

Application of a home-based exercise program combined with tele-rehabilitation in previously hospitalized patients with COVID-19: A feasibility, single-cohort interventional study

Eleni A. Kortianou¹, Dimitrios Tsimouris¹, Aspasia Mavronasou¹, Sotirios Lekkas¹, Nikolaos Kazatzis¹, Zoi E. Apostolara¹, Maria Isakoglou¹, Georgia Dimakou², Zafeiria Barmparessou³, Stamatoula Tsikrika⁴, Vissaria Sakka⁵, Angelos Liontos⁵, Maria Christaki⁵, Haralambos Milionis⁵, Ioannis Kalomenidis³

ABSTRACT

INTRODUCTION Telehealth for COVID-19 patients is still limited. We aimed to assess the clinical effects of a home-based tele-rehabilitation exercise program following hospital discharge during the first lockdown in Greece, April to July 2020.

METHODS A pre- and post-intervention design was applied in two stages. Firstly, patients were instructed to use a specially designed for COVID-19, e-book during four tele-health sessions. Afterwards, a 2-month home-based program consisted of self-practice exercise and one-hour supervised tele-rehabilitation exercise sessions every 10 days, was delivered. At baseline and at the end of the program, participants were interviewed about their physical, psychological status and quality of life (QoL) during the post-hospitalization period. The IPAQ-Gr, the HADS and the SF-36 questionnaires were used, respectively, and the participants were functionally assessed via teleconferences, using the 60 sec Sit to Stand Test (60secSTS), the Short Physical Performance Battery (SPPB) and the 3 min Step Test (3MST).

RESULTS Seventy-four patients, median age 52.5 (IQR: 43–61) years were included at the first stage. From those, only 22 patients, mean \pm SD age 50.1 \pm 13.2 years completed the 2-month exercise program. The training program was well tolerated by all 22 patients. The mean number of unsupervised exercise sessions was 18.4 \pm 3.5. No adverse effects were observed either during initial and follow-up assessment via tele-communication or during home-exercise sessions. Training improved significantly ($p < 0.001$) lower limb muscle performance [median (IQR) 60secSTS: 22 (20–26) to 31 (25–36)], anxiety [median (IQR) HADS: 9 (6–13) to 4.3 (3.2–9.6)], depression [median (IQR) HADS: 5 (3–8) to 1.8 (0.9–3.7)], QoL [mean \pm SD SF-36pcs: 37.5 \pm 10.3 to 52.1 \pm 6, and mean \pm SD SF-36mcs: 42.9 \pm 11.6 to 45.5 \pm 12.3].

CONCLUSIONS Tele-rehabilitation may be feasible and may improve physical and psychological status of COVID-19 patients after hospital discharge.

AFFILIATION

- 1 Clinical Exercise Physiology and Rehabilitation Laboratory, Department of Physiotherapy, School of Health Sciences, University of Thessaly, Lamia, Greece
- 2 Department of Nutrition and Dietetics, 251 Air Force General Hospital, Athens, Greece
- 3 1st Department of Critical Care Medicine, School of Medicine, National and Kapodistrian University of Athens, Evaggelimos Hospital, Athens, Greece
- 4 Intensive Care Unit, Thoracic Diseases General Hospital of Athens 'Sotiria', Athens, Greece
- 5 Internal Medicine Sector, Faculty of Medicine, University of Ioannina, Ioannina, Greece

CORRESPONDENCE TO

Eleni A. Kortianou. Clinical Exercise Physiology and Rehabilitation Laboratory, Department of Physiotherapy, School of Health Sciences, University of Thessaly, 3rd km Old National Road Lamia-Athens, 35100, Lamia, Greece. E-mail: ekortianou@uth.gr ORCID ID: <https://orcid.org/0000-0003-2214-5545>

KEYWORDS

coronavirus disease 2019, post COVID-19 rehabilitation, home-exercise rehabilitation, tele-rehabilitation

Received: 20 October 2021

Revised: 7 January 2022

Accepted: 8 February 2022

INTRODUCTION

By mid April to early May 2020, as the first pandemic wave was declining in Greece, hundreds of hospitalized patients were discharged with instructions to remain in home isolation¹. The restriction of physical activity following a hospitalization is inevitable, with obvious effects on both physical and emotional health^{2,3}. Even healthy adults who have been infected, experience the devastating effects of bed rest and isolation, regardless of hospital stay length⁴. The phenomenon is more pronounced in patients with chronic underlying diseases, such as chronic respiratory, cardiac and vascular diseases, hypertension, diabetes, and cancer, or obese adults who require additional care to recover to

their prior physical ability status⁵. There is a growing concern about the potential long-term consequences of COVID-19 in hospitalized patients (with or without comorbidities) and in those returning home⁶. Medical care after hospital discharge should include evaluation of any rehabilitative needs and prioritizing effective and comprehensive interventions, in order to improve patients' physical, functional, and psychological status⁶. As tele-rehabilitation provides effective clinical services from a distance, it could be an appropriate intervention at the post-acute period, in order to achieve basic gains in physical capacity, symptoms and quality of life in patients with SARS-CoV-2 infection⁷. In this context, we aimed to deliver a short-term home-exercise

program through tele-rehabilitation sessions for previously hospitalized COVID-19 patients who remained at home isolation during the first lockdown in Greece, emphasizing on patients' recruitment and retention into the study.

