$) are highlighted in bold. SF-36: short form-36 health survey questionnaire; PAM: Patient Activation Measure questionnaire; HLS-EUQ16: Health Literacy Europe questionnaire.

pointing towards its use as a viable and effective option in the recovery of these patients, and identifying significant improvements in quality of life, physical functioning, and some specific symptoms such as fatigue and dyspnea [26, 32]. Later, in 2022, the first RCTs began to be implemented, such as that of Li et al. [33], based on a post-COVID-19 exercise program at home, without supervision, which lasted 6 weeks and did show significant improvements in favor of the intervention group in their quality of life (SF-12), although no long-term effects were obtained [33].

Regarding the most recent evidence, the systematic review by Chuang et al. [10] states that therapies based on physical exercise are essential for recovery from Long COVID, including the telerehabilitation modality [10]. On the other hand, the scoping review conducted by Rinn et al. [34] maintains that digital interventions have the potential to help control some persistent symptoms, not only physical, but also psychological [34].

Thus, the use of digital interventions—such as telerehabilitation—is being progressively implemented for a multitude of pathologies, and published research suggests that this is also true for Long COVID [34]. Several studies on telerehabilitation have already evaluated quality of life, obtaining—unlike in this study—significant improvements in the intervention group [33, 35–37]. However, the limited research on effective digital tools for Long COVID patients still requires the implementation of large-scale RCTs with a high degree of clinical evidence.

4.2. Key Secondary Outcomes Following the Use of the ReCOVery APP. Only a trend improvement in the secondary outcome of cognitive status was observed in favor of the intervention group, which could be explained by greater adherence to this section of the APP as a result of the playful and interactive nature of the exercises [38]. This highlights the critical role of adherence in the effectiveness of the

intervention. Future research must address adherence, as previous studies have reported poor adherence and numerous participant dropouts [26, 33, 39].

The results of this study related to the time of use of the APP confirm this fact, mainly in the last stage of the intervention, despite telerehabilitation based on mobile APPs having been considered a practical and profitable option that increases adherence in patients with other diseases [40]. This poor adherence could be solved in forthcoming research and uses of the APP by amplifying the intermediation of professionals. For instance, this could involve maintaining regular communication with patients via phone calls or monitoring them while they perform physical or breathing exercises through videoconferences [41]. It could also be beneficial to conduct qualitative interviews with participants at the 3- and 6-month marks of using the APP. The interviews would allow for a deeper understanding of the reasons behind the observed low adherence, helping to identify barriers and facilitators to the continued use of the APP, and providing valuable insights for adapting the APP and improving its acceptance and effectiveness.

The results of the regression models carried out in this essay showed a significant relationship between the decrease in the number of symptoms and the improvement in quality of life. Malik et al. [42], in their systematic review, maintain that some symptoms such as fatigue, dyspnea, chest and joint pain, or sleep disorders can have a significant impact on the long-term quality of life of this population [42]. Taking the above into account, the Long COVID approach guidelines available to date have already supported patient-centered care and symptom management with the ultimate goal of recovering their quality of life [43].

It is worth mentioning the almost significant relationship that was also observed between physical and mental health–related quality of life with patient activation and health literacy, respectively. These constructs play key roles in health management, as they allow them to develop a "mindset" of lifestyle change as well as the necessary skills in health management [44]. Some previous research would support the results of this study. For example, Kanu et al. [45] have stated that those patients who actively participate in their health management and medical care are more likely to have a higher health-related quality of life [45]. Similarly, Yadav et al. [46] express that the understanding and use of health information when making decisions, as well as the activation of the patients themselves to control their pathologies, have a positive effect on self-care, health outcomes, and quality of life [44].

4.3. Limitations and Strengths. This research has some limitations. Firstly, the context in which it was carried out may have limited the achievement of results since it was developed during the vaccination process and in a period of increased number of infections. Additionally, due to the nature of the study intervention, participants could not be blinded to their trial assignment group, a common limitation in research on medical or psychological interventions. However, blind assessment by independent researchers was possible.

