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Early View

Original research article

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Title

Group-based pulmonary telerehabilitation is feasible, safe, beneficial and well-received in patients that have been hospitalised with Covid-19

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Running head: Group-based pulmonary telerehabilitation for Covid-19

Governance

Health Research Authority (HRA) and NHS Research Ethics Committee approval was obtained (reference number: 20/IEC08/0017) and the trial registered with clinicaltrials.gov (reference: 285205).

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Declaration of conflicting interests

The authors have no conflicts of interests

Abstract

Introduction. Covid-19 has caused worldwide mass hospitalisation. The need for multi-disciplinary post-hospitalisation rehabilitation is becoming increasingly apparent and telerehabilitation has been endorsed. The aim of study was to investigate the feasibility and efficacy of pulmonary telerehabilitation for Covid-19 survivors. Methods: A single centre, mixed-methods, fast-track (wait-list), randomised controlled trial of telerehabilitation for patients who have been hospitalised with Covid-19. Participants: Forty patients discharged from two University Teaching Hospitals in the North of England. Interventions: Telerehabilitation consisted of twelve exercise classes, six education events and opportunity for peer support. Patients commenced telerehabilitation 14 days after randomisation in the fast-track group and 56 days after randomisation in the wait-list group. Outcome measures and results: Descriptive and statistical improvements were noted is several clinical outcome measures. Exercise capacity increased from a median (Q1-Q3) 20 (14- 24) sit-to-stand repetitions in one-minute at baseline to 25 (24-30) post-telerehabilitation. Breathlessness rated using the MRC changed from 3.5 (3-4) at baseline to 2 (1.5-3) post-telerehabilitation, with additional favourable outcomes noted in respiratory symptoms measured using numerical rating scales and visual analogue scales (VAS). Quality of life measured using the EQ-VAS improved from 55 (60-70) units at baseline to 70 (55-80) units following telerehabilitation. Improvements in fatigue (FACIT-F) and mood (HADS-D) were also observed. Natural recovery was observed in the wait-list group prior to receiving telerehabilitation, however, improvements were accelerated by early telerehabilitation in the fast-track group. Conclusions: We have shown that group-based telerehabilitation is feasible, safe, beneficial and well-received in this population.

ClinicalTrials.gov Identifier: NCT04511962

Introduction

Coronavirus disease 2019 (Covid-19), caused by the novel severe acute respiratory syndrome coronavirus-2 (SARS-Cov-2), has caused worldwide mass hospitalisation with around 17% of patients admitted with Covid-19 requiring organ support in high dependency or intensive care units (1). Following discharge from hospital, patients report a plethora of on-going symptoms, including: fatigue, dyspnoea, joint pain, chest pain, and cough (2). The need for multi-disciplinary post-hospitalisation rehabilitation for Covid-19 is becoming increasingly apparent (3).

The British Society of Rehabilitation (4), Chartered Society of Physiotherapy (5) and the British Thoracic Society (6) have all produced policy documents on rehabilitation for Covid-19. However, there remains limited available evidence about the optimum way of delivering rehabilitation in this context. Although the optimal rehabilitation strategy for Covid-19 is not yet known, three components are applicable to rehabilitation of almost all conditions: i) exercise training; ii) education, including self-management; and iii) psychosocial management (7). Pulmonary rehabilitation encompasses these three components and, due to the predominance of respiratory dysfunction, proposals for post-hospitalisation rehabilitation for Covid-19 survivors are based around pulmonary rehabilitation. An additional consideration, endorsed by The World Health Organisation (WHO), is that telerehabilitation should be used to deliver rehabilitation wherever feasible in order to facilitate social distancing and increase capacity (8).

Pulmonary rehabilitation has a strong body of evidence for improving exercise capacity, quality of life, respiratory symptoms, anxiety and depression in patients with chronic obstructive pulmonary disease (COPD) (9). However, there is currently very limited evidence with regards to the feasibility and efficacy of pulmonary rehabilitation for Covid-19. Whilst there is reasonable evidence for telerehabilitation in other clinical populations, the body of evidence for pulmonary telerehabilitation

for Covid-19 survivors is even smaller, with heterogeneity surrounding the telerehabilitation protocols (10).

Here we conducted a single centre, mixed-methods, fast-track (wait-list), randomised controlled trial of telerehabilitation in patients who have been hospitalised with Covid-19. The aims were to determine the feasibility and efficacy of group-based pulmonary telerehabilitation in patients hospitalised with Covid-19. We hypothesise that improvements will be noted following telerehabilitation in exercise capacity, breathlessness, quality of life, fatigue and mood and that these improvements will exceed that seen during the 'wait-list' period.

Method

Trial design

A single centre, fast-track (wait-list), randomised, mixed-methods, feasibility trial of telerehabilitation for patients hospitalised with Covid-19. Trial design and timing of trial assessments are presented in figure 2. The trial commenced in August 2020 and completed August 2021.

Governance

Health Research Authority (HRA) and NHS Research Ethics Committee approval was obtained (reference number: 20/IEC08/0017) and the trial registered with clinicaltrials.gov (reference: NCT04511962). The original protocol for this trial is available (11).

Setting and recruitment

Patients discharged from two University Teaching Hospitals within a single NHS Trust in the North of England. Patients that received high-level respiratory support [i.e., continuous positive airway pressure (CPAP), high flow oxygen or intubation] during their inpatient care were contacted 4-6 weeks post-discharge as part of routine clinical care. Hospitalised patients that did not receive high-level respiratory support were identified as potentially eligible by their clinician within the post-Covid follow-up service. Following a protocol amendment, and acknowledgement that non-hospitalised patients could also benefit from the intervention, participants were identified through the local Long Covid Service.

Randomisation

Block randomisation was utilised to ensure equal group size using a commercial web-based randomisation system (Sealed Envelope Ltd, London, UK) to wait-list or fast-track groups, prior to baseline measures. Patients randomised to the fast-track group commenced telerehabilitation 14 ± 7 days after randomisation. Patients randomised to the wait-list group commenced telerehabilitation 56 ± 7 days after randomisation.

Telerehabilitation programme

The telerehabilitation programme included twelve sessions of group exercises, with additional opportunities of education sessions and peer support. All sessions were delivered using a video conference platform (Cisco WebEx Meetings, Cisco Systems Inc, USA).

Exercise programme

Prior to the first exercise class, a virtual consultation was conducted to ensure accessibility and safety to exercise. Twice a week, for six weeks, participants completed a synchronised exercise

session in a group of 3-5 people, lasting 45-60 minutes. The exercise sessions were led by a physiotherapist and included a structured warm-up, guidance/demonstration and observations of exercises, consisting of cardiovascular, flexibility, strength-based movements, balance work and a cool down. Each session finished with a guided relaxation element. An additional member of the research team monitored the video conference platform. Participants received an individualised exercise programme and were advised to undertake exercise on up to 3 additional days each week.

Education sessions and peer support

Once a week, participants were invited to an education session on relevant topics, including; rehabilitation of Covid-19, principles of exercise, managing breathlessness, managing fatigue, return to work/social issues, and nutrition. Following each education session, the video platform remained open for questions and allowed time for participants to socialise with their peers.

