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Original research

Validity and responsiveness of the Daily- and Clinical visit-PROactive Physical Activity in COPD (D-PPAC and C-PPAC) instruments

Judith Garcia-Aymerich ^{1,2,3}, Milo A Puhan,⁴ Solange Corriol-Rohou,⁵ Corina de Jong,^{6,7} Heleen Demeyer,^{8,9} Fabienne Dobbels,¹⁰ Damijan Erzen,¹¹ Anja Frei,⁴ Elena Gimeno-Santos ^{12,13}, Nicholas S Hopkinson ¹⁴, Nathalie Ivanoff,¹⁵ Niklas Karlsson,¹⁶ Zafeiris Louvaris,^{9,17} Michael I Polkey,¹⁸ Roberto A Rabinovich,¹⁹ Mario Scuri,²⁰ Maggie Tabberer,²¹ Ioannis Vogiatzis,^{17,22} Thierry Troosters,^{8,9} PROactive consortium

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For numbered affiliations see end of article.

Correspondence to

Dr Judith Garcia-Aymerich, ISGlobal, Doctor Aiguader 88, 08003 Barcelona, Spain; judith.garcia@isglobal.org

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ABSTRACT

Background The Daily-PROactive and Clinical visit-PROactive Physical Activity (D-PPAC and C-PPAC) instruments in chronic obstructive pulmonary disease (COPD) combines questionnaire with activity monitor data to measure patients' experience of physical activity. Their amount, difficulty and total scores range from 0 (worst) to 100 (best) but require further psychometric evaluation.

Objective To test reliability, validity and responsiveness, and to define minimal important difference (MID), of the D-PPAC and C-PPAC instruments, in a large population of patients with stable COPD from diverse severities, settings and countries.

Methods We used data from seven randomised controlled trials to evaluate D-PPAC and C-PPAC internal consistency and construct validity by sex, age groups, COPD severity, country and language as well as responsiveness to interventions, ability to detect change and MID.

Results We included 1324 patients (mean (SD) age 66 (8) years, forced expiratory volume in 1 s 55 (17)% predicted). Scores covered almost the full range from 0 to 100, showed strong internal consistency after stratification and correlated as a priori hypothesised with dyspnoea, health-related quality of life and exercise capacity. Difficulty scores improved after pharmacological treatment and pulmonary rehabilitation, while amount scores improved after behavioural physical activity interventions. All scores were responsive to changes in self-reported physical activity experience (both worsening and improvement) and to the occurrence of COPD exacerbations during follow-up. The MID was estimated to 6 for amount and difficulty scores and 4 for total score.

Conclusions The D-PPAC and C-PPAC instruments are reliable and valid across diverse COPD populations and responsive to pharmacological and non-pharmacological interventions and changes in clinically relevant variables.

INTRODUCTION

Research has consistently shown that patients with chronic obstructive pulmonary disease (COPD)

Key messages

What is the key question?

► What is the validity and responsiveness of the Daily-PROactive and Clinical visit-PROactive Physical Activity (D-PPAC and C-PPAC) instruments in chronic obstructive pulmonary disease (COPD)?

What is the bottom line?

► The D-PPAC and C-PPAC instruments, combining questionnaire with activity monitor data, are reliable and valid across diverse COPD populations and responsive to drug and non-drug interventions.

Why read on?

► This study combined more than 1300 patients from seven randomised controlled trials, covering a range of countries, languages, COPD disease severities, ages, objective physical activity levels and clinical determinants, wider than what is usually seen in other questionnaire/patient-reported outcome development programmes.

have lower physical activity levels than their healthy peers,¹ that reduced physical activity predicts both exacerbations and mortality,² and that many patients limit their physical activity to avoid symptoms.³ Hence, understanding physical activity is a key to improve the prognosis in patients with COPD.

Physical activity in COPD has been mostly assessed in terms of frequency, intensity, time and type⁴ and quantified by means of activity monitors or questionnaires.⁵ Other instruments have focused on quantifying the symptoms or quality of life in relation to physical activities.^{6,7} However, the patients' experience of physical activity has been ignored despite patients with COPD typically describe an inability to complete the activities they enjoy because of their illness⁸ and report that treatments that improve physical activity are of value to them.⁹ Until recently, no valid measurement tools



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have been available to capture the experience of physical activity. In the framework of the European Union Innovative Medicines Initiative PROactive project, the PROactive Physical Activity in COPD instruments (Daily and Clinical visit versions, D-PPAC and C-PPAC) were developed following the recommendations of the US Food and Drug Administration (FDA) guidance.¹⁰ In contrast with previous research, results of the development phase of PPAC instruments clearly showed that neither questionnaires nor activity monitors alone could discriminate well within the latent patient-centred construct ‘experience of physical activity’, while the combination of both achieved good discrimination at all ranges of the scale.¹¹ In agreement with previous qualitative work,¹² the development and initial validation of the PPAC instruments suggested that the concept ‘physical activity experience’ in patients with COPD is structured in two domains: ‘amount of physical activity’ and ‘difficulty with physical activity’. Thus, D-PPAC and C-PPAC combine questionnaire items and activity monitor variables to measure amount of physical activity, difficulty with physical activity and total physical activity experience.

A first validation study showed that both instruments are simple, reliable and valid measures of physical activity experience in COPD.¹¹ However, data on responsiveness (response to interventions and ability to detect change) and minimal important difference (MID), which are necessary for the effective use of PPAC instruments as study outcomes, have not yet been reported. Moreover, reliability and validity of PPAC instruments across different severity stages, countries and languages need to be reported in order to support their widespread use.

This study aimed to confirm the reliability and validity of the PPAC instruments in multiple independent patient samples, to test their responsiveness and to define their MIDs in a large

population of patients with varying COPD severity from diverse settings and countries.

METHODS

A complete version of methods is available in an online supplemental file.

Study design and subjects

We retrospectively pooled data from seven prospective randomised controlled trials testing the effect of pharmacological and non-pharmacological interventions in patients with COPD from 17 countries in Europe and North America: the ACTIVATE (Effect of Acclidinium/Formoterol on Lung Hyperinflation, Exercise Capacity and Physical Activity in Moderate to Severe COPD Patients, NCT02424344),¹³ ATHENS (Pulmonary Rehabilitation Program and PROactive Tool, NCT02437994),¹⁴ EXOS (Exercise Outcome Study: a comprehensive comparison of the sensitivity of common exercise outcome measures for COPD, ISRCTN:64759523),¹⁵ MrPAPP (Impact of Telecoaching Program on Physical Activity in Patients With COPD, NCT02158065),¹⁶ PHYSACTO (Effect of Inhaled Medication Together With Exercise and Activity Training on Exercise Capacity and Daily Activities in Patients With Chronic Lung Disease With Obstruction of Airways, NCT02085161),¹⁷ TRIGON-T9 (Efficacy and Safety of Glycopyrrolate Bromide of COPD Patients, NCT02189577)¹⁸ and URBAN TRAINING (Effectiveness of an Intervention of Urban Training in Patients With COPD: a Randomised Controlled Trial, NCT01897298)¹⁹ studies. Online supplemental table S1 provides details on each trial’s purpose, inclusion and exclusion criteria, design and intervention. Trials contributed differently to the evaluation of different measurement properties depending on when D-PPAC

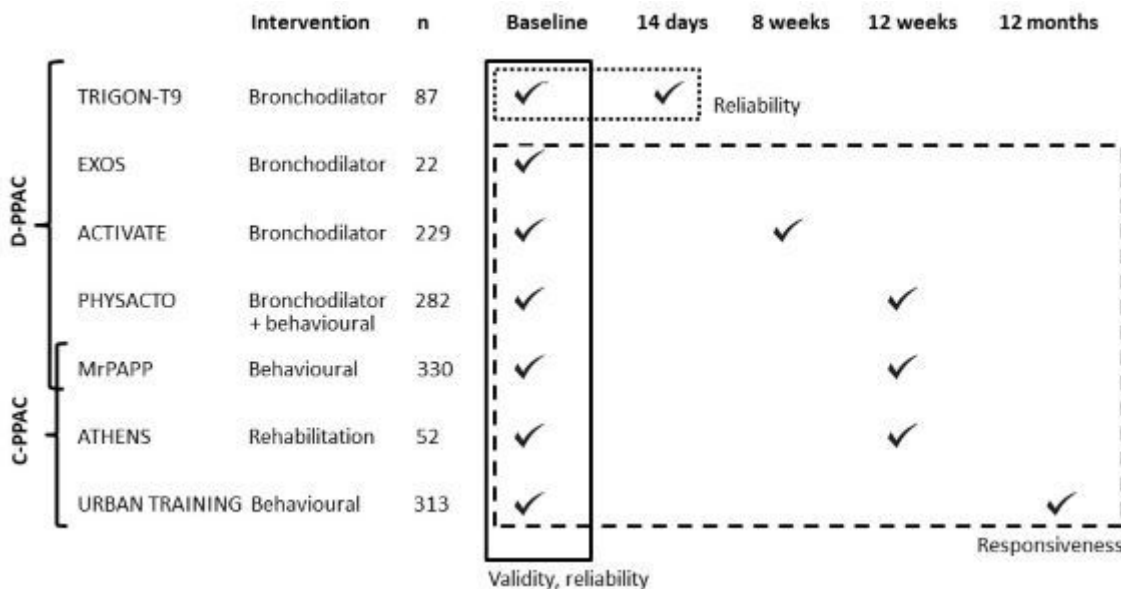


Figure 1 Contribution of each trial to the assessment of measurement properties of Daily-PROactive and Clinical visit-PROactive Physical Activity (D-PPAC and C-PPAC) instruments. ACTIVATE, Effect of Acclidinium/Formoterol on Lung Hyperinflation, Exercise Capacity and Physical Activity in Moderate to Severe patients with chronic obstructive pulmonary disease (COPD), NCT02424344; ATHENS, Pulmonary Rehabilitation Program and PROactive Tool, NCT02437994; EXOS, Exercise Outcome Study: a comprehensive comparison of the sensitivity of common exercise outcome measures for COPD, ISRCTN:64759523; MrPAPP, Impact of Telecoaching Program on Physical Activity in patients with COPD, NCT02158065; PHYSACTO, Effect of Inhaled Medication Together with Exercise and Activity Training on Exercise Capacity and Daily Activities in Patients with Chronic Lung Disease With Obstruction of Airways, NCT02085161; TRIGON-T9, Efficacy and Safety of Glycopyrrolate Bromide of patients with COPD, NCT02189577; URBAN TRAINING, Effectiveness of an Intervention of Urban Training in patients with COPD: a randomised controlled trial, NCT01897298.

and C-PPAC were measured (figure 1). Briefly, all studies contributed to reliability–internal consistency and validity analyses with their baseline data; TRIGON-T9 contributed to reliability–test–retest analysis with baseline and 14 days data; ACTIVATE (bronchodilator intervention) contributed to responsiveness with baseline and 8 weeks of data; PHYSACTO (bronchodilator with behavioural physical activity intervention), MrPAPP (behavioural physical activity intervention) and ATHENS contributed to responsiveness with baseline and 12 weeks of data and URBAN TRAINING (behavioural physical activity intervention) contributed to the responsiveness analysis with baseline and 12 months of data. All trials recruited patients with stable COPD defined by spirometry (according to the American Thoracic Society and European Respiratory Society criteria)²⁰ and invited all patients to answer one of the PPAC questionnaires (except in MrPAPP that answered both D-PPAC and C-PPAC) and record physical activity data by wearing activity monitors. All trials were registered and approved by appropriate institutional review boards. Written informed consent was obtained from all patients.

Measures

D-PPAC and C-PPAC instruments require both questionnaire and activity monitor data. Patients completed D-PPAC and/or C-PPAC questionnaires, which had been previously developed using appropriate qualitative and quantitative research methods and culturally sensitive translations¹² and a rigorous item reduction process following current European Medicines Agency (EMA)²¹ and US FDA¹⁰ guidance, as described elsewhere.¹¹ In brief, the D-PPAC questionnaire consists of 7-items with a daily recall and needs to be completed every evening for a week via an electronic-handled device. The C-PPAC questionnaire has 12 items with a 1-week recall and is completed at the day of each study visit in an electronic-handled device, a web-based system or using paper and pen. Patients also wore one of the activity monitors validated to be part of the PPAC instruments (DynaPort MoveMonitor, McRoberts B.V., The Netherlands or Actigraph G3Tx, Actigraph, Pensacola, Florida, USA) during waking time in 1 week at each study visit. Data from individuals were considered valid if they recorded more than 8 hour of wearing time on at least 3 days (not necessarily consecutive) within 1 week. We calculated D-PPAC and C-PPAC scores by combining questionnaire items with two variables from activity monitors (steps/day and vector magnitude units (VMU)/min). Both for D-PPAC and C-PPAC instruments, three scores are generated (amount of physical activity, difficulty with physical activity and total physical activity experience) ranging from 0 to 100, where higher numbers indicate a better score. For the D-PPAC instrument, we obtained scores for each day and calculated a weekly mean of D-PPAC amount, difficulty and total scores. For the C-PPAC instrument, a weekly measure for each score was obtained. D-PPAC and C-PPAC items and scoring equivalences are reported in the online supplemental file.

