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Effectiveness of tele-exercise training on physical fitness, functional capacity, and health-related quality of life in non-hospitalized individuals with COVID-19: The COFIT-HK study

Eric Tsz-Chun Poon [a,*], Fenghua Sun [b], Andy Choi-Yeung Tse [b], Jaclyn Hei Tsang [c], Aaron Yiu-Huen Chung [b], Yannis Yuet-Yan Lai [b], Sam Wing-Sum Wong [d]

[a] Department of Sports Science and Physical Education, The Chinese University of Hong Kong, Shatin, Hong Kong
[b] Department of Health and Physical Education, The Education University of Hong Kong, Taipo, Hong Kong
[c] Fitness Nutrition and Training Center, Sheungwan, Hong Kong
[d] Physical Fitness Association of Hong Kong, China

A B S T R A C T

Background: The use of tele-exercise programs as an option for post-COVID-19 rehabilitation has been suggested, but its effectiveness in non-hospitalized individuals is not well understood.

Objective: This study aimed to determine the effectiveness of an 8-week tele-exercise training program (COFIT-HK) on physical fitness, functional capacity, and health-related quality of life (HRQoL) in non-hospitalized post-COVID-19 individuals.

Methods: Forty-one non-hospitalized individuals (age:47.4 ± 7.8 yrs) who had COVID-19 history were divided into two groups: the tele-exercise training group (TELE; n = 21) and the non-intervention control group (CON; n = 20). TELE engaged in online supervised multicomponent low-to-moderate intensity exercise training (including respiratory muscle, aerobic, and resistance training) three times per week, whereas CON received standardized educational leaflets based on World Health Organization (WHO) guidelines for post-COVID-19-related illness rehabilitation only. Various components of physical fitness, functional capacity, and HRQoL were assessed at baseline and after the 8-week intervention.

Results: TELE showed significant improvements in handgrip strength, arm flexibility, functional lower extremity endurance, and HRQoL after the 8-week intervention (all $p < 0.05$, ES = 0.50–1.10). When comparing the groups, TELE demonstrated significantly greater improvements in both the physical and mental component summary scores of HRQoL compared to CON (both $p < 0.05$). Other outcomes did not reveal significant group differences.

Conclusion: Our tele-exercise intervention was effective in improving physical fitness, functional capacity and HRQoL among non-hospitalized post-COVID-19 individuals. Further research is needed to explore the utility and limitations of tele-exercise programs for post-COVID-19 rehabilitation and beyond.

1. Introduction

The novel coronavirus disease (COVID-19) pandemic has had detrimental effects on various lifestyle components and lead to physical inactivity, sedentary behaviours, and suboptimal dietary habits.[1,2] The World Health Organization (WHO) has suggested that while most people who have developed COVID-19 will fully recover, some may experience a variety of post-COVID conditions including persistent fatigue, dyspnea, myalgia, and reduced physical fitness and functional capacity.[3] These conditions can significantly impact individuals' quality of life and hinder their ability to return to their pre-illness level of functioning. Therefore, effective rehabilitation strategies are crucial to support the recovery of individuals with post-COVID-19 conditions.[3]

In recent years, telehealth programs have emerged as a promising approach for delivering health-related services and information via electronic information and telecommunication technologies in real-time or asynchronously.[4] They are increasingly recognized by many health and fitness professionals to support long-distance clinical health care, professional health-related education, public health and health administration.[5,6] In particular, telehealth offers several potential advantages for post-COVID-19 rehabilitation, including increased accessibility, personalized care, and the ability to monitor and support rehabilitation program remotely. In a recent systematic review examining healthcare practices in COVID-19, it is highlighted that telehealth program improves the provision of health services while minimizing the risk of cross-contamination caused by close contacts and should be the first treatment option for people at home.[7] Within the realm of telehealth, tele-exercise programs have gained attention as a potential strategy for

* Corresponding author.
E-mail address: eric.poon@cuhk.edu.hk (E.T.-C. Poon).

