



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

Andrew J. Simpson ¹, Angela Green ², Marion Nettleton², Lucy Hyde¹, Joanne Shepherdson², Clare Killingback ¹, Phil Marshall¹ and Michael G. Crooks^{2,3}

¹School of Sport, Exercise and Rehabilitation Sciences, University of Hull, Hull, UK. ²Hull University Teaching Hospitals National Health Service Trust, Hull, UK. ³Hull York Medical School, University of Hull, Hull, UK.

Corresponding author: Andrew Simpson (a.simpson2@hull.ac.uk)



Shareable abstract (@ERSpublications)

This study shows that group-based pulmonary telerehabilitation is feasible, safe and well-received in patients who have been hospitalised with COVID-19 <https://bit.ly/3GyT9t9>

Cite this article as: Simpson AJ, Green A, Nettleton M, *et al.* Group-based pulmonary telerehabilitation is feasible, safe, beneficial and well-received in patients who have been hospitalised with COVID-19. *ERJ Open Res* 2023; 9: 00373-2022 [DOI: 10.1183/23120541.00373-2022].

Copyright ©The authors 2023

This version is distributed under the terms of the Creative Commons Attribution Non-Commercial Licence 4.0. For commercial reproduction rights and permissions contact permissions@ersnet.org

Received: 26 July 2022
Accepted: 9 Nov 2022

Abstract

Introduction Coronavirus disease 2019 (COVID-19) has caused worldwide mass hospitalisation. The need for multidisciplinary 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 This was a single-centre, mixed-methods, fast-track (wait-list), randomised controlled trial of telerehabilitation for patients who had been hospitalised with COVID-19. 40 patients discharged from two university teaching hospitals in the north of England were recruited. Telerehabilitation consisted of 12 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 in several clinical outcome measures. Exercise capacity increased from a median (interquartile range) 20 (14–24) sit-to-stand repetitions in 1 min at baseline to 25 (24–30) post-telerehabilitation. Breathlessness rated using the Medical Research Council dyspnoea scale 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 EuroQol VAS improved from 55 (60–70) units at baseline to 70 (55–80) units following telerehabilitation. Improvements in fatigue (modified Functional Assessment of Chronic Illness Therapy: Fatigue) and mood (Hospital Anxiety and Depression Scale – Depression) 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.

Introduction

Coronavirus disease 2019 (COVID-19), caused by the novel severe acute respiratory syndrome coronavirus-2, has caused worldwide mass hospitalisation with ~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 ongoing symptoms, including fatigue, dyspnoea, joint pain, chest pain and cough [2]. The need for multidisciplinary post-hospitalisation rehabilitation for COVID-19 is becoming increasingly apparent [3].



The British Society of Rehabilitation Medicine [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: 1) exercise training; 2) education, including self-management; and 3) 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 Organization, 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 COPD [9]. However, there is currently very limited evidence with regards to the feasibility and efficacy of pulmonary rehabilitation for COVID-19. While 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 (RCT) of telerehabilitation in patients who had 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 hypothesised that improvements would be noted following telerehabilitation in exercise capacity, breathlessness, quality of life, fatigue and mood and that these improvements would exceed those 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 1. The trial commenced in August 2020 and was completed in August 2021.

Governance

Health Research Authority and National Health Service (NHS) research ethics committee approval was obtained (reference number: 20/IEC08/0017) and the trial registered with clinicaltrials.gov (identifier 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 who received high-level respiratory support (*i.e.* continuous positive airway pressure, high-flow oxygen or intubation) during their inpatient care were contacted 4–6 weeks post-discharge as part of routine clinical care. Hospitalised patients who 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, London, UK) to the 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 12 sessions of group exercises, with additional opportunities for education sessions and peer support. All sessions were delivered using a video conference platform (Cisco WebEx Meetings; Cisco Systems, San Jose, CA, 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 6 weeks, participants completed a synchronised exercise session in a group of between three and five people, lasting 45–60 min. The exercise sessions were led by a physiotherapist and included a structured warm-up, guidance/demonstration and observations of exercises, consisting of