We also obtained information about: time in moderate-to-vigorous physical activity per day (>3 metabolic equivalents, MVPA) from the activity monitor; lung function by spirometry after reversibility testing; exercise capacity by 6 min walking distance (6MWD); the modified Medical Research Council Dyspnoea scale (mMRC), the Chronic Respiratory Disease Questionnaire (CRQ), the Clinical COPD Questionnaire (CCQ) and/or the COPD Assessment Test (CAT) and demographics, smoking history and clinical data (medical and COPD histories) from patients and medical records. Patients participating in follow-up visits also rated the global change of their physical

activity experience in amount, difficulty and overall since baseline to follow-up on a 7-point Likert-type scale, ranging from ‘much worse’ to ‘much better’ (see online supplemental file).

Statistical analysis

The sample size calculations and complete statistical analysis are available in the online supplemental file. The analysis sets and statistical analysis plan were defined a priori based on study objectives. We used different study samples for the different measurement properties (figure 1). All analyses were performed separately for D-PPAC and C-PPAC amount, difficulty and total scores.

Reliability was evaluated in terms of internal consistency by the Cronbach’s alpha and test–retest reproducibility, using intraclass correlation coefficients (ICC) and Bland-Altman plots. (Internal consistency of the total scores was not tested because total scores are calculated as the mean of amount and difficulty scores and not from a list of items). Convergent validity was explored by testing the Spearman correlations between D-PPAC and C-PPAC scores and related constructs. A matrix of expected correlations for each variable was built a priori (online supplemental table S2 and Methods (complete version) in online supplemental file). We also tested known-group validity using one-way ANOVA test and pairwise comparisons of means adjusting for multiple comparisons using Bonferroni correction between groups a priori expected to have differences in physical activity experience. Reliability and validity analyses were done in all patients and stratifying by sex, age groups, COPD severity, country and language.

To quantify responsiveness (response to interventions and ability to detect change), we calculated the change (8 weeks, 12 weeks or 12 months minus baseline) and the standardised response mean (SRM) in (1) each intervention group, using each study separately (a priori expected significant differences ($p < 0.05$) in the changes between groups and $SRM > |0.5|$ in difficulty and total scores after bronchodilator and pulmonary rehabilitation interventions, and in amount and total scores after behavioural physical activity interventions, see online supplemental table S3), (2) groups defined by the self-reported change in physical activity experience, using a pooled dataset (a priori expected significant differences ($p < 0.05$) and $SRM > |0.5|$ in PPAC scores between much worse/worse/slightly worse versus no change/slightly better and better/much better versus no change/slightly better, see online supplemental table S3) and (3) groups defined according to having had COPD exacerbations during follow-up, using a pooled dataset (a priori expected significant differences ($p < 0.05$) and $SRM > |0.5|$ in PPAC scores between those having any COPD exacerbation during follow-up versus none). We established the MID by triangulation using an anchor-based approach²² and calculated distribution-based estimates to provide insight into minimal detectable change (MDC) (not formally established because of scarcity of data for C-PPAC). Analyses were performed using complete cases in STATA V.14 (StataCorp, College Station, Texas, USA).

RESULTS

Distribution of D-PPAC and C-PPAC scores

From a total of 1595 patients with stable COPD participating in the original trials, 1324 (83%) had available data on activity monitor and D-PPAC and/or C-PPAC questionnaires. Among them, 950 and 651 patients were included in the D-PPAC and C-PPAC-related analyses, respectively. Baseline characteristics are shown in table 1 (overall) and S4 (stratified by study; or

Table 1 Baseline demographic and clinical characteristics of patients with COPD included in the validation of D-PPAC and C-PPAC instruments

	D-PPAC dataset n=950		C-PPAC dataset n=651	
	n*	m (SD)/n (%)	n*	m (SD)/n (%)
Age (years)	950	64.5 (7.7)	651	67.7 (8.5)
Gender: male	950	597 (63)	651	486 (75)
Working status: employed	352	48 (14)	643	79 (12)
Current smoker	950	394 (41)	651	157 (24)
BMI (kg/m ²)	950	27.0 (5.1)	651	27.3 (5.1)
Any cardiovascular disease	721	178 (25)	593	255 (43)
Diabetes	950	91 (10)	593	112 (19)
Musculoskeletal disorders	720	193 (27)	599	95 (16)
FEV ₁ (% predicted)	949	54 (17)	651	56 (20)
ATS/ERS stages:	949		651	
I—mild (FEV ₁ ≥80%)		55 (6)		80 (12)
II—moderate (FEV ₁ <80% and ≥50%)		489 (51)		308 (47)
III—severe (FEV ₁ <50% and ≥30%)		339 (36)		202 (31)
IV—very severe (FEV ₁ <30%)		66 (7)		61 (10)
FVC (% predicted)	949	96 (21)	651	84 (21)
FEV ₁ /FVC (%)	949	48 (12)	651	51 (14)
6MWD (m)	631	446 (102)	648	462 (105)
Dyspnoea (mMRC 0–4)	861	1.6 (0.9)	650	1.4 (1.0)
Any COPD exacerbations last 12 m	862	268 (31)	641	323 (51)
Any COPD exacerbations requiring admissions last 12 m	633	66 (10)	641	82 (13)
CRQ dyspnoea (1–7)	304	5.1 (1.4)	52	2.3 (0.7)
CRQ fatigue (1–7)	304	4.6 (1.2)	52	1.7 (0.5)
CRQ emotional (1–7)	304	5.2 (1.1)	52	3.4 (1.1)
CRQ mastery (1–7)	304	5.3 (1.3)	52	2.0 (0.6)
CCQ symptoms (0–6)	328	1.9 (1.1)	597	1.7 (1.1)
CCQ functional (0–6)	328	1.8 (1.3)	597	1.5 (1.2)
CCQ mental (0–6)	328	1.4 (1.4)	597	1.3 (1.4)
CCQ total (0–6)	328	1.8 (1.0)	649	1.6 (1.0)
CAT (0–40)	21	20 (6)	365	13 (7)
Steps per day (n/day)	950	5723 (3768)	651	6500 (4001)
VMU/min	950	428 (287)	651	442 (320)
Time in moderate-to-vigorous physical activity (min/day)	950	89 (51)	574	98 (48)
PPAC-amount (0–100)	950	54 (14)	651	70 (16)
PPAC-difficulty (0–100)	950	70 (14)	651	78 (15)
PPAC-total (0–100)	950	62 (10)	651	74 (12)

*Some variables have missing values and/or are only available in some studies. Online supplemental table S4 shows patients' characteristics stratified by study. ATS/ERS, American Thoracic Society and European Respiratory Society; BMI, body mass index; CAT, chronic obstructive pulmonary disease assessment test; CCQ, clinical chronic obstructive pulmonary disease questionnaire; COPD, chronic obstructive pulmonary disease; C-PPAC, Clinical visit version of PROactive Physical Activity in COPD instrument; CRQ, chronic respiratory questionnaire; D-PPAC, Daily version of PROactive Physical Activity in COPD instrument; FEV₁, forced expiratory volume in 1 s; FVC, forced vital capacity; IC, inspiratory capacity; mMRC, modified medical research council dyspnoea scale; 6MWD, 6 min walking distance; PPAC, PROactive physical activity in COPD; VMU, vector magnitude unit.

note, differences between samples reflect intentional differences in inclusion/exclusion criteria between studies). Both D-PPAC and C-PPAC samples covered a wide range of COPD severity and objective physical activity levels and included patients from 17 countries completing the PPAC instruments in 11 languages (online supplemental table S5). D-PPAC and C-PPAC amount

scores covered the full range between 0 and 100 and were more heterogeneous than difficulty scores (figure 2). There were no patients reporting difficulty scores between 0 and 25 (ie, high difficulty). We observed small significant differences by gender and age group in the amount and total D-PPAC scores but not in any of C-PPAC scores. There was a trend towards lower values of all scores by airflow severity group.

Reliability and validity

D-PPAC and C-PPAC scores showed strong internal consistency in all subjects (online supplemental table S6) and after stratification (figure 3). D-PPAC scores were reproducible over the 2-week period with ICCs>0.8 (online supplemental table S7). Bland-Altman plots showed no relevant differences between weeks 1 and 2 D-PPAC scores in stable patients (mean difference of 0 for amount, 1.2 for difficulty and 0.6 for total on the 100-point scores). Agreement laid within predefined limits and there was no pattern in differences over the range of values (online supplemental figure S1).

Both overall and after stratification, D-PPAC and C-PPAC amount scores exhibited weak correlations with health-related quality of life (HRQoL) measures, moderate correlations with exercise capacity and strong correlations with objective physical activity levels. Difficulty scores showed moderate-to-strong correlations with dyspnoea, HRQoL and exercise capacity and low correlations with objective physical activity level except for one country (The Netherlands) (table 2, figure 4). All D-PPAC and C-PPAC scores differentiated statistically across moderate-to-very severe COPD severity stages, dyspnoea grades (0–4) and tertiles of 6MWD, suggesting good known-group validity (online supplemental table S8).

Responsiveness and MID

Large SRM values and significant between-arm differences were found for (follow-up—baseline) changes in D-PPAC difficulty scores after the PHYSACTO and ACTIVATE (bronchodilators) interventions and for changes in the D-PPAC amount score after MrPAPP (behavioural physical activity) intervention (table 3). Changes in C-PPAC difficulty score were significantly different after the ATHENS (pulmonary rehabilitation) intervention, as were changes in C-PPAC amount score after MrPAPP and URBAN TRAINING (behavioural physical activity) interventions. All scores were responsive to the self-reported rating of changes in physical activity experience (both worsening and improvement) and to the presence of COPD exacerbations during follow-up.

From anchor-based estimates (online supplemental tables S4 and S9), we suggest a MID of 6 for the D-PPAC and C-PPAC amount and difficulty scores and 4 for the total scores. Distribution estimates for MDC produced very similar values.

DISCUSSION

By pooling data from a diverse population of patients with COPD from seven randomised controlled trials, we are the first to report the performance of the D-PPAC and C-PPAC instruments in COPD. Key findings are that D-PPAC and C-PPAC amount, difficulty and total scores (1) exhibit wide variation appropriate to patients with differing clinical characteristics, (2) show good internal consistency and construct validity across sex, age group, COPD severity, countries and languages, (3) are responsive to interventions and to changes in clinically relevant variables and (4) we established a MID of 6 for the amount and difficulty scores and of 4 for the total scores.

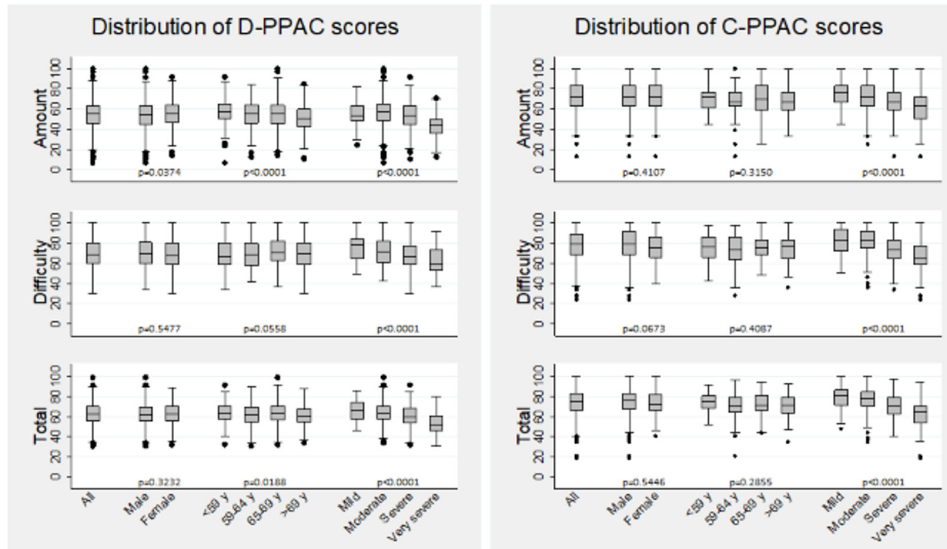


Figure 2 Distribution of D-PPAC and C-PPAC amount, difficulty and total scores, overall and stratified by gender, age group (quartiles) and COPD airflow severity groups. * $p < 0.05$. Box indicates the lower and upper quartiles, the line subdividing the box represents the median, and lines (whiskers) represent 1.5 IQR of the nearer quartile (lower/upper adjacent values). C-PPAC, Clinical visit version of PROactive Physical Activity in COPD instrument; COPD, chronic obstructive pulmonary disease; D-PPAC, Daily version of PROactive Physical Activity in COPD instrument.

