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1 **Behavioural modification interventions alongside pulmonary rehabilitation**  
2 **improve COPD patients' experiences of physical activity**

3

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## 1 **Abstract**

2 **Aims and objectives** The Clinical PROactive Physical Activity in COPD (C-PPAC)  
3 instrument, combines a questionnaire assessing the domains of amount and difficulty of  
4 physical activity (PA) with activity monitor data (steps/day and vector magnitude units) to  
5 assess patients' experiences of PA. The C-PPAC instrument is responsive to pharmacological  
6 and non-pharmacological interventions and to changes in clinically relevant variables. We  
7 compared the effect of PA behavioural modification interventions alongside pulmonary  
8 rehabilitation (PR) to PR alone on the C-PPAC scores in COPD patients with low baseline PA  
9 levels.

10 **Methods:** In this randomised controlled trial, 48 patients (means±SD: FEV<sub>1</sub>: 50±19%, baseline  
11 steps/day: 3450±2342) were assigned 1:1 to receive PR alone, twice weekly for 8 weeks, or  
12 PA behavioural modification interventions (comprising motivational interviews, monitoring  
13 and feedback using a pedometer and goal setting) alongside PR (PR+PA). The C-PPAC  
14 instrument was used to assess PA experience, including a perspective of the amount and  
15 difficulty of PA.

16 **Results:** There were clinically important improvements in favour of the PR+PA interventions  
17 compared to PR alone in: 1) the C-PPAC total score (mean [95% CI] difference: 8 [4 to 12]  
18 points,  $p=0.001$ ), the difficulty (mean [95% CI] difference: 8 [3 to 13] points,  $p=0.002$ ) and the  
19 amount (mean [95% CI] difference 8 [3 to 16] points,  $p=0.005$ ) domains and 2) the CAT score  
20 (mean [95% CI] difference: -2.1 [-3.8 to -0.3] points,  $p=0.025$ ).

21 **Conclusion:** PA behavioural modification interventions alongside PR improve the experiences  
22 of PA in patients with advanced COPD and low baseline PA levels. (NCT03749655).

### 23 **Key words:**

24 COPD, Physical Activity, Behavioural Modification, Physical Activity Experiences,  
25 Pulmonary Rehabilitation.

# 1 **Introduction**

2 Patients with Chronic Obstructive Pulmonary Disease (COPD) have lower levels of daily  
3 physical activity (PA) than their healthy age-matched peers [1-4]. It is recognised that reduced  
4 levels of PA in patients with COPD are associated with a faster rate of disease progression,  
5 greater risk for exacerbation of COPD (ECOPD), leading to increased rates of hospital  
6 admissions and mortality [5].

7 Pulmonary rehabilitation (PR) is an integral non-pharmacological component in COPD  
8 management [6]. However, while PR programs improve exercise capacity and health-related  
9 quality of life in people with COPD [6], these findings have not consistently progressed into  
10 improvements in daily PA [7], particularly in patients with advanced COPD and low baseline  
11 exercise capacity [8]. This is likely due to the complexity of PA as a health behaviour in COPD  
12 [9], with those patients exhibiting low baseline exercise capacity being less capable of  
13 increasing their PA levels due to a low functional reserve [8].

14 PA behavioural modification interventions have been employed to address the complex  
15 behaviour of PA, with the majority of previous studies demonstrating promising results in  
16 patients with COPD [10-16]. This is accomplished by stimulating patients to increase their PA  
17 levels by incorporating lifestyle activities into daily life in conjunction with patient monitoring  
18 and feedback of their daily steps alongside frequently adjusted goal setting [17]. A recently  
19 published systematic review and meta-analysis [18] reported that pedometer-based PA  
20 behavioural modification standalone interventions or alongside PR in patients with COPD  
21 improved accelerometer derived steps per day by clinically important margins [18, 19].  
22 However, in patients with advanced COPD and low baseline PA levels, PA was less likely to  
23 improve following PA behavioural modification interventions alongside PR [18], especially in  
24 those with poor baseline exercise capacity [8, 15, 16].

1 Studies investigating patients with advanced COPD and low baseline exercise capacity and PA  
2 levels [8, 15, 16] have focused primarily on the frequency, intensity, duration and type of PA,  
3 which are quantified by means of activity monitors validated in patients with COPD [20]. This  
4 method of assessment, however, fails to fully capture patients' experiences of PA [21].  
5 Qualitative research has indicated that while patients engage in daily physical activities, they  
6 experience symptoms which adversely impact on their lifestyle [22]. Such patient centred  
7 concepts are only quantifiable through a patient-reported outcome (PRO) questionnaire [23].  
8 However, implementing a PRO questionnaire alone removes the ability to assess the frequency,  
9 intensity and type of PA objectively [21].

10 In order to combine these features, the Clinical PROactive physical activity in COPD (C-  
11 PPAC) instrument was developed, and recently validated in patients with COPD [21]. The  
12 instrument provides a comprehensive measure of patients' experiences of PA, merging  
13 subjective questions regarding the amount and difficulty of PA alongside objective measures  
14 of PA, encompassing average steps per day and vector magnitude units (VMU), which refers  
15 to intensity rather than quantity of PA [21]. The instrument measures amount of PA, difficulty  
16 of PA and total PA experiences. A recent study [24] reported the effect of PA behavioural  
17 modification interventions or PR alone on patients' experiences of PA using the C-PPAC  
18 instrument, indicating clinically important improvements. The effect of adding PA behavioural  
19 modification interventions to PR as compared to PR alone on patient PA experiences was,  
20 however, not reported in that study [24]. We, therefore, evaluated the effect of PA behavioural  
21 modification interventions alongside PR on the PA experiences of COPD patients with low  
22 baseline PA and exercise capacity levels. It was hypothesised that PA behavioural modification  
23 interventions including motivational interviewing, goal setting, step count monitoring and  
24 feedback, alongside PR aiming to improve functional capacity, would be superior to PR alone  
25 in improving all dimensions of the C-PPAC instrument.

# 1 **Methods**

## 2 *Study design*

3 This is a single centre, two parallel-groups, randomised controlled trial (RCT) with 1:1  
4 individual allocation looking into patient compliance to PA behavioural modification  
5 interventions alongside PR (PR+PA) and its efficacy in comparison to PR alone in patients  
6 with COPD. The design of the study and flow of patients is presented in Figure 1. This study  
7 complies with NIHR HRA requirements (Ref: 18/YH/0376) and was prospectively registered  
8 at [clinicaltrials.gov](https://clinicaltrials.gov) online database (NCT03749655).