METHODS

Participants

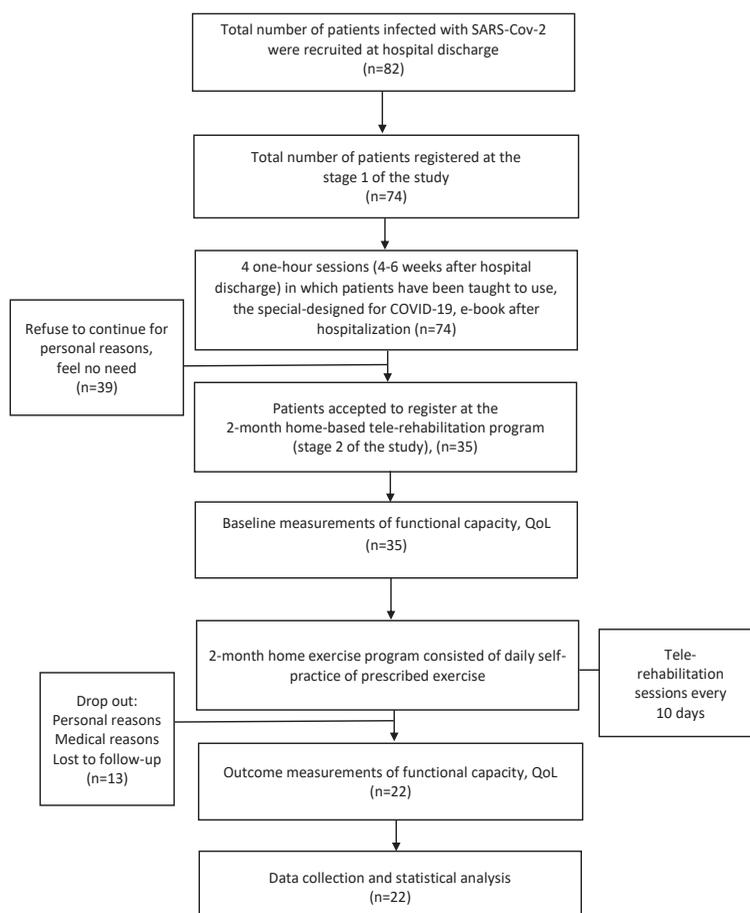
This prospective study recruited patients hospitalized at two referral hospitals, the General Hospital of Athens 'Evangelismos' and the University Hospital of Ioannina. Inclusion criteria were: aged 20–65 years, duration of hospitalization longer than 7 days, moderate disease⁸ during hospitalization and fatigue as the main symptom at hospital discharge. Patients were excluded from the study if they were admitted in the intensive care unit and/or they were advised to use oxygen at discharge. Additionally, patients who had severe cardiovascular, neuromuscular, orthopedic or renal disease, or any hearing, speaking, cognitive impairments and/or serious mental illness or could not communicate adequately in Greek, were excluded from the study⁸. All participants were maintained through optimal medication if needed due to comorbidities (e.g. diabetes, hypertension, thyroid disease). They were fully informed about the aims of the study and provided a written informed consent

sent via email. The study complies with the Declaration of Helsinki and the protocol was approved by both Scientific and Ethics Committees of Evangelismos Hospital (Protocol ID-160/2020) and University Hospital of Ioannina (Protocol ID-356/2020) as well as by the Ethics Committee of the Physiotherapy Department of the University of Thessaly (Protocol ID-336/2020). The study duration was 4 months, from April to July 2020.

Study design

A smartphone app (Viber) was used to establish a two-way tele-communication between physiotherapists and home-isolated patients following hospital discharge. The application enabled interviewing and monitoring patients from the beginning of the study and during all tele-rehabilitation sessions. The study consisted of two stages (Figure 1). During four 1-hour teleconference sessions in the first stage, patients were taught to use a specially designed e-book for patients with COVID-19 and they were asked about their physical and emotional status, their nutritional habits and quality of life after hospitalization. Before entering the second stage, they were assessed via tele-monitoring using three functional tests. During the following 2-month period, the participants continued a home-exercise program consisting

Figure 1. Flow chart of enrollment and completion of the study in patients with COVID-19



of daily unsupervised self-practice of prescribed exercise and a 1-hour individualized and supervised exercise tele-rehabilitation session with a physiotherapist, every 10 days (3 sessions per month). The study protocol was part of a multicenter randomized control trial study which had been registered on Clinical Trial database (NCT04368845).

Physiotherapists’ background

All physiotherapists had more than two years of clinical experience in pulmonary rehabilitation. Before their participation in this study, they had one week intense training regarding remote assessment procedures and tele-rehabilitation approach. Each individual patient was assessed and supervised by one well-trained in remote intervention physiotherapist.

A specific to COVID-19 e-book

As safety and efficacy data on rehabilitation and especially on tele-rehabilitation in patients with COVID-19 are lacking, authors paid attention to a specially designed e-book (<https://cutt.ly/AUHcbVw>). The e-book included breathing exercises, relaxation, aerobic and total body strengthening exercises along with dietician instructions.

Safety instructions and emergency contact details were also included at the end of the e-book. Each part of the e-book was taught to the patients by physiotherapists and a dietitian during the first stage of the study. Ensuring patients’ safety, special attention was given for understanding of all the written information in the e-book, especially those for breathing control during body exercises. More specifically, using the e-book, they were taught to control exercise intensity and to recognize any signs and symptoms of physical distress. They were also instructed how to measure blood pressure, heart rate and oxygen saturation with their own electronic sphygmomanometer and oximeter, respectively.

