Telerehabilitation for chronic respiratory disease: A randomised controlled equivalence trial

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Online supplement

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METHODS

Sites:

The trial was conducted at three tertiary centres in metropolitan Melbourne (Alfred Health, Austin Health and Western Health) and one rural centre (Wimmera Health Care Group, Horsham) in Victoria, Australia. The rural recruitment site was located in Horsham, 300 kilometres from metropolitan Melbourne, within the Wimmera-Southern Mallee region. The pulmonary rehabilitation service in Horsham is the only centre-based program for a population of 47000 people over a geographic area of 42000 km^2.

Eligibility criteria:

Included participants had a primary diagnosis of a chronic respiratory disease, aged ≥40 years, and were able to read and speak English. In Australia, all individuals with a chronic lung disease who are symptomatic are eligible for referral to pulmonary rehabilitation. Potential participants were excluded if they had a primary diagnosis of lung cancer or pulmonary hypertension, or unstable or brittle asthma; if they had undertaken pulmonary rehabilitation within the last 18 months and had not experienced a respiratory exacerbation requiring hospitalisation; or had comorbidities that precluded exercise training.

Intervention:

Individuals randomised to centre-based pulmonary rehabilitation attended the centre from which they were recruited. Centre-based pulmonary rehabilitation was conducted in groups of 8-12 people, who undertook aerobic exercise training through a combination of cycling and walking (treadmill or corridor). Exercise training was standardised across all centre-based pulmonary rehabilitation programs with the use of a protocol for prescription and

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progression.(1)

The initial exercise training session for individuals randomised to telerehabilitation was undertaken during a home-visit with the physiotherapist. This visit established the exercise program and ensured safety and understanding of equipment operation. The home telerehabilitation equipment package modelled earlier pilot work(2) and used readily available equipment: a step-through exercise bike to maximise safety (Bodyworkx A915); a 4G enabled tablet computer (Apple iPad, Apple, Cupertino, California, USA) with mobile data, fixed to a stand for videoconferencing; and a pulse oximeter (Nonin Palmsat 2500A; Nonin Medical Inc., Plymouth, Minnesota, USA) to monitor peripheral oxygen saturation (SpO_2) and pulse rate during training and at rest (Online Suppl Figure S1). The oximeter did not employ Bluetooth but was positioned such that the display was visible to the supervising physiotherapist throughout the session. A total of 12 home telerehabilitation equipment packages were re-used throughout the trial with an initial cost of $AUD2540 per package. Videoconferencing used Zoom videoconferencing software (San Jose, California, USA) to enable all participants to see and speak to each other. Thirty minutes of aerobic exercise training was accomplished using cycle ergometry, in two or more bouts. Intensity of cycle training was progressed each week by 5–10% of the initial workload as tolerated.(1)

At the conclusion of the eight-week intervention, where available, participants were offered referral to a community-based, maintenance exercise program to support ongoing exercise participation, in line with national standards.(3)

Equipment:

The equipment set-up was mirrored for each participant, to enable both the display of the pulse oximeter and the participant's face and trunk to be visible to the supervising physiotherapist throughout the session. The equipment footprint was 2.5metres x 1 metre and was positioned in a location within the home or workplace, as chosen by the participant. All

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equipment was supplied and set-up by the research team, and removed on completion of the 8-week rehabilitation period.

Figure S1: Telerehabilitation equipment set-up

Five minutes before the scheduled start of the rehabilitation session, telerehabilitation participants were encouraged to prepare for their session and turn on equipment. To access the virtual group via Zoom, the physiotherapist dialled each participant into the session.

Participants were provided with pictorial instructions, involving six steps, from turning on their tablet computer to accepting the incoming call to join the virtual group. Regardless of geographic location of participants, telerehabilitation was always delivered from the central research site located in metropolitan Melbourne. The physiotherapist conducted the telerehabilitation session from a closed office equipped with a laptop computer, and large display screen (Soniq, Soniq Australia Pty Ltd, Braeside, Victoria, Australia) to enhance visual acuity across multiple participants.

Exercise training protocol:

A standardised exercise training prescription and progression protocol was employed across both interventions and all sites. This protocol encompassed both endurance training and strength training. At least 30 minutes of lower limb endurance exercise training was prescribed each session, which could be completed in shorter intervals. For participants in the centre-based pulmonary rehabilitation group, this endurance training usually involved a combination of walking and cycling activities. For participants in the telerehabilitation group endurance training comprised solely cycle training. It was required that the target 30 minutes of endurance training was achieved before progression of intensity. Where participants were able to complete more than 30 minutes of endurance training, this was encouraged. Details of endurance training prescription and progression are summarised in Table S1.

Resistance training for the upper and lower limbs was prescribed using functional activities at an intensity that enabled achievement of 8–12 repetitions for three sets of each exercise. A minimum of four exercises, two each for the upper limb (e.g. wall push-ups, upright row, shoulder press) and lower limb (e.g. squats, sit-to-stand, step-ups), were prescribed. Once able to perform three sets of 12 repetitions comfortably, weight was increased. For lower limb exercises, this constituted the addition of hand weights or increasing squat depth as appropriate. For participants in the telerehabilitation group, strength training utilised appropriate and easily available household items (e.g. tins of soup or bags of rice) to substitute for free weights. All participants were prescribed a home walking program and were encouraged to perform an additional three unsupervised exercise sessions each week, which were documented in a home diary and reviewed weekly by the supervising clinician. Participants in the telerehabilitation were free to use the provided equipment during these additional sessions.

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Fidelity of the intervention was assessed 6-monthly by a pulmonary rehabilitation clinician independent of the trial, commencing after the first full calendar year of intervention delivery. Exercise training records of completed participants were assessed to determine:

i) Achievement of prescribed training intensity, during week one; and

ii) Progression of training according to protocol during Weeks 2-8 of rehabilitation.

Data were extracted and recorded on a standardised form. Where exercise prescription or progression deviated from protocol, recording of any documented reason for protocol deviation were noted.