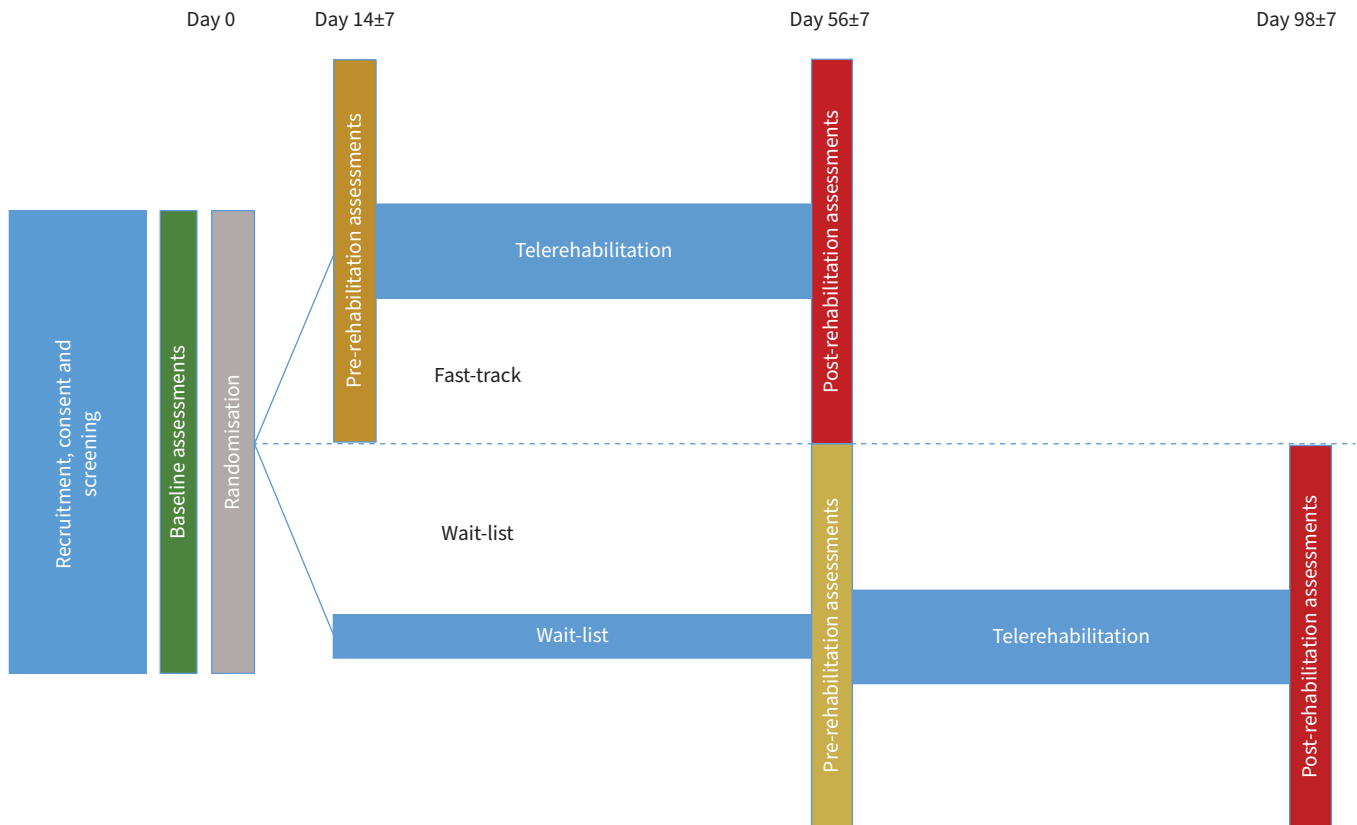


FIGURE 1 Trial design and timing of trial assessments for the fast-track (wait-list), randomised, mixed-methods, feasibility trial of telerehabilitation for patients who had been hospitalised with coronavirus disease 2019.

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 three 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 1-min 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 (MRC) dyspnoea scale [13]. Numerical Rating Scales (NRSs) [14] were used to investigate the following aspects of breathlessness

during the past 24 h: 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 EuroQol visual analogue scale (EQ-VAS) [15]. The EQ-5D-5L measures five dimensions of health (mobility, self-care, usual activities, pain/discomfort and anxiety/depression) using five levels: 1 (no problem) to 5 (extreme problems).

Fatigue

Fatigue was measured using the modified Functional Assessment of Chronic Illness Therapy – Fatigue (FACIT-F; 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 reporting period for this trial started at study enrolment and finished at the participants' final study visits.

Service evaluation questionnaire

Following the telerehabilitation programme, patients were asked to complete a service evaluation survey (Joint Information Systems Committee, 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 RCT 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 (interquartile range (IQR)), 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 groups were assessed using a paired samples t-test, Mann–Whitney U-test or Chi-squared 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 (1-min 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 minimal clinically important differences (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 (version 0.14; <https://jasp-stats.org/>).