Another noteworthy limitation was the possible impact of social desirability bias. This may have arisen due to two key factors: (1) the open-label design of the study, where participants in the intervention group were aware of the APP's intended benefits, and (2) the face-to-face assessment of outcomes, a method that has been historically linked to social desirability bias. In face-to-face settings, participants may feel inclined to provide responses they perceive as more favorable rather than entirely reflecting their true experiences. Future studies could minimize this bias by incorporating anonymous self-reported assessments, allowing participants to complete evaluations without disclosing their identity, or by using remote data collection methods, such as online surveys, mobile APPs, or virtual interviews. These strategies could help enhance the accuracy and reliability of the collected data while reducing potential response bias.

Regarding the evaluation instruments used, the MoCA questionnaire obtained a Cronbach's alpha of 0.49, thus reporting low reliability. Finally, the symptoms themselves (both physical and mental) and their fluctuation or worsening may also have been a significant limitation when it came to achieving the results sought in this intervention. Additionally, the results of the regression model with physical health–related quality of life as the dependent variable was not significant, which may have implications for interpreting the overall findings of the study.

This study also has several strengths. Unlike other research, a specific APP has been designed for Long COVID patients, easy to use and access from any location with an Internet connection. To our knowledge, there are no clinical trials in our country with a similar number of Long COVID participants and a long follow-up time, using a telerehabilitation intervention for this disease.

5. Conclusions

In conclusion, this study evaluated the effectiveness of the ReCOVery APP in improving quality of life among Long COVID patients over a 6-month period. While the primary outcome of quality of life did not show significant improvement, the positive trend observed in cognitive status suggests that aspects of the intervention may be beneficial, particularly for those who engaged more fully with the APP's interactive features. This highlights the critical importance of adherence in achieving desired outcomes, which aligns with findings from previous studies that documented challenges related to patient adherence and participant retention.

The literature supports the idea that digital interventions, especially telerehabilitation, hold promise for enhancing quality of life in individuals recovering from Long COVID. However, our findings underscore the necessity for further large-scale clinical trials to validate these interventions and to develop effective strategies to improve adherence among patients.

Moreover, the study emphasizes the potential benefits of integrating ongoing professional support into digital health interventions, which may enhance patient engagement and ultimately lead to better health outcomes. Future research should focus on personalizing treatment approaches and

exploring the long-term impacts of these interventions, thereby addressing the multifaceted nature of Long COVID and contributing to a deeper understanding of effective management strategies for this complex condition.

Data Availability Statement

The data that support the findings of this study are openly available in Zenodo at https://doi.org/10.5281/zenodo.10843363.

Ethics Statement

Ethical approval for this study was granted by the Aragon Clinical Research Ethics Committee (PI21/454), ensuring compliance with all ethical standards set by the committee. Additionally, the procedures conducted for the creation of this work also complied with the Declaration of Helsinki of 1975.

Consent

Prior to the start of the intervention, all participants provided informed consent. Furthermore, all data obtained during the course of this research were anonymized and used only for the purposes of the research.

Disclosure

The funders had no role in study design, data collection, analysis, decision to publish, or manuscript preparation.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Sandra León-Herrera, Mario Samper-Pardo, Bárbara Oliván-Blázquez, and Raquel Sánchez-Recio. Rosa Magallón-Botaya, Verónica Casado-Vicente, and Rafael Sánchez-Arizcuren participated in the study's supervision, result interpretation, and critical revision of the manuscript. The first draft of the manuscript was written by Sandra León-Herrera, and all authors provided feedback on previous versions. All authors read and approved the final manuscript.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. *(Supporting Information)*

Supporting information includes CONSORT Checklist and detailed information about each mobile APP module, and a comprehensive list of assessed symptoms.

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