## 9 *Participants*

10 Patients were recruited from Newcastle upon Tyne Foundation Health Care Trust (NuTH)  
11 Chest Clinic and PR waiting lists. Respiratory nurses and physiotherapists informed eligible  
12 patients about the study and asked their willingness to participate in the study. Patients  
13 inclusion criteria included: (i) COPD confirmed by obstructive spirometry (post-  
14 bronchodilator forced expiratory volume in the first second [FEV<sub>1</sub>] to forced vital capacity  
15 [FVC] ratio <0.70); (ii) clinically stable male or female COPD patients aged 40 years or older;  
16 (iii) optimised medical therapy; (iv) able to provide informed consent. Patients exclusion  
17 criteria included: (i) orthopaedic, neurological or other concomitant disease that significantly  
18 impaired normal biomechanical movement patterns, as judged by the investigator; (ii)  
19 moderate or severe COPD exacerbation (ECOPD) within 4 weeks prior to study enrolment;  
20 (iii) unstable ischaemic heart disease, including myocardial infarction within 6 weeks prior to  
21 study enrolment; (iv) moderate or severe aortic stenosis or hypertrophic obstructive  
22 cardiomyopathy; (v) uncontrolled hypertension and another condition likely to limit life  
23 expectancy to less than one year (principally metastatic malignancy). Upon meeting the study  
24 entry criteria, patients who agreed to participate were contacted by the research team. Detailed

1 information regarding the study was provided and written informed consent was obtained prior  
2 to the study.

### 3 *Pulmonary Rehabilitation*

4 The 8-week PR programme was delivered according to the BTS guidelines on PR [25],  
5 comprising two 60-minute sessions of exercise training and one 30-minute education session  
6 per week between November 2018 to November 2020. Due to the pandemic 6 patients (n=3 in  
7 the PR intervention and n=3 in the PR+PA intervention) completed one exercise session under  
8 supervision and one unsupervised at home. Each supervised exercise session was delivered by  
9 a respiratory physiotherapist and involved progressive, individualised tailored aerobic and  
10 resistance training in accordance with the BTS guidelines on PR [25]. A multidisciplinary team  
11 comprising physiotherapists, psychologists, dieticians, respiratory nurses and occupational  
12 therapists, delivered the education component of the PR programme. As per the BTS guidelines  
13 on PR [25], the educational component of PR aims to support aspects of lifestyle and behaviour  
14 change and assist the promotion of self-management to support patients decision making and  
15 self-efficacy. Specific educational talks across the 8-week PR programme included guidance  
16 and support on dyspnea/symptom management, chest clearance/breathing techniques,  
17 nutritional advice, and advice on improving PA. Regardless of group allocation in the study,  
18 generic advice on improving PA was provided with an emphasis on barriers and facilitators to  
19 improving levels of PA. Furthermore, each patient received a British Lung Foundation exercise  
20 handbook which provided added support regarding the educational sessions as well as  
21 resources to record exercise and PA conducted outside of the weekly PR sessions. Patients in  
22 both groups with a baseline hospital anxiety and/or depression score (HADS)  $\geq 8$  (either for  
23 anxiety or depression) received up to three sessions of Cognitive Behavioural Therapy (CBT)  
24 by a specialist respiratory nurse lasting for 30 minutes. The number of CBT sessions suggested  
25 and timescale for such sessions were co-developed with the patients depending on the patients'

1 individual response to treatment to manage symptoms based on their subjective feedback,  
2 HADS questionnaire results and patient preference [26]. CBT focused on understanding how  
3 experiences were interpreted, and made up of four elements: behaviour, cognition/thoughts,  
4 feelings/emotions, and physical sensations [27].

#### 5 *PA behavioural modification interventions*

6 Prior to the initiation of the PA behavioural modification interventions, patients received a one-  
7 to-one semi-structured motivational interview with the researcher discussing motivational  
8 issues, favourite activities, facilitators and barriers to PA and strategies to become more  
9 physically active [28]. Throughout the interview, patients were questioned about their self-  
10 efficacy and motivational levels. On completion of the interview, each patient created a plan  
11 with the researcher consisting of three concrete actions, which could be used to increase PA  
12 levels. This plan consisted of favourite activities and was implemented throughout the PA  
13 behavioural modification interventions to stimulate patient's self-motivation. Following this,  
14 the PA behavioural modification interventions involved the provision of a pedometer (Fitbug,  
15 Camden, London), an individualised daily step-count target (reviewed twice weekly for 8  
16 weeks), and a step-count diary that was brought to every PR session (twice weekly). Patients  
17 were encouraged to achieve the agreed target each day and to record the attained pedometer  
18 step count in their step count diary each evening. Patients were asked to attend each PR session  
19 with their step count diary, enabling the researcher to frequently observe their activity levels,  
20 assess overall compliance to the intervention and provide the appropriate level of support based  
21 on their recorded activity levels. Based on the feedback from step count diaries, the researcher  
22 calculated a daily step-count target based on an increase of 10% from the preceding week's  
23 average daily step-count, with the first week's target derived from baseline accelerometer step  
24 count data (Actigraph wGT3X, Actigraph LLC, Pensacola, FL, USA) [29] and during  
25 subsequent weeks from the pedometer (Fitbug) step count data. During the weekly step-count



1 review, education on the importance of PA and advice on how to increase PA levels were  
2 provided, including a focus on the barriers and facilitators to PA, whilst taking into  
3 consideration the three concrete actions that were outlined in the motivational interview [29].

#### 4 *Outcome measures*

5 The Clinical PROactive C-PPAC instrument, which was previously validated for use in  
6 patients with COPD [22], required both questionnaire and accelerometer-derived PA data  
7 (Actigraph wGT3X, Actigraph LLC, Pensacola, FL, USA) and was implemented one week  
8 prior to the onset of the PR programme and one week following completion of the PR  
9 programme. The C-PPAC questionnaire included 12-items with a 7-day recall and was  
10 completed using paper and pen as shown in the online supplementary materials (Table S1).  
11 Patients were also instructed to wear an accelerometer previously validated to be part of the C-  
12 PPAC tool (Actigraph wGT3X, Actigraph LLC, Pensacola, FL, USA) [21] during waking  
13 hours for seven consecutive days prior to the onset of the PR programme [30]. A valid  
14 assessment of patient's PA was considered if patients recorded more than 8 hours of wear time  
15 on at least 4 weekdays within the 7-day period [21]. C-PPAC scores were calculated by  
16 combining questionnaire items with two objective variables from the activity monitor  
17 (steps/day and VMU). Three scores were generated (amount of PA, difficulty of PA and total  
18 PA experience) ranging from 0 to 100, where higher numbers indicated a better score [21].  
19 Other outcome measures taken prior to the onset of PR and immediately following completion  
20 of PR included: the 6 minute walking distance (6MWD) [31]; leg muscle strength and  
21 endurance (one leg extension repetition maximum using a calibrated Myometer (MIE Medical  
22 Research Ltd, Leeds, UK) and 30 second sit to stand repetitions), respectively [32, 33];  
23 handgrip strength [34]; health-related quality of life (COPD assessment test [CAT]) [35], the  
24 clinical COPD questionnaire [CCQ] [36]); and anxiety and depression (Hospital Anxiety and  
25 Depression Scale [HADS] [37]); [38].