Results

Feasibility outcomes

The contact (those receiving a participant information sheet)-to-consent ratio was 51%, and the retention rate was 79% of participants who attended the pre-rehabilitation assessments and 68% from study consent,

with 27 participants completing the study (figure 2). There were no significant differences in any participant characteristics or baseline outcome measures between the participants who completed the study and those who withdrew.

Participant characteristics

The mean \pm SD participant age was 58 \pm 12 years, and more males (n=23) than females (n=17) were recruited to the study. Participants had a median (IQR) 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 groups.

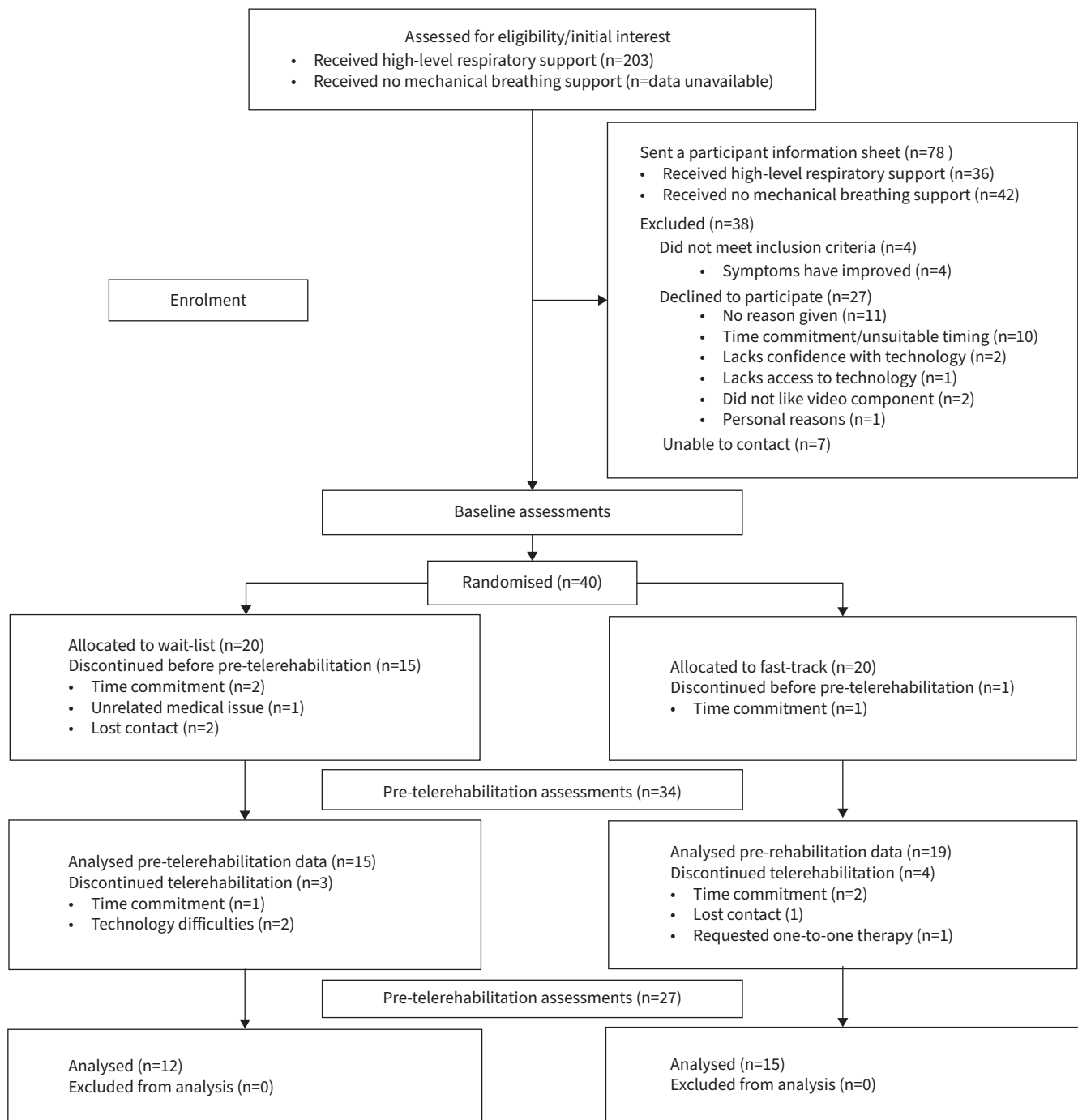


FIGURE 2 Consort flow diagram of the randomised, wait-list, controlled study.