Daily self-practice of unsupervised exercise

The patients who accepted to continue to the second stage were advised to set 30 minutes per exercise session, 5 times per week. The intensity of exercise training in each session was determined by using the Borg scale 6–20 and it was set at low to moderate level (Borg 9–13) for all participants (Table 1). Some of them gave more attention to upper and lower limb muscle strengthening and others to aerobic training, depending on their individual needs, interest and

Table 1. Home-based exercise program of the post COVID-19 patients

Session part	Exercise type	Intensity (Borg 6–20)	Duration (min)			
Warm-up	Breathing at sitting position Diaphragmatic breathing Deep breathing Pursed lip breathing	very light, light (9–11) 8–12 repetitions each	5–10			
	Neck rotation					
	Upper limb at sitting or standing position Arm abduction, flexion, rotation					
	Lower limb at supine position Hip flexion, abduction, rotation					
	Balance training Side steps Heel raises One leg standing (supported if needed) Tandem stands and tandem walking					
	Main workout			Strengthening training (starting from 0.5 kg and progressively increasing to 1.5 kg)	somewhat hard (12–13) 8–12 repetitions each increased to 15–20 repetitions	15–20
				Upper limb at standing position Shoulder abduction, flexion, rotation, elbow flexion, extension		
				Lower limb at standing position Hip flexion, extension, abduction, rotation, mini-squats		
				Body weight for upper limb at standing position Push-ups		
	Cool-down			Stretching Muscles of the trunk, upper and lower limbs	very light (8–9) 2–3 repetitions slowly counting to 10 each	5–10

abilities. Each exercise session consisted of a 5–10 min warm-up session of breathing exercises combined with dynamic movements exercises (e.g. arm rotations, chest expansions) and balance training (one-leg stands, tandem stands, and tandem walking). The main workout consisted of 15–20 min of lower limb strengthening exercises and weight bearing training. Individualized strengthening exercises for upper and lower limbs were carried out in a progressive sequence from the seated position to the standing position using dumbbells, ankle weights and elastic bands. Strengthening exercises started with 0.5 kg weight and progressed by applying additional weight (0.5 kg every week up to 1.5 kg). Participants were initially instructed to complete up to one set of 8–12 repetitions for each type of exercise (e.g. arm abduction, flexion, rotation; elbow flexion, extension; hip abduction, flexion, rotation; knee extension; body weight exercises for upper and lower limbs; body weight squats), which gradually increased even to 15–20, so that the training load would produce muscle fatigue up to 12–13 (somewhat hard) on Borg 6–20 scale. At the end of the main workout, all participants did 5–10 minutes of cool-down exercises focused on slow movements and stretching of the upper and lower limbs, allowing the heart rate to return back to normal values and to improve flexibility. During each exercise session, heart rate and arterial oxygen saturation (SpO₂) were monitored continuously by pulse oximeter placed on the right middle finger⁹. Additionally, patients were prompted to focus and correct their breathing pattern in order to avoid hyperinflation while exercising¹⁰. Before and after each exercise session they had to measure and to report their blood pressure, heart rate and oxygen saturation. Both Borg scales 0–10 and 6–20 were used by patients to evaluate any dyspnea (breath discomfort) or fatigue (body discomfort), respectively. The use of both Borg scales was decided by the physiotherapy team in order to avoid false reporting by the patients and misinterpretation. At the end of each exercise session, all reports (heart rate, SpO₂, fatigue and dyspnea) were sent by patients or by their caregivers, via Google Forms to an electronic database in order to monitor adherence and exercise safety. Patients were asked to stop exercising and call the team coordinator (EK) if any signs of physical distress such as muscle weakness, shortness of breath, chest pain were observed. Additionally, the team coordinator checked daily the patient electronic database to detect any adverse sign during exercise sessions. During the individualized tele-rehabilitation session, the exercise training was supervised by a physiotherapist and new goals were set (e.g. adjust training intensity, training time) in collaboration with each individual. Furthermore, the physiotherapist confirmed that all exercise reports had been successfully submitted during the last 10 days.

Measurements at the 1st Stage

Following 2 to 8 weeks after hospital discharge patients participated in four 1-hour teleconference sessions to

provide all the demographics and medical history data. Additionally, they were asked about their physical activity status, anxiety, depression, dyspnea during activities and quality of life after COVID-hospitalization, using the International Physical Activity Questionnaire (IPAQ-Gr)¹¹, the Hospital Anxiety and Depression Scale (HADS)¹², the modified Medical Research Scale for dyspnea (mMRC)¹³ and the Short Form-36 generic questionnaire (SF-36)¹⁴, respectively.

Physical activity

IPAQ-Gr includes 7 questions about frequency, duration and intensity of participation in physical activities over the previous 7-day period and used to generate a total physical activity score, expressed in metabolic equivalent (MET-min/week)¹¹. The mMRC scale is a five-category scale to characterize the level of dyspnea during physical activity. The higher scores reflect increased level of dyspnea¹³.

Health-related quality of life

The Short-Form 36 acute form questionnaire was used. It consists of 36 questions divided into eight subscales of physical and mental health concepts: physical functioning, role physical, bodily pain, general health, vitality, social functioning, role emotional, and mental health. The scores of each subscale range from 0 to 100 with higher scores indicating better physical and mental status. Two overall scales are derived from these eight subscales, one for total physical function (SF-36pcs) and one for total mental function (SF-36mcs)¹⁴.

Anxiety and depression

The HADS measures generalized symptoms of anxiety and depression in medically ill patients aged 16–65 years¹². Each dimension has 7 items and responses are rated on a 4-point Likert scale ranging from 0 to 3. Total score for each dimension can range from 0 to 21. The higher the score the more severe is the anxiety/depression. The following interpretation of scores is recommended: 0–7 normal or no anxiety/depression; 8–10 mild; 11–12 moderate; 14–21 severe anxiety/depression. The mean optimal cut-off score is approximately 8 plus in each dimension resulting mean sensitivity and specificity at 80% and at 90% for detecting anxiety and/or depression disorders in a community cohort¹⁵.

Measurements at the 2nd Stage

All patients were assessed in two separate sessions, one at the baseline of the second stage and another at the end of the 2-month exercise program, via teleconference using the Short Physical Performance Battery (SPPB)¹⁶, the 60 sec sit to stand test (60secSTS)¹⁷ and the 3-min step test (3MST)¹⁸. Written information and a demonstration video were given for each test procedure so as to keep patients well prepared and aware. Patients' measurements were monitored using the smartphone Viber App by the same physiotherapist. The SPPB was performed initially,

followed by the 60secSTS and the 3MST, 30 minutes later. For safety and convenience concerns, a third person (caregiver or partner) witnessed tele-monitoring. Patients were continuously monitored by an oximeter during all tests.