1 *Patient acceptability and compliance*

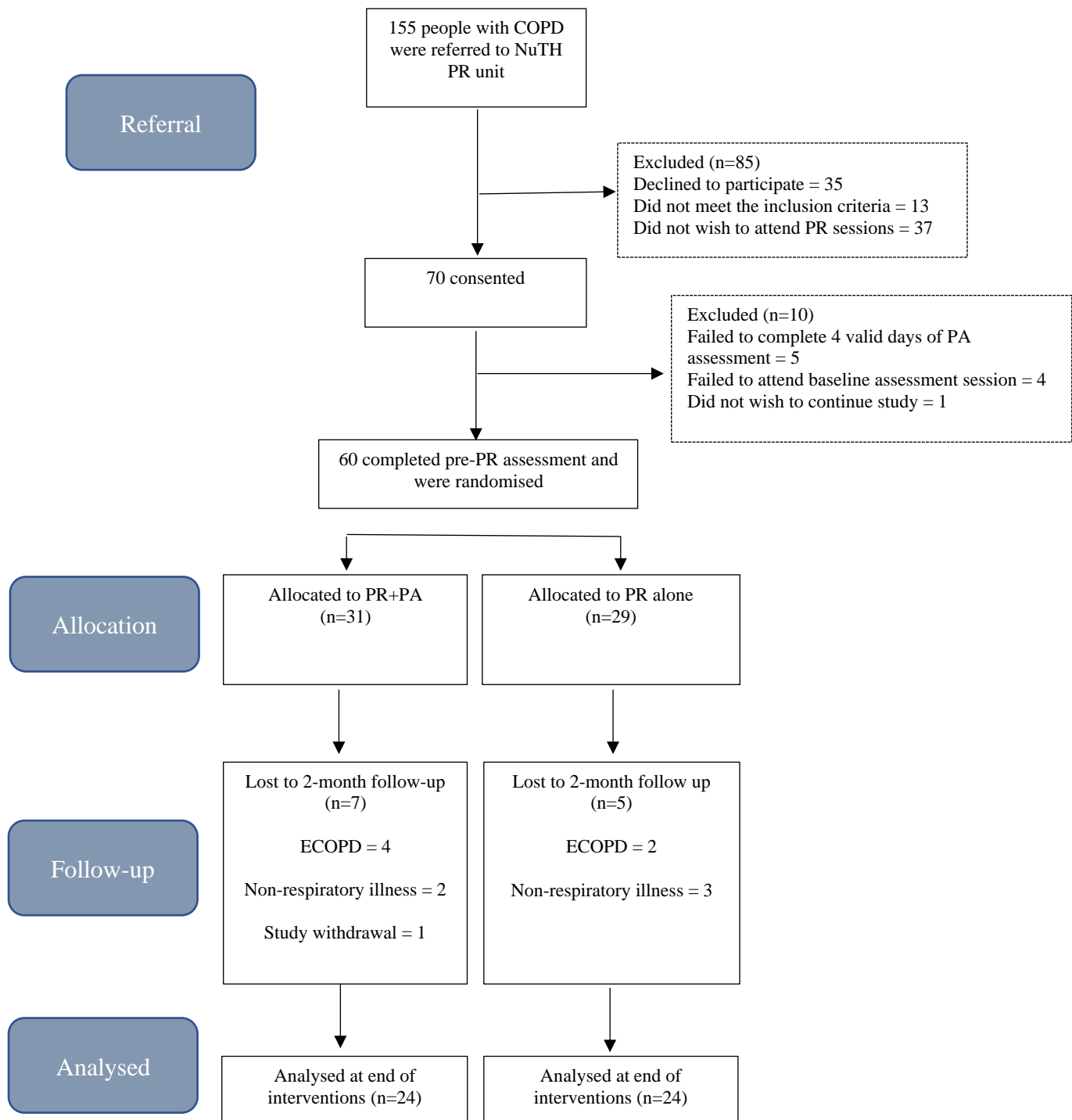
2 Patient acceptability of the PA behavioural modification interventions was assessed through a  
3 project-tailored questionnaire modified from another study [39]. During the final visit of the  
4 study, patients filled in a self-administered, project tailored, multiple choice questionnaire  
5 about their experiences with the intervention and the usefulness of its components on a 10-  
6 point Likert scale as previously described [39] and shown in Table S2 of the online  
7 supplementary material. Data from the project-tailored questionnaire were scored as  
8 categorical variables and reported as frequencies and percentages (number of patients  
9 indicating each answer), except for the usefulness ratings of the components, which were  
10 expressed as median [P25-P75]. Patient compliance to components of the behavioural  
11 modification interventions was assessed via the following means: i) fractional number of  
12 weekly goal setting targets met; ii) fractional number of weekly completions of PA diaries and  
13 iii) average weekly wear time of the pedometer. Data on patient compliance were reported as  
14 percentages and median (P25-P75) and as mean  $\pm$  SD depending on the variable assessed.

15 *Data analysis*

16 Verification of the sample size was based on the study by Louvaris et al [40] comparing PR to  
17 usual care (UC). Based on the mean difference in the C-PPAC total score (7.4 units) between  
18 PR and UC and observed SD (8.5 units), an alpha significance level of 0.05 (2-sided) and 80%  
19 power, a minimum sample of 24 patients per group was considered to be sufficient to detect  
20 significant differences in the total C-PPAC score between PR+PA and PR. Based on previous  
21 studies on similar PR programmes in the UK [15], considering an attrition rate of 20% the total  
22 sample size was increased to 58 patients. Randomisation was stratified by the 6MWD (<350  
23 meters or  $\geq$  350 metres), and the average HADS score for anxiety and depression (<8 points or  
24  $\geq$ 8 points) using a block size of 4 at the onset of the PR programme.

1 Patient characteristics and outcome data at baseline and following PR are reported as  
2 means±SD unless otherwise stated. Within and between group differences pre- to post  
3 interventions are reported as mean, 95% confidence intervals (CI). Independent samples *t* tests  
4 were implemented to compare baseline group characteristics. A two-way repeated measures  
5 ANOVA was implemented for all outcome variables to identify differences between the two  
6 interventions. Statistical significance was set at  $p < 0.05$  for all analyses.