TABLE 1 Participant characteristics and baseline measures

	Combined	Wait-list	Fast-track
Participants	40	20	20
Age, years	58±12	61±13	55±11
Gender			
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			
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 past 24 h	1.5 (0–3)	1 (0–3)	1.5 (0–3)
Worst in past 24 h	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)
1-min sit-to-stand	20 (14–24)	20 (14.75–23.25)	20 (14–24.25)

Data are presented as n, mean±sd, n (%) or median (interquartile range). CPAP: continuous positive airway pressure; MRC: Medical Research Council; NRS: numerical rating scale; VAS: visual analogue scale; FACIT-F: modified Functional Assessment of Chronic Illness Therapy – Fatigue; HADS: Hospital Anxiety and Depression Scale.

Intervention fidelity

Median (IQR) participation in the available exercise classes was 92% (83–100%). 11 participants had 100% attendance, and all but one participant attended $\geq 50\%$ 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 1 min at baseline to 25 (24–30) post-telerehabilitation ($p < 0.001$). Dyspnoea rated using the MRC scale 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 $p = 0.007$, coping $p = 0.013$). Several domains of the EQ-5D-5L (mobility $p = 0.026$, self-care $p = 0.037$, activities of daily living $p = 0.009$, 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 1 min pre-telerehabilitation to 25 (24–30)

TABLE 2 Attendance at educational events in 27 participants who completed 6 weeks of telerehabilitation for recovery from coronavirus disease 2019 (COVID-19)

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)
Data are presented as n (%).	

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).

TABLE 3 Outcome measures pre- and post-telerehabilitation

	Combined		Wait-list		Fast-track	
	Pre-rehabilitation	Post-rehabilitation	Pre-rehabilitation	Post-rehabilitation	Pre-rehabilitation	Post-rehabilitation
Participants	34	27	15	12	19	15
MRC dyspnoea scale	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)
1-min sit-to-stand	20 (15–23)	25 (24–30)***,###	20 (18–23)	26 (23–30)**,##	17 (14–25)	25 (24–29)***,##

Data are presented as n or median (interquartile range). MRC: Medical Research Council; NRS: numerical rating scale; VAS: visual analogue scale; FACIT-F: modified Functional Assessment of Chronic Illness Therapy – Fatigue; HADS: Hospital Anxiety and Depression Scale. *: p<0.05, **: p<0.01, ***: p<0.001 (versus baseline); #: p<0.05, ##: p<0.01, ###: p<0.001 (versus pre-rehabilitation).