Outcome measures

Outcome measures were recorded at three time points: baseline (prior to randomisation), pre-rehabilitation (on the first day of telerehabilitation) and post-rehabilitation (within 1 week of finishing telerehabilitation). The post-rehabilitation measurement in the fast-track group was designed to align with the pre-rehabilitation measurements in the wait-list group, creating a parallel group phase, acting as the natural recovery comparator (wait-list control).

Clinical outcomes

Exercise capacity

Exercise capacity was measured using the one-minute sit-to-stand test (12). In-short, participants were timed for 1 min and the number of sit-to-stand repetitions recorded.

Breathlessness

Respiratory symptoms were measured using the Medical Research Council dyspnoea scale (MRC) (13). Numerical Rating Scales (NRSs) (14) were used to investigate the following aspects of breathlessness during the past 24 hours: best breathlessness, worst breathlessness, distress caused by breathlessness and coping with breathlessness.

Cough

A 0-10 NRS was used for the assessment of cough 0 (no cough) to 10 (worst cough).

Quality of life

Quality of life was measured using the EuroQol 5D-5L and the EuroQual visual analogue scale (EQ-5D-VAS) (15). The EQ-5D-5L measures 5 dimensions of health (mobility, self-care, usual activities, pain/discomfort and anxiety/depression) using 5 levels; 1 (no problem) to 5 (extreme problems).

Fatigue

Fatigue was measured using the modified Functional Assessment of Chronic Illness Therapy: Fatigue (version 4) (16). The FACIT-F scale is a self-reported scale, where subjects respond to each item by choosing one of five options; 4 (not at all) to 0 (very much). Overall scores of the FACIT-F scale range from 0 to 52, with higher scores signifying less fatigue

Mood

The hospital anxiety and depression scale (HADS) (17) was used to calculate anxiety and depression scores.

Safety monitoring

The adverse events (AE) reporting period for this trial started at study enrolment and finished at the participant's final study visit.

Service evaluation questionnaire

Following the telerehabilitation programme, patients were asked to complete a service evaluation survey [Joint Information Systems Committee (JISC), Bristol, UK] covering programme content, satisfaction with therapy staff, and satisfaction with technology.

Data analysis

As this is a feasibility study, no formal power calculation was undertaken and outcome data were planned to be presented descriptively at each time point per-protocol. Due to rapid developments in the field and lack of available randomised controlled trial data, the trial management group agreed to undertake post-hoc statistical analysis as follows.

Data were tested for normality using the Shapiro-Wilk test. The majority of data were not normally distributed and therefore presented as Median (Q1-Q3), unless otherwise stated. Participant characteristics and outcome measures at baseline, pre-telerehabilitation and post-telerehabilitation are presented descriptively between groups; 'fast-track', 'wait-list' and all participants 'combined'. Differences between fast-track and wait-list group were assessed using a Paired Samples T-Test, Mann-Whitney U Test or Chi Square Test, as appropriate.

Natural recovery over the wait period in the wait-list group was analysed descriptively and underwent inferential analysis using Wilcoxon signed-rank tests. To explore the effect of telerehabilitation, outcome measures are presented descriptively at baseline, pre- and post-telerehabilitation. Inferential analysis was conducted within each group, between each time point, using Wilcoxon Signed Rank Tests (before and after analysis).

Data from potential primary outcomes (one-minute sit-to-stand, MRC, FACIT-F and EQ VAS) are presented graphically to visualise trajectories of change. To control for natural recovery, data were anchored to time, and change from baseline to pre-rehabilitation in the wait-list group were compared to change from baseline to post-rehabilitation in the fast-track group, visually using a dot plot and inferentially using Mann-Whitney U Tests and independent sample T-tests as appropriate. Where MCIDs were known, individual pre- to post-rehabilitation data are presented graphically using before after plots categorised in relation to MCIDs and differences explored inferentially using Mann-Whitney U Tests and independent sample T-tests as appropriate (Parallel Group Phase Analysis).

Significance was set at $P<0.05$. Data analysis was supported by JASP, JASP Team (2020), (Version 0.14) (Computer software).

Results

Feasibility outcomes

The contact (those receiving a participant information sheet) to consent ratio was 51% and the retention rate was 79% of participants that attended the pre-rehabilitation assessments and 68% from study consent; with 27 participants completing the study (Figure 1). There were no significant differences in any participant characteristics or baseline outcome measures between the participants that completed the study and those that withdrew.

Participant characteristics

The mean (SD) participant age was 58 (12) and more males (n=23) than females (n=17) were recruited to the study. Participants had a median (Q1-Q3) hospital stay of 8 (4-15) days and 48% of participants required high-level respiratory support during their inpatient care (Table 1). There were no significant differences in participant characteristics between the fast-track and wait-list group.

Intervention fidelity

Median (Q1-Q3) participation in the available exercise classes was 92 (83-100)%. Eleven participants had 100% attendance and all but one participant attended at least 50% of available classes. The overall attendance for the offered educational sessions was 86% (Table 2).

Impact of Telerehabilitation (Before and After Analysis)

Tables 1 and 3 show baseline, pre- and post-telerehabilitation outcome measures for all study participants. Statistical differences were noted in exercise capacity with improvements from 20 (14-24) sit-to-stand repetitions in one-minute at baseline to 25 (24-30) post-telerehabilitation, $P<0.001$. Dyspnoea rated using the MRC changed from 3.5 (3-4) at baseline to 2 (1.5-3) post-telerehabilitation, $P<0.001$, with several domains of the respiratory NRS also showing improvements (Distress, $P=0.007$ and Coping, $P=0.013$). Several domains of the EQ-5D-5L (Mobility, $P=0.026$, Self-care, $P=0.037$ ADL, $P=0.009$, EQ VAS, $P=0.017$), FACIT-F (General, $P=0.024$, Psychosocial, $P=0.029$, Overall, $P=0.012$) and HADS (Depression, $P=0.009$) questionnaires also showed significant improvements (Table 3).

Several outcome measures that showed statistical differences between the pre-rehabilitation and the post-rehabilitation assessments were explored on an individual level in relation to MCIDs (Figure 3). Exercise capacity increased from 20 (15- 23) sit-to-stand repetitions in one-minute pre-telerehabilitation to 25 (24-30) post-telerehabilitation (Table 3); with 21 (84%) participants, achieving an improvement beyond the MCID of 2.5 repetitions (Figure 3). Breathlessness rated using the MRC changed from 3 (2-4) to 2 (1.5-3) pre- to post-telerehabilitation, respectively (Table 3); with 16 (60%) participants showing a MCID of 1 AU, Figure 3.

Quality of life measured using the EQ-VAS improved from 55 (60-70) units at baseline to 70 (55-80) units following telerehabilitation, with 13 (48%) participants reporting improvements above the MCID of 8 units (18), Figure 3. Further, differences pre- to post-telerehabilitation were noted in the

distress domain of the NRS and psychosocial domain of the FACIT-T (Table 3). Assessment of quality of life (EQ-VAS) and fatigue (FACIT-F, overall domain) showed a significant improvement from baseline to post-rehabilitation in the combined group analysis and within the fast-track group, but not the wait-list group (Table 3, Figure 4).

Natural recovery (Wait-list group only)

The mean (SD) time between baseline and the pre-rehabilitation was 63 (5) days. A small and statistically significant improvement was seen in the MRC and the self-care domain of the EQ-5D-5L from baseline to pre-rehabilitation in the wait-list group (Table 3).