7



1

2 Figure 1: Consolidation Standards of Reporting Trials diagram of the study. COPD = Chronic

3 Obstructive Pulmonary Disease, NuTH = Newcastle upon Tyne Healthcare trust, PR =

4 Pulmonary Rehabilitation, n = number, PA = Physical Activity, ECOPD = exacerbation of

5 COPD

6

# 1 Results

## 2 Participants

3 In total, 70 patients provided consent for the study at visit 1, while 60 patients were randomised  
4 at visit 2 to PR+PA (n=31) and PR alone (n=29) (Figure 1). Reasons for withdrawal following  
5 consent are provided in Figure 1. There were no significant between-group differences in any  
6 of the baseline characteristics (Table 1). Throughout the study, 12 patients were lost due to:  
7 ECOPD (n=6), non-respiratory illness' (n=5) and inability to attend the PR programme (n=1).  
8 Therefore, 48 patients completed the post-PR assessment visit, with 24 patients completing  
9 PR+PA and 24 completing PR alone.

10

Table 1: Baseline Characteristics

Variable	PR alone (n=24)	PR+PA (n=24)	p value
Gender (male/female)	9/15	9/15	n/a
Age (years)	73±9	71±9	0.395
BMI (kg/m <sup>2</sup> )	25.5±2.9	28.8±7.4	0.084
FEV <sub>1</sub> (L)	1.21±0.5	1.27±0.5	0.733
FEV <sub>1</sub> (% predicted)	50±17	51±19	0.425
FEV <sub>1</sub> /FVC (% predicted)	51±15	51±15	0.894
Step/day	3446±2342	3450±2168	0.608
6MWD (m)	276±92	285±92	0.240
mMRC	3±1	3±1	0.667
HADS (A)	7±4	7±4	0.678
HADS (D)	7±4	6±6	0.567

*Definition of abbreviations:* PR = Pulmonary Rehabilitation, PA = Physical Activity, BMI = Body Mass Index, FEV<sub>1</sub> = Forced Expiratory Volume in the 1<sup>st</sup> second, L = Litres, FVC = Forced Vital Capacity, 6MWD = Six Minute Walk Distance, m = metres, HADS = Hospital Anxiety and Depression Scale, A = Anxiety, D = Depression, n/a = not available. Values are mean±SD.

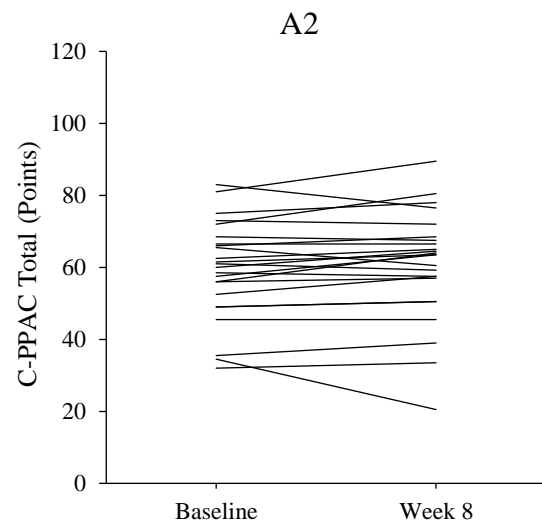
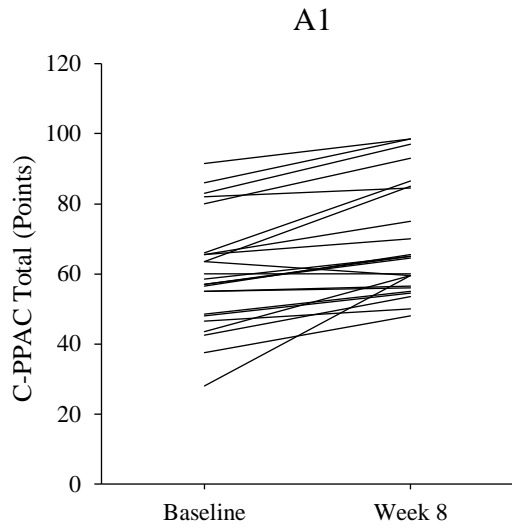
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## 12 Patient experience of PA

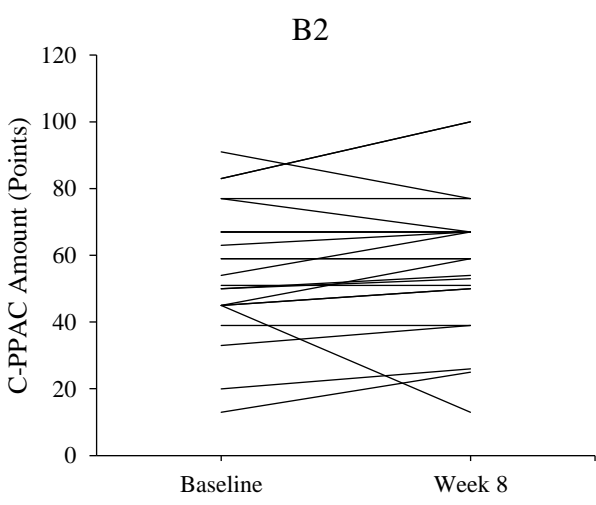
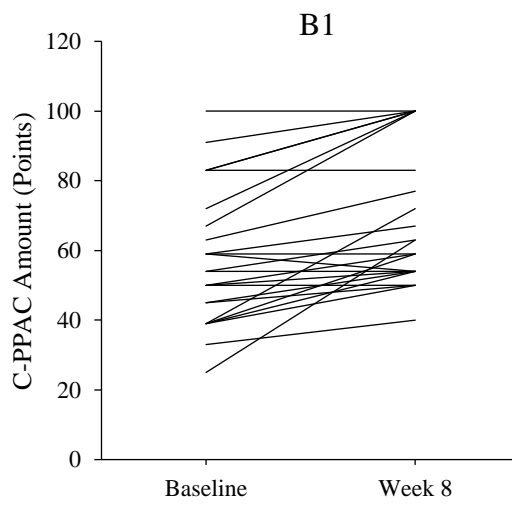
13 The effect of PR+PA compared to PR alone on all dimensions of the C-PPAC instrument for  
14 each patient is shown in Figure 2. Post-interventions, the *total score* of the C-PPAC instrument  
15 was improved by a clinically important margin (>4 points) [21] in the PR+PA group compared

1 with the PR alone group, with a between group difference of 8 points (95% CI 4 to 12 points;  
2  $p=0.001$ ) (Table 2). In regard to the *difficulty score* of the C-PPAC instrument, clinically  
3 important ( $>6$  points) [21] improvements were reported in the PR+PA group compared with  
4 the PR alone group, with a between group difference of 8 points (95% CI 3 to 13 points;  
5  $p=0.002$ ) (Table 2). Finally, clinically important ( $>6$  points) [21] improvements in the *amount*  
6 *score* of the C-PPAC tool were reported in the PR+PA group compared to the PR alone group,  
7 with a between group difference of 8 points; (95% CI 3 to 16 points,  $p=0.005$ ) (Table 2).

