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ORIGINAL RESEARCH

Short Physical Performance Battery: Response to Pulmonary Rehabilitation and Minimal Important Difference Estimates in Patients With Chronic Obstructive Pulmonary Disease

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Abstract

Objective: To determine the response to a pulmonary rehabilitation (PR) program and minimal important differences (MIDs) for the Short Physical Performance Battery (SPPB) subtests and SPPB summary score in patients with chronic obstructive pulmonary disease (COPD).

Design: Retrospective analysis using distribution- and anchor-based methods.

Setting: PR center in the Netherlands including a comprehensive 40-session 8-week inpatient or 14-week outpatient program.

Participants: A total of 632 patients with COPD (age, 65±8y; 50% male; forced expiratory volume in the first second=43% [interquartile range, 30%-60%] predicted).

Interventions: Not applicable.

Main Outcome Measure: Baseline and post-PR results of the SPPB, consisting of 3 balance standing tests, 4-meter gait speed (4MGS), and 5-repetition sit-to-stand (5STS). The chosen anchors were the 6-Minute Walk Test and COPD Assessment Test. Patients were stratified according to their SPPB summary scores into low-performance, moderate-performance, and high-performance groups.

Results: 5STS (Δ=−1.14 [−4.20 to −0.93]s) and SPPB summary score (Δ=1 [0-2] points) improved after PR in patients with COPD. In patients with a low performance at baseline, balance tandem and 4MGS significantly increased as well. Based on distribution-based calculations, the MID estimates ranged between 2.19 and 6.33 seconds for 5STS and 0.83 to 0.96 points for SPPB summary score.

Conclusions: The 5STS and SPPB summary score are both responsive to PR in patients with COPD. The balance tandem test and 4MGS are only responsive to PR in patients with COPD with a low performance at baseline. Based on distribution-based calculations, an MID estimate of 1 point

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for the SPPB summary score is recommended in patients with COPD. Future research is needed to confirm MID estimates for SPPB in different centers.

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The Short Physical Performance Battery (SPPB) is an easy-to-perform measure for assessment of mobility and balance and its use is intended and recommended for older persons (>65y).[1] However, there is an increasing interest in SPPB performance for diseased populations, including individuals with chronic obstructive pulmonary disease (COPD). COPD is defined by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) as "a common, preventable and treatable disease that is characterized by persistent respiratory symptoms and airflow limitation that is due to airway and/or alveolar abnormalities caused by significant exposure to noxious particles or gases."[2] Patients with COPD have an increased risk of mortality and readmission and exhibit poorer physical function and health status,[3] which emphasizes the clinical relevance of SPPB performance.

The SPPB summary score has a good interobserver reliability[4] and has been used to classify patients as having low, moderate, or high performance in mobility and balance.[5-7] Furthermore, its potential as an alternative to the 6-Minute Walk Test (6MWT) in the BODE index has recently been reported[8] and physical and emotional correlates of the SPPB summary score have been identified.[5,7] The latter might suggest a positive effect of pulmonary rehabilitation (PR) on the SPPB summary score. To date, the response of the SPPB summary score to PR has only been described in 1 peer-reviewed manuscript[9] and 2 congress abstracts,[10,11] which all reported a significant increase.

Estimated minimal important differences (MIDs) are available for the SPPB subtests 4-meter gait speed (4MGS)[12] and 5-repetition sit-to-stand (5STS) in patients with COPD[13] but are currently lacking for the SPPB summary score. This complicates the evaluation of intervention efficacy using the SPPB.[14,15] Thus, to improve the interpretation of intervention efficacy at individual and group levels, the aims of the present study were to determine the response to a PR program on the SPPB subtests and summary score in patients with COPD and to estimate MIDs for the SPPB subtests and summary score in patients with COPD.

List of abbreviations:

4MGS	**4-meter gait speed**
5STS	**5-repetition sit-to-stand**
6MWT	**6-Minute Walk Test**
CAT	**COPD Assessment Test**
COPD	**chronic obstructive pulmonary disease**
FFM	**fat-free mass**
GOLD	**Global Initiative for Chronic Obstructive Lung Disease**
HP	**high-performance**
ICC	**intraclass correlation coefficient**
LP	**low-performance**
MID	**minimal important difference**
MP	**moderate-performance**
PR	**pulmonary rehabilitation**
SPPB	**Short Physical Performance Battery**

Methods

In this observational study, a retrospective analysis was performed on baseline and post-PR data of 953 patients between January 2016 and January 2018 in CIRO, a specialized PR center in the Netherlands.[16] This study was performed in accordance with the principles of the Declaration of Helsinki and was approved by the board of directors. The authors were informed by the Medical Ethics Committee of Maastricht University that the Medical Research Involving Human Subjects Act does not apply and no official approval was required (MEC no. 2018-0541). Therefore, no informed consent from participants was obtained.