Effect of telerehabilitation beyond natural recovery (Parallel Group Phase Analysis)

Potential benefits beyond natural recovery were assessed by anchoring the changes between groups to time i.e., assessing the change from baseline to pre-rehabilitation in the wait-list group and the change from baseline to post-rehabilitation in the fast-track group (the parallel group phase of the trial).

The mean (SD) change in exercise capacity from baseline to post-rehabilitation in the fast-track group, 7.6 (5.2) sit-to-stand repetitions, was significantly greater than the change from baseline to the pre-rehabilitation assessment in the wait-list group, 1.9 (2.9) repetitions, (P=0.004) (Online Supplement Table, Figure 4). The change in the psychosocial domain of FACIT-F and the overall FACIT-F score from baseline to post-rehabilitation was greater in the Fast-Track group compared to the baseline to pre-rehabilitation change in the wait-list group (Online Supplement Table, Figure 4). The improvement in breathlessness (MRC) from baseline to post-telerehabilitation in the fast-track group, 1 (0-1.5), was numerically greater than the natural recovery seen at the same time point in the wait-list group 0.5 (0-1, p=0.506), however this difference did not reach statistical significance (Online Supplement Table, Figure 4).

Further, when examining the trajectories of change in the wait-list group, an inflection can be seen at the start of the telerehabilitation, supporting that telerehabilitation had an affect above that of natural recovery in exercise capacity, breathlessness, quality of life and fatigue (Figure 4).

Service evaluation

Twenty-two participants completed the service evaluation questionnaire (Table 4). All respondents indicated that that they believed that telerehabilitation helped them manage their recovery from Covid-19 and would recommend this programme to others. Open text responses indicate that the participant's perception of the most useful aspects of the telerehabilitation include; the exercise components (cardiovascular, flexibility and balance exercise), the opportunity to see and speak to other people that are recovering from Covid-19 and healthcare professionals, and the education sessions (Table 5, supplementary material).

Adverse events

Two serious adverse events were recorded during the study period. Both occurred prior to the pre-rehabilitation assessment and were deemed not related to the study protocol.

Discussion

To the best of our knowledge, this is the first study to explore the feasibility and efficacy of a remotely delivered, group-based, supervised, pulmonary rehabilitation programme for patients hospitalised with Covid-19. We have shown that group-based telerehabilitation is feasible, safe, beneficial and well-received in this population. Indeed, data show improvements from baseline to post-rehabilitation in: exercise capacity, respiratory symptoms, quality of life, fatigue and mental health. Improvements in well-being appear to be accelerated by telerehabilitation, with positive effects observed following telerehabilitation in the fast-track group exceeding the natural recovery

observed during the wait-list period by more than the MCID. These results will help to inform larger randomised control trials (RCT) of telerehabilitation post-COVID and, in the meantime, provide an additional degree of evidence underpinning clinical guidelines and policy.

The feasibility of group-based telerehabilitation for Covid-19 was assessed using recruitment rate, dropout numbers, intervention fidelity and monitoring of adverse events. Due to the method of recruitment, our study team were only able to collect reliable rates of recruitment from patients that required a high-level respiratory support. These data show that roughly 1 in 5 hospitalised Covid-19 patients were eligible and showed initial interest in the study and approximately half of these individuals consented to participate. The reason for non-participation, following initial interest, commonly included suitability of class timings; for logistical reasons, we were only able to offer one option for session timing for the participants in this study. These logistical issues could be minimised by economies of scale; a benefit of telerehabilitation is that geographical constraints no longer exist (19), and therefore national, rather than regional, telerehabilitation programmes could be envisaged.

The final cohort consisted of slightly more males than females, reflecting that men are more at risk of severe Covid-19 (20). However, post-Covid-19 syndrome appears more female dominant (20,21). Consent to completion rate was 68%, with all but one of the participants that completed telerehabilitation attending at least 50% of the exercise sessions. This intervention fidelity is higher than that commonly reported for in-person pulmonary rehabilitation for COPD (9). The observed recruitment and completion rates would fulfil recruitment requirements for an RCT and would translate into a high service demand.

Only two adverse events occurred during the course of our study and both were considered unrelated to the study protocol. Data from our feasibility trial suggests that telerehabilitation is a safe intervention in patients that have been hospitalised with Covid-19. The safety profile in our trial complements that from trials of in-person pulmonary rehabilitation (22-26) and unsupervised telerehabilitation (27,28), which have not identified a concern with rehabilitation in this population.

Rehabilitation may benefit anyone with a longer-term disabling illness, at any stage, and maybe delivered in a variety of settings (7). The improvements in exercise capacity and dyspnoea observed in our trial are in-line with improvements noted following in-patient (22-24) and outpatient (25,26) in-person pulmonary rehabilitation for Covid-19 survivors. In studies where rehabilitation is delivered remotely, the interventions have focused primarily on the exercise component of rehabilitation, and tend to neglect the education and psychosocial elements. Several studies have now demonstrated unsupervised telerehabilitation improved exercise capacity and dyspnoea (27,28). The novelty of the present study is that the pulmonary rehabilitation programme was delivered entirely remotely, but maintained the supervised group dynamics. We hypothesise that these aspects contributed to the additional favourable outcomes we noted in the psychosocial outcome measures. The importance of group dynamics during rehabilitation in psychosocial health outcomes have been previously identified (29,30) and mentioned by participants in the service evaluation questionnaire.

Participant feedback was overwhelmingly positive with regard to the programme content, satisfaction with staff and, albeit to a lesser extent, technology. Indeed, all participants indicated that that they believed telerehabilitation helped their recovery from Covid-19. The finding that participants would recommend this programme to others is a testament to the acceptability of the

telerehabilitation programme and strongly supports a wider role for telerehabilitation following Covid-19.

We acknowledge that individuals that were unwilling to participate in telerehabilitation or without access to appropriate digital technology would be ineligible for our study; therefore introducing selection bias. Indeed, digital health inequality is a major challenge when considering adoption of digital interventions in healthcare (31). A pragmatic suggestion may be that telerehabilitation could be conceived as an option in place of face-to-face rehabilitation, or vice versa, where appropriate. Indeed, a recent report from Healthwatch (32), suggests that post-Covid digital healthcare should maintain traditional models of care alongside remote methods.

This study has other limitations worthy of discussion. Firstly, the initial protocol (11) suggested that data analysis would be purely descriptive in nature. However, due to the developments in the field and lack of available randomised controlled trial data, the trial management group agreed to conduct inferential statistical analysis on all outcome measures. Given that the sample size is two-fold larger than that of a 8 week unsupervised pulmonary telerehabilitation programme, that showed positive improvements in exercise capacity and exercise-induced dyspnoea in patients recovering from Covid-19 (27), we would consider the study adequately powered. Nonetheless, without a pre-defined primary clinical outcome measure, the probability of type 1 errors should be considered. Longer term follow-up would also allow for assessment of any long-term health and/or behaviour changes resulting from telerehabilitation. Indeed, although positive improvements were seen in many health outcomes following telerehabilitation, these often remained below population-based reference values, e.g., exercise capacity (33).