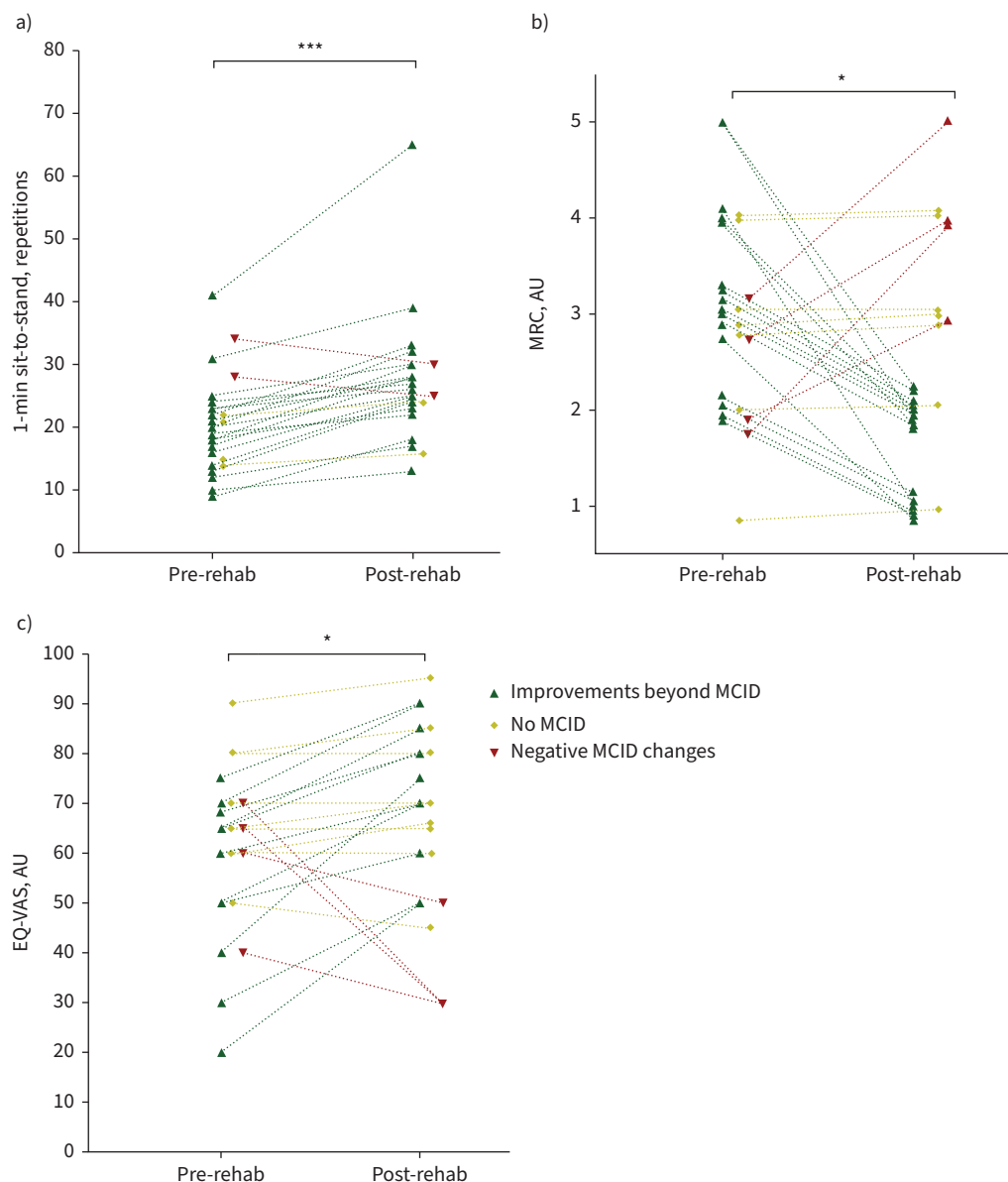


FIGURE 3 Change from the pre-rehabilitation (pre-rehab) assessment to the post-rehabilitation (post-rehab) assessment in **a)** 1-min sit-to-stand repetitions, **b)** breathlessness (Medical Research Council (MRC) dyspnoea scale and **c)** quality of life (EuroQol visual analogue scale (EQ-VAS), in patients hospitalised with coronavirus disease 2019. MCID: minimal clinically important difference. *: $p < 0.05$, ***: $p < 0.001$.

Quality of life measured using the EQ-VAS improved from 55 (60–70) at baseline to 70 (55–80) following telerehabilitation, with 13 (48%) participants reporting improvements above the MCID of 8 AU [18] (figure 3). Furthermore, 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 \pm SD time between baseline and the pre-rehabilitation was 63 \pm 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).