This study provides important information for the future use of PPAC instruments. First, we found a wide distribution of D-PPAC and C-PPAC amount, difficulty and total scores, as

expected by the fact that patients included in the seven clinical trials were quite diverse in terms of disease severity and recruitment settings. Such variability in the scores supports the use of PPAC instruments to capture diversity in physical activity amount and difficulty as experienced by patients with COPD. Second, patients scored generally higher, that is, better, in the difficulty than in the amount domain. Qualitative and quantitative data from the development and initial validation studies of PPAC instruments,^{11 20} and current knowledge on physical activity and COPD,²³ support that amount and difficulty are indeed two different dimensions of physical activity experience. Third, the amount domain covered virtually all potential values from 0 to 100, which favours the notion that combining few questionnaire items with two activity monitor variables allows better capture of a wide spectrum of the patient-centred construct ‘amount of physical activity’ than with an activity monitor alone, as previously shown.¹¹ Fourth, the lack of patients scoring less than 25 in the difficulty domain (ie, reporting most difficulty) could be due to underreporting or to the fact that none of the trials included exacerbating or extremely severe COPD patients. Further studies should test the PPAC instruments in these subpopulations. Finally, C-PPAC scores were higher than D-PPAC scores in all domains, with differences of > 10 points in the amount domain (see MrPAPP D-PPAC and C-PPAC scores in online supplemental table S4). This could be attributed to recall bias in the weekly report towards higher amount of physical activity or to different cut-offs used for steps and VMU/min between D-PPAC and C-PPAC versions (although the latter could not mathematically explain a > 10 point difference). In any case, these results suggest that D-PPAC and C-PPAC instruments should not be used interchangeably in the same patient or study.

All scores of D-PPAC and C-PPAC instruments demonstrated good internal consistency and construct validity across sexes, age groups, COPD severities, countries and languages and very similar to those presented in the original development and validation study.¹¹ One exception was the moderate correlation (higher than expected) between D-PPAC difficulty and MVPA in the Netherlands, including only 34 patients, that we consider a

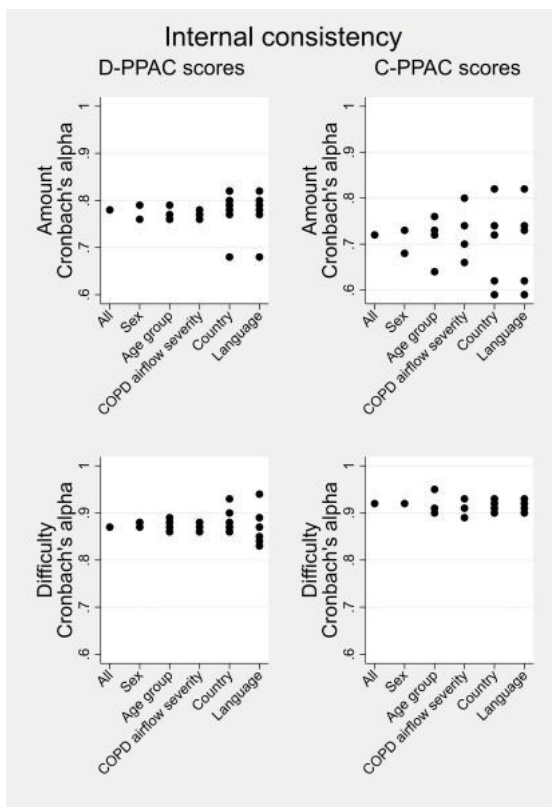


Figure 3 Cronbach’s alpha of D-PPAC and C-PPAC amount and difficulty scores, overall and stratified by gender, age group (quartiles) and COPD airflow severity groups (reliability, internal consistency). C-PPAC, Clinical visit version of PROactive Physical Activity in COPD instrument; COPD, chronic obstructive pulmonary disease; D-PPAC, Daily version of PROactive Physical Activity in COPD instrument.

Table 2 Spearman correlation coefficients* of D-PPAC and C-PPAC scores with dyspnoea, health-related quality of life, exercise capacity and objective physical activity level (convergent validity)

	D-PPAC						C-PPAC					
	Amount		Difficulty		Total		Amount		Difficulty		Total	
	Correlation	P value	Correlation	P value	Correlation	P value	Correlation	P value	Correlation	P value	Correlation	P value
mMRC	-0.20	<0.001	-0.40	<0.001	-0.40	<0.001	-0.40	<0.001	-0.64	<0.001	-0.65	<0.001
CRQ dyspnoea	0.16	0.006	0.68	<0.001	0.59	<0.001	0.28	0.045	0.61	<0.001	0.56	<0.001
CRQ fatigue	0.15	0.011	0.61	<0.001	0.52	<0.001	0.28	0.045	0.55	<0.001	0.51	<0.001
CRQ emotional	0.05	0.393	0.54	<0.001	0.41	<0.001	-0.20	0.028	-0.13	0.027	-0.18	0.008
CRQ mastery	0.08	0.143	0.53	<0.001	0.42	<0.001	0.00	0.989	0.64	<0.001	0.39	0.005
CCQ symptoms	-0.20	<0.001	-0.56	<0.001	-0.50	<0.001	-0.18	<0.001	-0.55	<0.001	-0.45	<0.001
CCQ functional	-0.36	<0.001	-0.77	<0.001	-0.74	<0.001	-0.34	<0.001	-0.76	<0.001	-0.69	<0.001
CCQ mental	-0.28	<0.001	-0.55	<0.001	-0.52	<0.001	-0.19	<0.001	-0.50	<0.001	-0.42	<0.001
CCQ total	-0.33	<0.001	-0.75	<0.001	-0.70	<0.001	-0.31	<0.001	-0.75	<0.001	-0.65	<0.001
CAT total		n.a.		n.a.		n.a.	-0.24	<0.001	-0.62	<0.001	-0.54	<0.001
6MWD	0.41	<0.001	0.40	<0.001	0.53	<0.001	0.49	<0.001	0.46	<0.001	0.53	<0.001
MVPA	0.67	<0.001	0.12	<0.001	0.53	<0.001	0.80	<0.001	0.30	<0.001	0.67	<0.001

*Correlation coefficients are in bold font when they met our assumptions (see online supplemental table S2 in the online data supplement) and normal font when they are higher or lower than expected. CAT, chronic obstructive pulmonary disease assessment test; CCQ, clinical chronic obstructive pulmonary disease questionnaire; C-PPAC, Clinical visit version of PROactive Physical Activity in COPD instrument; CRQ, chronic respiratory questionnaire; D-PPAC, Daily version of PROactive Physical Activity in COPD instrument; mMRC, modified medical research council dyspnoea scale; MVPA, moderate-to-vigorous physical activity; 6MWD, 6 min walk distance; n.a., Not available.

chance finding given that the rest of correlations in the Netherlands as well as all correlations for patients in Belgium (sharing the same language and geographic/climatic conditions as the Dutch) were within the range of other countries. Remarkably,

observed correlations between PPAC scores and dyspnoea, HRQoL, exercise capacity and objective physical activity were very close to the a priori hypothesised, supporting that the PPAC instruments measure what they are meant to measure.

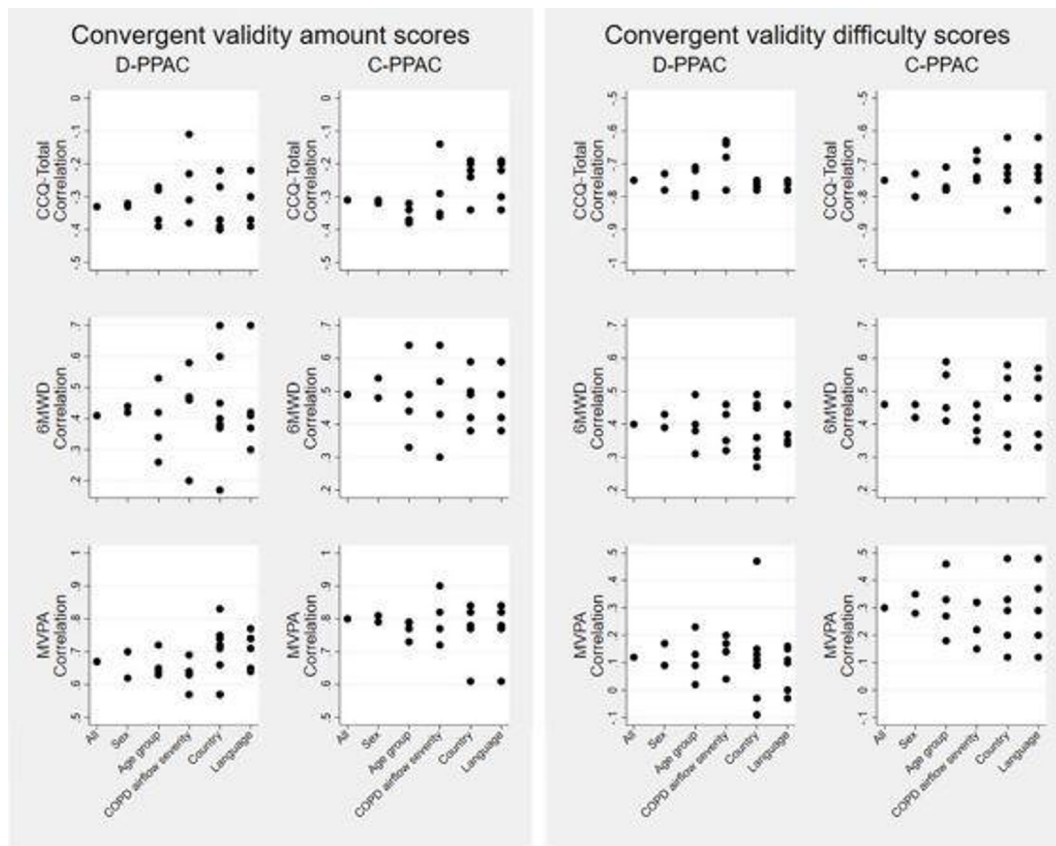


Figure 4 Correlation of D-PPAC and C-PPAC scores with CCQ-total, 6MWD and MVPA (convergent validity), overall and stratified by gender, age group (quartiles), COPD airflow severity groups, country and language. CCQ, Clinical COPD Questionnaire; C-PPAC, Clinical visit version of PROactive Physical Activity in COPD instrument; COPD, chronic obstructive pulmonary disease; D-PPAC, Daily version of PROactive Physical Activity in COPD instrument, MVPA, moderate-to-vigorous physical activity; 6MWD, 6 min walking distance.