In conclusion, we have shown that group-based pulmonary telerehabilitation is feasible, safe and well-received in patients that have been hospitalised with Covid-19. Further, we have identified physical and psychosocial benefits of telerehabilitation in this population, which could inform a larger multi-centre randomised controlled trial and, in the meantime, supports development of clinical guidance and policies relating to rehabilitation following Covid-19. The utility of telerehabilitation for delivery of a pulmonary rehabilitation service, which can radically increase service capacity whilst maintaining social distancing, may be essential in the national recovery from this widespread disease.

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Table 1. Participant characteristics and baseline measures

	Combined (n=40)	Wait-List (n=20)	Fast-Track (n=20)
Age in years, mean (SD)	58 (12)	61 (13)	55 (11)
Gender, n (%)			
Male	23 (58)	11 (55)	12 (60)
Female	17 (43)	9 (45)	8 (40)
Days in hospital	8 (4-15)	7 (3-14)	8 (4-15)
Respiratory support, n (%)			
CPAP	3 (8)	0 (0)	3 (15)
High flow oxygen	8 (20)	3 (15)	5 (25)
Intubation / ventilation	8 (20)	5 (25)	3 (15)
Oxygen	18 (45)	10 (50)	8 (40)
No support	3 (8)	2 (10)	1 (5)
MRC Dyspnoea Scale	3.5 (3-4)	4 (3-4)	3 (2-4)
Breathlessness NRSs			
Best in last 24 hours	1.5 (0-3)	1 (0-3)	1.5 (0-3)
Worst in last 24 hours	6 (4-7)	6 (3.75-7.25)	6 (4-7)
Distress caused	3 (1.75-7)	4 (2-7)	3 (0-4.25)
Coping	3 (1.5-5.5)	5 (2.5-7)	2 (1.5-4)
Cough NRS	2 (1-5)	2 (0.75-3)	3.5 (1-6)
EQ-5D-5L			
Mobility	3 (2-4)	3 (2-4)	3 (2-3)
Self-Care	2 (1-3)	2 (1-3)	1.5 (1-2.25)
Usual activities	3 (2-3.25)	3 (2-3)	2.5 (2-4)
Pain/discomfort	2 (1-3)	2 (1-3)	2 (1.75-3)
Anxiety/depression	2 (1-3)	2 (2-3)	2 (1-3.25)
EQ (VAS)	60 (40-71.25)	57.5 (47.5-71.25)	60 (40-71.25)
FACIT-F			
General	11 (5-13)	11 (6-12.25)	11 (3.75-14)
Function	2.5 (2-4)	3 (2-4)	2 (1.75-4)
Psychosocial	3 (1.75-5)	2.5 (2-4)	4 (0-6.5)
Overall	16.5 (9-20)	16 (9.75-20)	17 (8-22)
HADS			
Anxiety	7.5 (4-13)	7.5 (4-12)	8.5 (4.75-13.25)
Depression	8 (5-10)	7.5 (5.75-10)	8.5 (5-10.25)
One-minute Sit-to-stand	20 (14-24)	20 (14.75-23.25)	20 (14-24.25)

Data are Median (Q1-Q3), unless otherwise stated. CPAP, continuous positive airway pressure; MRC, Medical Research Council dyspnoea scale; NRS, Numerical Rating Scale; VAS, Visual Analogue Scale; FACIT-F, modified Functional Assessment of Chronic Illness Therapy Fatigue; HADS, Hospital Anxiety and Depression Scale.

Table 2. Attendance at educational events in 27 participants that completed 6 weeks telerehabilitation for the recovery from Covid-19.

Education session	n (%)
Rehabilitation of Covid-19	
Attended	21 (78)
Did not attend	6 (22)
Principles of exercise	
Attended	24 (89)
Did not attend	3 (11)
Managing breathlessness	
Attended	26 (96)
Did not attend	1 (4)
Managing fatigue	
Attended	25 (93)
Did not attend	2 (7)
Return to work / occupational health	
Attended	9 (33)
Did not attend	1 (4)
Not applicable / was not offered	17 (63)
Nutrition	
Attended	20 (74)
Did not attend	7 (26)

Table 3. Outcome measures pre- and post-telerehabilitation

	Combined		Wait-List		Fast-Track	
Outcome measure	**Pre-rehabilitation (n=34)**	**Post-rehabilitation (n=27)**	**Pre-rehabilitation (n=15)**	**Post-rehabilitation (n=12)**	**Pre-rehabilitation (n=19)**	**Post-rehabilitation (n=15)**
MRC	3 (2-4)*	2 (1.5-3)$^{***,\#}$	3 (2-3.5)*	2 (1-3)$^{*,\#}$	3 (2-4)	2 (2-3)*
Breathlessness NRS						
Best in 24 h	2 (0-4.75)	3 (1-3)	2 (0-4.5)	2.5 (1-3.25)	2 (0-4.5)	3 (0.5-3)
Worst in 24 h	6 (5-7)	5 (4-7)	6 (3.5-7)	7 (4-7)	6 (5-7)	5 (3.5-7)
Distress	2 (0-5)	0 (0-1.5)$^{**,\#\#}$	2 (0-4)	0 (0-1.5)*	3 (0-5.5)	0 (0-1.5)
Coping	2 (0-4.75)	1 (0-3)*	3 (0-5)	1.5 (0-3)*	2 (0-3.5)	1 (0-3.5)
Cough NRS	2 (0.25-5.75	2 (1-3.5)	1 (0-2)	2.5 (1-3.25)	4 (1-6)	1 (0-4)**
EQ-5D-5L						
Mobility	3 (2-3)*	2 (1.5-3)*	3 (2-3)	3 (1-4)	3 (2-3)	2 (2-2.5)*
Self-Care	1 (1-2)**	1 (1-2)*	1 (1-2)*	1.5 (1-2)	1 (1-2)	1 (1-2)
Usual activities	3 (2-3)	2 (2-3)**	3 (2-3)	2 (1-3)	3 (2-3)	2 (2-3)
Pain/discomfort	2 (2-3)	2 (1-3)	3 (2-3)	2 (1-3)	2 (1.5-2.5)	2 (1.5-3)
Anxiety/depression	2 (1-3)	1 (1-3)	2 (1-3)	2 (1-2.25)	2 (1-3)	2 (1-3)
EQ (VAS)	65 (60-70)	70 (55-80)$^{*,\#}$	65 (60-75)	68 (57.5-80)	65 (50-70)	70 (55-85)*
FACIT-F						
General	11.5 (7.25-14.75)	14 (10-15.5)*	10 (6.5-13)	11.5 (11-15)	12 (7.5-16)*	15 (9.5-16)*
Function	3 (2-4.75)	3 (2-4)	4 (1.5-5)	3 (2-4)	3 (2-4)	4 (2-4.5)
Psychosocial	3 (1-5)	4 (3-6.5)$^{*,\#}$	2 (0.5-5)	4 (3-5.25)	4 (2-5)	5 (2-7.5)
Overall	15.5 (11-24)	19 (15-27)*	15 (9.5-23)	18.5 (16.5-23.25)	16 (12-24.5)	22 (14.5-28)*
HADS						
Anxiety	7 (3.25-9.75)**	6 (2-11)	7 (3.5-9)	6 (2-9.5)	7 (4-9.5)**	8 (3-12.5)
Depression	8 (3.5-10.75)	6 (3-10)**	5 (2.5-9)	5 (3-9.25)*	8 (5-11)	6 (4-10.5)
One-minute Sit-to-stand	20 (15-23)	25 (24-30)$^{***,\#\#\#}$	20 (18-23)	26 (23-30)$^{**,\#\#}$	17 (14-25)	25 (24-29)$^{***,\#\#}$

Data are Median (Q1-Q3), unless otherwise stated. MRC, Medical Research Council dyspnoea scale; NRS, Numerical Rating Scale; VAS, Visual Analogue Scale; FACIT-F, modified Functional Assessment of Chronic Illness Therapy Fatigue; HADS, Hospital Anxiety and Depression Scale; *, different to baseline, $^{\#}$, different to pre-rehabilitation. *,$^{\#}$ P<0.05, **,$^{\#\#}$ P<0.01, ***,$^{\#\#\#}$ P<0.001.