Education and self-management training:

Education and self-management training was standardised for participants in both groups through the provision of resources from Lung Foundation Australia (a printed book and a brochure detailing the location of online resources). These resources were specifically developed by Lung Foundation Australia to support pulmonary rehabilitation participants to undertake relevant education at their convenience. Education opportunities were also available in a group format – in-person for centre-based rehabilitation participants, and in a virtual group for telerehabilitation participants. For all participants, self-management education included discussion of long-term exercise planning. Recognising and managing an acute exacerbation was included in self-management training for participants with COPD or asthma. Additional education and self-management training topics were individualised for participants who identified a relevant health goal; with information provided through dedicated discussion with staff (either one-on-one or in a group format) and/or provision of resources, as appropriate. Opportunity to review or discuss individual health goals, or specific topics relating to education and self-management training, were provided at each session irrespective of intervention location.

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Table S1. Summary of endurance training prescription and progression

	Training mode	Time	Intensity	Progression	Variations
Centre-based rehabilitation	Walking training	Minimum 15 mins	Initial speed 70-80% of maximum speed achieved in baseline 6MWT. This speed is maintained for Week 1.	Each week speed is increased by 0.25km/hr where initial speed ≤ less than 3km/hr; or 0.5km/hr where initial speed >3km/hr. Once training at 5km/hr, speed is reduced to 4.5km/hr and incline is introduced and increased weekly.	If unable to progress to a walking speed of 5km/hr due to leg length or musculoskeletal reasons, incline may be introduced earlier.
	Cycle training	Minimum 15 mins	Set at the work rate (watts) corresponding to 60% of the peak VO_2 achieved on CPET (Borg 3-4);(4) OR* predicted from 6MWT distance using equation of Hill et al 2008 (Borg 3-4).(5)	Progressed each week by 5-10% of the initial workload as tolerated; aiming to maintain a dyspnoea score of BORG 3-4.(6)	Progression increments can be increased by 15% if target Borg intensity is not reached. Interval training may be used for participants with severe deconditioning, dyspnoea, desaturation or claudication pain. i.e. Target intensity for 3-5 mins, interspersed with rest periods of 2-3 mins. Only exercise periods count towards the total exercise time.
Telerehabilitation	Cycle training	Minimum 30 mins; usually in 2x15 min blocks	Set at the work rate (watts) corresponding to 60% of the peak VO_2 achieved on CPET (Borg 3-4);(4) OR* predicted from 6MWT distance using equation of Hill et al 2008 (Borg 3-4).(5)	Progressed each week by 5-10% of the initial workload as tolerated; aiming to maintain a dyspnoea score of BORG 3-4.(6)	Progression increments can be increased by 15% if target Borg intensity is not reached. Interval training may be used for participants with severe deconditioning, dyspnoea, desaturation or claudication pain. i.e. Target intensity for 3-5 mins, interspersed with rest periods of 2-3 mins. Only exercise periods count towards the total exercise time.

LEGEND: Peak VO_2 = peak oxygen consumption; CPET = cardiopulmonary exercise test; 6MWT = 6 minute walk test

*where participant unable to undertake baseline CPET. Prediction equation: Wmax (W)=(0.122x6MWD)+(72.683xheight [m])–117.109

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Outcomes:

The primary outcome, CRQ dyspnoea domain (CRQ-D), comprises a valid measure of health-related quality of life (HRQoL) and is responsive to change with pulmonary rehabilitation in people with chronic respiratory diseases including COPD,(7) bronchiectasis(8) and ILD.(9) Secondary outcomes were: program completion; HRQoL as measured by the CRQ fatigue, emotion and mastery domains and the SF-36v2 physical and mental component summary scores (PCS and MCS respectively, derived using orthogonal principal components and reference data sourced from a US adult (non-institutionalised) population)(QualityMetric Health Outcomes^{TM} Scoring Software 4.0, Quality Metric Incorporated, Lincoln RI, USA); Pulmonary Rehabilitation Adapted Index of Self Efficacy (PRAISE); modified Medical Research Council (mMRC) dyspnoea score; and levels of anxiety and depression as measured by the Hospital Anxiety and Depression scale. Exercise capacity was measured using both the 6-minute walk distance (6MWD) and endurance cycle time. The work rate for the endurance cycle test was set at 75% of the peak work rate established during a maximal cardiopulmonary exercise test (CPET) using cycle ergometry with expired gas analysis, completed as part of the baseline assessment. Only participants recruited in metropolitan Melbourne undertook baseline CPET assessment and endurance cycle testing due to a lack of available testing facilities in the rural location. Physical activity levels were measured objectively using a wrist-worn activity monitor over seven days (GeneActiv; ActivInsights Ltd., Kimbolton, Cambridgeshire, United Kingdom). At baseline, participants were asked to rate their experience and confidence in using computers with a 5-point Likert-scale (experience: none – extensive; confidence: strongly disagree – strongly agree). A medical record review was undertaken after 12-months of follow-up to determine hospitalisations during the study period, which were verified by monthly telephone calls to participants.

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Physical activity data analysis:

Physical activity levels were assessed objectively using a wrist-worn activity monitor over 7-days (GeneActiv; ActivInsights Ltd., Kimbolton, Cambridgeshire, United Kingdom). Assessment of physical activity was undertaken prior to commencing rehabilitation, at the conclusion of the 8-week rehabilitation period and at 12-months follow-up.

Raw data were downloaded from the Geneactiv device and processed using a data macro supplied by ActivInsights. This produced minute-by-minute output for all wear time, including average metabolic equivalent (MET) values for each minute of wear and identification of non-wear time and time spent in bed. For physical activity data to be included in the analysis, participants needed a minimum of 4 days of data, including at least one weekend day, with a minimum of 10 hours of wear time per included day.(10) A day of data was considered midnight to 23:59 hours. To reduce bias, the first and last day of wear were removed from the analysis.(11) All non-wear time and time spent in bed were excluded from the analysis. Average time per day spent sedentary, as well as in light and moderate-vigorous intensity activity was calculated from the per minute MET values. Sedentary behaviour was classified as <1.5 METs, light intensity activity as ≥1.5-2.99 METs, and moderate-vigorous intensity activity as ≥3 METs.(12)

Statistical analysis:

In accordance with the pre specified protocol statistical analyses would account for stratification by trial site, and explicit sub-group analyses by diagnosis would be carried out. As the majority of participants (70%) had a diagnosis of COPD it was not feasible to account for this stratification factor in the analysis models. We were unable to perform a sub-group analysis based on acuity (i.e stable disease state versus post-exacerbation) due to the very small number of recruited participants who were randomised within four weeks of hospital discharge (n=5 total; n=3 telerehabilitation; n=2 centre-based pulmonary rehabilitation).