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post-COVID-19 rehabilitation. These programs involve the delivery of exercise training and therapeutic interventions through online platforms, allowing individuals to engage in rehabilitation from the comfort of their homes. For instance, the WHO has provided advice for healthcare professionals on physical activity maintenance during social distancing that includes the support of online resources.[8] It is thus suggested that telehealth, including tele-exercise, has the potential to address many critical challenges in providing health service during the outbreak of COVID-19.[5]

Despite the potential benefits of tele-exercise programs, there is still a need for research to evaluate their effectiveness, particularly in non-hospitalized individuals with post-COVID-19 conditions. A recently published systematic review[9] has recognized physical exercise-based rehabilitation as a potential therapeutic strategy for individuals recovered from COVID-19, but also reported several limitations in existing literature. For instance, previous studies have predominantly focused on hospitalized patients with relatively severe conditions, limiting the generalizability of their findings to non-hospitalized populations. Additionally, much of the existing research in this area has been conducted in Western countries, with limited representation from countries or regions in East Asia.[9] To the best of our knowledge, only one study related to post-COVID-19 recovery has been reported in Hong Kong.[10] It was found that more than 40 % COVID-19 survivors were still suffering from the symptoms of "long COVID" including fatigue and lower limb muscle weakness, 6 and 12 months after diagnosis from COVID-19, posing a negative impact to their daily life. This geographical imbalance hinders our understanding of how regional factors may influence the outcomes of tele-exercise programs. Furthermore, many previous studies have utilized a one-group pretest-posttest design (i.e., without a control group),[11–16] making it challenging to attribute the observed rehabilitation effects solely to the exercise training itself rather than natural recovery processes. Therefore, there is a need for studies employing more robust study designs to elucidate the specific effects of tele-exercise programs on post-COVID-19 rehabilitation outcomes, where a healthy lifestyle can be promoted amidst the COVID-19/post-COVID pandemic.

In light of these research gaps, the present study aimed to investigate the effectiveness of a 8-week tele-exercise training program (COFIT-HK) on physical fitness, functional capacity, and health-related quality of life (HRQoL). It was hypothesized that the program could induce significant improvements in physical fitness, functional capacity, and HRQoL in a cohort of non-hospitalized post-COVID-19 individuals in Hong Kong.

2. Methods

This study is a controlled clinical trial (CCT) consisting of one tele-exercise training group (TELE) and one non-intervention control group (CON).

2.1. Participants

Twenty-one physically inactive and post-COVID-19 individuals aged 35–59 years were initially enrolled in our study and allocated to the TELE group. An additional twenty-one participants were subsequently recruited to serve as the control group. This particular age range (i.e., working adults) was chosen purposefully for the study, since this cohort is typically associated with relatively higher cardiovascular risk and poorer psychosocial wellbeing than their younger counterparts.[17] Participants were recruited through online advertisements and flyers in the university, associated clinics and community centers. Participants were considered eligible if they have tested positive for COVID-19 within 6 months. Our criteria for COVID-19 infection followed the guideline by the Government of Hong Kong Special Administrative Region,[18] in which participants had to be tested positive for nucleic acid test in clinical settings or had registered in the "Declaration System for Individuals Tested Positive for COVID-19 Using Rapid Antigen Test" (www.chp.gov.hk/ratp). Participants were considered physically inactive if they reported less than150 min of moderate or 75 min of vigorous PA per week, as assessed by the International Physical Activity Questionnaire.[19] Exclusion criteria included 1) severe high blood pressure (≥180/100 mm Hg); 2) taking prescribed medication for chronic health and medical conditions, including but not limited to myocardial infarction, uncompensated heart failure, or unstable angina pectoris; 3) any pre-existing medical or physical issue that could affect training and experimental tests, as outlined by current exercise prescription guidelines[20] and; 4) hospitalized for COVID-19 over the past 6 months. The screening procedure was conducted by a certified exercise physiologist in which participants were asked to complete written consents and a health history questionnaire with a specific focus on cardiometabolic diseases that may preclude participation in the study.