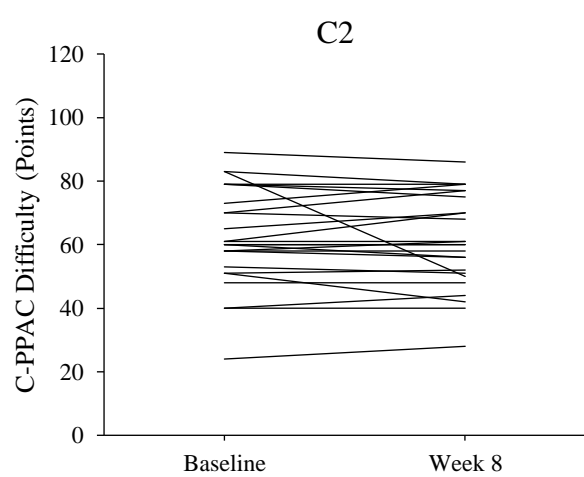
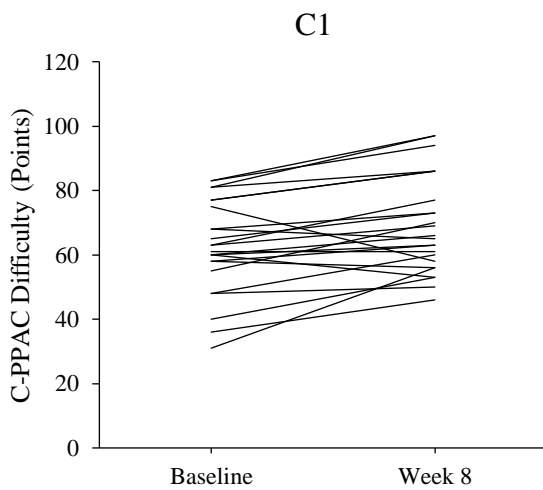
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4 Figure 2: Individual responses to the C-PPAC instrument for A1: total score for PR+PA, A2:  
 5 total score for PR alone, B1: amount score for PR+PA, B2: amount score for PR alone, C1:  
 6 difficulty score for PR+PA, C2: difficulty score for PR alone.

1 *Physical activity outcomes*

2 Changes in accelerometer-derived PA variables are shown in Table 2. Post intervention,  
3 clinically important (600-1100 steps/day) [19] improvements in accelerometer steps/day data  
4 were found in the PR+PA intervention only, with a between group difference of 1016 steps/day  
5 (95% CI 556 to 1474 steps/day,  $p=0.001$ ) (Table 2). Following the completion of the PR  
6 programme a significant improvement in accelerometer movement intensity was recorded in  
7 PR+PA group only, with a between group difference of 93 VMU (95% CI 41 to 145 VMU,  
8  $p=0.001$ , Table 2). Finally, following completion of the PR programme, a significant  
9 improvement in time spent in light PA was recorded only in the PR+PA intervention, with a  
10 between group difference of 22 minutes (95% CI 2 to 43,  $p=0.030$ ) (Table 2).

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1 Table 2: Changes in PA parameters in the PR+PA and PR alone interventions.

	Group	Baseline	2 Months	Within Group Mean Difference	P value	Between Group Difference	P value
C-PPAC Total score	PR+PA	60±16	69±16	9 (6 to 12)	0.001	8 (4 to 12)	0.001
	PR alone	59±14	60±15	1 (-1 to 4)	0.369		
C-PPAC Difficulty score	PR+PA	62±15	69±15	7 (3 to 10)	0.001	8 (3 to 13)	0.002
	PR alone	62±16	61±15	-1 (-4 to 2)	0.525		
C-PPAC Amount score	PR+PA	58±20	69±20	11 (7 to 16)	0.001	8 (3 to 16)	0.005
	PR alone	56±19	59±21	3 (-2 to 7)	0.315		
Steps/day	PR+PA	3450±2168	4426±2577	976 (651 to 1300)	0.001	1016 (556 to 1474)	0.001
	PR alone	3446±2342	3406±2095	-40 (-365 to 284)	0.805		
Movement intensity (VMU)	PR+PA	337±154	410±231	73 (37 to 109)	0.001	93 (41 to 145)	0.001
	PR alone	307±170	287±133	-20 (-57 to 17)	0.281		
Sedentary time (min)	PR+PA	495±84	458±111	-37 (12 to 62)	0.005	-15 (-51 to 21)	0.406
	PR alone	541±90	519±103	-22 (-48 to 3)	0.088		
Light time (min)	PR+PA	167±56	187±73	20 (6 to 35)	0.006	22 (2 to 43)	0.030
	PR alone	135±57	133±48	-2 (-17 to 12)	0.741		
MVPA (min)	PR+PA	7±8	10±14	3 (0 to 6)	0.041	3 (-1 to 7)	0.185
	PR alone	7±10	7±8	0 (-3 to 3)	0.791		

*Definition of abbreviations:* C-PPAC = Clinical visit-PROactive physical activity in COPD, Min = Minutes, PA = Physical activity, PR = pulmonary rehabilitation, MVPA = moderate to vigorous physical activity. Values are mean±SD. Within and between group differences are reported with 95% confidence intervals (CI).

1 *Other outcomes*

2 The 6MWD improved following both PR+PA and PR alone interventions, with similar within  
3 group changes (Table 3). Significant between group improvements were reported in upper and  
4 lower body strength and clinically important differences in the CAT score in favour of the  
5 PR+PA group (Table 3).