Short Physical Performance Battery (SPPB)

It consists of three timed sub-tests: standing balance test, 4-meter self-paced gait speed (4mGS) and 5-repetition sit-to-stand (5STS). Each sub-test scores from 1–4 units, so the overall SPPB score ranges from 4–12 units. All participants performed the SPPB as described previously¹⁶.

The 60 sec Sit-to-stand test (60secSTS)

The test was performed using a chair (45 or 46 cm height, without arm rests). Participants were asked to fold their arms across their shoulders and start to stand up and sit down completely for one minute without any support, as many times as possible and at their own pace¹⁷. No encouragement was given during the test and the number of completed repetitions was recorded.

The 3-min Step Test (3MST)

The 3MST was performed on a stair tread (17–20 cm height) at home stairs. If necessary, participants were authorized to put their hand on the wall in case of imbalance. The test started from the standing position; the patients had to step up and down the stair tread with a rhythm of 96 beats per min (24 steps per min), given by a metronome, for 3 min continuously¹⁸. The following parameters were recorded throughout the test by a pulse oximeter: oxygen saturation (SpO₂) and heart rate. Dyspnea (Borg scale 0–10) and leg fatigue (Borg 6–20) were recorded at the beginning and at the end of the test.

Statistical analysis

Categorical variables were expressed as frequencies and percentages. All variables were tested for normality using the Shapiro-Wilk test. Normal distributed variables are presented as mean and standard deviation (mean ± SD) and not normally distributed variables as median and IQR (25th–75th percentile). Two-tailed paired t-tests were used for within-period comparisons for normal distributed variables, otherwise comparisons were performed by using the Wilcoxon matched-pair test. Differences between independent groups (patients who completed the second stage versus those who dropped out) were tested with independent samples t-tests or Mann Whitney test, where appropriate. All statistical analyses were performed using SPSS for Windows 22.0 (SPSS Inc, Chicago, IL, USA). The level of statistical significance was set a priori at p<0.05.

RESULTS

Results from the 1st Stage

Eighty-two (61 males) clinically stable patients hospitalized for SARS-CoV-2 were recruited from mid April to early June

2020. Of these, 74 (90.2%) clinically stable individuals met all the inclusion criteria and participated at the initial four teleconference sessions, following a median 32 (IQR: 22–40) days from hospital discharge. They presented slight to moderate functional limitations at hospital discharge (Post-Covid-19 Functional Scale, PCFS grade 2 to 3)¹⁹. A total of 33 participants (44.6%) were ex-smokers (mean pack-years: 18.6 ± 11.4); 6 participants (8.1%) were current smokers (mean pack-years: 16.3 ± 11.1). Patients' characteristics, comorbidities and their habits for technology use are presented in Table 2. Most of the participants, 31 (41.9%), were overweight (25 < BMI < 29.9 kg/m²); 26 (35.1%) obese (BMI > 30 kg/m²) and 17 (22.9%) had normal weight (BMI < 24.9 kg/m²). Duration of hospitalization ranged 9–17 days, with a mean 13.1 ± 2.9 days.

Results from the 2nd Stage

Thirty-five (47.3%) patients accepted to participate at the second stage of the study. Those who dropped out (n=39) had better physical function after COVID-19 hospitalization, median SF-36pcs score 40.56 (IQR: 37.42–53.79) versus 39.15 (IQR: 27.96–44.33) (p=0.025); were heavier smokers, mean 21.77 ± 11.3 versus 10.4 ± 5.8 pack-years (p<0.001); with lower BMI, mean 27.54 ± 5.5 versus 29.81 ± 2.4 kg/m² (p=0.022) than those (n=35) who accepted to continue at the second stage. Twenty-two (29.7%) (18 males) completed the 2-month exercise program. Thirteen patients stopped participation 22.6 ± 2.3 days after initiation of the program either for personal reasons (family obligations,

Table 2. Characteristics, comorbidities and habits of technology use in patients with COVID-19 included at the first stage of the study (N=74)

Characteristics	n (%)
Age (years), median (25th–75th percentile)	52.5 (43–61)
BMI (kg/m ²), mean ± SD	28.3 ± 4.9
Male	54 (72.9)
Comorbidities	
Dyslipidemia	13 (17.5)
Hypertension	11 (14.8)
Chronic Respiratory Diseases	9 (12.1)
Thyroid Dysfunction	4 (5.4)
Chronic Heart Failure	2 (2.7)
Cancer	2 (2.7)
Diabetes	4 (5.4)
Gastroesophageal Reflux Disease	1 (1.3)
Technology use	
Smartphone use	70 (94.6)
App use for detect physical activity	21 (28.3)

BMI: body mass index.

lack of personal time, etc.) or for medical reasons (n=1) (scheduled surgical procedures) (Figure 1). The mean age of the participants (n=22) at the second stage was 50.1 ± 13.2 years and the mean BMI was 29.8 ± 2.4 kg/m². Obesity (54.5%; n=12), dyslipidemia (18.2%; n=4) and hypertension (27.3%; n=6) were the presented comorbidities. The time period elapsed between the onset of COVID-19 infection (positive swab) and the onset of the home-based exercise program (n=22) was 37.1 ± 15.2 days. At the beginning of the intervention the main persistent symptoms were anxiety (n=19; 86.3%), body fatigue (n=16; 72.7%), and cough (n=2; 9.1%). All participants attended in total 6 private tele-rehabilitation sessions with the same physiotherapist. The mean number of self-practice exercise sessions was

18.4 ± 3.5. The training program was well tolerated by all 22 patients and no adverse effects were observed either during initial and follow-up assessment via Viber tele-communication or during home-exercise sessions. There were no dropouts related to symptom worsening. For all exercise sessions, the mean final SpO₂ was 95.6% ± 1.4% and the mean final heart rate was 128.2 ± 7.6 pulses per min; 70.9% ± 4.1% of the predicted maximum heart rate. Most of the participants (n=20) followed a strengthening exercise program for both upper and lower limbs and only 2 participants combined strengthening and aerobic (in-home cycling) exercise. At baseline and after the program completion, all physical capacity and psychological results are presented in Table 3 and Table 4, respectively.