Based on a recent meta-analysis published on the effect of physical exercise-based rehabilitation on post-COVID recovery,[9] a sample size of 19 participants per group would be required to detect an effect size of $d = 0.6$ following interventions on the majority of health and fitness related outcomes, with a power of 0.80 at an alpha level of 0.05 (G*Power version 3.0.10). Ethical approval was obtained from the Research Ethical Committee at The Education University of Hong Kong.

2.2. Intervention components, delivery and implementation strategies

The TELE group engaged in an 8-week multicomponent exercise program, which was composed of respiratory muscle training, aerobic exercise, and resistance training (see Supplementary for detailed exercise program). It is suggested that as individuals infected with COVID may have diverse symptoms, a mixed-type physical exercise program may provide more comprehensive health benefits than a single type of exercise-based rehabilitation.[9] Practical exercise sessions were conducted via an online digital platform (i.e., Zoom), with small groups consisting of 5–10 participants per session. A certified fitness instructor led the sessions, which were designed to train various muscle groups and improve cardiorespiratory and muscle performance to aid participants regaining fitness for daily activities. Each practical session lasted for 60 min, and participants were expected to perform the same exercise routine at home two additional times per week. This resulted in a total exercise duration of 180 min per week for the TELE group.

To ensure safety and proper supervision during the online sessions, each participant in the TELE group was provided with a heartrate (HR) fitness tracker (Xi band 7, Xiaomi) and instructed to use the rating of perceived exertion (RPE) method to monitor their exercise intensity. The overall exercise sessions progressed gradually from light intensity (~55 % HRmax or 9–11/20 RPE) to moderate intensity (~75 % HRmax or 12–13/20 RPE) over the 8-week training period. To maintain participants' interest in practical sessions while effectively delivering the prescribed exercises, a variety of whole-body home-based workout routines were introduced, including upper body, lower body, and the core of the body. Demonstration of these workout routines were performed in the practical sessions. Considering the potential individual differences in baseline fitness levels, variations around different exercises were provided to cater to the range of participants in the group. Additionally, resources including online videos demonstrating exercise and educational booklets with exercise tips were developed and provided to the participants.

Adherence to the intervention was assessed via the exercise record uploaded from the fitness tracker of each participant, which was reviewed weekly by a research assistant. Furthermore, participants were motivated to stay on track with the exercise program. SMS/WhatsApp reminders were sent to participants weekly or if the exercise record showed missing sessions. They were encouraged to contact our research assistants if they encountered any difficulties in delivering the program. In contrast, participants in the non-intervention CON group received standardized educational leaflets based on World Health Organization (WHO) guidelines for post-COVID-19-related illness rehabilitation[8] but did not participate in the tele-health exercise program.

2.3. Measurement

To capture the holistic nature of the COFIT-HK intervention, a comprehensive range of fitness measurements was conducted. All measurements were conducted at: (i) baseline and (ii) at least 48 h (within 5 days) after the final session of the 8-week intervention at a local health and fitness testing center. Participants were instructed to avoid strenuous exercise for at least 24 h and caffeine consumption for at least 12 h, prior to each visit for testing.

2.3.1. Body composition, anthropometry and blood pressure

Participants' height was measured using a stadiometer. Body mass, BMI and body fat percentage were determined by a multi-frequency segmental body composition analyser (InBody 270, Hong Kong) after voiding bladder. To indicate central obesity, waist circumference (i.e., narrowest part of the waist) was measured with an anthropometric tape.[20] Blood pressure was measured using a clinical automatic blood pressure monitor (M7 Intelli IT, Omron, Japan). Participants rested for 10 min in a quiet place (seated position) before taking the measurement. The cuff was placed around participants' brachial artery (left arm). Two readings (with 1-min interval) of systolic blood pressure (SBP), diastolic blood pressure and (DBP) were averaged.