6 *Intervention acceptability and compliance*

7 Overall, the PR+PA intervention was well received by patients, with 75% indicating they  
8 “liked taking part in the intervention a lot”. Furthermore, 58% of patients claimed the  
9 intervention “helped them a lot” regarding completing more PA outside of PR. The majority  
10 of patients (79%) experienced the proposed weekly increases in step goals as “reasonable”,  
11 whereas 21% of patients experienced these increases as “a little too high” or “a little too low”.  
12 The usability of the pedometer was deemed “very easy” in 96% of patients. Patients rated the  
13 usefulness of components of the PR+PA intervention with scores based on a satisfaction scale  
14 (0 terrible to 10- perfect) with the step counter (median [P25-P75]; 9 [8-10]), daily step goals  
15 (8 [8-9]) and feedback from researcher (9 [8-10]) all deemed useful parts of the intervention.  
16 Regarding patient compliance, the average weekly wear time of the Fitbug pedometer was high  
17 equivalent to  $6.6 \pm 0.2$  days worn. Compliance with the PA diary to self-reported daily step  
18 counts was also high ( $91 \pm 18\%$ ), with a median number of 55 [49-56] recorded days over the 8  
19 weeks. Finally, compliance with step goal targets throughout the 8 weeks was high, with an  
20 average  $68 \pm 12\%$  of step goals achieved. In terms of pedometer (Fitbug) steps/day (PR+PA  
21 patients only), significant improvements were reported from baseline to end of the intervention  
22 (by 1566 steps/day: 95% CI 681 to 2357,  $p=0.001$ ).

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1 Table 3: Changes in functional capacity, muscular strength/endurance, health-related quality of life and anxiety and depression parameters in the  
 2 PR+PA and PR alone interventions.

3

	Group	Baseline	2 Months	Within Group Mean Difference	P value	Between Group Difference	P value
6MWD (m)	PR+PA	285±92	339±90	54 (36 to 72)	0.001	16 (-10 to 41)	0.236
	PR alone	276±92	314±99	38 (20 to 57)	0.001		
HG (kg)	PR+PA	22.7±8.9	26.0±9.2	3.3 (2.1 to 4.5)	0.001	2.1 (0.3 to 3.9)	0.022
	PR alone	18.3±6	19.5±7	1.2 (0.2 to 2.5)	0.083		
QMVC (kg)	PR+PA	24.6±8.7	29.6±9.7	5.0 (3.4 to 6.8)	0.001	2.5 (0.2 to 4.9)	0.033
	PR alone	21.0±10.2	23.5±10.7	2.5 (0.8 to 4.20)	0.005		
Sit to Stand (reps)	PR+PA	10±3	13±4	3 (2 to 4)	0.001	1 (-1 to 2)	0.446
	PR alone	11±4	13±5	2 (1 to 3)	0.001		
CCQ (T)	PR+PA	2.5±1.1	2.2±1.1	-0.3 (-0.6 to 0.02)	0.068	-0.2 (-0.7 to 0.2)	0.349
	PR alone	2.5±1.3	2.4±1.3	-0.1 (-0.4 to 0.2)	0.599		
CCQ (S)	PR+PA	2.5±1.2	2.2±1.1	-0.3 (-0.7 to 0.1)	0.169	-0.2 (-0.9 to 0.4)	0.435
	PR alone	2.7±1.2	2.6±1.4	-0.1 (-0.5 to 0.4)	0.805		
CCQ (F)	PR+PA	2.4±1.2	2.1±1.3	-0.3 (-0.7 to 0.1)	0.134	-0.1 (-0.7 to 0.5)	0.722
	PR alone	2.4±1.4	2.2±1.4	-0.2 (-0.6 to 0.2)	0.326		
CCQ (M)	PR+PA	1.8±1.5	1.7±1.6	-0.1 (-0.5 to 0.8)	0.677	-0.1 (-1.0 to 0.8)	0.869
	PR alone	1.9±1.5	1.9±1.5	-0 (-0.7 to 0.6)	0.859		
CAT	PR+PA	25.9±6.4	21.7±6.1	-4.2 (-5.4 to -2.9)	0.001	-2.1 (-3.8 to -0.3)	0.025
	PR alone	27.0±6.4	24.9±7.1	-2.1 (-3.4 to -0.8)	0.002		
HADS (A)	PR+PA	7±6	6±4	-1 (-2 to 0)	0.065	-1 (-2 to 1)	0.421
	PR alone	7±4	7±4	0 (-2 to 1)	0.461		
HADS (D)	PR+PA	6±6	5±4	-1 (-2 to 0)	0.004	0 (-2 to 1)	0.527
	PR alone	7±4	6±3	-1 (-2 to -1)	0.036		

*Definition of abbreviations:* 6MWD = Six Minute Walk Distance, HG = Hand grip strength, QMVC = Quadriceps Muscle Voluntary Capacity, CCQ = Clinical COPD Questionnaire, T = Total, S = Symptoms, F = Functional, M = Mental, CAT = COPD Assessment Test, HADS = Hospital Anxiety and Depression Scale, A = Anxiety, D = Depression, m = Metres, PA = Physical activity, PR = Pulmonary Rehabilitation. Values are mean±SD. Within and between group differences are reported with 95% confidence intervals (CI).

## 1 **Discussion**

2 The novel finding of this study is the clinically important improvements in COPD patients'  
3 experiences of PA following PR+PA compared to PR alone in patients with advanced COPD  
4 exhibiting low baseline PA levels. Improvements in the 6MWD were similar for both  
5 interventions, however the magnitude of improvement in upper and lower muscle strength was  
6 greater in the PR+PA intervention. Collectively these findings suggest that PA behavioural  
7 modification interventions alongside PR provide insightful support to patients with low  
8 baseline levels of PA to translate PR-induced improvements in functional capacity into  
9 improvements in patients' experiences of PA.

10 Previous literature has documented the response of the C-PPAC instrument in two behavioural  
11 modification interventions [29, 41]. Demeyer and colleagues [29] found a significant between  
12 group difference in both the total and amount dimensions of the C-PPAC instrument following  
13 12 weeks of semi-automated PA tele-coaching delivered via a smartphone app. It should be  
14 noted that the usual care group reported a large decrease in C-PPAC scores following a 12-  
15 week period, with only small improvements in C-PPAC scores reported following the tele-  
16 coaching intervention, thereby suggesting that the tele-coaching intervention only had marginal  
17 effects on the C-PPAC tool [29]. Furthermore, Demeyer and colleagues were unable to  
18 demonstrate an improvement in the difficulty dimension of the C-PPAC instrument [29]. The  
19 difficulty dimension has demonstrated a moderate-strong correlation with health status, chronic  
20 dyspnea and exercise capacity [21], which is not captured by the amount dimension. The study  
21 by Demeyer et al [29] did not include any specific exercise training and as a result was  
22 unsuccessful in demonstrating improvements in exercise capacity, which may be the reason for  
23 not reporting an improvement in the difficulty domain following 12-weeks of tele-coaching  
24 [29].