Table 3. Functional capacity at baseline and after the 2-month exercise program in patients with COVID-19 (N=22)

Variable	Pre Intervention Median (Q1-Q3) *	Post Intervention Median (Q1-Q3) *	p
SPPB total score, units	9 (8–11)	10 (8–12)	0.174
SPPB subtests			
Balance, units	4 (4–4)	4 (4–4)	1.000
4mGS, units	2 (2–3)	3 (2–4)	0.459
5STS, units	3 (2–4)	3 (2–4)	0.397
60secSTS, number of repetitions	22 (20–25)	31 (25–36)	<0.001
3MST			
HR, beats/min (end test)	101 (92–122)	101 (92–113)	0.569
Delta HR	28 (19–45)	19.5 (10–34)	0.852
SpO ₂ (%) (end test)	96 (95–97)	97 (95–98)	0.180
Delta SpO ₂	0 (-3–0)	0 (0–1)	0.120
Dyspnea (end test), Borg (0–10)	1.5 (0–4)	1 (0–2)	0.957
Lower limb fatigue (end test), Borg (6–20)	7.5 (7–13)	7 (6–9)	0.050

*Q1–Q3: 25th–75th percentile. SPPB: Short Physical Performance Battery. 4mGS: four-meter gait speed. 5STS: five sit-to-stand. 60secSTS: 60 second sit-to-stand test. 3MST: 3-Minute Step Test. HR: heart rate. Delta HR: HR end of the test - HR start of the test. SpO₂: pulsed oximetry. Delta SpO₂: SpO₂ end of the test - SpO₂ start of the test.

Table 4. The level of physical activity, quality of life, anxiety, depression, mMRC at baseline and after the two-month exercise program in patients with COVID-19 (N=22)

Variable	Pre Intervention Median (Q1-Q3) *	Post Intervention Median (Q1-Q3) *	p
IPAQ-Gr			
Total score, METs-min/week	693 (80–1314)	825 (422–2220)	0.131
SF-36			
Physical Component Summary, units Mean ± SD	37.5 ± 10.3	52.1 ± 6.0	<0.001
Mental Component Summary, units Mean ± SD	42.9 ± 11.6	45.5 ± 12.3	<0.001
Physical functioning, units	40.2 (29.9–48.6)	52.7 (50.7–54.7)	<0.001
Role physical, units	27.4 (20.1–56.8)	54.5 (35.7–54.5)	0.001

Continued

Table 4. Continued

Variable	Pre Intervention Median (Q1–Q3) *	Post Intervention Median (Q1–Q3) *	p
Bodily pain, units	45.2 (24.5–57.9)	53.1 (35.2–55.5)	0.235
General health, units	44.8 (38.6–48.1)	50.1 (47.6–57.5)	0.008
Vitality, units Mean ± SD	42.7 ± 11.6	48.8 ± 11.1	0.006
Social functioning, units	35.0 (24.1–40.4)	57.9 (52.4–57.9)	<0.001
Role emotional, units	48.1 (32.5–55.8)	56.9 (33.2–56.9)	0.175
Mental health, units	44.3 (33.1–52.8)	51.0 (22.2–53.8)	0.638
HADS			
HADS anxiety score, units	9.0 (6.0–13.0)	4.3 (3.2–9.6)	0.006
HADS depression score, units	5.0 (3.0–8.0)	1.8 (0.9–3.7)	0.001
mMRC score, units	1.0 (0–1.0)	0 (0–0.9)	0.001

*Q1–Q3: 25th–75th percentile. IPAQ-Gr: International Physical Activity Questionnaire–Greek. SF-36: 36-Item Short Form Survey. HADS: Hospital Anxiety and Depression Scale. mMRC: modified Medical Research Council dyspnea score.

DISCUSSION

This single-cohort interventional study demonstrated that a 2-month home-based rehabilitation program combined with regular tele-rehabilitation sessions, for home-isolated post-COVID-19 patients with slight to moderate functional limitation, was safe, feasible and effective for improving anxiety, depression, quality of life as well as lower extremity physical performance after hospitalization (Tables 3 and 4). Early in 2020, there were studies reporting that COVID-19 patients had reduced levels of physical function, muscle weakness and fatigue, as well as impaired psychological health and poor quality of life^{20–22}. More recent studies have shown that these consequences were evident even at 6 months post hospitalization²³. To date, very few randomized controlled trials have demonstrated a slight improvement in physical function (as it was assessed using either the 6MWT or the 60secSTS) and in QoL within the first short-term rehabilitation period (3–6 weeks) following hospitalization^{21,24,25}. Two of these RCTs used unsupervised tele-rehabilitation approaches lasting one or six weeks (3–4 sessions per week)^{24,25}. For patients' reinforcement and exercise feedback, the home-based exercise program was monitored every week via videoconferences by physiotherapists. All the functional outcomes (6MWT, sit-to-stand tests) and QoL have been improved after intervention; however, none of them has been assessed remotely, using smartphone applications. Adding to previous research, in this study we used an 8-week tele-rehabilitation approach which included remote functional assessment and we found a partial recovery in physical performance with no adverse event or symptom worsening. During this period, there were strict lockdown measures in Greece in combination with the successful prevention of the health system oversaturation¹. In this 3-month timeframe all state or private rehabilitation

programs were cancelled to prevent disease spread. Nevertheless, our intervention was well-designed in order to provide immediate and prompt care in patients with physical and psychological impairment who remained in isolation after hospitalization. With the assistance of technology, our remote intervention achieved the desired result and the adherence to program implementation was satisfactory (patients completed a mean of 18 exercise sessions). Personal reasons and lack of time for regular exercise were reported only from those who dropped out (n=13) after three weeks of participation.