2.3.2. Cardiovascular fitness

Participants performed a standardized Bruce Protocol ramp treadmill test to assess their cardiovascular fitness (i.e., estimated VO_{2max}).[20] Briefly, participants started exercising at 1.7 miles per hour (mph) on a 10 % grade. The speed and incline of the treadmill increased every 3 min until volition exhaustion. HR was recorded continuously during the test using HR telemetry (H10 Sensor, Polar, Finland). The end time of the test was recorded and was used to estimate VO_{2max} based on a validated equation.[21]

2.3.3. Pulmonary function

Peak expiratory flow (PEFR) is the volume of air forcefully expelled from the lungs in one quick exhalation and is a reliable indicator of ventilation adequacy as well as airflow obstruction.[22] Participants placed the mouthpiece of a peak flow meter (Mini Wrights, UK) and blasted the air out as hard and as fast as possible. The highest reading out of three attempts was recorded. This test has demonstrated good reliability (intra-class correlation coefficients [ICC] > 0.9 and coefficient of variation < 6 %) and deemed suitable for both screening and monitoring purposes.[23]

2.3.4. Muscular strength

Participants performed a standardized handgrip test using a handheld dynamometer with the arm hanging by the side. They were required to squeeze the dynamometer with all of their strength three times with each hand. A total score was then calculated using the best measurements from both hands. The handgrip strength obtained by dynamometry showed good to excellent reliability (ICC > 0.80)[24] and high absolute reliability by the standard error of measurement (SEM) and minimal detectable change (MDC), respectively.[25]

2.3.5. Functional lower extremity endurance

Participants performed a 30-sec sit-to-stand test. They first seated on a chair and were asked to complete as many full stands as possible within 30 s for testing lower body endurance. This test has demonstrated good reliability (ICC > 0.70) among older adults.[26]

2.3.6. Arm flexibility

Participants performed back scratch test which measures flexibility in the shoulder joint and shoulder arch on the right and on the left side. Participants started the test by standing up right, placing one arm (either side) on the lower back, moving it up the spine toward their head. The opposite arm was placed behind their neck, moving it down the spine, aiming to place the long finger of each hand as near each other as possible or to overlap the other hand as much as possible. The gap between the fingertips of the long finger of both hands was measured to the nearest half cm. The best record out of three attempts was recorded. The back scratch test demonstrated excellent reliability (ICC> 0.90) and high absolute reliability by the SEM and MCD, respectively.[27]

2.3.7. Health-related quality of life (HRQoL)

HRQoL was assessed through the Medical Outcomes Study 12-Item Short-Form Health Survey (SF-12).[28] SF-12 is a self-reported outcome measure assessing the impact of health on an individual's everyday life. Scores of physical component summary (PCS; combined four aspects including physical functioning, role-physical, bodily pain and general health) and mental component summary (MCS) were calculated using norm-based methods. Higher scores indicate better HRQoL. The SF-12 instrument demonstrated satisfactory internal consistency reliability as reflected by the Cronbach's α value (0.910) and the split-half reliability coefficient (0.812) among Chinese community population.[29]

2.4. Statistical analysis

Data were analyzed using SPSS (Version 27.0). The descriptive statistics data were summarized and reported as means ± SD for continuous variables and as proportion of participants for categorical variables. Paired-sample t-tests were used to examine the within-group time effect. Mean differences among groups for each outcome variable were tested by one-way analysis of covariance (ANCOVA), while controlling for baseline values, age and sex (i.e., comparison will lie within post-test values). This statistical approach was chosen as it has shown to be generally more powerful than a two-way repeated-measures ANOVA (group main effect and time by group interaction) when interest lies in group differences in change from pre-test to post-test. P-value was set at <0.05. Effect size (ES) comparing pre-post within groups were calculated using Cohen's d to indicate the magnitude of mean difference where appropriate.[30] Scores of 0.2, 0.5 and > 0.8 were considered small, moderate and large effect sizes, respectively.

3. Results

One participant in the CON group did not attend the posttest due to scheduling issues, resulting in forty-one participants included in the final analysis (see Fig. 1 and Table 1 for participants' characteristics). No incidence of adverse events related to training was reported. Exercise adherence in the TELE group was satisfactory as participants reported 80.4 ± 7.5 % of prescribed sessions completed.