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RESULTS

Ten participants did not proceed to randomisation due to change of mind (n=6) or exclusion at CPET (n=4). Of potentially eligible participants who declined to participate (n=246), most (39%) wished to attend centre-based rehabilitation. The baseline characteristics of all randomised participants (n=142) are presented in Table S2.

Table S2. Characteristics of randomised participants

	Telerehabilitation n=71	**Centre-based PR n=71**
Age, years	68 (9)	67 (9)
Male/female, n	30 / 41	36 / 35
Diagnosis, n (%)		
- COPD	50 (70)	50 (70)
- ILD	5 (7)	6 (8.5)
- Bronchiectasis	10 (14)	9 (13)
- Asthma	6 (8)	6 (8.5)
Smoking status, n (%)		
- Current smoker	11 (15.5)	8 (11)
- Ex smoker	49 (69)	53 (75)
- Never smoker	11 (15.5)	10 (14)
Pack years, median [IQR]	40 [15 to 60]	35 [14 to 53]
FEV_1, L	1.5 (0.7)	1.6 (0.7)
FEV_1, %predicted	59 (25)	63 (26)
FVC, L	2.9 (0.9)	2.9 (1.1)
FVC, %predicted	84 (21)	86 (26)
FEV_1/FVC, %	54 (20)	56 (19)
BMI, kg/m^2	28 (6)	28 (7)
6 min walk distance, m	418.6 (117.2)	433.6 (86.7)
CPET	n=47	n=48
- %predicted VO_2 max	59 (20)	59 (21)
- Peak watts	71 (26)	73 (23)

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Endurance cycle time, seconds median [IQR]	n=47 237 [146 to 335]	n=45 246 [171 to 330]
LTOT, n (%)	9 (13)	3 (4)
CRQ		
Dyspnoea	15 (6)	15 (5)
Fatigue	15(7)	15 (5)
Emotion	33(9)	32 (10)
Mastery	20 (9)	20 (5)
Total	83 (22)	83 (21)
MMRC, median [IQR]	2 [1 to 3]	2 [1 to 2]
MMRC, n (%)		
0	2 (3)	1 (1)
1	25 (35)	37 (52)
2	25 (35)	21 (30)
3	15 (21)	11 (16)
4	4 (6)	1 (1)
HADS anxiety*, n (%)		
No case	46 (65)	44 (62)
Borderline	9 (13)	12 (17)
Case	16 (22)	15 (21)
HADS depression*, n(%)		
No case	49 (69)	59 (83)
Borderline	13 (18)	7 (10)
Case	9 (13)	5 (7)
SF-36		
PCS	37 (9)	40 (7)
MCS	49 (13)	49 (12)
PRAISE	48 (7)	47 (9)
Physical activity, minutes/day		
Sedentary (<1.5METs)		
Light (≥1.5-2.99 METs)	531 (163)	495 (147)
Moderate-Vigorous (≥3METs) median [IQR]	267 (107)	283 (90)

	58 [28 to 110]	64 [38 to 99]
Number of comorbidities, median [IQR]	3 [2 to 5]	4 [2 to 5]
Participants with a hospital admissions in the year prior to PR, n(%)	11 (16%)	16 (23%)
Metropolitan/rural, n (%)	49 / 22 (69% / 31%)	50/21 (70%/30%)
Naïve to PR, n (%)	52 (73%)	60 (85%)

LEGEND: Data are Mean (SD) unless indicated

n, number; COPD, chronic obstructive pulmonary disease; ILD, interstitial lung disease; FEV_1, forced expiratory volume in one second; L, litres; %predicted, percentage of predicted normal; FVC, forced vital capacity; TLCO, transfer factor of the lung for carbon monoxide; BMI, body mass index; CPET, cardiopulmonary exercise test; VO_2max, maximum oxygen uptake; LTOT, long-term oxygen therapy; CRQ, Chronic Respiratory disease Questionnaire; mMRC, modified Medical Research Council; HADS, Hospital Anxiety and Depression Scale; SF36-v2, Medical Outcomes Survey Short-form 36-v2; PCS, physical component summary; MCS, mental component summary; PRAISE, Pulmonary Rehabilitation Adapted Index of Self-Efficacy; METs, metabolic equivalent; PR, pulmonary rehabilitation.

*HADS case definition scoring: 0 ≤ 7 = no case; 8-10 = borderline case; ≥11case

Nearly one-third (n=43, 30%) of participants were recruited from the rural site. These participants lived between 240m up to 110km from the rural centre-based pulmonary rehabilitation site, and over 400km from the location of the physiotherapist delivering telerehabilitation.

The majority of participants (n=135, 95%) had a least one comorbidity (median [interquartile range (IQR)] number of comorbidities: telerehabilitation 3 [2 to 5], centre-based 4 [2 to 5]).

A total of 141 participants commenced exercise training. Exercise training prescription was progressed according to protocol 79% of the time. On a further 10% of occasions, a clear reason for protocol variation was documented, such as a medical or musculoskeletal limitation. Summary data for fidelity of the exercise training intervention by group allocation is presented in Table S3.

Education and self-management training was individualised and offered to all participants. A total of 127 participants (n=68 (97%) telerehabilitation versus n=59 (84%) centre-based PR; $\chi(1)=6.9$, p=0.009) undertook some combination of 30 different education topics (Table S4). The median number of education topics covered by each participant was three (median [IQR]: telerehabilitation 3 [2 to 4]; centre-based PR 3 [2 to 5]).

The proportion of participants categorised as reaching the threshold for a diagnosis of depression was greater in the telerehabilitation group at 12-month follow-up (14% versus 2%, $\chi(1)=5.7$, p=0.02) (see Figure S2a and S2b).

Physical activity data were available for n=63 (90%) and n=61 (87%) in the telerehabilitation and centre-based rehabilitation groups, respectively. There was no difference between groups for time spent sedentary, or in light or moderate-vigorous intensity activity. There was no change from baseline in any physical activity parameter within either group at end rehabilitation or 12-months follow-up.

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The number of participants referred for ongoing maintenance rehabilitation at the end of the intervention was not different between groups (n=29 (40%) telerehabilitation versus n=25 (35%) centre-based PR; $\chi(1)=0.02$, p=0.9).

Details relating to adverse events are presented in Table S5. The per protocol analysis for the primary and secondary outcomes is presented in Table S6. Participants who completed at least 70% of the prescribed exercise training sessions (≥11 sessions) were classified as program completers and included in the per protocol analysis. A sub-group analysis of participants with COPD is presented in Table S7. A post-hoc analysis of participants who were naïve to pulmonary rehabilitation is presented in Table S8.