The study of Belli et al.²² in a large cohort of patients (n=103) showed that after 3 weeks of mobilization, physical function was not improved in all patients. The SPPB score was still low (0–6 units) to moderate (7–9 units) in 70.8% of the patients, and 33.3% of the patients noticed 60secSTS repetitions less than the normal reference values¹⁷. In our study, the baseline SPPB score was moderate, indicating a population with a low risk of disability¹⁶ and it was slightly but not significantly (p=0.174) increased to high performance score (10–12 units) after the 2-month rehabilitation program, indicating full recovery. Although the number of repetitions in the 60secSTS improved significantly after the rehabilitation program and also exceeded the minimal clinical importance difference (2.5 repetitions), previously reported for patients with chronic respiratory diseases²⁶, it was still lower (Table 3) than the normal reference values (median > 34 and 37 repetitions for healthy women and men aged up to 64 years, respectively)¹⁷.

Published research findings showed that the 6MWT was the main outcome measure for testing physical function in patients with COVID-19^{20,21}. However, knowing that the 6-minute walking distance cannot be accurately assessed at home in patients with chronic respiratory disease²⁷, the 3

min step test was used in our cohort of COVID-19 patients as an alternative test to assess cardiovascular and respiratory fitness. Both 60secSTS test and 3MST are correlated to 6MWT in healthy young people²⁸ and in patients with COPD²⁹. To the best of our knowledge, no previous studies used 3MST for assessing cardiorespiratory fitness in post COVID-19 patients, although more rigorous step tests had been used in the past in patients recovering from SARS³⁰. In our study, no adverse effects or desaturation were observed during the test and improvement was reported only on leg fatigue. To validate these findings, further research is needed to determine whether 3MST can accurately assess functional capacity when used remotely.

Finally, health-related quality of life as well as anxiety and depression improved over the 2-month period (Table 4), however, we cannot deduce that this was due to the exercise program due to the absence of a control group. The scores are somehow lower than in healthy individuals³¹ and similar to those previously presented in studies with long-term outcomes (up to 6 months after hospitalization) from other coronavirus infections (SARS, MERS)^{30,32}.

During the study we faced barriers to the remote physical assessment and to the delivery of the exercise program. During the remote assessment, one of the barriers could be providing comprehensive guidance to both the patients, when performing the functional tests, and the third person (caregiver or partner) who witnessed the tele-monitoring (for observing any adverse effects, e.g. high blood pressure, excess breath discomfort, high heart rate, etc.). Another barrier could be the short-time of the intense training that each physiotherapist had to complete, in order to be able to deliver the functional assessment by distance and to supervise exercise program. To overcome some of the above barriers, we took actions to facilitate our intervention. Written instructions and videos were given to the patients; four 1-hour sessions included at the first stage of the study, in which all participants were taught how to perform exercises at home and to control exercise intensity; direct uploading of the results of each session to an electronic database via Google Forms facilitated patients' understanding on exercise prescription and enabled the rehabilitation team to monitor program adherence and any exercise adverse effects. We propose that future tele-rehabilitation should also assess the validity of commonly used functional tests when they are performed remotely, as well as the competency of the healthcare professionals in remote assessment and clinical practice. We recognize that this was not a formal comprehensive interdisciplinary rehabilitation program as was previously described in chronic respiratory patients³³. However, early April 2020, it was proposed that rehabilitation programs can be conducted remotely by healthcare professionals in isolated COVID-19 patients³⁴. Later on, the feasibility and the potential of success of telehealth physical therapy implementations has been provided³⁵ and we think that the present study adds further to this field.

Limitations

The study has several limitations, mainly owing to the nature of the assessment environment and the absence of a control group. Due to isolation restrictions, all assessments were made through tele-conferences. Therefore, we cannot rule out experimenter bias or guarantee reliability of the functional tests in domestic environment. Important factors should be taken into consideration when evaluating outcomes of remote assessment conditions and we point out that further research is needed in this field. The single-group experimental design is not able to establish whether the intervention led to the changes in these specific outcomes. Nevertheless, this design has been adopted from other studies which tried to deliver early rehabilitation services in post-COVID-19 patients (n=30)³⁶ following the first published recommendations of European Respiratory Society and American Thoracic Society⁶. Of course, more randomized control trials, exploring rehabilitation outcomes in patients with COVID-19 who participate in remote exercise interventions, may provide further information, with acknowledgement of the results of both this study and previous observational single-cohort studies³⁶.

An additional limitation was the small number of participants who completed the second stage of the study, maybe due to the loss of human contact (face-to-face interaction) with physical therapists, the sparse tele-rehabilitation sessions (every 10 days) or even patients' perceptions of their real needs. For example, many patients declined to participate in this study as they felt they had other health and/or personal issues to face. Nevertheless, for patients who completed, adherence to the exercise program (completing in total 24–28 exercise sessions in 2 months) was comparable to that previously reported in the outpatient pulmonary rehabilitation setting³³.

Finally, this study included only patients aged 18–65 years, hospitalized at medical wards. Up to 30 June 2020, the National Public Health Organization in Greece reported 2328 cases of COVID-19 in patients up to this age. The choice of this age group was made to diminish any limitations to technology access and provide services to the age group that is most often hospitalized³⁷. Therefore, this approach may limit the generalizability of these findings to all the spectrum of the severity of COVID-19 disease and patients' age.