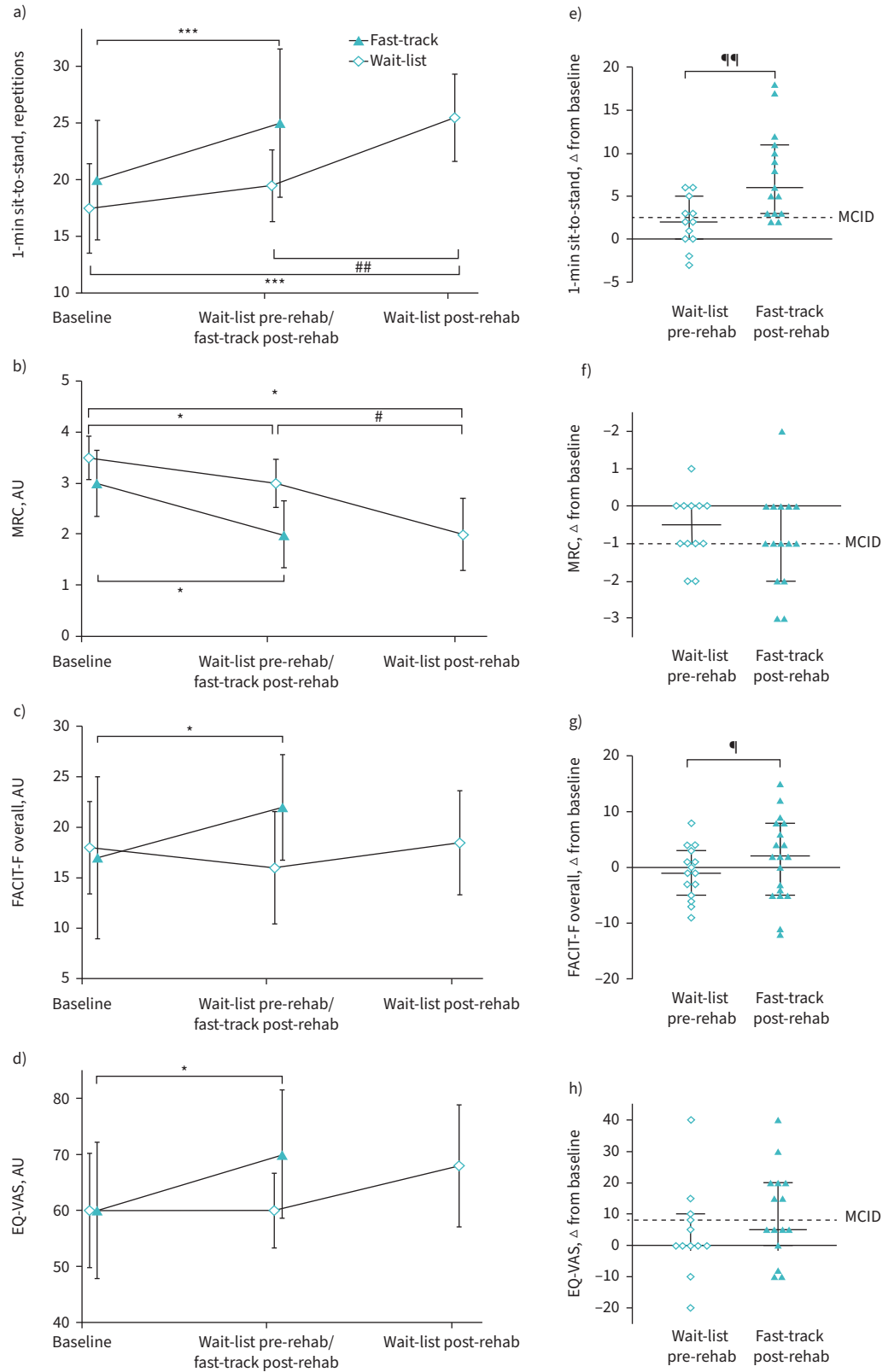


FIGURE 4 a–d) Temporally aligned outcome assessments at baseline, post-rehabilitation (fast-track)/pre-rehabilitation (wait-list) and post-rehabilitation (wait-list). **e–h)** Median (95% CI) and individual changes (Δ) from baseline to post-rehabilitation (fast-track) and pre-rehabilitation (wait-list). **a, e)** 1-min sit-to-stand repetitions, **b, f)** breathlessness (Medical Research Council (MRC) dyspnoea scale), **c, g)** fatigue (Functional

Assessment of Chronic Illness Therapy – Fatigue (FACIT-F) and *d, h*) quality of life (EuroQol visual analogue scale (EQ-VAS)). MCID: minimal clinically important difference. *: $p < 0.05$, ***: $p < 0.001$ (*versus* baseline); #: $p < 0.05$, ##: $p < 0.01$ (*versus* pre-rehabilitation); †: $p < 0.05$, ††: $p < 0.01$ (wait-list *versus* fast-track groups).

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 \pm SD change in exercise capacity from baseline to post-rehabilitation in the fast-track group (7.6 \pm 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 \pm 2.9 repetitions) ($p=0.004$) (supplementary table S1, 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 (supplementary table S1, 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 (supplementary table S1, figure 4).

Furthermore, 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

22 participants completed the service evaluation questionnaire (table 4). All respondents indicated 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 participants' perceptions 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 who are recovering from COVID-19 and healthcare professionals; and the education sessions (supplementary table S2).