The following inclusion criteria were applied: primary diagnosis of COPD according to the GOLD criteria[2] and complete SPPB data (baseline and post-PR) available. Participants younger than 40 years old, participation in the PR program more than once, or a baseline SPPB summary score of 12, because of a possible ceiling effect,[9] were excluded from further analyses. Baseline findings have been published previously.[5]

Patients' characteristics

Baseline characteristics including age, sex, weight, body mass index, exacerbation and hospitalization frequency in the last 12 months, Charlson Comorbidity Index, and use of long-term oxygen therapy were systematically collected during an extensive PR assessment. Furthermore, forced expiratory volume in 1 second and its ratio to forced vital capacity were assessed in accordance with the European Respiratory Society recommendations[17] using spirometry (MasterScreen PFT/Body[a]). The degree of airflow limitation was classified according to GOLD classification.[2]

Short Physical Performance Battery

Baseline and post-PR performance of the SPPB was in accordance with the National Institute on Aging protocol.[18] The SPPB includes 3 subtests: the standing balance test, 4MGS, and 5STS. During the standing balance test the patient was instructed to maintain 3 stances (feet placed side by side, semi-tandem, tandem) for 10 seconds. Secondly, the 4MGS was performed in duplicate to obtain the habitual gait speed over 4 m (normal walking aids were allowed). In the 5STS, the patient was required to perform 5 sit-to-stand maneuvers as fast as possible with arms folded in front of their chest. Each of the 3 components was scored from 0 (extreme mobility impairment) to 4 points (no mobility impairment), resulting in a SPPB summary score ranging from 0-12 points (table E1, available online only at http://www.archives-pmr.org/). A flowchart of the SPPB subtests and its scoring system was previously reported by Nogueira et al.[19] According to their baseline SPPB summary score, patients were classified as low performance (LP; 0-6 points), moderate performance (MP; 7-9 points), or high performance (HP; 10-12 points).[20]

Clinical outcomes

Fat-free mass (FFM) was measured using dual-energy x-ray absorptiometry (Lunar iDXA[b]).[21] The FFM index was calculated by dividing FFM by height squared. The modified Medical Research Council dyspnoea scale[22] was used to evaluate shortness of breath and a cutoff of ≥2 was used to identify patients with "more breathlessness."[23] The COPD Assessment Test (CAT) assessed the health status of the patients and a threshold of ≥18 points indicated patients who were highly symptomatic.[24] The 6MWT and incremental cardiopulmonary exercise test (Ergoselect[c]) were performed to determine physical capacity, both in accordance with the corresponding guidelines.[25-27] Exercise tolerance was assessed with the constant work rate test, performed at 75% of the predetermined maximal workload, during which patients cycled until symptom limitation (with a maximum test duration of 20 min).[28] Isokinetic quadriceps peak torque and total work of the right leg (or left leg in case of complications with the right leg) were assessed with a computerized dynamometer (Biodex Multi-joint System 3[d]). Patients performed a set of 30 repetitions at an angular speed of 90°/s. Reference values from Borges were used.[29] Symptoms of anxiety and depression were evaluated using the Hospital Anxiety and Depression Scale with a cutoff value of ≥10 points for each domain[30] to classify patients with indications for anxiety or depression.

Pulmonary rehabilitation

The 8-week inpatient and 14-week outpatient PR programs were in line with the American Thoracic Society/European Respiratory Society Statement on PR[31] and consisted of 40 sessions. Patients were supervised by an interdisciplinary team, including a chest physician, respiratory nurse, dietician, occupational therapist, physiotherapist, psychologist, and social worker. The cornerstone of the patient-tailored PR program was physical exercise training consisting mainly of exercises to strengthen muscles of the upper and lower extremities, treadmill walking, stationary cycling, flexibility exercises, and daily supervised outdoor walks.[32] Furthermore, the program included (if indicated) nutritional support, psychological counseling, and educational sessions.[32-34] Further description of the PR program was provided by Spruit et al.[34]

Statistical analyses

Statistical analyses were performed using SPSS statistical software[e], v25.0. Data were presented and/or tested as appropriate. Descriptive data are presented as means ± SD, medians (interquartile 1-interquartile 3), or percentages. Baseline and delta differences between 2 groups were tested by independent *t* test or Mann-Whitney *U* test. Categorical data were tested with Fisher exact test or chi-square test of homogeneity. Differences between baseline and post-PR data were tested by paired sample *t* test or Wilcoxon signed-rank test, and categorical data were tested with McNemar's test or related samples marginal homogeneity test. Differences in deltas between 3 groups were tested by 1-way analysis of variance, Kruskal-Wallis test, or chi-square test of homogeneity. When a statistically significant difference was obtained, pairwise Tukey's post hoc test was performed and Bonferroni correction was applied for multiple comparisons. Because of the many statistical tests performed in this study, $P \leq .01$ was considered significant.

As recommended,[14,15] both distribution-based and anchor-based techniques were used to determine MID estimates for the SPPB subtests and summary score. Four distribution-based techniques were applied: $SEM = SD_{baseline} * \sqrt{1 - \text{intraclass correlation coefficient}}$; empirical rule effect size=$0.08*6*SD_{delta}$; Cohen's effect size=$0.5*SD_{delta}$; $0.5*SD_{baseline}$.[35] The intraclass correlation coefficients (ICCs) were derived from previous studies (interobserver ICC_{SPPB}=0.81[4] and test-retest ICC_{4MGS}=0.97[12] and ICC_{5STS}=0.97[13]). The SEM method could not be performed for the standing balance tests because no ICCs have been determined in patients with COPD or in older persons.