Participants in the trial were not required to have any experience of using computers or the internet. On two occasions there was a state-wide failure of the national mobile data carrier, which prevented the running of two individual telerehabilitation training sessions. Thirty participants (42%) in the telerehabilitation group required additional support to use the equipment or solve a technology issue. Additional support was primarily provided by telephone (telephone calls for technology support median 2 [IQR 1 to 4], range 0-12). Issues relating to sound were most commonly experienced (total n=76; median [IQR] per participant 1 [1 to 3]), followed by video-related problems (total n=42; median [IQR] per participant 2 [1 to 4]) and general iPad operation issues (total n=38; median [IQR] per participant 2 [1 to 3]). Only four participants required an additional home visit to support the use of equipment or troubleshoot a technology issue.

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Table S3. Summary of intervention fidelity by group allocation

		Week 1				Weeks 2-8			
		Prescribed according to protocol and achieved	**Not achieved, with reason**	**Not achieved, no reason**	**Not documented**	**Progressed according to protocol and achieved**	**Not progressed by protocol, with reason**	**Not progressed by protocol, no reason**	**Not documented**
Centre-based rehabilitation	Walking training	84.1%	11.6%	1.4%	2.9%	77.1%	13.2%	4.1%	5.6%
	Cycle training	87%	5.8%	2.9%	4.3%	75.1%	6.3%	3.1%	15.5%
Telerehabilitation	Cycle training	76.1%	19.7%	2.8%	1.4%	84%	10.6%	1.7%	3.7%

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Table S4. Education topics covered, number of participants by group

Topic	Telerehabilitation n	Centre-based PR n
Managing an exacerbation	65	48
Ongoing exercise participation	59	55
Medications (including inhaler technique and devices)	31	27
Energy conservation and stress management	6	23
Managing breathlessness	9	6
Diet, nutrition and weight management	6	18
Advanced care planning	-	14
Airway clearance techniques	11	10
Managing chronic cough	1	-
Living with IPF	1	2
Equipment	1	6
Oxygen therapy	2	1
Continence	1	2
Smoking cessation	3	1
Swallowing and speech	-	3
Sinus care	7	-
Medical management of lung disease	-	13
Managing chronic illness	1	4
Progressing exercise and activity	4	1
Pain management	2	-
Respiratory nurse	-	3
Sleep hygiene	1	-
Breathing pattern dysfunction	1	-
Musculoskeletal health	-	1
Reflux	1	-
BP management	-	1
Diabetes management	-	1
Monitoring peak flow	1	-
Self management	-	1
Transplant education	1	-

LEGEND: IPF, Interstitial Pulmonary Fibrosis; BP, blood pressure

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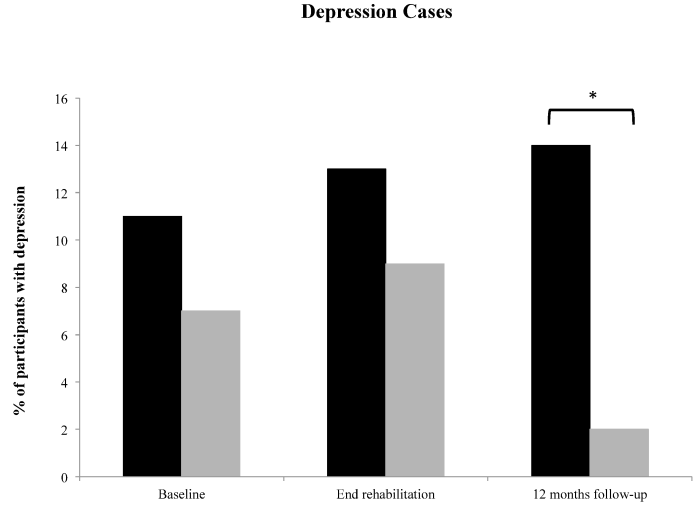

Fig S2a – Depression cases

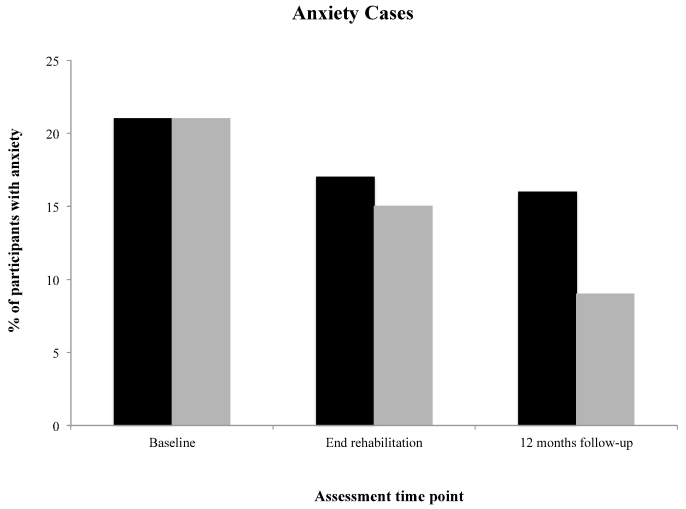

Fig S2b – Anxiety cases

Figure S2. Proportion of participants categorised as case[¥] for depression (FigS2a) and anxiety (FigS2b) on HADS at each timepoint.

Black bars = telerehabilitation; Grey bars = centre-based PR

* = Significant difference in number of cases $p<0.05$; [¥]HADS case definition scoring: 0 < 11 = no case; ≥11 = case

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Table S5. Adverse events

	All	Telerehabilitation	Centre-based rehabilitation	Related to intervention
Associated with CPET	**n=1 dizziness, blurred vision post test n=1tachycardic at rest n=4 ECG changes requiring cardiology follow-up**			
Respiratory hospitalisation during rehabilitation period		**n=4**	**n=2**	
Blurred vision requiring hospitalisation and testing			**n=1**	**Unrelated**
Hypotensive			**n=1**	**Possibly related**
Gash to leg whilst gardening requiring stitches		**n=1**		**Unrelated**
Mouth ulcer requiring ED		**n=1**		**Unrelated**

LEGEND: CPET = cardiopulmonary exercise test; ECG = electrocardiogram; ED = emergency department