Table 3 Changes in D-PPAC and C-PPAC scores after interventions and in relation to clinically relevant variables (responsiveness)

D-PPAC	n	Amount score				Difficulty score				Total score		
		Change*		SRMs	Pt	Change*		SRMs	Pt	M (SD)	M (SD)	Pt
		M (SD)	M (SD)	M (SD)		M (SD)						
Response to interventions												
PHYSACTO (12 week)												
SMBM+placebo (ref.)	63	1.8 (12.3)	0.2 (1.1)	0.8 (9.2)	0.1 (0.9)	1.3 (7.9)	0.2 (1.0)					
SMBM +tiotropium	58	2.3 (9.8)	0.2 (0.9)	6.2 (12.0)	0.6 (1.2)	4.3 (8.2)	0.6 (1.2)	0.021	0.178	0.6 (1.2)		
SMBM +tiotropium/olodaterol	60	4.7 (10.7)	0.4 (1.0)	5.9 (10.8)	0.6 (1.0)	5.3 (7.5)	0.6 (1.0)	0.037	0.02	0.7 (1.0)		
SMBM+tiotropium/olodaterol+exercise training	62	4.4 (9.6)	0.4 (0.9)	5.9 (8.3)	0.6 (0.8)	5.1 (6.2)	0.6 (0.8)	0.034	0.026	0.7 (0.8)		
MrPAPP (12 week)												
Usual care (ref.)	144	-2.9 (9.0)	-0.3 (0.8)	0.9 (9.4)	0.1 (1)	-1.0 (6.4)	-0.1 (0.9)					
Telecoaching for physical activity	141	2.1 (11.8)	0.2 (1.1)	-0.8 (10.1)	-0.1 (1)	0.6 (7.7)	-0.1 (1)	0.123	0.055	0.1 (1)		
ACTIVATE (8 week)												
Placebo (ref.)	95	2.8 (14.3)	0.2 (1.2)	-0.3 (8.5)	-0.03 (0.9)	1.2 (6.7)	0.2 (1.0)					
Acidinium bromide/formoterol fumarate	105	2.5 (8.5)	0.2 (0.7)	3.0 (9.5)	0.3 (1.0)	2.7 (6.7)	0.3 (1.0)	0.01	0.123	0.4 (1.0)		
Change in relation to self-reported global rating of change (12 week for PHYSACTO and MrPAPP)												
Change in physical activity experience overall												
Much worse, worse, slightly worse	74	-5.3 (9.2)	-0.5 (0.9)	-2.4 (9.5)	-0.2 (1.0)	-3.8 (6.4)	-0.2 (1.0)	0.009	<0.001	-0.5 (0.9)		
No change, slightly better (ref.)	244	0.4 (9.7)	0.04 (0.9)	1.6 (9.8)	0.2 (1.0)	1.0 (6.6)	0.2 (1.0)	-	-	0.1 (0.9)		
Better, much better	197	4.8 (11.5)	0.5 (1.1)	4.7 (10.7)	0.5 (1.1)	4.8 (8.0)	0.5 (1.1)	0.005	<0.001	0.6 (1.1)		
Change in difficulty with physical activity												
Much more/more/a little more difficult	82	-5.6 (10.6)	-0.5 (1.0)	-3.7 (9.5)	-0.4 (1.0)	-4.7 (6.7)	-0.4 (1.0)	<0.001	<0.001	-0.6 (0.9)		
No change, a little easier (ref.)	281	1.1 (9.5)	0.1 (0.9)	1.9 (9.5)	0.2 (1.0)	1.5 (6.3)	0.2 (1.0)	-	-	0.2 (0.9)		
More easy, much more easy	154	5.4 (11.6)	0.5 (1.1)	6.0 (10.7)	0.6 (1.1)	5.7 (8.0)	0.6 (1.1)	<0.001	<0.001	0.8 (1.1)		
Change in amount of physical activity												
Much less/less/a little less active	97	-6.0 (9.9)	-0.6 (0.9)	-2.1 (10.1)	-0.2 (1.0)	-4.1 (6.9)	-0.2 (1.0)	0.001	<0.001	-0.6 (1.0)		
No change, slightly better (ref.)	222	0.3 (9.3)	0.03 (0.9)	2.3 (9.5)	0.2 (0.9)	1.3 (6.3)	0.2 (0.9)	-	-	0.2 (0.9)		
More/much more active	198	6.2 (10.8)	0.6 (1.0)	4.3 (10.8)	0.4 (1.1)	5.2 (7.5)	0.4 (1.1)	0.127	<0.001	0.7 (1.1)		
Changes according to COPD exacerbations during follow-up (8 week for ACTIVATE; 12 week for PHYSACTO and MrPAPP)												
Any COPD exacerbation												
No (ref.)	443	2.1 (11.0)	0.2 (1.0)	2.8 (10.2)	0.3 (1.0)	2.5 (7.5)	0.3 (1.0)			0.3 (1.0)		
Yes	96	-3.0 (8.6)	-0.3 (0.8)	-0.6 (9.6)	-0.0 (1.0)	-1.8 (6.6)	-0.0 (1.0)	0.002	<0.001	-0.3 (1.0)		

Continued

Table 3 Continued

C-PPAC	n	Amount score			Difficulty score			Total score			
		Change*		Pt	Change*		Pt	Change*		Pt	
		M (SD)	SRMs		M (SD)	SRMs		M (SD)	SRMs		
Response to interventions											
MRPAPP (12 week)											
Usual care (ref.)	114	-4.3 (12.5)	-0.3 (1.0)		-1.7 (10.7)		-0.2 (1.1)		-3.0 (8.4)		-0.4 (1.0)
Telecoaching for physical activity	112	2.9 (12.8)	0.2 (1)	<0.001	0.2 (8.5)	0.157	0.02 (0.9)		1.5 (8.1)	<0.001	0.2 (1.0)
ATHENS (12 week)											
Usual care (ref.)	27	-0.5 (13.3)	-0.0 (1.0)		-3.1 (10.4)		-0.3 (1.0)		-1.8 (8.5)		-0.2 (1.0)
Pulmonary rehabilitation	25	5.9 (11.5)	0.5 (0.9)	0.071	5.3 (9.2)	0.003	0.5 (0.9)		5.6 (7.5)	0.002	0.6 (0.8)
URBAN TRAINING‡ (12 m)											
Usual care (ref.)	74	-0.2 (12.6)	-0.0 (1.0)		0.4 (12.4)		0.0 (1.0)		0.2 (10.4)		0.0 (1.0)
Urban training for physical activity	29	4.6 (10.9)	0.4 (0.9)	0.072	4.8 (11.2)	0.096	0.4 (0.9)		4.7 (8.9)	0.04	0.5 (0.9)
Change in relation to self-reported global rating of change (12 week for MRPAPP, 12 m for URBAN TRAINING‡)											
Change in physical activity experience overall											
Much worse, worse, slightly worse	77	-6.8 (12.7)	-0.5 (1.0)	<0.001	-3.4 (13.5)	0.016	-0.4 (1.2)		-4.9 (10.1)	<0.001	-0.6 (1.1)
No change, slightly better (ref.)	165	-0.4 (11.0)	-0.0 (0.9)	-	0.6 (9.8)	-	0.0 (0.9)		0.0 (7.4)	-	-0.0 (0.8)
Better, much better	84	5.8 (13.0)	0.5 (1.0)	<0.001	2.3 (9.1)	0.68	0.2 (0.9)		4.1 (9.0)	0.001	0.5 (1.0)
Change in difficulty with physical activity											
Much more/more/a little more difficult	84	-6.3 (12.3)	-0.5 (1.0)	<0.001	-4.4 (13.0)	<0.001	-0.4 (1.2)		-5.1 (10.0)	<0.001	-0.6 (1.1)
No change, a little easier (ref.)	185	0.4 (11.5)	0.0 (0.9)	-	1.0 (9.5)	-	0.1 (0.9)		0.6 (7.6)	-	0.1 (0.8)
More easy, much more easy	58	5.9 (13.5)	0.5 (1.0)	0.006	3.9 (9.3)	0.177	0.4 (0.8)		5.0 (8.7)	0.001	0.6 (0.9)
Change in amount of physical activity											
Much less/less/a little less active	91	-6.7 (12.1)	-0.5 (1.0)	<0.001	-2.4 (13.1)	0.128	-0.2 (1.2)		-4.3 (10.0)	<0.001	-0.5 (1.1)
No change, slightly better (ref.)	175	0.7 (11.8)	0.1 (0.9)	-	0.4 (10.0)	-	-0.0 (0.9)		0.4 (8.2)	-	0.0 (0.9)
More/much more active	77	4.8 (12.5)	0.4 (1.0)	0.039	2.5 (9.0)	0.441	0.2 (0.9)		3.7 (7.8)	0.017	0.4 (0.9)
Changes according to COPD exacerbations during follow-up (12 week for MRPAPP, 12 m for URBAN TRAINING‡)											
Any COPD exacerbation											
No (ref.)	218	0.8 (12.8)	0.1 (1.0)		0.9 (9.8)		0.1 (0.9)		0.8 (8.4)		0.1 (0.9)
Yes	108	-3.0 (12.5)	-0.2 (1.0)	0.008	-1.9 (12.4)	0.022	-0.2 (1.1)		-2.3 (10.2)	0.003	-0.3 (1.1)

Parameters are in bold font when they met our assumptions (p value<0.05 and SRM≥0.5).

*Change calculated as 8 weeks score—baseline score in patients from ACTIVATE trial; 12 weeks score—baseline score in patients from PHYSACTO and MRPAPP trials; and 12 months—baseline in patients from Urban Training trial.

†P value of the score difference between groups, using multiple comparisons (Bonferroni method) after ANOVA test.

‡Using per protocol population.

ACTIVATE, Effect of Acclidinium/Formoterol on Lung Hyperinflation, Exercise Capacity and Physical Activity in Moderate to Severe COPD Patients; ANOVA, analysis of variance; ATHENS, Pulmonary Rehabilitation Program and PROactive Tool; COPD, chronic obstructive pulmonary disease; C-PPAC, Clinical visit version of PROactive Physical Activity in COPD instrument; D-PPAC, Daily version of PROactive Physical Activity in COPD instrument; MRPAPP, Impact of Telecoaching Program on Physical Activity in Patients With COPD; PHYSACTO, Effect of Inhaled Medication Together With Exercise and Activity Training on Exercise Capacity and Daily Activities in Patients With Chronic Lung Disease With Obstruction of Airways; SMBM, self-management behaviour-modification; SRM, standardised response mean; URBAN TRAINING, Effectiveness of an Intervention of Urban Training in Patients With COPD.

Table 4 Anchor-based estimates of the MID and distribution-based estimates of the MDC for D-PPAC and C-PPAC amount, difficulty and total scores

	D-PPAC			C-PPAC		
	Amount	Difficulty	Total	Amount	Difficulty	Total
Anchor based						
Change in CCQ total*		5.7	2.5		5.5	3.3
Change in amount of physical activity†	6.2		5.2	4.8		3.7
Change in difficulty with physical activity†	5.4	6.0	5.7	5.9		5.0
Change in physical activity experience overall†	4.8		4.8	5.8		4.1
Distribution based						
0.5 of Cohen's effect size	6.7	7.2	5.3	7.6	7.2	6.0
1 SEM (of ICC)	5.4	5.4	3.8			

*Mean difference (final–baseline) in scores in patients who changed ≤ -0.4 points in CCQ score.

†Mean difference (final–baseline) in scores in patients who rated their physical activity change as 'better' in amount, difficulty or overall.

CCQ, clinical COPD questionnaire; COPD, chronic obstructive pulmonary disease; C-PPAC, Clinical visit version of PROactive Physical Activity in COPD instrument; D-PPAC, Daily version of PROactive Physical Activity in COPD instrument; ICC, intraclass correlation coefficient; MDC, minimal detectable change; MID, minimal important difference; SEM, standard error of measurement.

In studies using pharmacological interventions, significant differences were observed in the D-PPAC difficulty score after treatment with bronchodilators (ACTIVATE and PHYSACTO).^{12 16} In non-pharmacological intervention studies, both D-PPAC and C-PPAC amount scores significantly improved after 12 weeks of telecoaching (MrPAPP),¹⁵ a signal also observed in the 'control' group of PHYSACTO, which also received a self-management behavioural intervention that included coaching towards physical activity. As expected, C-PPAC difficulty score significantly improved after 12 weeks of an outpatient pulmonary rehabilitation programme (ATHENS).¹³ Finally, the C-PPAC total score was able to detect even after 12 months a significant improvement following a behavioural and community-based exercise intervention (URBAN TRAINING).¹⁸ It is of note that prior to the trials included in this study, no interventions were available with a known effect on patients' experience of physical activity. Our analyses support positive effects of bronchodilator therapy, pulmonary rehabilitation and physical activity behavioural interventions on these domains, which is relevant to COPD management. Finally, PPAC scores were able to detect changes (improvement or worsening) in self-reported physical activity experience and to decrease (worsen) significantly in patients who had experienced exacerbations during follow-up (8 weeks, 12 weeks or 12 months, depending on the study). Altogether makes these tools useful to serve as endpoints in clinical trials.

We suggest a MID of 6 for the amount and difficulty scores and of 4 for the total score, in scales ranging from 0 to 100. These values can identify differences in clinically relevant concepts such as HRQoL and patient self-report of physical activity change. Importantly, distribution-based estimates approximating the MDC gave very similar values (table 4), suggesting that changes that are important to patients can be detected by the PPAC instruments. Given the prognostic value of objective physical activity,² as traditionally measured by an activity monitor, further studies should assess whether the defined MIDs for physical activity experience relate to morbidity and mortality of COPD.