Table 4. Summary responses from the service evaluation questionnaire

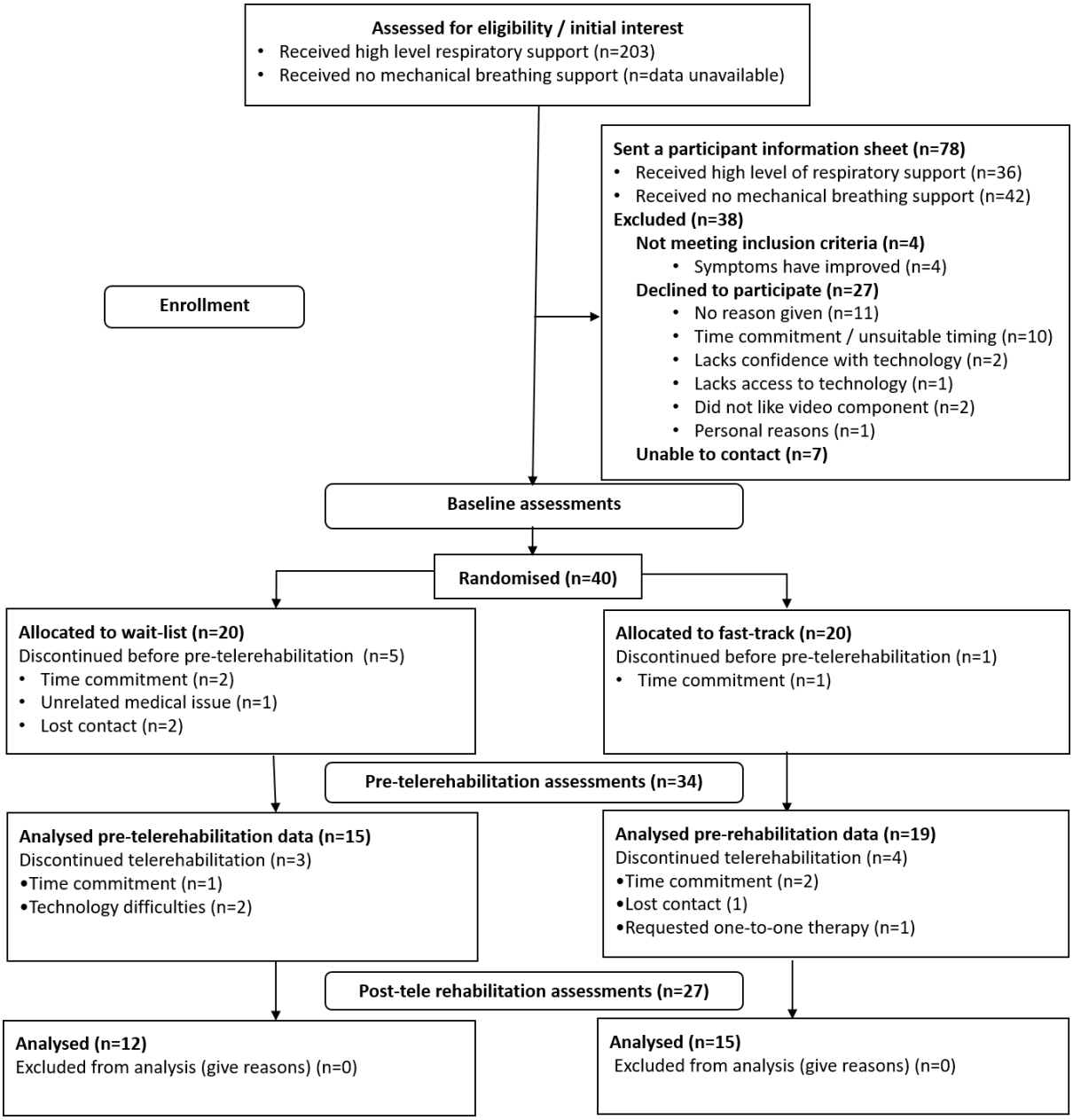
	Agree	Neutral	Disagree
Programme content			
The programme has helped me manage my recovery after COVID-19 more effectively	22 (100)	-	-
The information in the education sessions (the topics, amount and level of detail) was just right for me	19 (86)	3 (14)	-
The exercises were set at the right level for me	19 (86)	2 (9)	1 (5)
I was able to progress the exercises when I felt I was ready	22 (100)	-	-
The home programme was realistic and achievable	22 (100)	-	-
The home programme was tailored to my needs	20 (91)	2 (9)	-
The programme met my expectations	22 (100)	-	-
I now feel more confident to undertake physical activities	18 (82)	3 (14)	1 (5)
The programme was a good use of my time	22 (100)	-	-
The times of my classes suited me	21 (96)	1 (5)	-
The length of the classes was too long	1 (5)	4 (18)	17 (77)
I felt encouraged by the other group members	18 (82)	4 (18)	-
I was satisfied with the length of time between my discharge from hospital and starting the programme	8 (36)	7 (32)	7 (32)
I would recommend this programme to others recovering from COVID-19	22 (100)	-	-
Satisfaction with therapy staff			
The therapists explained the exercises clearly	22 (100)	-	-
The therapists answered all of my questions	22 (100)	-	-
The therapists treated me with respect	22 (100)	-	-
The therapists did not spend enough time with me	1 (5)	-	21 (96)
The therapists did not listen to my concerns	2 (9)	-	20 (81)
The therapists were professional	22 (100)	-	-
The therapists were caring and friendly	22 (100)	-	-
The therapists did what they could to protect my privacy	21 (96)	1 (5)	-
The therapists were helpful when there were problems with the technology	21 (96)	1 (5)	-
The therapists advised me on ways to avoid future problems	21 (96)	1 (5)	-
I felt that everything possible had been done to ensure my safety whilst I was exercising	22 (100)	-	-
Satisfaction with the technology			
I found it easy to get onto the website	21 (96)	5 (5)	-
I had problems with the website freezing	4 (18)	4 (18)	14 (64)
I was able to hear what the therapists were telling me most of the time	20 (91)	2 (9)	-
I was able to see the therapists clearly	20 (91)	2 (9)	-
I would have received better quality care if I had attended a group exercise session at the hospital	3 (14)	3 (14)	16 (72)
I felt confident in using the video technology -	20 (91)	1 (5)	1 (5)
I would have preferred a one to one video consultation rather than being in a group	1 (5)	5 (23)	16 (73)
I was able to get the therapist's attention if I had a question	22 (100)	-	-
Receiving telerehabilitation in my home was as good as seeing a physiotherapist in the hospital	16 (73)	5 (23)	1 (5)
The video classes started on time	20 (91)	2 (9)	-
I would be happy to receive live physiotherapy advice over the internet again	22 (100)	-	-