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Table S6. Clinical outcomes – Per protocol analysis

		Within group differences from baseline (95% CI)				Between group differences	
		TELEREHABILITATION n=59 (84%)		CENTRE-BASED REHABILIATION n=55 (79%)		Telerehabilitation – Centre (95% CI)	
		End rehabilitation	1 year	End rehabilitation	1 year	End rehabilitation	1 year
Primary outcome	**CRQ – Dyspnoea**	4 (2.4 to 5.7)	0.6 (-1.4 to 2.6)	4.9 (2.8 to 7.1)	1.8 (-1 to 4.5)	-1.1 (-3.6 to 1.3)†	-1.2 (-3.7, 1.3)†
Secondary outcomes	**CRQ-Emotion**	2.5 (-0.4 to 5.4)	3.5 (0.4 to 6.5)	4 (1.3 to 6.7)	2.8 (0.4 to 5.2)	-1.0 (-4.0 to 2.0)	1.6 (-1.5 to 4.7)*
	Fatigue	2.5 (1.0 to 4.3)	2.2 (0.5 to 3.9)	2.1 (0.3 to 3.8)	1.7 (0.03 to 3.3)	-0.4 (-2.2 to 1.4)	-0.0 (-1.9 to 1.9)
	Mastery	0.5 (-1.3 to 2.3)	1.1 (-1 to 3.1)	2.5 (1.1 to 3.8)	1.6 (0.2 to 3.0)	-1.4 (-3.1 to 0.3)	0.3 (-1.4 to 2.1)*
	Total	9.3 (2.4 to 16.1)	7.4 (0.9 to 14.0)	13.5 (7.1 to 19.9)	7.9 (1.5 to 14.3)	-4.1 (-11.1 to 3.0)	0.8 (-6.5 to 8.1)
	6MWD, metres	22 (9 to 36)	22 (1 to 42)	23 (9 to 36)	-2 (-25 to 21)	-3 (-25 to 18)	15 (-10 to 39)*
	Endurance cycle time, seconds	324 (172 to 476)	121 (-9 to 250)	199 (56 to 343)	75 (-67 to 217)	120 (-66 to 305)*	-7 (-211 to 197)*†
	PRAISE	1.4 (-0.3 to 3.1)	0.2 (-1.8 to 2.3)	0.8 (-1 to 2.5)	0.5 (-1.2 to 2.2)	1.1 (-1.2 to 3.4)	0.1 (-2.3 to 2.5)
	MMRC	-0.4 (-0.7 to -0.2)	-0.2 (-0.5 to 0.02)	-0.3 (-0.5 to -0.1)	0.1 (-0.2 to 0.3)	0.0 (-0.3 to 0.3)	-0.2 (-0.5 to 0.1)
	HADS-A	-1.1 (-2.5 to 0.2)	-1.5 (-3.1 to 0.02)	-1.1 (-2.4 to 0.2)	-1.5 (-2.9 to -0.1)	-0.1 (-1.6 to 1.4)	-0.4 (-1.9 to 1.2)
	HADS-D	-0.5 (-1.3 to 0.3)	-0.4 (-1.5 to 0.7)	-0.9 (-2.1 to 0.2)	-1.5 (-2.6 to 0.3)	0.5 (-0.7 to 1.7)	1.0 (-0.3 to 2.2)
	SF36-v2						
	PCS	2.3 (0.4 to 4.2)	0.6 (-1.6 to 2.8)	0.02 (-1.8 to 1.8)	-1.4 (-3.7 to 0.9)	0.4 (-2.4 to 3.1)	1.3 (-1.6 to 4.1)
	MCS	0.3 (-1.8 to 2.4)	2.4 (-0.3 to 5.2)	1.8 (-0.6 to 4.2)	0.01 (-2.6 to 2.6)	-1.4 (-4.6 to 1.7)	2.3 (-0.5 to 6.1)

	Physical activity, mins						
	Sedentary	-20.2 (-64.7 to 24.3)	-20.7 (-69.5 to 28.0)	-31.2 (-80.0 to 17.6)	6.4 (-49.3 to 62.0)	46.9 (-5.7 to 99.6)	8.6 (-51.7 to 69.0)
	LIPA	-1.1 (-35.8 to 33.6)	6.6 (-29.4 to 42.7)	15.9 (-18.3 to 50.0)	-12.1 (-48.3 to 24.1)	-25.2 (-67.2 to 16.8)	19.7 (-28.3 to 67.6)
	MVPA	9.5 (-2.5 to 21.4)	1.2 (-7.9 to 10.3)	7.8 (-7.6 to 23.2)	-4.6 (-15.9 to 6.7)	-2.5 (-19.1 to 14.1)	5.8 (-13.0 to 24.6)

LEGEND:

Data are mean difference and 95% CIs adjusted for baseline values.

*CI exceeds the upper equivalence limit of the minimal important difference and cannot exclude superiority

†CI exceeds the lower equivalence limit and cannot exclude inferiority

6MWD, 6 min walk distance; CRQ, Chronic Respiratory disease Questionnaire; PRAISE, Pulmonary Rehabilitation Adapted Index of Self-Efficacy; MMRC, modified Medical Research Council scale; HADS-A, Hospital Anxiety and Depression Scale – anxiety score; HADS-D, Hospital Anxiety and Depression Scale – depression score; PCS, physical composite score; MCS, mental composite score; LIPA, light intensity physical activity; MVPA, moderate-vigorous intensity physical activity; SF36-v2, Medical Outcomes Survey Short-form 36-v2; PCS – physical component summary; MCS – mental component summary

Table S7. COPD sub-group analysis - Clinical outcomes – Intention to treat analysis