CONCLUSIONS

A two-month personalized, unsupervised, home-based exercise program combined with tele-rehabilitation sessions was safe, feasible and it partially improved the impaired physical performance and psychological status in COVID-19 patients after hospitalization. There was positive adherence to the tele-rehabilitation program and these findings encourage implementation of telehealth for the long-term management of post-COVID-19 patients' physical and psychological health.

CONFLICTS OF INTEREST

The authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none was reported.

FUNDING

There was no source of funding for this research.

ETHICAL APPROVAL AND INFORMED CONSENT

The study was approved by both Scientific and Ethics Committees of Evangelismos Hospital (Protocol ID-160/2020) and University Hospital of Ioannina (Protocol ID-356/2020) as well as by the Ethics Committee of the Physiotherapy Department (Protocol ID-336/2020). All participants provided a written informed consent.

DATA AVAILABILITY

The data supporting this research are available from the authors on reasonable request.

AUTHORS' CONTRIBUTIONS

EK, DT, HM and IK: concept and the design of the study. EK, DT, AM, GD and IK: interpretation and analysis of the data. Authors from the Clinical Exercise Physiology and Rehabilitation Laboratory were responsible for the data collection. All authors agreed to be accountable for all aspects of the study and approved the final version of the manuscript.

PROVENANCE AND PEER REVIEW

Not commissioned; externally peer reviewed.

REFERENCES

- Moris D, Schizas D. Lockdown During COVID-19: The Greek Success. *In Vivo*. 2020;34(suppl 3):1695-1699. doi:10.21873/invivo.11963
- Kwek SK, Chew WM, Ong KC, et al. Quality of life and psychological status in survivors of severe acute respiratory syndrome at 3 months postdischarge. *J Psychosom Res*. 2006;60(5):513-519. doi:10.1016/j.jpsychores.2005.08.020
- Meesters J, Conijn D, Vermeulen HM, Vliet Vlieland TPM. Physical activity during hospitalization: Activities and preferences of adults versus older adults. *Physiother Theory Pract*. 2019;35(10):975-985. doi:10.1080/09593985.2018.1460429
- Saumur TM, Gregor S, Mochizuki G, Mansfield A, Mathur S. The effect of bed rest on balance control in healthy adults: A systematic scoping review. *J Musculoskelet Neuronal Interact*. 2020;20(1):101-113.
- Yang J, Zheng Y, Gou X, et al. Prevalence of comorbidities and its effects in patients infected with SARS-CoV-2: a systematic review and meta-analysis. *Int J Infect Dis*. 2020;94:91-95. doi:10.1016/j.ijid.2020.03.017
- Spruit MA, Holland AE, Singh SJ, Tonia T, Wilson KC, Troosters T. COVID-19: interim guidance on rehabilitation in the hospital and post-hospital phase from a European Respiratory Society- and American Thoracic Society-coordinated international task force. *Eur Respir J*. 2020;56(6):2002197. doi:10.1183/13993003.02197-2020
- Salawu A, Green A, Crooks MG, Brixey N, Ross DH, Sivan M. A Proposal for Multidisciplinary Tele-Rehabilitation in the Assessment and Rehabilitation of COVID-19 Survivors. *Int J Environ Res Public Health*. 2020;17(13):4890. doi:10.3390/ijerph17134890
- Living guidance for clinical management of COVID-19. World Health Organization. November 23, 2021. Accessed January 7, 2022. <https://www.who.int/publications/i/item/WHO-2019-nCoV-clinical-2021-2>
- Basaranoglu G, Bakan M, Umutoğlu T, Zengin SU, İdin K, Salihoglu Z. Comparison of SpO2 values from different fingers of the hands. *Springerplus*. 2015;4:561. doi:10.1186/s40064-015-1360-5
- Ofir D, Laveneziana P, Webb KA, Lam YM, O'Donnell DE. Mechanisms of Dyspnea during Cycle Exercise in Symptomatic Patients with GOLD Stage I Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med*. 2008;177(6):622-629. doi:10.1164/rccm.200707-10640C
- Papathanasiou G, Georgoudis G, Papandreou M, et al. Reliability Measures of the Short International Physical Activity Questionnaire (IPAQ) in Greek Young Adults. *Hellenic J Cardiol*. 2009;50(4):283-294. Accessed January 7, 2022. https://www.hellenicjcardiol.org/archive/full_text/2009/4/2009_4_283.pdf
- Zigmond AS, Snaith RP. The Hospital Anxiety and Depression Scale. *Acta Psychiatr Scand*. 1983;67(6):361-370. doi:10.1111/j.1600-0447.1983.tb09716.x
- Mahler DA, Wells CK. Evaluation of Clinical Methods for Rating Dyspnea. *Chest*. 1988;93(3):580-586. doi:10.1378/chest.93.3.580
- Ware JE, Kosinski M, Dewey JE. How to score version 2 of the SF-36 health survey. *Quality Metric*; 2000.
- Bjelland I, Dahl AA, Haug TT, Neckelmann D. The validity of the Hospital Anxiety and Depression Scale. An updated literature review. *J Psychosom Res*. 2002;52(2):69-77. doi:10.1016/s0022-3999(01)00296-3
- Guralnik JM, Ferrucci L, Pieper CF, et al. Lower Extremity Function and Subsequent Disability: Consistency Across Studies, Predictive Models, and Value of Gait Speed Alone Compared With the Short Physical Performance Battery. *J Gerontol A Biol Sci Med Sci*. 2000;55(4):M221-M231. doi:10.1093/gerona/55.4.m221
- Strassmann A, Steurer-Stey C, Lana KD, et al. Population-based reference values for the 1-min sit-to-stand test. *Int J Public Health*. 2013;58(6):949-953. doi:10.1007/s00038-013-0504-z
- Borel B, Wilkinson-Maitland CA, Hamilton A, et al. Three-minute constant rate step test for detecting exertional dyspnea relief after bronchodilation in COPD. *Int J Chron Obstruct Pulmon Dis*. 2016;11:2991-3000. doi:10.2147/COPD.S113113