All baseline and post-test results from the two groups are summarized in Table 2. Overall, participants in TELE group showed significant improvements in handgrip strength, arm flexibility, functional lower extremity endurance, as well as both the physical and mental component summary scores of HRQoL after the 8-week intervention (all $p < 0.05$, ES = 0.50–1.1, Table 2). No significant improvements were observed for body composition, cardiorespiratory fitness in the TELE group. On the other hand, participants in the CON group revealed a significant improvement in functional lower extremity endurance ($p < 0.05$, Table 2), despite no significant changes for other measurement outcomes ($p > 0.05$).

When comparing the differences between groups, TELE demonstrated significantly greater improvements in both physical and mental component summary scores of HRQoL compared to CON (both $p < 0.05$, Table 2). Other outcomes did not show significant group differences ($p > 0.05$).

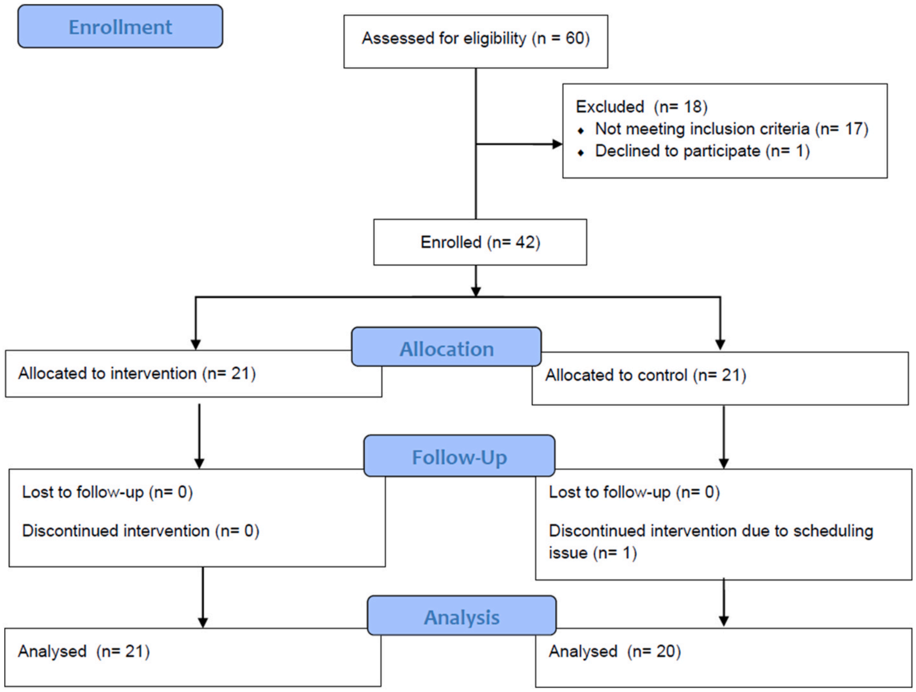

Fig. 1. Flow diagram of participants.

Table 1
Participants' demographics.

	All (n = 41)	Female (n = 28)	Male (n = 13)
Age (yr)	47.0 ± 7.8	47.3 ± 8.4	46.2 ± 6.8
Height (cm)	163.2 ± 8.5	159.0 ± 5.2	172.0 ± 7.4
Body mass (kg)	61.9 ± 13.8	54.8 ± 6.0	76.9 ± 13.8
Waist circumference (cm)	78.8 ± 11.6	73.6 ± 6.9	89.9 ± 12.1
Body Fat (%)	26.6 ± 6.4	28.4 ± 5.9	22.8 ± 5.9
BMI (kg/m^2)	23.0 ± 3.1	21.6 ± 1.9	25.8 ± 3.2
Enrollment time (days after diagnosis) *[range]*	95 ± 11 *[30–148]*	92 ± 14 *[30–140]*	98 ± 13 *[39–148]*

Remark: Common symptoms reported by participants (n = 41) at baseline: phlegm in throat (48.7 %), persistent muscle fatigue (46.3 %), cognitive impairment/"brain fog"(41.4 %); shortness of breath (26.8 %), dyspnea (17.0 %), chest pain (7.3 %) and cough (4.9 %).