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 wellbeing 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 RCTs 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 who required a high-level respiratory support. These data show that roughly one in five 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 nonparticipation, following initial interest, commonly included suitability of class timings; for logistical reasons, we were only able to offer one session timing option 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 to be more female-dominant [20, 21]. The

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)		
Data are presented as n (%). COVID-19: coronavirus disease 2019.			

consent-to-completion rate was 68%, with all but one of the participants who completed telerehabilitation attending $\geq 50\%$ 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 suggest that telerehabilitation is a safe intervention in patients who 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 may be 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 inpatient [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 that 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 noted in the psychosocial outcome measures. The importance of group dynamics during rehabilitation in psychosocial health outcomes have been identified previously [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 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 who 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 optional alternative to 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 RCT 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 an 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 predefined 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 who have been hospitalised with COVID-19. Furthermore, we have identified physical and psychosocial benefits of telerehabilitation in this population, which could inform a larger multicentre RCT 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 while maintaining social distancing, may be essential in the national recovery from this widespread disease.

Acknowledgements: The authors would like to thank the following individuals and teams for the delivery of the education sessions as part of the telerehabilitation: Abayomi Salawu, staff from the nutrition and dietetic department, staff from the occupational therapy department, and staff from the Physiotherapy Acute Respiratory COPD service (Hull University Teaching Hospitals NHS Trust, Hull, UK).

Provenance: Submitted article, peer reviewed.

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

This study is registered at www.clinicaltrials.gov with identifier number NCT04511962. Data will be provided to researchers who provide a methodologically sound proposal.

Conflict of interest: The authors have nothing to disclose.

References

- 1 Docherty AB, Harrison EM, Green CA, *et al.* Features of 20 133 UK patients in hospital with COVID-19 using the ISARIC WHO Clinical Characterisation Protocol: prospective observational cohort study. *BMJ* 2020; 369: m1985.