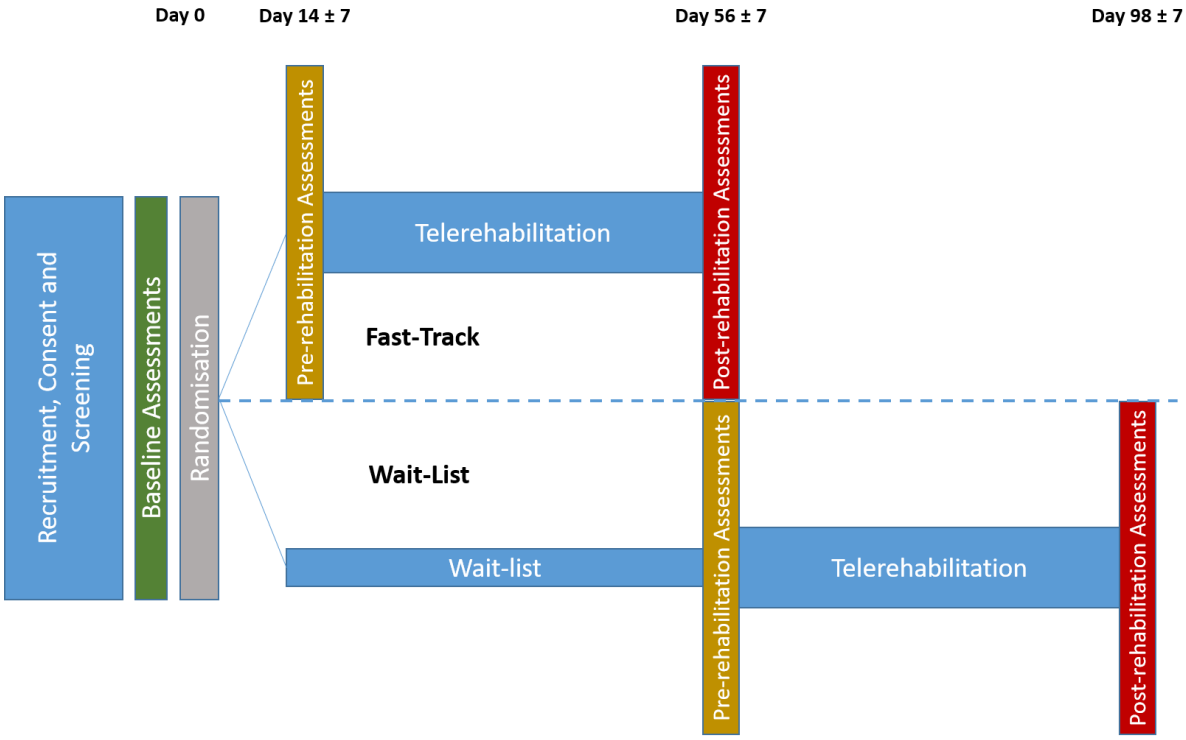
Figure 1. Consort flow diagram of the randomised, wait-list, controlled study.

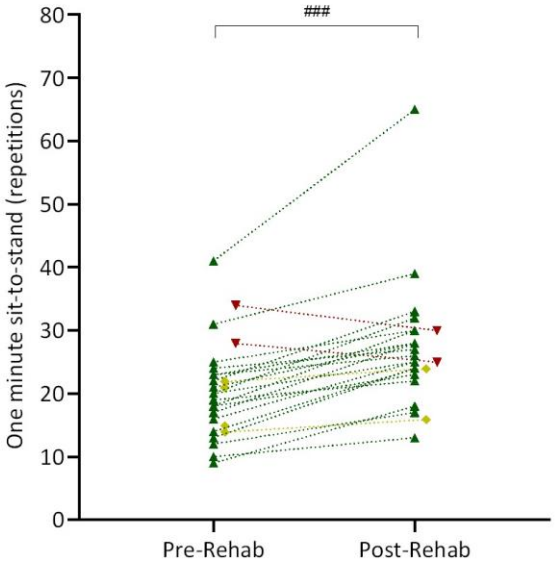
Figure 2. Trial design and timing of trial assessments for the fast-track (wait-list), randomised, mixed-methods, feasibility trial of telerehabilitation for patients who have been hospitalised with Covid-19.

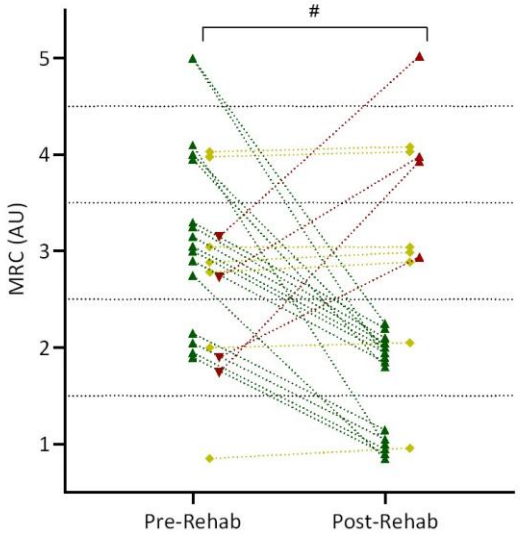
Figure 3. Change from the pre-rehabilitation assessment (Pre-Rehab) to the post-rehabilitation assessment (Post-Rehab) in one-minute sit-to-stand repetitions (Top), Breathlessness (MRC) (Middle) and Quality of Life (EQ VAS) (Bottom), in patients hospitalised with Covid-19. Green triangles indicate improvements beyond the minimal clinical important difference (MCID); amber diamonds indicate no MCID and red triangles indicate negative MCID changes.

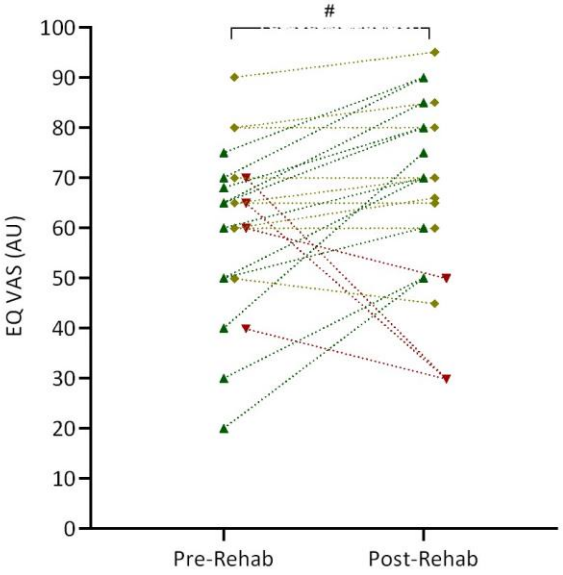
Figure 4. Panels A-D demonstrate temporally aligned outcome assessments at baseline, post-rehabilitation (fast-track) / pre-rehabilitation (wait-list), and post-rehabilitation (wait-list). Panels E-H demonstrate median (95% CI) and individual changes from baseline to post-rehabilitation (fast-track) and pre-rehabilitation (wait-list). Panels A and E: one-minute sit-to-stand repetitions, Panels B and F: Breathlessness (MRC), Panels C and G: Fatigue FACIT-F, and Panels D and H: Quality of Life (EQ-VAS), Open diamonds indicate wait-list group and closed triangles indicate fast-track group. Dotted line indicates MCID from baseline. *, different to baseline, #, different to pre-rehabilitation. $ different between Wait-List and Fast Track. * $P<0.05$, ** $P<0.01$, *** $P<0.001$.