4. Discussion

The findings of our study suggest that a 8-week telehealth program can effectively enhance handgrip strength, flexibility, functional lower extremity endurance, and HRQoL in non-hospitalized post-COVID-19 individuals. These improvements are crucial for individuals recovering from COVID-19, as they may experience physical deconditioning and functional limitations as a result of the illness.[3] Such positive findings from the within-group analysis are also in line with a number of studies utilizing one-group pretest-posttest design,[11–16] which demonstrated the therapeutic effects of physical exercise-based rehabilitation against post-COVID-19 conditions.

Interestingly, we observed that most of these physical fitness outcomes did not show significant group differences upon comparisons with the CON group. These results are somewhat different from several previous studies that reported superior rehabilitation effects following exercise-based programs versus non-exercise intervention treatment in COVID-19 patients.[31–34] Several potential explanations for these discrepancies can be considered. Firstly, due to safety and supervision concerns in online training, we limited the exercise intensity to low-to-moderate levels. However, previous studies suggested that exercising with higher intensities may yield better improvements in cardiorespiratory fitness[35,36] and reducing adiposity.[37] This may explain why certain outcomes in our study, such as body composition and cardiorespiratory fitness, did not show significant improvements as seen in other post-COVID rehabilitation studies that employed face-to-face interventions.[32,38] Additionally, previous studies often included hospitalized COVID-19 patients with relatively poorer initial fitness levels, while our study focused on non-hospitalized individuals who may have been able to gradually increase their physical activity levels following spontaneous recovery. Even the CON group participants who received standardized educational leaflets based on World Health Organization (WHO) guidelines for post-COVID recovery may have been able to improve their fitness through self-driven physical activity. This may also explain the significant improvement in functional lower extremity endurance observed among our participants in the CON group.

Despite the lack of significant group differences in most physical fitness outcomes, the TELE group demonstrated significantly greater improvements in both PCS and MCS of HRQoL compared to the CON group. This indicates that our program not only had positive effects on physical health but also contributed to enhancing mental well-being in this population. The improvement in PCS scores among the TELE participants could be attributed to the enhanced physical aspects including handgrip strength, flexibility, and lower body functional capacity as aforementioned, whereas the significant improvement in MCS scores highlights the positive impact of our tele-exercise program on mental health outcomes. Addressing mental health issues among individuals recovering from COVID-19 is crucial, given a 25 % increase in global anxiety and depression reported by WHO in 2022.[39] Such an alarming increase is partly due to the disruption of physical habits during the pandemic.[40] A local study conducted in Hong Kong also suggested that the population stress level, prevalence of anxiety, and the depression symptoms drastically increased during the COVID-19 outbreak as compared with 2016 and 2017.[41] Our finding aligns with previous research indicating the positive relationship between physical exercise and mental health. Engaging in regular exercise has been associated with the release of neurotransmitters involved in mood regulation, fostering social connections, and providing a sense of community and support.[42] Overall, our present findings support the notion that

Table 2
Result of baseline test and posttest in tele-exercise and control group.