The main limitation of our study is the lack of inclusion of exacerbating or recently exacerbated patients, which neither allow us to test the validity of the PPAC instruments in patients experiencing the most difficulty with physical activity nor to test the responsiveness of PPAC scores to interventions during exacerbations. Also, the PPAC instruments were tested in participants

of clinical trials, who do not always reflect the general population of patients with COPD. However, some of the included trials recruited patients from primary care or with severe comorbidities. Finally, the heterogeneity in interventions and recruitment periods did not allow us to analyse if responsiveness differed by season, as previously shown in pulmonary rehabilitation.²⁴

By using a number of different studies, conducted in different patient populations, the main strength of this study is that it covered a wider range of COPD disease severities, ages, objective physical activity levels and clinical determinants than what is usually seen in other questionnaire/patient-reported outcome development programmes. Moreover, patients from different countries and language groups were enrolled, supporting the use of the PPAC instruments in millions of patients with COPD in Europe and the North America. Also, responsiveness was tested against different types of interventions, which allowed understanding of how different domains of physical activity experience vary in response to different types of interventions, as discussed above. The diverse follow-up periods, that reflect expectations about when changes will occur after each intervention, show that PPAC scores are able to identify changes in physical activity experience occurring at different time spans. Finally, although the study pooled data from independent drug and non-drug clinical trials with their own research objectives, the analysis was based on a priori defined hypothesis for all validation parameters.

Based on the previous¹¹ and above evidence supporting the content validity, psychometric properties and usability of the PPAC instruments, the EMA in its final qualification opinion agrees that both instruments are suitable to capture physical activity experience in COPD patients and can thus be used as endpoints in clinical trials.²⁵ Our results further support their use in future clinical trials and observational research studies. The fact that more than 1300 patients with COPD (83% of those participating in the original trials) completed the PPAC questionnaires and wore an activity monitor for at least 3 days in a week, which confirms acceptability and feasibility in a range of countries, languages and clinical scenarios. The use of the D-PPAC or C-PPAC version should depend on study objectives and try to balance patients' burden. The D-PPAC questionnaire is shorter (seven questions) and less prone to recall bias, but requires daily report and availability of electronic-handled devices to fill in the questionnaire. Thus, the D-PPAC instrument is more likely to

be used where daily variations in physical activity experience or other outcomes or covariates are expected or in regulatory clinical trials (by industry members) where physical activity experience is a primary outcome to obtain a label claim. The C-PPAC questionnaire (12 questions) is answered only once in a week and can also be completed in a website or in paper and pen, which increases feasibility but is subjected to some degrees of recall bias. Therefore, the C-PPAC instrument is more likely to be used where physical activity experience stability can be expected in a 1-week window, where patient burden of completing questionnaires is high or in pragmatic studies to gather 'real-world' evidence. A 'PPAC User's Guide' is available from the authors describing the instruments, their administration procedures, scoring and translations available.

In conclusion, the D-PPAC and C-PPAC instruments are valid and reliable across sexes, age groups, COPD severities, countries and languages and are responsive to drug and non-drug treatments and changes in clinically relevant variables.

Author affiliations

- ¹ISGlobal, Barcelona, Spain
- ²Universitat Pompeu Fabra (UPF), Barcelona, Spain
- ³CIBER Epidemiología y Salud Pública (CIBERESP), Barcelona, Spain
- ⁴Epidemiology, Biostatistics & Prevention Institute, University of Zurich, Zurich, Switzerland
- ⁵AstraZeneca R&D, Paris, France
- ⁶Groningen Research Institute for Asthma and COPD (GRIAC), University of Groningen, University Medical Center Groningen (UMCG), Groningen, The Netherlands
- ⁷Department of General Practice and Elderly Care, University of Groningen, University Medical Center Groningen (UMCG), Groningen, The Netherlands
- ⁸Department of Respiratory Diseases, University Hospital Leuven, Leuven, Belgium
- ⁹Department of Rehabilitation Sciences, KU Leuven -University of Leuven, Leuven, Belgium
- ¹⁰Academic Centre for Nursing and Midwifery, Department of Public Health and Primary Care, KU Leuven, Leuven, Belgium
- ¹¹Global Clinical Operations, Boehringer Ingelheim Pharma GmbH and Co. KG, Biberach, Germany
- ¹²Respiratory Clinic Institute, Hospital Clinic of Barcelona, Barcelona, Spain
- ¹³Institut d'Investigacions Biomèdiques Agust Pi i Sunyer (IDIBAPS), Barcelona, Spain
- ¹⁴National Heart and Lung Institute, Imperial College London, London, UK
- ¹⁵Almirall S A, Barcelona, Spain
- ¹⁶AstraZeneca, BioPharmaceuticals Medical, Gothenburg, Sweden
- ¹⁷First Department of Respiratory Medicine, National and Kapodistrian University of Athens, Athens, Greece
- ¹⁸Royal Brompton & Harefield NHS Foundation Trust, London, UK
- ¹⁹ELEGI and COLT Laboratories, The Queen's Medical Research Institute, The University of Edinburgh, Edinburgh, UK
- ²⁰Global Pharmacovigilance, Chiesi Pharmaceutici, Parma, Italy
- ²¹GlaxoSmithKline, London, UK
- ²²Department of Sport, Exercise and Rehabilitation, School of Health and Life Sciences, Northumbria University Newcastle, Newcastle, UK

Twitter Judith Garcia-Aymerich @judithgarciaaym, Heleen Demeyer @Demeyer_H, Elena Gimeno-Santos @EleGim and Nicholas S Hopkinson @COPDdoc

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ORCID iDs

Judith Garcia-Aymerich <http://orcid.org/0000-0002-7097-4586>
 Elena Gimeno-Santos <http://orcid.org/0000-0001-5149-2015>
 Nicholas S Hopkinson <http://orcid.org/0000-0003-3235-0454>

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Validity and responsiveness of the Daily- and Clinical visit-PROactive Physical Activity in COPD (D-PPAC and C-PPAC) instruments

Judith Garcia-Aymerich, Milo A Puhan, Solange Corriol-Rohou, Corina de Jong, Heleen Demeyer, Fabienne Dobbels, Damijan Erzen, Anja Frei, Elena Gimeno-Santos, Nicholas S Hopkinson, Nathalie Ivanoff, Niklas Karlsson, Zafeiris Louvaris, Michael I Polkey, Roberto Rabinovich, Mario Scuri, Maggie Tabberer, Ioannis Vogiatzis, Thierry Troosters, on behalf of PROactive consortium.

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METHODS (complete version)

Study Design and Subjects

We retrospectively pooled data from seven prospective randomised controlled trials testing the effect of pharmacological and non-pharmacological interventions in COPD patients from 17 countries in Europe and North America. Briefly, the ACTIVATE study (NCT02424344) evaluated the effects of acclidinium/formoterol on lung hyperinflation, exercise capacity and objective physical activity in GOLD II-III COPD patients, and used D-PPAC instrument daily during one week at baseline and at 8 weeks of follow-up¹. The ATHENS study (NCT02437994) was an open label study conducted to assess pulmonary rehabilitation effectiveness on objective physical activity, exercise capacity and dyspnoea, and used C-PPAC instrument at baseline and at 12 weeks². The EXOS study (ISRCTN:64759523) was an open label 3 arm study to assess the functional capacity of GOLD II-IV COPD patients following 6-9 weeks of pulmonary rehabilitation, inhaled bronchodilator (LAMA) therapy or placebo, and used D-PPAC instrument daily during one week at baseline³. MrPAPP study (NCT02158065) was a semi-automated tele coaching intervention designed to increase objective physical activity in COPD patients (all GOLD stages) after 12 weeks, and used both D-PPAC and C-PPAC instruments at baseline and at 12 weeks⁴. The PHYSACTO study (NCT02085161) evaluated the effects of tiotropium/olodaterol with/without exercise training on exercise capacity and objective physical activity in GOLD II-III COPD patients, and used D-PPAC instrument daily during one week at baseline and at 12 weeks⁵. The TRIGON-T9 (NCT02189577) 2-way crossover study was designed to demonstrate the superiority of glycopyrronium bromide vs. placebo over a 4-week treatment period in GOLD III-IV COPD patients, and used D-PPAC instrument daily during 14 days during the run-in period⁶. The URBAN TRAINING study

(NCT01897298) assessed the long-term efficacy and effectiveness of a behavioural and community-based exercise intervention (Urban Training) to increase objective physical activity in patients with COPD (all GOLD stages), and used C-PPAC instrument at baseline and at 12 months⁷. Trials contributed differently to the evaluation of different measurement properties depending on when D-PPAC and C-PPAC were measured (Figure 1). Briefly, all studies contributed to reliability-internal consistency and validity analyses with their baseline data; TRIGON-T9 contributed to reliability-test-retest analysis with baseline and 14 days data; ACTIVATE (bronchodilator intervention) contributed to responsiveness with baseline and 8 weeks data; PHYSACTO (bronchodilator with behavioural physical activity intervention), MrPAPP (behavioural physical activity intervention) and ATHENS contributed to responsiveness with baseline and 12 weeks data; and URBAN TRAINING (behavioural physical activity intervention) contributed to the responsiveness analysis with baseline and 12 months data. All trials recruited patients with stable COPD defined by spirometry (according to the American Thoracic Society and European Respiratory Society (ATS/ERS) criteria)⁸ and invited all patients to answer one of the PPAC questionnaires (except in MrPAPP that answered both D-PPAC and C-PPAC) and record physical activity data by wearing activity monitors. Table S1 below provides details on each trial's purpose, inclusion and exclusion criteria, design and intervention. The studies were approved by appropriate institutional review boards. Written informed consent was obtained from all patients.

Measures

D-PPAC and C-PPAC instruments require both questionnaire and activity monitor data. Patients completed D-PPAC and/or C-PPAC questionnaires, which had been previously developed using appropriate qualitative and quantitative research methods and culturally

sensitive translations⁹ and a rigorous item reduction process¹⁰ following current European Medicines Agency (EMA)¹¹ and US FDA¹² published standards. More details on the development and initial validation of the D-PPAC and C-PPAC instruments is described elsewhere¹⁰. In brief, the D-PPAC questionnaire consists of 7-items with a daily recall, and needs to be completed every evening for a week via an electronic handled device. The C-PPAC questionnaire has 12-items with a one-week recall, and is completed at the day of each study visit in an electronic handled device, a web-based system or using paper and pen. Patients also wore one of the activity monitors validated to be part of the PPAC instruments (DynaPort MoveMonitor, McRoberts B.V., The Netherlands; or Actigraph G3Tx, Actigraph, Pensacola, FL, United States) during waking time in one week at each study visit. Data from individuals was considered valid if they recorded more than 8 h of wearing time on at least 3 days (not necessarily consecutive) within 1 week. We calculated D-PPAC and C-PPAC scores by combining questionnaire items with two variables from activity monitors (steps/day and vector magnitude units (VMU)/min) if there was a minimum of 3 days of simultaneously collected monitoring and questionnaire items. Both for D-PPAC and C-PPAC, three scores are generated (amount of physical activity, difficulty with physical activity and total physical activity experience) ranging from 0 to 100, where higher numbers indicate a better score. For the D-PPAC instruments, we obtained scores for each day and calculated a weekly mean of D-PPAC amount, difficulty and total scores. For the C-PPAC instruments, only a weekly measure for each score was obtained. D-PPAC and C-PPAC items and scoring equivalences are reported below. For additional description of the study sample we also retrieved time in moderate-to-vigorous physical activity per day (>3 metabolic equivalents, MVPA) from the activity monitor. Lung function was evaluated by spirometry after reversibility testing and exercise capacity by six-minute walking distance (6MWD). Patients also completed the modified Medical Research

Council Dyspnoea scale (mMRC), the Chronic Respiratory Disease Questionnaire (CRQ), the Clinical COPD Questionnaire (CCQ) and/or the COPD Assessment Test (CAT). We also recorded demographics, smoking history and clinical data (medical and COPD histories) from patients and medical records. Finally, patients participating in follow-up visits also rated the global change of their physical activity experience in amount, difficulty and overall since baseline to follow-up on a 7-point Likert-type scale, ranging from 'much worse' to 'much better' (see below).

Statistical Analysis

Using a two-sided $\alpha=0.05$ and a power of 80%, we estimated that (i) 30 patients were required per stratum of sex, age, COPD severity, country and language in order to identify a statistically significant Cronbach's alpha ≥ 0.7 (for internal consistency), intraclass correlation ≥ 0.8 (for test-retest reliability) and correlations ≥ 0.5 (for convergent and discriminant validity), and that (ii) 23 patients were needed per group (in known-groups validity, responsiveness and ability to detect change) to detect a difference of minimum 10 points in PPAC scores between two groups equally sized assuming a standard deviation of 12 (based on own data). Calculations were done with the software GRANMO 7.10¹³. The analysis sets and statistical analysis plan were defined *a priori* based on study objectives. We used different study samples for the different measurement properties (Figure 1). All analyses were performed separately for D-PPAC and C-PPAC amount, difficulty and total scores.