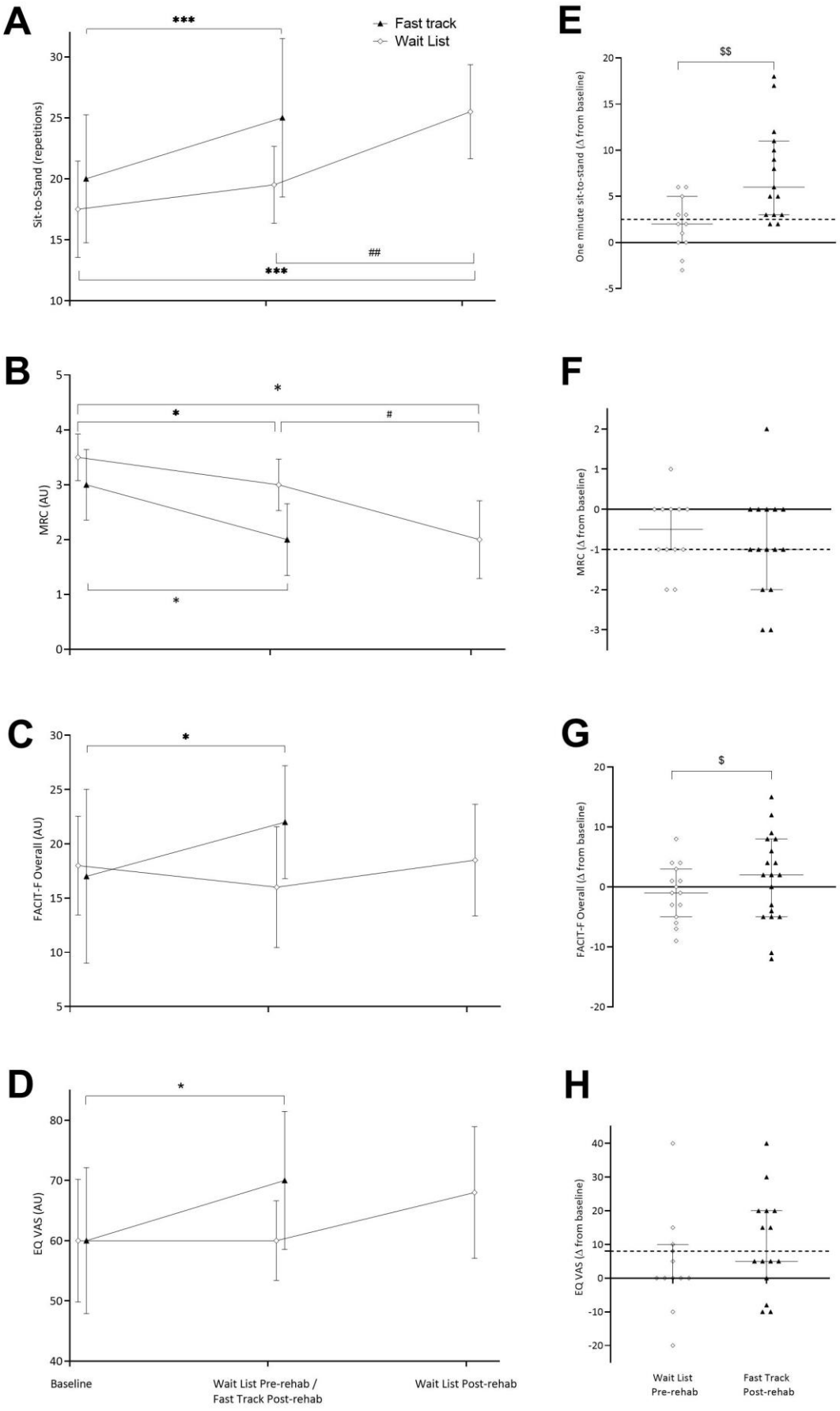

Assessed for eligibility / initial interest
• Received high level respiratory support (n=203)
• Received no mechanical breathing support (n=data unavailable)
Enrollment
Sent a participant information sheet (n=78)
• Received high level of respiratory support (n=36)
• Received no mechanical breathing support (n=42)
Excluded (n=38)
Not meeting inclusion criteria (n=4)
• Symptoms have improved (n=4)
Declined to participate (n=27)
• No reason given (n=11)
• Time commitment / unsuitable timing (n=10)
• Lacks confidence with technology (n=2)
• Lacks access to technology (n=1)
• Did not like video component (n=2)
• Personal reasons (n=1)
Unable to contact (n=7)
Baseline assessments
Randomised (n=40)
Allocated to wait-list (n=20)
Discontinued before pre-telerehabilitation (n=5)
• Time commitment (n=2)
• Unrelated medical issue (n=1)
• Lost contact (n=2)
Allocated to fast-track (n=20)
Discontinued before pre-telerehabilitation (n=1)
• Time commitment (n=1)
Pre-telerehabilitation assessments (n=34)
Analysed pre-telerehabilitation data (n=15)
Discontinued telerehabilitation (n=3)
•Time commitment (n=1)
•Technology difficulties (n=2)
Analysed pre-rehabilitation data (n=19)
Discontinued telerehabilitation (n=4)
•Time commitment (n=2)
•Lost contact (1)
•Requested one-to-one therapy (n=1)
Post-tele rehabilitation assessments (n=27)
Analysed (n=12)
Excluded from analysis (give reasons) (n=0)
Analysed (n=15)
Excluded from analysis (give reasons) (n=0)


Day 0
Day 14 ± 7
Day 56 ± 7
Day 98 ± 7
Recruitment, Consent and Screening
Baseline Assessments
Randomisation
Pre-rehabilitation Assessments
Telerehabilitation
Post-rehabilitation Assessments
Fast-Track
Wait-List
Wait-list
Pre-rehabilitation Assessments
Telerehabilitation
Post-rehabilitation Assessments


###
One minute sit-to-stand (repetitions)
80
70
60
50
40
30
20
10
0
Pre-Rehab
Post-Rehab


#
MRC (AU)
5
4
3
2
1
Pre-Rehab
Post-Rehab


#
EQ VAS (AU)
100
90
80
70
60
50
40
30
20
10
0
Pre-Rehab
Post-Rehab


A
Fast track
Wait List
Sit-to-Stand (repetitions)
***
##
***
E
One minute sit-to-stand (Δ from baseline)
$$
B
MRC (AU)
*
*
#
*
F
MRC (Δ from baseline)
C
FACIT-F Overall (AU)
*
G
FACIT-F Overall (Δ from baseline)
$
D
EQ VAS (AU)
*
H
EQ VAS (Δ from baseline)
Baseline
Wait List Pre-rehab / Fast Track Post-rehab
Wait List Post-rehab
Wait List Pre-rehab
Fast Track Post-rehab