- 2 Carfi A, Bernabei R, Landi F. Persistent symptoms in patients after acute COVID-19. *JAMA* 2020; 324: 603–605.
- 3 Salawu A, Green A, Crooks MG, *et al.* A proposal for multidisciplinary tele-rehabilitation in the assessment and rehabilitation of COVID-19 survivors. *Int J Environ Res Public Health* 2020; 17: 4890.
- 4 British Society of Rehabilitation Medicine. Rehabilitation in the Wake of COVID-19 – a Phoenix from the Ashes. 2020. www.bsrm.org.uk/downloads/covid-19bsrmissue1-published-27-4-2020.pdf Date last accessed: 6 December 2021.
- 5 Chartered Society of Physiotherapy. Rehabilitation and COVID-19 – CSP Policy Statement. 2020. www.csp.org.uk/professional-clinical/improvement-innovation/community-rehabilitation/rehab-covid-19-policy-statement Date last accessed: 6 December 2021.
- 6 British Thoracic Society. Delivering Rehabilitation to Patients Surviving COVID-19 Using an Adapted Pulmonary Rehabilitation Approach – BTS guidance. 2020. Available from: www.brit-thoracic.org.uk/covid-19/covid-19-information-for-the-respiratory-community/ Date last accessed: 6 December 2021.
- 7 Wade DT. What is rehabilitation? An empirical investigation leading to an evidence-based description. *Clin Rehabil* 2020; 34: 571–583.
- 8 World Health Organization. Rapid Assessment of Service Delivery for NCDs During the COVID-19 Pandemic. 2020. www.who.int/publications/m/item/rapid-assessment-of-service-delivery-for-ncds-during-the-covid-19-pandemic Date last accessed: 6 December 2021.
- 9 Bolton CE, Bevan-Smith EF, Blakey JD, *et al.* British Thoracic Society guideline on pulmonary rehabilitation in adults. *Thorax* 2013; 68: Suppl. 2, ii1-ii30.
- 10 National Health Library and Knowledge Service. Question 176: What is the Current Best Evidence for Virtual Pulmonary Rehabilitation for COVID-19 Patients? 2021. <https://hselibrary.ie/wp-content/uploads/2021/03/Evidence-Summary-COVID-19-Virtual-Pulmonary-Rehabilitation-for-COVID-19-Patients.pdf> Date last accessed: 6 December 2021.
- 11 Hyde L, Simpson AJ, Nettleton M, *et al.* Tele-rehabilitation for patients who have been hospitalised with COVID-19: a mixed methods feasibility trial protocol. *Phys Ther Rev* 2022; 27: 230–238.
- 12 Crook S, Büsching G, Schultz K, *et al.* A multicentre validation of the 1-min sit-to-stand test in patients with COPD. *Eur Respir J* 2017; 49: 1601871.
- 13 Bestall JC, Paul EA, Garrod R, *et al.* Usefulness of the Medical Research Council (MRC) dyspnoea scale as a measure of disability in patients with chronic obstructive pulmonary disease. *Thorax* 1999; 54: 581–586.
- 14 Wysham NG, Miriovsky BJ, Currow DC, *et al.* Practical dyspnea assessment: relationship between the 0–10 numerical rating scale and the four-level categorical verbal descriptor scale of dyspnea intensity. *J Pain Symptom Manage* 2015; 50: 480–487.
- 15 Herdman M, Gudex C, Lloyd A, *et al.* Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). *Qual Life Res* 2011; 20: 1727–1736.
- 16 Al-shair K, Muellerova H, Yorke J, *et al.* Examining fatigue in COPD: development, validity and reliability of a modified version of FACIT-F scale. *Health Qual Life Outcomes* 2012; 10: 100.
- 17 Zigmond AS, Snaith RP. The hospital anxiety and depression scale. *Acta Psychiatr Scand* 1983; 67: 361–370.
- 18 Zanini A, Aiello M, Adamo D, *et al.* Estimation of minimal clinically important difference in EQ-5D visual analog scale score after pulmonary rehabilitation in subjects with COPD. *Respir Care* 2015; 60: 88–95.
- 19 Blandford A, Wesson J, Amalberti R, *et al.* Opportunities and challenges for telehealth within, and beyond, a pandemic. *Lancet Glob Health* 2020; 8: e1364–e1365.
- 20 Sykes DL, Holdsworth L, Jawad N, *et al.* Post-COVID-19 symptom burden: what is long-COVID and how should we manage it? *Lung* 2021; 199: 113–119.
- 21 Heightman M, Prashar J, Hillman TE, *et al.* Post-COVID-19 assessment in a specialist clinical service: a 12-month, single-centre, prospective study in 1325 individuals. *BMJ Open Respir Res* 2021; 8: e001041.
- 22 Gloeckl R, Leidl D, Jarosch I, *et al.* Benefits of pulmonary rehabilitation in COVID-19: a prospective observational cohort study. *ERJ Open Res* 2021; 7: 00108-2021.
- 23 Büsching G, Zhang Z, Schmid J, *et al.* Effectiveness of pulmonary rehabilitation in severe and critically ill COVID-19 patients: a controlled study. *Int J Environ Res Public Health* 2021; 18: 8956.
- 24 Hermann M, Pekacka-Egli A, Witassek F, *et al.* Feasibility and efficacy of cardiopulmonary rehabilitation after COVID-19. *Am J Phys Med Rehabil* 2020; 99: 865–869.
- 25 Everaerts S, Heyns A, Langer D, *et al.* COVID-19 recovery: benefits of multidisciplinary respiratory rehabilitation. *BMJ Open Respir Res* 2021; 8: e000837.
- 26 Al Chikhanie Y, Veale D, Schoeffler M, *et al.* Effectiveness of pulmonary rehabilitation in COVID-19 respiratory failure patients post-ICU. *Respir Physiol Neurobiol* 2021; 287: 103639.
- 27 Stavrou VT, Tourlakopoulos KN, Vavougiou GD, *et al.* Eight weeks unsupervised pulmonary rehabilitation in previously hospitalized of SARS-CoV-2 infection. *J Pers Med* 2021; 11: 806.
- 28 Li J, Xia W, Zhan C, *et al.* A telerehabilitation programme in post-discharge COVID-19 patients (TERECO): a randomised controlled trial. *Thorax* 2022; 77: 697–706.
- 29 Lacasse Y, Guyatt GH, Goldstein RS. The components of a respiratory rehabilitation program: a systematic overview. *Chest* 1997; 111: 1077–1088.

- 30 Thorpe O, Johnston K, Kumar S. Barriers and enablers to physical activity participation in patients with COPD: a systematic review. *J Cardiopulm Rehabil Prev* 2012; 32: 359–369.
- 31 Stone E. Digital Exclusion and Health Inequalities. 2021. <https://www.goodthingsfoundation.org/wp-content/uploads/2021/08/Good-Things-Foundation-2021-%E2%80%93-Digital-Exclusion-and-Health-Inequalities-Briefing-Paper.pdf> Date last accessed: 6 January 2022.
- 32 Healthwatch. Locked Out: Digitally Excluded People’s Experiences of Remote GP Appointments. 2021. www.healthwatch.co.uk/report/2021-06-16/locked-out-digitally-excluded-peoples-experiences-remote-gp-appointments Date last accessed: 6 January 2022.
- 33 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: 949–953.