19. Klok FA, Boon GJAM, Barco S, et al. The Post-COVID-19 Functional Status scale: a tool to measure functional status over time after COVID-19. *Eur Respir J*. 2020;56(1):2001494. doi:10.1183/13993003.01494-2020
20. Curci C, Pisano F, Bonacci E, et al. Early rehabilitation in post-acute COVID-19 patients: data from an Italian COVID-19 Rehabilitation Unit and proposal of a treatment protocol. *Eur J Phys Rehabil Med*. 2020;56(5):633-641. doi:10.23736/S1973-9087.20.06339-X
21. Liu K, Zhang W, Yang Y, Zhang J, Li Y, Chen Y. Respiratory rehabilitation in elderly patients with COVID-19: A randomized controlled study. *Complement Ther Clin Pract*. 2020;39:101166. doi:10.1016/j.ctcp.2020.101166
22. Belli S, Balbi B, Prince I, et al. Low physical functioning and impaired performance of activities of daily life in COVID-19 patients who survived hospitalisation. *Eur Respir J*. 2020;56(4):2002096. doi:10.1183/13993003.02096-2020
23. Huang C, Huang L, Wang Y, et al. 6-month consequences of COVID-19 in patients discharged from hospital: a cohort study. *Lancet*. 2021;397(10270):220-232. doi:10.1016/S0140-6736(20)32656-8
24. Rodriguez-Blanco C, Gonzalez-Gerez JJ, Bernal-Utrera C, Anarte-Lazo E, Perez-Ale M, Saavedra-Hernandez M. Short-Term Effects of a Conditioning Telerehabilitation Program in Confined Patients Affected by COVID-19 in the Acute Phase. A Pilot Randomized Controlled Trial. *Medicina (Kaunas)*. 2021;57(7):684. doi:10.3390/medicina57070684
25. Li J, Xia W, Zhan C, et al. A telerehabilitation programme in post-discharge COVID-19 patients (TERECO): a randomised controlled trial. *Thorax*. 2021;1-10. doi:10.1136/thoraxjnl-2021-217382
26. Vaidya T, de Bisschop C, Beaumont M, et al. Is the 1-minute sit-to-stand test a good tool for the evaluation of the impact of pulmonary rehabilitation? Determination of the minimal important difference in COPD. *Int J Chron Obstruct Pulmon Dis*. 2016;11:2609-2616. doi:10.2147/COPD.S115439
27. Holland AE, Rasekaba T, Fiore JF, Burge AT, Lee AL. The 6-minute walk distance cannot be accurately assessed at home in people with COPD. *Disabil Rehabil*. 2015;37(12):1102-1106. doi:10.3109/09638288.2014.956815
28. Gurses HN, Zeren M, Denizoglu Kulli H, Durgut E. The relationship of sit-to-stand tests with 6-minute walk test in healthy young adults. *Medicine (Baltimore)*. 2018;97(1):e9489. doi:10.1097/MD.00000000000009489
29. Reyhler G, Boucard E, Peran L, et al. One minute sit-to-stand test is an alternative to 6MWT to measure functional exercise performance in COPD patients. *Clin Respir J*. 2018;12(3):1247-1256. doi:10.1111/crj.12658
30. Lau HM, Ng GY, Jones AY, Lee EW, Siu EH, Hui DS. A randomised controlled trial of the effectiveness of an exercise training program in patients recovering from severe acute respiratory syndrome. *Aust J Physiother*. 2005;51(4):213-219. doi:10.1016/s0004-9514(05)70002-7
31. Horner-Johnson W, Krahn GL, Suzuki R, et al. Differential Performance of SF-36 Items in Healthy Adults With and Without Functional Limitations. *Arch Phys Med Rehabil*. 2010;91(4):570-575. doi:10.1016/j.apmr.2009.12.015
32. Ahmed H, Patel K, Greenwood DC, et al. LONG-TERM CLINICAL OUTCOMES IN SURVIVORS OF SEVERE ACUTE RESPIRATORY SYNDROME (SARS) AND MIDDLE EAST RESPIRATORY SYNDROME (MERS) CORONAVIRUS OUTBREAKS AFTER HOSPITALISATION OR ICU ADMISSION: A SYSTEMATIC REVIEW AND META-ANALYSIS. *J Rehabil Med*. 2020;52(5):jrm00063. doi:10.2340/16501977-2694
33. Spruit MA, Singh SJ, Garvey C, et al. An Official American Thoracic Society/European Respiratory Society Statement: Key Concepts and Advances in Pulmonary Rehabilitation. *Am J Respir Crit Care Med*. 2013;188(8):e13-e64. doi:10.1164/rccm.201309-1634ST
34. Vitacca M, Carone M, Clini EM, et al. Joint Statement on the Role of Respiratory Rehabilitation in the COVID-19 Crisis: The Italian Position Paper. *Respiration*. 2020;99(6):493-499. doi:10.1159/000508399
35. Miller MJ, Pak SS, Keller DR, Barnes DE. Evaluation of Pragmatic Telehealth Physical Therapy Implementation During the COVID-19 Pandemic. *Phys Ther*. 2021;101(1):pzaa193. doi:10.1093/ptj/pzaa193
36. Daynes E, Gerlis C, Chaplin E, Gardiner N, Singh SJ. Early experiences of rehabilitation for individuals post-COVID to improve fatigue, breathlessness exercise capacity and cognition – A cohort study. *Chron Respir Dis*. 2021;18:1-4. doi:10.1177/14799731211015691
37. Daily report of epidemiological surveillance of new coronavirus infection (COVID-19): Data until June 30, 2020, at 15:00. Hellenic National Public Health Organization; 2020. Accessed January 7, 2022. <https://eody.gov.gr/wp-content/uploads/2020/06/covid-gr-daily-report-20200630.pdf>