Supplementary Data

Table 5. Summary of open text responses from the service evaluation questionnaire

Free Text Questions	Free text response themes
Was there anything you would have liked to be included?	Nothing More education on persistent breathlessness Forum for partners to ask questions Follow-up review Advice / directions for continuing exercises
What were the most useful aspects of the programme?	Seeing and speaking to other people recovering from Covid-19 (shared experience) Cardiovascular work to improved fitness Stretching / balance to improve flexibility Encouragement and confidence to exercise Speaking to health care professionals Reassurance in recovery from Covid-19 Educational sessions Breathing advice
How has the programme changed the way you manage your recovery after COVID-19 (if at all)?	It hasn't Knowledge of how to exercise Knowledge of Covid-19 and how to manage the disease Tolerant / knowledge of the pace of recovery Encouragement / motivation / confidence / less fearful to exercise More positive mind set Improvements health
Are there any specific comments or feedback you would like to give regarding the online video platform?	Satisfied Easy to connect Sound problems / freezing screens on occasion Missed a few sessions with technology problems

Online Supplement Table. Change in outcome measures: Baseline to Pre-rehabilitation, Baseline to Post-rehabilitation and Pre-rehabilitation to Post-rehabilitation

	Combined (n=27)			Wait-list (n=12)			Fast-Track (n=15)		
Outcome measure	**Δ Baseline – Pre-rehabilitation**	**Δ Baseline – Post-rehabilitation**	**Δ Pre-rehabilitation – Post-rehabilitation**	**Δ Baseline – Pre-rehabilitation**	**Δ Baseline – Post-rehabilitation**	**Δ Pre-rehabilitation – Post-rehabilitation**	**Δ Baseline – Pre-rehabilitation**	**Δ Baseline – Post-rehabilitation**	**Δ Pre-rehabilitation – Post-rehabilitation**
MRC	0 (-1-0)	-1(-2-0)	-1(-1-0)	-0.5 (-1-0)	-2(-2-0)	-1(-1.25-0)	0 (-1-0)	-1(-1.5-0)	-1(-1-0)
Breathlessness NRS									
Best in 24 h	0.6 (2)	0.5 (1.5)	-0.1 (1.9)	0.6 (2.2)	1.2 (1)	0.6 (1.8)	0.5 (1.9)	-0.1 (1.5)[&]	-0.6 (1.8)
Worst in 24 h	-0.3 (2.1)	-0.1 (2.1)	0.3 (1.7)	-0.5 (2.9)	0.5 (2.4)	1 (1.7)	-0.2 (1.3)	-0.5 (1.8)	1 (1.7)[&]
Distress	-0.9 (3.7)	-2.3 (3.8)	-1.4 (2.7)	-2 (3.6)	-3.2 (4.1)	-1.7 (2)	0 (3.7)	-1.7 (3.7)	-1.7 (3.1)
Coping	-1.1 (2.8)	-1.5 (2.8)	-0.4 (1.8)	-2.3 (3.6)	-2.8 (3.3)	-0.4 (0.9)	-0.2 (1.7)[&]	-0.5 (2)[&]	-0.3 (2.3)
Cough VAS	-1 (-1-0)	0 (-1.5-0.5)	0 (-1-1)	0 (-1-0)	0.5 (-0.3-2)	0 (0-1.3)	-1 (-1-0.5)	-1 (-2-0)[&]	-1 (-2-0.5)
EQ-5D-5L									
Mobility	0 (-1-0)	0 (-1-0)	0 (-1-0)	0 (-1-0)	0 (-1-0)	0 (-0.3-0.3)	0 (-0.5-0)	0 (-1-0)	0 (-1-0)
Self-care	0 (-1-0)	0 (-1-0)	0 (0-0)	0 (-1-0)	0 (-1-0)	0 (-0.3-0)	0 (-1-0)	0 (-1-0)	0 (0-0)
Usual activities	0 (-1-0.5)	0 (-1-0)	0 (-1-0)	-0.5 (-1-0.3)	-1 (-1-0)	-0.5 (-1-0.3)	0 (-1-0)	0 (-1-0)	0 (-1-0)
Pain / discomfort	0 (0-0)	0 (-1-0)	0 (0-0)	0 (0-0.3)	0 (-1-0.3)	0 (-0.3-0)	0 (-0.5-0)	0 (-1-0)	0 (0-0)
Anxiety/depression	0 (-0.5-1)	0 (-0.5-0.5)	0 (-1-0.5)	0 (0-1)	0 (-1-0.3)	-0.5 (-1-0.3)	0 (-1-0.5)	0 (0-0.5)	0 (0-0.5)
EQ (VAS)	0 (-5-10)	5 (0-20)	6 (0-20)	0 (0-8.5)	5.5 (-1.3-16.3)	2.5 (-1.3-10.5)	0 (-17.5-10)	5 (2.5-20)	20 (2.5-20)
FACIT-F									
General	1.3 (3.8)	1.9 (4.2)	0.6 (4.4)	0. 3 (3.4)	0.7 (3.7)	0.3 (5.2)	2.1 (4)	2.8 (4.4)	0.7 (3.9)
Function	0.2 (1.9)	0.5 (1.6)	0.3 (2)	0.3 (2.5)	0 (1.5)	0.1 (2.4)	0.1 (1.3)	0.7 (1.8)	0.5 (1.7)
Psychosocial	-0.1 (1.7)	0.8 (1.8)	1 (1.9)	-0.6 (1.3)	0.5 (1.6)	1.1 (1.8)	0.2 (2)	1.1 (1.9)[$]	0.9 (2.0)
Overall	1.1 (5.4)	3.2 (5.8)	2.1 (6.1)	-0.6 (4.9)	1.6 (5.1)	2.2 (6.7)	2.4 (5.5)	4.5 (6.1)[$]	2.1 (5.9)
HADS									
Anxiety	-1.2 (2.3)	-0.9 (2.3)	0.3 (3.1)	-0.75 (1.9)	-0.8 (2.5)	-0.1 (1.6)	-1.5 (2.6)	-0.9 (2.4)	0.6 (3.9)
Depression	-0.6 (2.7)	-1.5 (2.6)	-1 (3.1)	-1 (2.3)	-1.8 (1.8)	-0.8 (1.7)	-0.2 (3)	-1.3 (3.2)	-1.1 (4)
One-minute Sit-to-stand	1.4 (3.5)	8.2 (4.7)	6.7 (5.7)	1.9 (2.9)	9 (3.8)	6.8 (3.5)	0.9 (4)	7.6 (5.2[)$$]	6.7 (.9)

Data are Median (Q1-Q3) or Mean (SD); Δ, Change; MRC, Medical Research Council dyspnoea scale; NRS, Numerical Rating Scale; VAS, Visual Analogue Scale; FACIT-F, modified Functional Assessment of Chronic Illness Therapy Fatigue; HADS, Hospital Anxiety and Depression Scale; [&], different to wait-list, [$], Fast-Track Δ Baseline – Post-rehabilitation different Wait-List Baseline to Δ Baseline – Pre-rehabilitation. [&,$] P<0.05, [$$,] P<0.01.