Reliability was evaluated in terms of (i) internal consistency, by the Cronbach's alpha of D-PPAC daily scores and of C-PPAC scores, *a priori* defined as adequate: 0.7–0.9, in all subjects and stratified by sex, age group, COPD severity, country and language, and (ii) test-retest reproducibility, using intraclass correlation coefficients [ICC] and Bland-Altman plots

comparing the mean of D-PPAC scores from days 1-7 with the mean scores from days 8-14, *a priori* defined as adequate: ICC \geq 0.8; limit of agreement defined at the mean difference \pm 2 standard deviations (SD). (Internal consistency of the total scores was not tested because total scores are calculated as the mean of amount and difficulty scores and not from a list of items). Convergent validity was explored by testing the Spearman correlations between D-PPAC and C-PPAC scores and related constructs, namely dyspnoea (mMRC), health-related quality of life (HRQoL) (CRQ, CCQ, CAT), exercise capacity (6MWD) and objective physical activity (MVPA). A matrix of expected correlations for each variable was built using bibliography at the time of analysis (see below in Table S2). Correlations with CCQ-total, 6MWD and MVPA were stratified by sex, age groups, COPD severity, country and language. We also tested the ability of the D-PPAC and C-PPAC scores to discriminate between groups *a priori* expected to have differences in physical activity experience (known-groups validity), using one-way ANOVA test and pairwise comparisons of means adjusting for multiple comparisons using Bonferroni correction: ATS/ERS COPD severity stages defined by spirometry (mild, moderate, severe and very-severe), groups defined by mMRC grades of dyspnoea (0, 1, 2, 3, and 4), and tertiles of 6MWD.

To quantify responsiveness (response to interventions and ability to detect change), we calculated the change (8 weeks, 12 weeks or 12 months minus baseline) and the standardised response mean (SRM, mean difference divided by SD of the difference) in (i) each intervention group, using each study separately (*a priori* expected significant differences ($p < 0.05$) in the changes between groups and SRM $> |0.5|$ in difficulty and total scores after bronchodilator and pulmonary rehabilitation interventions, and in amount and total scores after behavioural physical activity interventions, see below Table S3); (ii) groups defined by the self-reported global rating of change in physical activity experience, using a pooled dataset (*a priori*

expected significant differences ($p < 0.05$) and $SRM > |0.5|$ in PPAC scores between much worse/worse/slightly worse vs no change/slightly better, and better/much better vs no change/slightly better, see Table S3); and (iii) groups defined according to having had COPD exacerbations during follow-up, using a pooled dataset (*a priori* expected significant differences ($p < 0.05$) and $SRM > |0.5|$ in PPAC scores between those having any COPD exacerbation during follow-up vs none, see Table S3).

We established the MID by triangulation against the anchors 6MWD, CCQ and self-reported global rating of change in physical activity experience (only for the scores where the correlation between changes in scores and changes in anchor was $> |0.3|$)¹⁴. To provide insight on minimal detectable change (MDC), we calculated 0.5 of Cohen's effect size for D-PPAC and C-PPAC scores, and standard error of measurement (SEM) for D-PPAC scores. However, we did not aim to establish MDC because only one distribution-based estimate was available for C-PPAC. Analyses were performed using complete cases in STATA version 14 (StataCorp, College Station, TX, USA).

Table S1. Main characteristics of studies included in validation of D-PPAC and C-PPAC instruments.

Study name	ACTIVATE	ATHENS	EXOS	MrPAPP	PHYSACTO	TRIGON-T9	URBAN TRAINING
Sponsor	AstraZeneca	Thorax Research Foundation	UK NHS Trust	KU Leuven	Boehringer Ingelheim	Chiesi Farmaceutici S.p.A.	ISGlobal
CT number	NCT02424344	NCT02618746	ISRCTN 64759523	NCT02158065	NCT02085161	NCT02189577	NCT01897298
N included in PPAC validation	229	52	22	330	282	87	313
Key Inclusion criteria	GOLD II/III; Age ≥ 40 y; Current/ex-smokers; mMRC ≥ 2 ; Willing to participate in a telecoaching program during four last weeks and to enhance their physical activity	All COPD patients entering pulmonary rehabilitation.	GOLD II-IV; MRC ≥ 2 ; Age 40-85 years.	COPD of all stages.	GOLD II-III; Age >40 y; Current/ex-smokers.	FEV1 $<60\%$ pred.; Age >40 y; Current/ex-smokers; Positive response to reversibility test defined as change in FEV1 $\geq 5\%$; BDI score ≤ 10 ; No exacerbations for at least 1 month.	Any COPD patient visiting a public primary care centre of five municipalities (Barcelona province); Age >45 ; clinical stability, defined as at least 4 weeks without antibiotics or oral corticosteroids.
Key exclusion criteria	Asthma; Hospitalized for acute exacerbation within 3 m prior to recruitment; Use of long-term oxygen therapy (≥ 15 hours/day); BMI ≥ 40 kg/m ² ; Evidence of clinically significant	Orthopaedic, neurological, and other musculoskeletal complaints that could impair normal movement patterns; Asthma; Hospital admission or COPD exacerbations	Co-morbidity that limits the ability to walk/ cycle (e.g. musculoskeletal, arthritic, or neurological disorders); Participation in rehabilitation over the last 12 months; Patients on long	Unable to increase physical activity; Asthma; Any complaints that impair normal biomechanical movement patterns, as judged by the investigator.	A limitation of exercise performance as a result of factors other than fatigue or exertional dyspnoea; A CI for exercise testing; Asthma; A completed rehabilitation	Asthma; Oxygen therapy for chronic hypoxia (at least 12 hours); Clinically significant cardiovascular condition.	Living >6 mths/year outside of the included municipalities; Mental disability; Comorbidity that could interfere with study tests; Severe psychiatric disease or severe

	respiratory and/or cardiovascular conditions; Pulmonary rehabilitation during at least 3 months prior to the screening	within the previous 4 weeks; Not on an optimal pharmacotherapy.	term oxygen therapy; Patients requiring oxygen therapy during the course of an exercise test (i.e. de-saturation documented <85%).		program in the 6 wks prior to screening, or currently in a rehabilitation program.		comorbidity limiting survival at one year.
Design	Double-blind, randomised, parallel group, placebo controlled, multicentre and multinational clinical trial	Randomised controlled trial open labelled	Randomised controlled trial cross over 2 groups (only baseline data used in PPAC validation)	Randomised controlled trial open labelled	Randomised controlled trial placebo controlled parallel groups	Randomised controlled trial double blind placebo controlled 2 way cross over study	Multicentre randomised controlled trial, blinded to outcome assessment
Intervention	Acclidinium bromide+ formoterol DPI FDC vs. Placebo; All patients take part in a coaching program.	Rehabilitation programme vs. placebo	n.a.	Telecoaching vs. Usual care program	Olodaterol + tiotropium vs. tiotropium vs. Behavioural modification; All supervised exercise training	Glycopyrrolate bromide (CHF 5259) vs. placebo	Urban training (behavioural intervention + unsupervised walking intervention) vs. Usual care
Phase	Ph4	n.a.	n.a.	n.a.	Ph3	Ph2b	n.a.
D-PPAC	Exploratory endpoint		Primary endpoint	Key 2 nd endpoint	Key 2 nd endpoint	Exploratory endpoint	
C-PPAC		Primary endpoint		Key 2 nd endpoint			Exploratory endpoint
Activity Monitor(s) used in PPAC validation	Dynaport	Dynaport	ActiGraph	Dynaport	Dynaport	Dynaport	Dynaport

Length of study as used in PPAC validation	8 weeks	12 weeks	Baseline	12 weeks	12 weeks	2 weeks	12 months
Countries of recruitment	Canada, Germany, Hungary, Spain	Greece	UK	UK, Netherlands, Greece, Germany, Switzerland	Australia, Austria, Belgium, Canada, Denmark, Germany, New Zealand, Poland, Portugal, UK, USA	Bulgaria, Germany, Poland, UK	Spain

PROactive Physical Activity in COPD (PPAC) instruments

The PROactive Physical Activity in COPD (PPAC) instruments are **reproduced below** to help understanding the main manuscript but **CAN NOT** be used without a licensing agreement.

License to use D-PPAC and C-PPAC can be requested from the PROactive team, and will include a commitment to use and score the instruments as outlined in the Users Guide. This will guarantee that the estimates of PPAC scores are valid and reliable, and will increase interpretability across studies.

Only **approved translations** may be used. If new languages are required, the translation process must be agreed with the PROactive team who can provide a translation guidance document and perform developer review. All new translations and associated certification will be provided to the PROactive team as part of the licensing agreement, to maintain the integrity of the instruments.

The **User's Guide**, available from PROactive team, includes all details about context of use, development and validation process, instruments description, procedures to administer the questionnaire, procedures to use (and process data of) the activity monitors, data aggregation between questionnaires and activity monitors, scoring, and translations available.



DAILY PROACTIVE PHYSICAL ACTIVITY IN COPD: D-PPAC

INSTRUCTIONS TO PATIENTS DAY 1:

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 since you woke up TODAY.

Please complete this questionnaire in the evening before going to bed. Please select the box next to the response that best applies to you TODAY.

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

INSTRUCTIONS FOR SUBSEQUENT DAYS:

We would like to know how you experienced your physical activity since you woke up TODAY. Please complete this questionnaire in the evening before going to bed. Please select the box next to the response that best applies to you TODAY.

	Difficulty score	Amount score
How much walking did you do outside today? <input type="checkbox"/> None at all <input type="checkbox"/> A little bit (up to 10 minutes in total) <input type="checkbox"/> Some (up to 30 minutes in total) <input type="checkbox"/> A lot (up to 1 hour in total) <input type="checkbox"/> A great deal (more than 1 hour in total)		0 1 2 3 4
How many chores did you do outside the house today? Some examples are gardening, taking the rubbish out, or doing small errands. <input type="checkbox"/> None at all <input type="checkbox"/> A few <input type="checkbox"/> Some <input type="checkbox"/> A lot <input type="checkbox"/> A large amount		0 1 2 3 4
How much difficulty did you have getting dressed today? <input type="checkbox"/> None at all <input type="checkbox"/> A little bit <input type="checkbox"/> Some <input type="checkbox"/> A lot <input type="checkbox"/> A great deal	4 3 2 1 0	
How often did you avoid doing activities because of your lung problems today? <input type="checkbox"/> Not at all <input type="checkbox"/> Rarely <input type="checkbox"/> Sometimes <input type="checkbox"/> Frequently <input type="checkbox"/> All the time	4 3 2 1 0	

How breathless were you in general during your activities today?		4		
<input type="checkbox"/> Not at all		3		
<input type="checkbox"/> A little bit		2		
<input type="checkbox"/> Moderately		1		
<input type="checkbox"/> Very		0		
How tired were you in general during your activities today?		4		
<input type="checkbox"/> Not at all		3		
<input type="checkbox"/> A little bit		2		
<input type="checkbox"/> Moderately		1		
<input type="checkbox"/> Very		0		
How often did you have to take breaks during your physical activities today?		4		
<input type="checkbox"/> Not at all		3		
<input type="checkbox"/> Rarely		2		
<input type="checkbox"/> Sometimes		1		
<input type="checkbox"/> Frequently		0		
Daily steps: <i>(please adhere to Users Guide procedures)</i>	Measured by Actigraph <1000	Measured by Dynaport <1900		0
	1001-3000	1901-3700		1
	3001-5000	3701-5500		2
	5001-7000	5501-7300		3
	>7000	>7300		4
Daily VMU/min: <i>(please adhere to Users Guide procedures)</i>	Measured by Actigraph <100	Measured by Dynaport <50		0
	101-200	51-110		1
	201-300	111-190		2
	301-400	191-270		3
	401-600	271-440		4
>600	>440	5		
		Difficulty raw score	Amount raw score	
Sum above:				
		Difficulty score	Amount score	
See equivalences raw-Rasch:				
		Total score (average of amount and difficulty)		

Table of equivalences between D-PPAC raw scores and D-PPAC 0-100 Rasch scaled scores:

Difficulty score				Amount score			
raw	Rasch 0-100	raw	Rasch 0-100	raw	Rasch 0-100	raw	Rasch 0-100
0	0	11	56	0	0	11	57
1	10	12	59	1	10	12	61
2	20	13	62	2	19	13	65
3	26	14	65	3	25	14	71
4	32	15	68	4	31	15	80
5	36	16	72	5	35	16	90
6	40	17	77	6	39	17	100
7	43	18	84	7	43		
8	46	19	92	8	47		
9	49	20	100	9	50		
10	52			10	54		



CLINICAL VISIT 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.