		Within group differences from baseline (95% CI)				Between group differences	
		TELEREHABILITATION n=47		CENTRE-BASED REHABILIATION n=49		Telerehabilitation – Centre (95% CI)	
		End rehabilitation	1 year	End rehabilitation	1 year	End rehabilitation	1 year
Primary outcome	**CRQ – Dyspnoea**	4.0 (2.2 to 5.8)	-0.7 (-3.0 to 1.7)	4.8 (2.7 to 6.9)	1.6 (-1.0 to 4.3)	-1.8 (-4.3 to 0.8)[†]	-3.4 (-6.1 to -0.7)[§†]
Secondary outcomes	**CRQ-Emotion**	1.9 (-1.3 to 5.1)	2.9 (-1.1 to 6.9)	3.0 (-0.3 to 6.3)	2.2 (-0.8 to 5.2)	-1.0 (-4.6 to 2.7) [†]	-0.3 (-4.2 to 3.6) [*†]
	Fatigue	2.2 (0.3 to 4.2)	2.1 (-0.1 to 4.3)	1.3 (-0.7 to 3.2)	1.6 (-0.1 to 3.3)	0.1 (-2.0 to 2.2)[*]	-0.7 (-3.0 to 1.5)[†]
	Mastery	0.04 (-2.1 to 2.1)	-0.3 (-2.7 to 2.1)	2.0 (0.5 to 3.5)	1.0 (-0.6 to 2.5)	-1.3 (-3.2 to 0.7)[†]	-0.6 (-2.7 to 1.5)[†]
	Total	7.5 (-0.2 to 15.1)	4.3 (-4.7 to 13.3)	11.2 (4.1 to 18.2)	6.4 (-0.5 to 13.3)	-5.7 (-13.6 to 2.1)	-3.1 (-11.4 to 5.1)
	6MWD, metres	20 (5 to 35)	18 (-4 to 41)	26 (8 to 44)	-2.0 (-31 to 28)	-10 (-36 to 17)[†]	11 (-20 to 42)[*]
	Endurance cycle time, seconds	214 (63 to 365)	42 (-65 to 149)	95 (-37 to 226)	56 (-109 to 220)	122 (-67 to 310)[*]	-28 (-245 to 188)[*†]
	PRAISE	1.0 (-0.8 to 2.7)	-0.1 (-2.5 to 2.4)	0.6 (-1.1 to 2.2)	-0.1 (-1.8 to 1.7)	0.1 (-2.2 to 2.3)	-0.5 (-3.0 to 2.0)
	MMRC	-0.5 (-0.8 to -0.2)	-0.2 (-0.6 to 0.1)	-0.4 (-0.6 to -0.1)	0.1 (-0.2 to 0.4)	0.0 (-0.3 to 0.4)	-0.2 (-0.6 to 0.2)
	HADS -A	-1.0 (-2.5 to 0.4)	-1.3 (-3.4 to 0.7)	-0.5 (-2.0 to 1.0)	-1.3 (-2.8 to 0.2)	0.1 (-1.5 to 1.8)	-0.1 (-1.9 to 1.6)
	HADS -D	-0.2 (-1.2 to 0.7)	-0.4 (-2.0 to 1.1)	-0.4 (-1.8 to 0.9)	-1.3 (-2.7 to 0.03)	0.9 (-0.5 to 2.3)	1.2 (-0.2 to 2.7)
	SF36-v2	2.3 (0.4 to 4.2)	0.01 (-2.6 to 2.6)	0.2 (-1.6 to 2.1)	-1.6 (-4.1 to 1.1)	0.4 (-2.4 to 3.2)	0.9 (-2.0 to 3.9)

	PCS	1.5 (-0.8 to 3.8)	3.1 (-0.4 to 6.5)	1.8 (-1.6 to 2.1)	-0.6 (-4.1 to 3.0)	-0.5 (-4.3 to 3.2)	3.1 (-0.9 to 7.2)
	MCS						
	Physical activity, mins						
	Sedentary	-2 (-55 to 52)	-30 (-94 to 35)	-14 (-58 to 31)	-19 (-84 to 46)	33 (-26 to 92)	21 (-48 to 90)
	LIPA	-14 (-53 to 26)	18 (-33 to 69)	0.5 (-33 to 34)	0.3 (-43 to 43)	-28 (-76 to 19)	20 (-35 to 75)
	MVPA	-1 (-8 to 7)	-2 (-13 to 9)	-3.0 (-14 to 7)	-6.0 (-17 to 5)	-3 (-15 to 9)	6 (-7 to 19)

LEGEND:

Data are mean difference and 95% CIs adjusted for baseline values.

[§]Statistically significant difference between groups

*CI exceeds the upper equivalence limit of the minimal important difference and cannot exclude superiority of telerehabilitation

†CI exceeds the lower equivalence limit and cannot exclude inferiority of telerehabilitation

6MWD, 6 min walk distance; CRQ, Chronic Respiratory disease Questionnaire; PRAISE, Pulmonary Rehabilitation Adapted Index of Self-Efficacy; MMRC, modified Medical Research Council scale; HADS-A, Hospital Anxiety and Depression Scale – anxiety score; HADS-D, Hospital Anxiety and Depression Scale – depression score; PCS, physical composite score; MCS, mental composite score; LIPA, light intensity physical activity; MVPA, moderate-vigorous intensity physical activity; SF36-v2, Medical Outcomes Survey Short-form 36-v2

Table S8. Post-hoc analysis. Participants naïve to pulmonary rehabilitation - Clinical outcomes – Intention to treat analysis