1 Arbillaga and colleagues [41] implemented a 12-month urban training programme that  
2 incorporated behavioural and community-based exercise interventions in patients with COPD.  
3 The C-PPAC instrument was able to detect a significant improvement from baseline to 12  
4 months in both the amount and difficulty C-PPAC scores, however improvements were not  
5 significant between the intervention and the usual care groups [41]. Considering the magnitude  
6 of change in the C-PPAC total scores between the intervention and control groups in the studies  
7 of Arbillaga-Extarri [41] (4.5 units) and Demeyer [29] (4.5 units) and that of the current study  
8 (8 units), it is clear that PA behavioural techniques added to PR are superior to PA behavioural  
9 interventions alone in improving the total score of the C-PPAC instrument.

10 Louvaris and colleagues [40] presented significant and clinically important improvements in  
11 the total score of the C-PPAC instrument following PR (5.6 units), which was not found in the  
12 PR alone group (1 unit) in the current study. Louvaris and colleagues [40] provided a different  
13 type of PR, with their programme consisting of 3 sessions per week for a total of 10 weeks,  
14 whilst the current study consisted of 2 sessions per week for 8 weeks. Secondly, Louvaris and  
15 colleagues [40] prescribed high-intensity interval exercise, whereas the current study  
16 implemented moderate intensity exercise. Furthermore, COPD patients in the Louvaris et al.  
17 study [40] presented greater baseline levels of PA and 6MWD than the current study, which  
18 has previously been documented to influence the effectiveness of interventions to improve PA  
19 [18]. With this in mind, it is plausible that the incorporation of PA behavioural modification  
20 interventions, in conjunction with improved functional capacity through PR exercise training,  
21 yielded clinically important improvements in all C-PPAC dimensions in patients with very low  
22 levels of PA at baseline (approximately 3000 steps/day) [21].

23 Importantly, several components of the PA behavioural modification interventions used in the  
24 current study, including patient education on the benefits of PA and incorporating behaviour  
25 change techniques such as goal setting, action planning and self-monitoring, may have

1 empowered and motivated patients to engage in more daily activity. Such behavioural  
2 modification components have been shown to benefit COPD patients' readiness, motivation  
3 and confidence to engage in PA and were associated with significant improvements in PA  
4 behaviour [42]. Furthermore, the initial motivation interview stimulated a discussion between  
5 patient and researcher regarding preferred and non-preferred activities, allowing the researcher  
6 to tailor weekly PA goals around activities that the patient enjoyed, encouraging self-  
7 motivation within the patient [12]. Finally, attending each PR session with a step count diary  
8 and twice-weekly face-to-face consultations gave the research team an insight into the  
9 compliance of each patient, and enabled researchers to intervene if patients were unable to cope  
10 with the present goals.

#### 11 *Study limitations*

12 There are several limitations that must be considered in this study. Our inability to blind  
13 patients to the study allocation may have impacted on the overall quality of evidence and  
14 increased the risk of bias towards the intervention. Our failure to blind patients was based on  
15 several reasons. Firstly, it would require a pedometer being issued to the PR alone group.  
16 Although the simple addition of a pedometer alongside generic advice on PA provided during  
17 PR doesn't necessary provide any form of PA counselling, the stimulus and incentive to self-  
18 manage and increase steps/day with the availability of a pedometer may impact upon the  
19 steps/day of the PR alone group. Secondly, in order to remain comparable with previous  
20 literature, we followed the procedure of several previous studies that implemented PA  
21 counselling alongside standard care PR [10, 12, 13, 15], of which pedometers were not  
22 provided to the control group. In future studies however, studies may wish to follow the  
23 blinding procedure of two recent studies in COPD [16, 41]. Varas and colleagues [16] blinded  
24 patients by allocating a pedometer to both intervention and control groups, but provided no  
25 pedometer specific instructions to the control group. Meanwhile, Arbillaga and colleagues [41]

1 took a different approach by refraining the existence of an alternative group to patients. The  
2 latter would be difficult to incorporate into the current study due to the lack of resources  
3 available to run two separate PR programmes simultaneously, in order to refrain the existence  
4 of groups from one another.

5 Due to all measures being administered in a face-to-face manner by a single researcher, bias  
6 related to the researcher providing the PA behavioural modification interventions couldn't be  
7 avoided and blinding of assessor was not possible.

8 This was a small-scale study, therefore, generalisability of the results to clinical practice may  
9 be limited. Finally, the present behavioral modification interventions alongside PR were well  
10 received by the vast majority of patients showing high compliance, however such behavioral  
11 interventions may require significant health care resources as they are more time consuming  
12 compared to PA tele-coaching [38].

13

## 14 **Conclusions**

15 Incorporating PA behavioural modification interventions alongside a PR programme conveys  
16 improvements in functional capacity into improved experiences of PA in COPD patients with  
17 low baseline PA and exercise capacity levels.

18

## 19 **CRedit authorship contribution**

20 **Matthew Armstrong:** conceptualization, data curation, formal analysis, investigation,  
21 methodology, writing- original draft, project administration. **Emily Hume:** Data curation,  
22 formal analysis, investigation, writing- review & editing. **Laura McNeillie:** Project  
23 administration, resources, investigation, writing – Review & Editing. **Francesca Chambers:**  
24 Project administration, resources, investigation, writing – Review & Editing. **Lynsey**  
25 **Wakenshaw:** Project administration, resources, investigation, writing – Review & Editing.

1 **Graham Burns:** conceptualization, methodology, supervision, writing- review & editing.  
2 **Karen Heslop Marshall:** conceptualization, methodology, investigation, supervision, writing-  
3 review & editing, writing- review & editing. **Ioannis Vogiatzis:** conceptualization, funding  
4 acquisition, investigation, supervision, writing- review & editing.

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# 1 Appendices

## 2 A1: The C-PPAC instrument



### Clinical Visit Of Proactive Physical Activity In COPD (C-PPAC)

**INSTRUCTIONS TO PATIENTS:**

Patients with chronic lung disease like you often report that they have problems during physical activity. By physical activity, we mean all activities that require movement of your body. Examples are household activities, walking, going to work, or getting dressed. However, please consider all activities you do, and not only these examples. We would like to know how you experienced your physical activity IN THE PAST 7 DAYS.

Please select the box next to the response that best applies to you IN THE PAST 7 DAYS.

There are no wrong answers. We very much value your response.