	Difficulty score	Amount score
In the past 7 days, how much walking did you do outside? <input type="checkbox"/> None at all <input type="checkbox"/> A little bit (about 10 minutes every day) <input type="checkbox"/> Some (about 30 minutes every day) <input type="checkbox"/> A lot (about 1 hour every day) <input type="checkbox"/> A great deal (more than 1 hour every day)		0 1 2 3 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 <input type="checkbox"/> A few <input type="checkbox"/> Some <input type="checkbox"/> A lot <input type="checkbox"/> A large amount		0 1 2 3 4
In the past 7 days, how much difficulty did you have getting dressed? <input type="checkbox"/> None at all <input type="checkbox"/> A little bit <input type="checkbox"/> Some <input type="checkbox"/> A lot <input type="checkbox"/> A great deal	4 3 2 1 0	
In the past 7 days, how much difficulty did you have getting out and about? <input type="checkbox"/> None at all <input type="checkbox"/> A little bit <input type="checkbox"/> Some <input type="checkbox"/> A lot <input type="checkbox"/> A great deal	4 3 2 1 0	
In the past 7 days, how often did you avoid doing activities because of your lung problems? <input type="checkbox"/> Not at all <input type="checkbox"/> Rarely <input type="checkbox"/> Sometimes <input type="checkbox"/> Frequently <input type="checkbox"/> All the time	4 3 2 1 0	
In the past 7 days, how breathless were you in general during your activities? <input type="checkbox"/> Not at all <input type="checkbox"/> A little bit <input type="checkbox"/> Moderately	4 3 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?			
<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 much time did you need to recover from your physical activities?			
<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, 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.			
<input type="checkbox"/> No		4	
<input type="checkbox"/> A little bit		3	
<input type="checkbox"/> Sometimes		2	
<input type="checkbox"/> A lot		1	
<input type="checkbox"/> A great deal		0	
Weekly mean steps of daily value:	Measured by Actigraph	Measured by Dynaport	
	<1300	<1500	0
	1301-2200	1501-2500	1
(please adhere to Users Guide procedures)	2201-4000	2501-4500	2
	4001-5700	4501-6500	3
	>5700	>6500	4

Weekly mean VMU/min of daily value: <i>(please adhere to Users Guide procedures)</i>	Measured by Actigraph ≤180 181-260 261-350 351-490 >490	Measured by Dynaport ≤60 61-130 131-210 211-370 >370		0 1 2 3 4
			Difficulty raw score	Amount raw score
		Sum above:		
			Difficulty score	Amount score
		See equivalences raw-Rasch:		
			Total score (average of amount and difficulty)	

* This is not a mistake. The last category should be scored 3.

Table of equivalences between C-PPAC raw scores and C-PPAC 0-100 Rasch scaled scores:

Difficulty score				Amount score	
raw	Rasch 0-100	raw	Rasch 0-100	raw	Rasch 0-100
0	0	21	60	0	0
1	8	22	61	1	13
2	15	23	63	2	25
3	20	24	65	3	33
4	24	25	66	4	39
5	28	26	68	5	45
6	31	27	70	6	50
7	34	28	72	7	54
8	36	29	73	8	59
9	38	30	75	9	63
10	40	31	77	10	67
11	42	32	79	11	72
12	44	33	81	12	77
13	46	34	83	13	83
14	48	35	86	14	91
15	50	36	89	15	100
16	51	37	92		
17	53	38	94		
18	55	39	97		
19	56	40	100		
20	58				

Global rating of change in physical activity experience

Instruction: This question should be used immediately before the patient completes other visit specific questionnaires. The investigator is to read out the question and response options to the patient. The patient's response should be noted in the e-CRF.

Rating of change; overall concept

The comparison to the time at which the patient answered the global rating of severity question (study start/randomisation) should be emphasised and the patient asked to think about the last week.

Compared to the start of the study –mention day and month-, how would you describe your experience with physical activity in the past week? (please select one answer):
<input type="checkbox"/> Much worse
<input type="checkbox"/> Worse
<input type="checkbox"/> Slightly worse
<input type="checkbox"/> No change
<input type="checkbox"/> Slightly better
<input type="checkbox"/> Better
<input type="checkbox"/> Much better

Rating of change; amount domain

The comparison to the time at which the patient answered the global rating of severity question (study start/ randomisation) should be emphasised and the patient asked to think about the last week.

Compared to the start of the study –mention day and month-, how physically active have you been in the last week? (amount) (please select one answer):
<input type="checkbox"/> Much less active
<input type="checkbox"/> Less active
<input type="checkbox"/> A little less active
<input type="checkbox"/> No change
<input type="checkbox"/> A little more active
<input type="checkbox"/> More active
<input type="checkbox"/> Much more active

Rating of change; difficulty domain

The comparison to the time at which the patient answered the global rating of severity question (study start/ randomisation) should be emphasised and the patient asked to think about the last week.

Compared to the start of the study, how difficult was it to conduct your physical activity in the last week was: (*difficulty*) (*please select one answer*):

- Much more difficult
- More difficult
- A little more difficult
- No change
- A little easier
- More easy
- Much more easy

Table S2. Matrix of *a priori* hypothesised correlations of D-PPAC and C-PPAC scores with dyspnea, health-related quality of life, exercise capacity and objective physical activity level (convergent validity)

	Amount	Difficulty	Total
mMRC	-0.5 to -0.8	-0.3 to -0.5	-0.4 to -0.7
CRQ Dyspnea	0 to 0.3	0.5 to 0.8	0 to 0.6
CRQ Fatigue	0 to 0.3	0.5 to 0.8	0 to 0.6
CRQ Emotional	0 to 0.3	0.5 to 0.8	0 to 0.6
CRQ Mastery	0 to 0.3	0.5 to 0.8	0 to 0.6
CCQ Symptoms	0 to 0.3	-0.5 to -0.8	0 to -0.6
CCQ Functional	-0.3 to -0.5	-0.5 to -0.8	0 to -0.7
CCQ Mental	0 to -0.3	-0.5 to -0.8	0 to -0.6
CCQ Total	-0.3 to -0.5	-0.5 to -0.8	0 to -0.7
CAT Total	0 to -0.3	-0.5 to -0.8	0 to -0.6
6MWD	0.3 to 0.5	0.5 to 0.8	0.3 to 0.7
MVPA	0.5 to 0.8	0 to 0.3	0 to 0.7

Table S3. *A priori* hypothesised statistically significant differences ($p < 0.05$) in the changes between groups and/or $SRM > |0.5|$ (responsiveness).

	Amount	Difficulty	Total
Interventions			
Bronchodilator interventions			
ACTIVATE		X	X
PHYSACTO		X	X
Pulmonary rehabilitation interventions			
ATHENS		X	X
Behavioural physical activity interventions			
MrPAPP	X		X
URBAN TRAINING	X		X
Self-reported global rating of change			
Change in physical activity experience overall	X	X	X
Change in difficulty with physical activity		X	X
Change in amount of physical activity	X		X
COPD exacerbations during follow-up	X	X	X

Table S4. Baseline demographic and clinical characteristics of COPD patients included in the validation of D-PPAC and C-PPAC instruments, by study

	D-PPAC dataset n = 950					C-PPAC dataset n = 651		
	ACTIVATE	EXOS	MrPAPP	PHYSACTO	TRIGON-T9	ATHENS	MrPAPP	URBAN TRAINING
	m (SD) / n (%)	m (SD) / n (%)	m (SD) / n (%)	m (SD) / n (%)	m (SD) / n (%)	m (SD) / n (%)	m (SD) / n (%)	m (SD) / n (%)
n	229	22	330	282	87	52	286	313
Age (years)	62.5 (7.7)	64.5 (7.1)	66.4 (8.0)	64.7 (6.6)	62.2 (8.1)	67.1 (8.8)	66.9 (8.0)	68.6 (8.9)
Gender: male	135 (59)	17 (77)	209 (63)	184 (65)	52 (60)	42 (81)	183 (64)	261 (83)
Working status: employed	n.a.	3 (14)	45 (14)	n.a.	n.a.	6 (12)	35 (12)	38 (13)
Current smoker	143 (62)	3 (14)	85 (26)	107 (38)	56 (64)	10 (19)	74 (26)	73 (23)
BMI (kg/m ²)	27.1 (5.0)	26.0 (5.7)	26.4 (5.0)	27.6 (4.9)	27.0 (6.0)	27.3 (5.1)	26.3 (5.0)	28.3 (5.1)
Any cardiovascular disease	n.a.	3 (14)	62 (19)	95 (34)	18 (21)	n.a.	61 (21)	194 (63)
Diabetes	36 (16)	5 (23)	27 (8)	23 (8)	0 (0)	n.a.	25 (9)	87 (28)
Musculoskeletal disorders	n.a.	3 (14)	65 (20)	122 (43)	3 (3)	n.a.	58 (20)	37 (12)
FEV ₁ (% predicted)	60.7 (10.7)	46 (20)	57 (22)	48 (13)	48 (12)	51 (20)	57 (22)	57 (18)
ATS/ERS stages:								
I - mild (FEV ₁ ≥80%)	0 (0)	0 (0)	53 (16)	1 (0)	1 (1)	4 (8)	45 (16)	31 (10)
II - Moderate (FEV ₁ <80% and ≥50%)	181 (79)	8 (36)	136 (41)	123 (44)	41 (47)	23 (44)	119 (41)	166 (53)
III - Severe (FEV ₁ <50% and ≥30%)	47 (21)	9 (41)	104 (32)	139 (49)	40 (46)	21 (40)	91 (32)	90 (29)
IV - very severe (FEV ₁ <30%)	0 (0)	5 (23)	37 (11)	19 (7)	5 (6)	4 (8)	31 (11)	26 (8)
FVC (% predicted)	100 (17)	83 (14)	92 (23)	104 (20)	80 (14)	79 (19)	92 (23)	77 (17)
FEV ₁ /FVC (%)	50 (9)	43 (14)	49 (15)	47 (10)	48 (13)	48 (14)	49 (16)	54 (12)
6MWD (m)	n.a.	315 (105)	443 (105)	452 (100)	n.a.	400 (113)	445 (107)	487 (94)
Dyspnea (mMRC 0-4)	2.1 (0.3)	2.0 (0.8)	1.4 (1.0)	1.3 (0.9)	n.a.	2.3 (1.0)	1.5 (1.0)	1.2 (0.9)
Any COPD exacerbations last 12 m	61 (27)	19 (86)	167 (51)	21 (7)	n.a.	46 (89)	138 (48)	139 (46)

Any COPD exacerbations requiring admissions last 12 m	n.a.	3 (14)	50 (15)	13 (5)	n.a.	23 (44)	42 (15)	17 (6)
CRQ dyspnea (1-7)	n.a.	2.8 (1.1)	n.a.	5.3 (1.2)	n.a.	2.3 (0.7)	n.a.	n.a.
CRQ fatigue (1-7)	n.a.	4.1 (0.9)	n.a.	4.6 (1.2)	n.a.	1.7 (0.5)	n.a.	n.a.
CRQ emotional (1-7)	n.a.	4.8 (1.1)	n.a.	5.2 (1.1)	n.a.	3.4 (1.1)	n.a.	n.a.
CRQ mastery (1-7)	n.a.	4.7 (1.4)	n.a.	5.4 (1.2)	n.a.	2.0 (0.6)	n.a.	n.a.
CCQ symptoms (0-6)	n.a.	n.a.	1.9 (1.1)	n.a.	n.a.	n.a.	1.9 (1.0)	1.6 (1.1)
CCQ functional (0-6)	n.a.	n.a.	1.8 (1.3)	n.a.	n.a.	n.a.	1.8 (1.2)	1.3 (1.1)
CCQ mental (0-6)	n.a.	n.a.	1.4 (1.4)	n.a.	n.a.	n.a.	1.4 (1.4)	1.3 (1.4)
CCQ total (0-6)	n.a.	n.a.	1.8 (1.0)	n.a.	n.a.	2.1 (1.2)	1.8 (1.0)	1.4 (0.9)
CAT (0-40)	n.a.	20 (6)	n.a.	n.a.	n.a.	16.7 (8.2)	n.a.	12.3 (6.9)
Steps per day (n/day)	5982 (3915)	4500 (2347)	5786 (3700)	5697 (3760)	5230 (3878)	4246 (3014)	5627 (3457)	7673 (4247)
VMU/min	437 (256)	426 (243)	394 (294)	434 (306)	492 (282)	397 (194)	417 (331)	472 (324)
Time in moderate-to-vigorous physical activity (min/day)	94 (52)	13 (17)	89 (47)	92 (50)	88 (53)	n.a.	88 (43)	107 (50)
PPAC-amount (0-100)	57 (14)	48 (13)	52 (13)	54 (13)	59 (14)	63 (17)	68 (15)	73 (16)
PPAC-difficulty (0-100)	70 (14)	63 (12)	71 (15)	71 (14)	63 (12)	70 (17)	75 (13)	82 (15)
PPAC-total (0-100)	63 (10)	55 (8)	62 (11)	62 (10)	61 (9)	66 (14)	71 (11)	78 (12)

n.a. Variable not available in a specific study. BMI: body mass index; FEV₁: forced expiratory volume in 1 second; FVC: forced vital capacity; 6MWD: 6-minute walking distance; mMRC: modified medical research council dyspnea scale; CRQ: chronic respiratory questionnaire; CCQ: clinical chronic obstructive pulmonary disease questionnaire; CAT: chronic obstructive pulmonary disease assessment test; VMU: vector magnitude unit; PPAC: PROactive physical activity in COPD.