		Within group differences from baseline (95% CI)				Between group differences	
		TELEREHABILITATION n=49		CENTRE-BASED REHABILIATION n=57		Telerehabilitation – Centre (95% CI)	
		End rehabilitation	1 year	End rehabilitation	1 year	End rehabilitation	1 year
Primary outcome	**CRQ – Dyspnoea**	4.0 (2.1 to 5.8)	0.4 (-1.8 to 2.6)	4.7 (2.6 to 6.9)	1.9 (-0.8 to 4.7)	-1.1 (-3.7 to 1.5)†	-1.8 (-4.6 to 0.9)†
Secondary outcomes	**CRQ-Emotion**	3.9 (0.6 to 7.1)	4.1 (0.5 to 7.7)	3.1 (0.3 to 5.8)	2.2 (-0.7 to 5.0)	0.8 (-2.7 to 4.2)*	1.0 (-2.6 to 4.7)*
	Fatigue	3.2 (1.3 to 5.0)	2.6 (0.7 to 4.6)	1.6 (-0.2 to 3.4)	1.7 (0.1 to 3.4)	1.2 (-0.8 to 3.1)*	0.0 (-2.0 to 2.1)*
	Mastery	1.1 (-0.7 to 3.0)	1.0 (-1.1 to 3.1)	2.0 (0.7 to 3.4)	1.5 (0.0 to 3.0)	-0.6 (-2.4 to 1.2)†	-0.3 (-2.3 to 1.6)†
	Total	12.1 (4.7 to 19.6)	8.1 (0.5 to 15.8)	11.5 (5.0 to 18.0)	7.8 (0.9 to 14.8)	-0.8 (-8.4 to 6.7)	0.4 (-7.5 to 8.3)
	6MWD, metres	25.3 (8.7 to 42.0)	29.2 (3.1 to 55.4)	30.9 (15.3 to 46.4)	-2.8 (-29.2 to 23.6)	-10.1 (-35.6 to 15.4)†	18.4 (-10.4 to 47.2)*
	Endurance cycle time, seconds	244.4 (34.7 to 454.1)	120.9 (-90.4 to 332.1)	141.8 (16.3 to 267.3)	-15.5 (-90.7 to 59.8)	104.0 (-103.9 to 312.0)*	12.6 (-217.5 to 242.8)†*
	PRAISE	0.5 (-1.5 to 2.5)	0.2 (-2.2 to 2.6)	0.3 (-1.5 to 2.1)	0.1 (-1.7 to 2.1)	0.7 (-1.8 to 3.2)	0.3 (-2.3 to 3.0)
	MMRC	-0.5 (-0.8 to -0.2)	-0.2 (-0.5 to 0.1)	-0.3 (-0.5 to -0.1)	0.0 (-0.3 to 0.3)	-0.1 (-0.4 to 0.2)	-0.1 (-0.4 to 0.2)
	HADS -A	-1.5 (-3.1 to 0.1)	-1.6 (-3.5 to 0.3)	-0.7 (-2.1 to 0.6)	-1.6 (-3.1 to -0.1)	-0.2 (-1.9 to 1.4)	-0.1 (-1.8 to 1.6)
	HADS -D	-0.3 (-1.4 to 0.7)	-0.4 (-1.7 to 0.9)	-0.6 (-1.8 to 0.6)	-1.4 (-2.6 to -0.1)	0.4 (-0.9 to 1.8)	0.9 (-0.6 to 2.3)

	SF36-v2						
	PCS	2.8 (0.6 to 4.9)	1.7 (-0.8 to 4.1)	-0.8 (-2.5 to 0.9)	-1.9 (-4.2 to 0.4)	2.3 (-0.5 to 5.0)	3.2 (0.4 to 6.1)
	MCS	1.6 (-0.8 to 4.1)	2.3 (-1.2 to 5.9)	3.3 (0.5 to 6.0)	-0.7 (-3.7 to 2.3)	-1.2 (-4.8 to 2.4)	3.3 (-0.5 to 7.1)
	Physical activity, mins						
	Sedentary	-24 (-78 to 30)	-14 (-64 to 35)	-8 (-49 to 34)	9 (-52 to 70)	16 (-37 to 70)	13 (-50 to 76)
	LIPA	2 (-42 to 46)	7 (-20 to 35)	2 (-31 to 34)	-13 (-53 to 27)	-9 (-53 to 35)	15 (-36 to 67)
	MVPA	10 (-6 to 27)	1.0 (-13 to 15)	-1 (-11 to 9)	-4 (-17 to 8)	8 (-9 to 25)	6 (-13 to 26)

LEGEND:

Data are mean difference and 95% CIs adjusted for baseline values.

[§]Statistically significant difference between groups

*CI exceeds the upper equivalence limit of the minimal important difference and cannot exclude superiority of telerehabilitation

†CI exceeds the lower equivalence limit and cannot exclude inferiority of telerehabilitation

6MWD, 6 min walk distance; CRQ, Chronic Respiratory disease Questionnaire; PRAISE, Pulmonary Rehabilitation Adapted Index of Self-Efficacy; MMRC, modified Medical Research Council scale; HADS-A, Hospital Anxiety and Depression Scale – anxiety score; HADS-D, Hospital Anxiety and Depression Scale – depression score; PCS, physical composite score; MCS, mental composite score; LIPA, light intensity physical activity; MVPA, moderate-vigorous intensity physical activity; SF36-v2, Medical Outcomes Survey Short-form 36-v2