	Tele-exercise group (n = 21; 7 M, 14F)				Control group (n = 20; 6 M, 14F)				Group Effect P Value
	Pre	Post	Time Effect Within-Group P Value	Cohen's d	Pre	Post	Time Effect Within-Group P Value	Cohen's d	
Body mass (kg)	62.6 ± 14.1	63.0 ± 13.9	0.147	0.33	60.4 ± 13.9	60.0 ± 13.7	0.130	0.53	0.08
Waist circumference (cm)	79 ± 12.3	78.4 ± 10.8	0.435	0.17	78.5 ± 10.5	79.2 ± 10.0	0.541	0.20	0.34
Body fat (%)	27.2 ± 7.2	27.1 ± 6.8	0.855	0.04	25.4 ± 4.3	25.2 ± 4.4	0.767	0.10	0.90
BMI (kg/m^2)	23.2 ± 3.3	23.4 ± 3.3	0.057	0.46	22.5 ± 2.8	22.4 ± 2.7	0.162	0.48	0.86
SBP (mmHg)	123.8 ± 15.9	123.3 ± 12.1	0.863	0.04	125.8 ± 14.1	118.6 ± 17.3	0.072	0.64	0.16
DBP (mmHg)	80.0 ± 11.5	82.1 ± 10.0	0.300	0.23	78.3 ± 10.4	74.6 ± 11.6	0.141	0.51	0.09
Total handgrip (kg)	63.6 ± 19.9	66.5 ± 22.0*	0.032	0.50	68.0 ± 20.6	69.4 ± 22.5	0.266	0.38	0.44
30s sit-and-stand test (rep)	23.2 ± 6.0	27.9 ± 5.2*	<0.001	1.13	26.0 ± 5.0	29.4 ± 3.4*	0.003	1.29	0.38
Arm flexibility (cm)	4.2 ± 6.6	7.4 ± 3.3*	0.011	0.61	5.2 ± 2.5	6.2 ± 1.7	0.279	0.36	0.12
PEFR (L/min)	470 ± 115	481 ± 124	0.384	0.19	522 ± 115	549 ± 117	0.156	0.49	0.24
End time of Bruce Protocol (min)	8.7 ± 2.1	8.8 ± 2.1	0.567	0.15	9.0 ± 1.7	9.1 ± 2.0	0.497	0.23	0.87
VO_{2max} (mL/kg/min)	32.2 ± 7.3	32.6 ± 7.6	0.519	0.14	33.6 ± 6.9	34.3 ± 7.7	0.490	0.23	0.89
PCS-12 (score)	43.1 ± 7.0	46.3 ± 6.3*#	0.027	0.52	48.8 ± 8.1	47.0 ± 7.6	0.352	0.30	0.03
MCS-12 (score)	45.4 ± 9.0	50.7 ± 8.0*#	0.032	0.50	47.0 ± 8.4	49.4 ± 7.9	0.266	0.38	0.04

Note: BMI: Body mass index, DBP: Diastolic blood pressure, MCS-12: Mental component summary, PCS-12: Physical component summary, PEFR: Peak expiratory flow, SBP: Systolic blood pressure, VO_{2max}: Maximal oxygen intake.
*pre vs post ($p < 0.05$), # indicates significant group difference compared to CON ($p < 0.05$).

tele-exercise programs, such as the one implemented in our study, can be promoted in the community to improve both the physical and mental aspects of HRQoL in non-hospitalized COVID-19 individuals, emphasizing the potential of applying such programs as routine rehabilitation practice among individuals recovering from COVID-19.[42]

Our study had several strengths, including the incorporation of a CON group that allows the comparison between the experimental intervention and the current standard recommendation from WHO on post-COVID rehabilitation, as well as the measurement of a comprehensive range of health-related outcomes. It is acknowledged that one major limitation of this study is the lack of objective assessment of the participants' daily physical activity levels. Without measuring and quantifying their actual physical activity, we cannot definitively determine whether the observed improvements in fitness among the CON group were solely due to increased physical activity following spontaneous recovery or if they were influenced by behavior changes resulting from the educational materials provided. This limitation highlights the need for future studies to incorporate objective measures of physical activity, such as activity trackers or accelerometers, to better understand the relationship between physical activity levels and fitness outcomes in post-COVID-19 individuals. Moreover, it would be beneficial to further investigate the comparative effectiveness of tele-exercise programs versus conventional exercise programs delivered in face-to-face formats. This will provide a more comprehensive understanding of the utility and limitations of tele-exercise interventions. Exploring long-term outcomes and evaluating the cost-effectiveness of telehealth programs would also contribute to their wider adoption and implementation in post-COVID-19 rehabilitation and beyond.

5. Conclusion

Our tele-exercise intervention was effective in improving physical fitness, functional capacity and HRQoL among non-hospitalized individuals with post-COVID-19 conditions. Tele-exercise may be a valuable alternative strategy for improving fitness in post-COVID-19 rehabilitation and beyond. Further research is needed to explore the utility and limitations of tele-exercise programs in comparison to conventional face-to-face exercise programs.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jesf.2024.01.003.

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