Table S5. Countries and languages of COPD patients included in the validation of D-PPAC and C-PPAC instruments.

	D-PPAC dataset n=950	C-PPAC dataset n=651
	n (%)	n (%)
Country		
Australia	25 (3%)	
Austria	7 (1%)	
Belgium	119 (13%)	81 (12%)
Bulgaria	13 (1%)	
Canada	43 (5%)	
Denmark	17 (2%)	
Germany	336 (35%)	
Greece	82 (9%)	127 (20%)
Hungria	5 (1%)	
Netherlands	34 (4%)	19 (3%)
New Zealand	10 (1%)	
Poland	48 (5%)	
Portugal	5 (1%)	
Spain	15 (2%)	313 (48%)
Switzerland	45 (5%)	38 (6%)
UK	122 (13%)	73 (11%)
USA	24 (3%)	
Language		
Bulgarian	13 (1%)	
Danish	17 (2%)	
Dutch/Flemish	153 (16%)	100 (15%)
English	194 (20%)	73 (11%)
French	30 (3%)	
German	388 (41%)	38 (6%)
Greek	82 (9%)	127 (20%)
Hungarian	5 (1%)	
Polish	48 (5%)	
Portuguese	5 (1%)	
Spanish	15 (2%)	313 (48%)

Table S6. Cronbach's alpha of D-PPAC and C-PPAC amount and difficulty scores (reliability, internal consistency).

D-PPAC			C-PPAC		
n ranging between 983 and 2075*	Amount	Difficulty	n=651	Amount	Difficulty
Day 1	0.79	0.84	Week 1	0.72	0.92
Day 2	0.77	0.87			
Day 3	0.78	0.87			
Day 4	0.78	0.88			
Day 5	0.81	0.89			
Day 6	0.78	0.88			
Day 7	0.77	0.89			

* N day 1=2075, n day 2=1764, n day 3=1758, n day 4=1714, n day 5=1645, n day 6=1454, n day 7=983

Table S7. Intraclass correlation coefficient (ICC) of week 1 mean vs week 2 mean of D-PPAC scores (reliability, test-retest reproducibility).

n=168	Amount ICC (95% CI)	Difficulty ICC (95% CI)	Total ICC (95% CI)
Week 1 vs week 2	0.84 (0.76-0.89)	0.86 (0.79-0.91)	0.87 (0.81-0.91)

Figure S1. Bland Altman plots (mean week 1 vs mean week 2) of D-PPAC amount, difficulty and total scores (test-retest reproducibility).

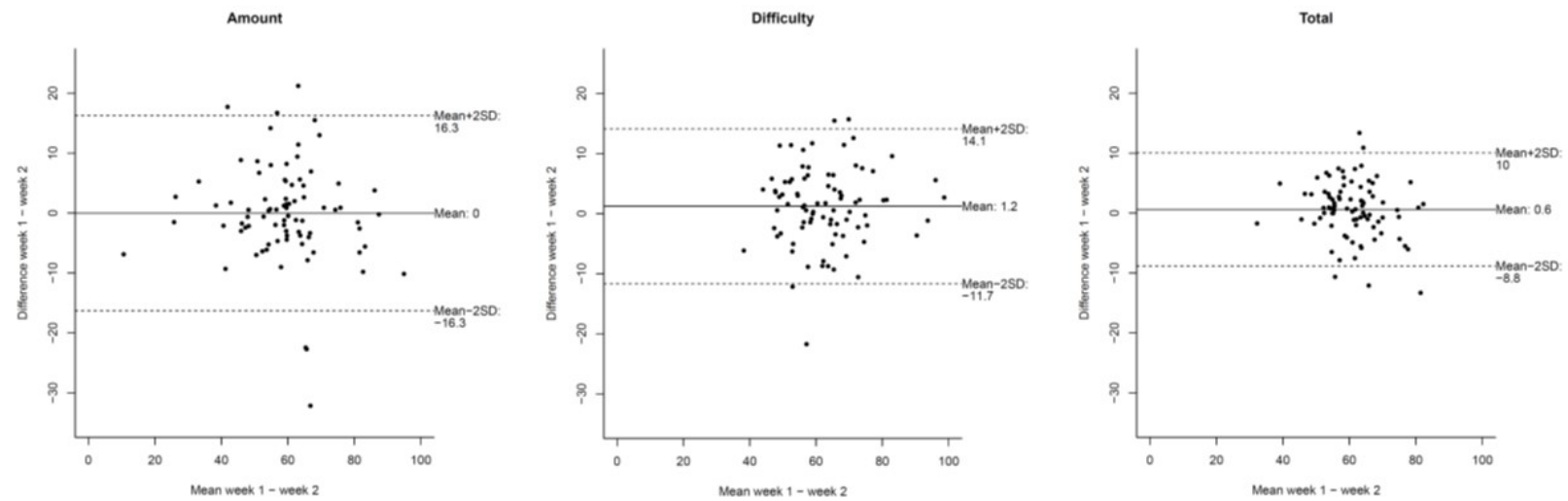


Table S8. Distribution of D-PPAC and C-PPAC scores according to COPD airflow severity groups, dyspnoea groups and exercise capacity groups (known-groups validity).

	D-PPAC						C-PPAC					
	Amount		Difficulty		Total		Amount		Difficulty		Total	
	m (SD)	<i>p</i> -value*	m (SD)	<i>p</i> -value*	m (SD)	<i>p</i> -value*	m (SD)	<i>p</i> -value*	m (SD)	<i>p</i> -value*	m (SD)	<i>p</i> -value*
ATS/ERS stages												
Mild	55 (12)	--	76 (14)	--	65 (10)	--	75 (13)	--	82 (14)	--	79 (11)	--
Moderate	56 (14)	<i>to mild:</i> >0.999	72 (14)	<i>to mild:</i> 0.211	64 (10)	<i>to mild:</i> >0.999	73 (14)	<i>to mild:</i> >0.999	82 (13)	<i>to mild:</i> >0.999	77 (11)	<i>to mild:</i> >0.999
Severe	54 (13)	<i>to mild:</i> >0.999	68 (14)	<i>to mild:</i> 0.001	61 (10)	<i>to mild:</i> 0.014	67 (15)	<i>to mild:</i> <0.001	74 (15)	<i>to mild:</i> <0.001	71 (12)	<i>to mild:</i> <0.001
		<i>to moderate:</i> 0.038		<i>to moderate:</i> 0.005		<i>to moderate:</i> <0.001		<i>to moderate:</i> <0.001		<i>to moderate:</i> <0.001		<i>to moderate:</i> <0.001
Very severe	43 (12)	<i>to mild:</i> <0.001	63 (13)	<i>to mild:</i> <0.001	53 (10)	<i>to mild:</i> <0.001	59 (20)	<i>to mild:</i> <0.001	66 (16)	<i>to mild:</i> <0.001	62 (15)	<i>to mild:</i> <0.001
		<i>to moderate:</i> <0.001		<i>to moderate:</i> <0.001		<i>to moderate:</i> <0.001		<i>to moderate:</i> <0.001		<i>to moderate:</i> <0.001		<i>to moderate:</i> <0.001
		<i>to severe:</i> <0.001		<i>to severe:</i> 0.014		<i>to severe:</i> <0.001		<i>to severe:</i> <0.001		<i>to severe:</i> 0.002		<i>to severe:</i> <0.001
		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001

Dyspnoea (mMRC)												
0	58 (14)	--	82 (13)	--	70 (10)	--	78 (14)	--	92 (8)	--	85 (8)	--
1	55 (12)	to 0: 0.573	74 (12)	to 0: <0.001	65 (8)	to 0: <0.001	74 (13)	to 0: 0.143	82 (11)	to 0: <0.001	78 (9)	to 0: <0.001
2	54 (14)	to 0: 0.042 to 1: >0.999	68 (13)	to 0: <0.001 to 1: <0.001	61 (10)	to 0: <0.001 to 1: <0.001	66 (15)	to 0: <0.001 to 1: <0.001	70 (12)	to 0: <0.001 to 1: <0.001	68 (9)	to 0: <0.001 to 1: <0.001
3	46 (14)	to 0: <0.001 to 1: <0.001 to 2: <0.001	62 (14)	to 0: <0.001 to 1: <0.001 to 2: 0.006	54 (10)	to 0: <0.001 to 1: <0.001 to 2: <0.001	59 (17)	to 0: <0.001 to 1: <0.001 to 2: 0.003	64 (16)	to 0: <0.001 to 1: <0.001 to 2: 0.004	62 (13)	to 0: <0.001 to 1: <0.001 to 2: <0.001
4	39 (10)	to 0: <0.001 to 1: 0.003 to 2: 0.007 to 3: >0.999 <0.001	55 (9)	to 0: <0.001 to 1: <0.001 to 2: 0.020 to 3: 0.831 <0.001	47 (6)	to 0: <0.001 to 1: <0.001 to 2: <0.001 to 3: 0.220 <0.001	52 (16)	to 0: <0.001 to 1: <0.001 to 2: 0.002 to 3: 0.707 <0.001	56 (11)	to 0: <0.001 to 1: <0.001 to 2: <0.001 to 3: 0.090 <0.001	54 (9)	to 0: <0.001 to 1: <0.001 to 2: <0.001 to 3: 0.037 <0.001
6MWD (m)												
1 st tertile	46 (13)	--	65 (14)	--	55 (10)	--	59 (15)	--	69 (15)	--	64 (12)	--
2 nd tertile	54 (12)	to 1 st tertile: <0.001	71 (13)	to 1 st tertile: <0.001	62 (9)	to 1 st tertile: <0.001	74 (12)	to 1 st tertile: <0.001	78 (13)	to 1 st tertile: <0.001	76 (10)	to 1 st tertile: <0.001
3 rd tertile	58 (12)	to 1 st tertile: <0.001 to 2 nd tertile: 0.001 <0.001	78 (14)	to 1 st tertile: <0.001 to 2 nd tertile: <0.001	68 (9)	to 1 st tertile: <0.001 to 2 nd tertile: <0.001	77 (12)	to 1 st tertile: <0.001 to 2 nd tertile: 0.049 <0.001	86 (12)	to 1 st tertile: <0.001 to 2 nd tertile: <0.001	82 (9)	to 1 st tertile: <0.001 to 2 nd tertile: <0.001

* Comparison between groups from the pairwise comparisons of means adjusting for multiple comparisons using Bonferroni correction, and overall comparison from one-way ANOVA.

Table S9. Correlations* of changes in D-PPAC and C-PPAC amount, difficulty and total scores with changes in potential anchors.

	D-PPAC			C-PPAC		
	Change in amount score	Change in difficulty score	Change in total score	Change in amount score	Change in difficulty score	Change in total score
Change 6MWD	0.14	0.18	0.20	0.16	0.16	0.22
Change total CCQ	-0.11	-0.32	-0.34	-0.20	-0.46	-0.39
Global rating change: overall	0.31	0.25	0.37	0.35	0.18	0.35
Global rating change: difficulty	0.31	0.32	0.42	0.32	0.26	0.37
Global rating change: amount	0.40	0.24	0.43	0.32	0.16	0.31

* Correlation coefficients are in bold when $>|0.3|$; these anchors were used to estimate MID (Table 4 in main text).

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