	Difficult y score	Amount score
In the past 7 days, how much walking did you do outside?		
<input type="checkbox"/> None at all		0
<input type="checkbox"/> A little bit (about 10 minutes every day)		1
<input type="checkbox"/> Some (about 30 minutes every day)		2
<input type="checkbox"/> A lot (about 1 hour every day)		3
<input type="checkbox"/> A great deal (more than 1 hour every day)		3
In the past 7 days, how many chores did you do outside the house? Some examples are gardening, taking the rubbish out, or doing small errands.		
<input type="checkbox"/> None at all		0
<input type="checkbox"/> A few		1
<input type="checkbox"/> Some		2
<input type="checkbox"/> A lot		3
<input type="checkbox"/> A large amount		4
In the past 7 days, how much difficulty did you have getting dressed?		
<input type="checkbox"/> None at all	4	
<input type="checkbox"/> A little bit	3	
<input type="checkbox"/> Some	2	
<input type="checkbox"/> A lot	1	
<input type="checkbox"/> A great deal	0	
In the past 7 days, how much difficulty did you have getting out and about?		
<input type="checkbox"/> None at all	4	
<input type="checkbox"/> A little bit	3	
<input type="checkbox"/> Some	2	
<input type="checkbox"/> A lot	1	
<input type="checkbox"/> A great deal	0	



In the past 7 days, how often did you avoid doing activities because of your lung problems?

- |                          |              |   |
|--------------------------|--------------|---|
| <input type="checkbox"/> | Not at all   | 4 |
| <input type="checkbox"/> | Rarely       | 3 |
| <input type="checkbox"/> | Sometimes    | 2 |
| <input type="checkbox"/> | Frequently   | 1 |
| <input type="checkbox"/> | All the time | 0 |

In the past 7 days, how breathless were you in general during your activities?

- |                          |              |   |
|--------------------------|--------------|---|
| <input type="checkbox"/> | Not at all   | 4 |
| <input type="checkbox"/> | A little bit | 3 |
| <input type="checkbox"/> | Moderately   | 2 |
| <input type="checkbox"/> | Very         | 1 |
| <input type="checkbox"/> | Extremely    | 0 |

In the past 7 days, how often did you lack physical strength to do things because of your lung problems?

- |                          |              |   |
|--------------------------|--------------|---|
| <input type="checkbox"/> | Not at all   | 4 |
| <input type="checkbox"/> | Rarely       | 3 |
| <input type="checkbox"/> | Sometimes    | 2 |
| <input type="checkbox"/> | Frequently   | 1 |
| <input type="checkbox"/> | All the time | 0 |

In the past 7 days, how tired were you in general during your activities?

- |                          |              |   |
|--------------------------|--------------|---|
| <input type="checkbox"/> | Not at all   | 4 |
| <input type="checkbox"/> | A little bit | 3 |
| <input type="checkbox"/> | Moderately   | 2 |
| <input type="checkbox"/> | Very         | 1 |
| <input type="checkbox"/> | Extremely    | 0 |

In the past 7 days, how often did you have to take breaks during your physical activities?

- |                          |              |   |
|--------------------------|--------------|---|
| <input type="checkbox"/> | Not at all   | 4 |
| <input type="checkbox"/> | Rarely       | 3 |
| <input type="checkbox"/> | Sometimes    | 2 |
| <input type="checkbox"/> | Frequently   | 1 |
| <input type="checkbox"/> | All the time | 0 |





In the past 7 days, how breathless were you when walking on level ground indoors and outdoors?

- Not at all 4
- A little bit 3
- Moderately 2
- Very 1
- Extremely 0

In the past 7 days, how much time did you need to recover from your physical activities?

- None at all 4
- A little bit 3
- Some 2
- A lot 1
- A great deal 0

In the past 7 days, did you need to consider your lung problems when you planned your activities because of your lung problems? Examples are a trip out, an appointment or expecting visitors.

- No 4
- A little bit 3
- Sometimes 2
- A lot 1
- A great deal 0

Weekly steps score	Measured by Actigraph	Measured by Dynaport	
<input type="checkbox"/> 0	<1000	<1500	0
<input type="checkbox"/> 1	1000-2000	1500-2500	1
<input type="checkbox"/> 2	2000-4000	2500-4500	2
<input type="checkbox"/> 3	4000-6000	4500-6500	3
<input type="checkbox"/> 4	>6000	>6500	4
Weekly VMU score	Measured by Actigraph	Measured by Dynaport	
<input type="checkbox"/> 0	<100	<60	0
<input type="checkbox"/> 1	100-200	60-130	1
<input type="checkbox"/> 2	200-300	130-210	2
<input type="checkbox"/> 3	300-500	210-370	3
<input type="checkbox"/> 4	>500	>370	4
Amount scores (sum above):			
Difficulty scores (sum above):			
Total scores (sum above):			

1  
2  
3

1 **A2: Project tailored patient satisfaction questionnaire.**



**Northumbria  
University**  
NEWCASTLE

The Newcastle upon Tyne Hospitals **NHS**  
NHS Foundation Trust

How much did you **enjoy taking part** in this activity program?

- I liked it a lot
- I liked it
- Neutral
- I did not like it
- No opinion

Explain why? .....

.....

.....

Did the intervention **coach you in increasing** your physical activity outside of pulmonary rehabilitation?

- Yes, it helped me a lot
- Yes, a little bit
- Not noticeable
- No, not at all
- No, it rather discouraged me

Explain why? .....

.....

.....





How did you **experience the weekly increases** proposed during the intervention?

- Much too low
- A little bit too low
- Reasonable
- A little bit to high
- Much too high

Explain why? .....  
.....  
.....

How was it for you to work with the **pedometer** provided?

- Very easy
- Easy
- Not easy, but I managed
- Difficult
- Very difficult

Explain why? .....  
.....  
.....

1  
2  
3



How useful did you find the following parts of the intervention for increasing physical activity?

1) The **step counter**

0 1 2 3 4 5 6 7 8 9 10

2) The **step count diary** provided

0 1 2 3 4 5 6 7 8 9 10

3) Daily **step goals** displayed on your step count diary each week

0 1 2 3 4 5 6 7 8 9 10

4) Activity **feedback** during each of the pulmonary rehabilitation sessions

0 1 2 3 4 5 6 7 8 9 10

5) If your HADS levels were >8, **your sessions of CBT**

0 1 2 3 4 5 6 7 8 9 10

How often did you (in general) perform the following actions?

	Several times per day	Once per day	Sometimes, but not every day	Once or twice per week	Never
Look at your step counter during the day					
Look and use your daily step diary					

Which part of the intervention would you be willing to use further in the future?



Which part of the intervention would you be willing to use further in the future?

- Nothing
- The step counter
- The step counter and daily step diary
- CBT (HADS >8 patients)
- Pulmonary rehabilitation alone
- All of the above interventions together

What component of the intervention would you like to change in the future?

Explain:

.....  
.....  
.....

Would you like to add a comment?

.....  
.....  
.....  
.....