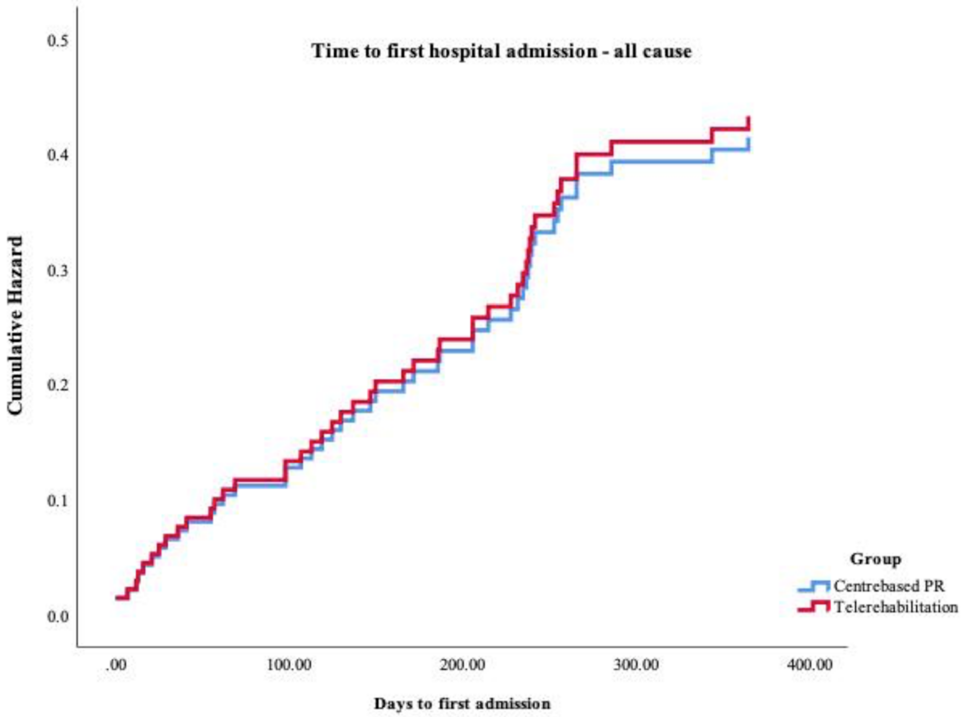

Figure S3. Time to first all cause hospitalisation by group

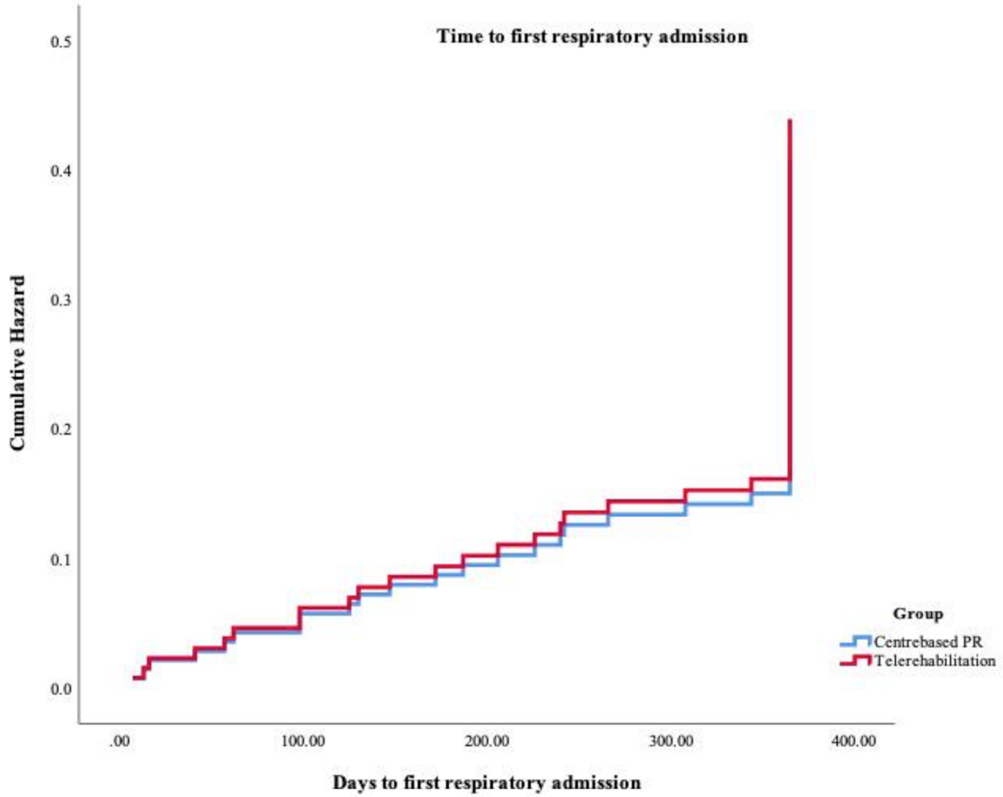

Figure S4. Time to first respiratory hospitalisation by group

REFERENCES

1. Cox NS, McDonald CF, Alison JA, Mahal A, Wootton R, Hill CJ, Bondarenko J, Macdonald H, O'Halloran P, Zanaboni P, Clarke K, Rennick D, Borgelt K, Burge AT, Lahham A, Wageck B, Crute H, Czupryn P, Nichols A, Holland AE. Telerehabilitation versus traditional centre-based pulmonary rehabilitation for people with chronic respiratory disease: protocol for a randomised controlled trial. BMC Pulm Med 2018; 18: 71.
2. Holland AE, Hill CJ, Rochford P, Fiore J, Berlowitz DJ, McDonald CF. Telerehabilitation for people with chronic obstructive pulmonary disease: feasibility of a simple, real time model of supervised exercise training. Journal of Telemedicine and Telecare 2013; 19: 222-226.
3. Alison J, McKeough Z, Johnston K, McNamara R, Spencer L, Jenkins S, Hill C, McDonald V, Frith P, Cafarella P, Brooke M, Cameron-Tucker H, Candy S, Cecins N, Chan A, Dale M, Dowman L, Granger C, Halloran S, Jung P, Lee A, Leung R, Matulick T, Osadnik C, Roberts M, Walsh J, Wootton S, Holland A. Australian and New Zealand Pulmonary Rehabilitation Guidelines. Respirology 2017; 22: 800-819.
4. Chodzko-Zajko WJ, Proctor DN, Fiatarone Singh MA, Minson CT, Nigg CR, Salem GJ, Skinner JS. American College of Sports Medicine position stand. Exercise and physical activity for older adults. Med Sci Sports Exerc 2009; 41: 1510-1530.
5. Hill K, Jenkins SC, Cecins N, Philippe DL, Hillman DR, Eastwood PR. Estimating maximum work rate during incremental cycle ergometry testing from six-minute walk distance in patients with chronic obstructive pulmonary disease. Arch Phys Med Rehabil. 2008; 89: 1782-7.
6. Gloeckl R, Marinov B, Pitta F. Practical recommendations for exercise training in patients with COPD. European respiratory review : an official journal of the European Respiratory Society 2013; 22: 178-186.
7. Williams J, Singh S, Sewell L, Guyatt G, Morgan M. Development of a self-reported Chronic Respiratory Questionnaire (CRQ-SR). Thorax 2001; 56: 954-959.
8. Vodanovich DA, Bicknell TJ, Holland AE, Hill CJ, Cecins N, Jenkins S, McDonald CF, Burge AT, Thompson P, Stirling RG, Lee AL. Validity and Reliability of the Chronic Respiratory Disease Questionnaire in Elderly Individuals with Mild to Moderate Non-Cystic Fibrosis Bronchiectasis. Respiration 2015; 90: 89-96.
9. Dowman LM, McDonald CF, Hill CJ, Lee AL, Barker K, Boote C, Glaspole I, Goh NSL, Southcott AM, Burge AT, Gillies R, Martin A, Holland AE. The evidence of benefits of exercise training in interstitial lung disease: a randomised controlled trial. Thorax 2017; 72: 610.

10. Byrom B, Rowe DA. Measuring free-living physical activity in COPD patients: Deriving methodology standards for clinical trials through a review of research studies. Contemporary clinical trials 2016; 47: 172-184.
11. Rabinovich RA, Louvaris Z, Raste Y, Langer D, Van Remoortel H, Giavedoni S, Burtin C, Regueiro EMG, Vogiatzis I, Hopkinson NS, Polkey MI, Wilson FJ, Macnee W, Westerterp KR, Troosters T, consortium PR. Validity of physical activity monitors during daily life in patients with COPD. Eur Respir J 2013; 42: 1205-1215.
12. Haskell W, Lee I-M, Pate RR, Powel K, Blair S, Franklin B, Macera C, Heath GW, Thompson P, Bauman A. Physical activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Medicine & Science in Sports & Exercise 2007; 39: 1423-1434.