To perform anchor-based methods, at least a moderate correlation between the anchors and change in SPPB subtests or summary score ($r \geq 0.3$, $P < .05$)[14,15] was required. The chosen anchors were CAT and 6MWT,[36,37] with known MIDs and expected correlations with the change in SPPB. In the presence of a sufficient correlation, linear regression and receiver operating characteristic analyses were performed between the change in SPPB as the dependent variable and the anchors as independent variables. For the receiver operating characteristic analyses, an area under the curve >0.7 was accepted as a meaningful relationship.[38]

MID estimates of SPPB summary score and SPPB subtests were only determined for tests that are responsive to PR on group level compared with baseline values.

Results

Of the 953 patients with COPD, 632 patients were eligible for analysis. Patients were excluded due to absence of baseline SPPB data (n=1), age younger than 40 years (n=5), and participation in the PR program for the second time (n=20). In addition, 27 patients were excluded because download of the data export showed multiple baseline values for 1 or more attributes. The exclusion of patients corresponds to the baseline study reported by Stoffels et al.[5] Furthermore, patients with missing post-PR assessment SPPB data (n=216) and a baseline SPPB summary score of 12 (n=52) were excluded.

A greater number of patients included in the study had a dyspnoea grade ≥2 and a different distribution of GOLD classification (n=632) than excluded patients (n=321; P=.002 and P=.008, respectively) (table E2, available online only at http://www.archives-pmr.org/).

Adherence and type of PR program

Adherence to the PR program was high in the included patients (completed sessions=40 sessions[39,40]). There were no differences in adherence between patients in the inpatient and outpatient programs (P=.209) or between LP, MP, and HP groups (P=.788).

Most patients participated in the inpatient PR program (61%). A larger percentage of these patients were females and experienced more severe symptoms, characterized by higher dyspnoea scores, poorer health status and pulmonary function, larger number of exacerbations and hospitalizations, and more frequent oxygen use compared with patients who participated in the outpatient program (table E3, available online only at http://www.archives-pmr.org/).

Baseline characteristics

The 632 patients with COPD had a severe degree of airflow limitation, an equal male-to-female ratio, and a normal body mass index. After stratification for SPPB summary score in LP (n=69), MP (n=300), and HP (n=263) groups, patients in the LP group were older and experienced higher levels of dyspnoea compared with the MP and HP groups. More clinical characteristics and pulmonary function data are shown in table 1.

Response to PR in clinical characteristics

Health status, dyspnoea, body composition, symptoms of anxiety and depression, and physical status improved in all patients with COPD who participated in PR (all $P<.001$) (table E4, available online only at http://www.archives-pmr.org/).

After stratification for baseline SPPB summary score, significant improvements in these clinical characteristics were observed in all 3 SPPB performance groups, with the exception of the anxiety subscale of the Hospital Anxiety and Depression Scale in the LP group, which did not improve after PR ($P=.020$). The Δ6MWT was the greatest in the LP group (47±78 m) in comparison to the MP group (24±53 m) and the HP group (12±49 m; $P<.001$) (table E5, available online only at http://www.archives-pmr.org/).

Differences in changes in clinical characteristics between patients participating in the inpatient and outpatient programs are depicted in table E6 (available online only at http://www.archives-pmr.org/).

Response to PR in SPPB

The 5STS was the only SPPB subtest responsive to PR, with a median Δ5STS of −1.14 (−4.20 to −0.93) seconds in patients with COPD ($P<.001$). Furthermore, SPPB summary score improved significantly from 9 (8-10) to 10 (9-11) points after PR ($P<.001$) (fig 1).

The baseline LP group showed improvements in balance tandem (median Δ=0.00 [0.00-10.00]s and mean Δ=3.36±4.96s), 4MGS (Δ=0.81 [0.37-1.40] m/s), and 5STS (Δ=−6.16 [−35.00 to 0.00]s) subtests of the SPPB after PR (all $P<.001$). The MP group showed a significant effect of PR on 4MGS (Δ=0.06 [−0.18 to 0.33] m/s) and 5STS (Δ=−2.40 [−6.40 to 0.17]s) subtests. The HP group only improved on 5STS (Δ=−0.74 [−2.40 to 1.00]s, $P<.001$) and even showed a decline in 4MGS (Δ=−0.27 [−0.44 to −0.05] m/s, $P<.001$). Improvements in the LP group were significant larger in contrast to MP and HP groups, which resulted in a larger increase in SPPB summary score for the LP group than the MP and HP groups (see fig 1). A maximum post-PR SPPB summary score of 12 was obtained in 23 patients in the MP group and 63 patients in the HP group.

Furthermore, baseline and post-PR proportion of patients per performance group were significantly different ($P<.001$). The flow and direction of this change in performance group classification is presented in figure 2.

Because differences in the type of PR program could potentially influence the SPPB response to PR, comparisons between changes in SPPB subtests and summary scores were made for patients participating in inpatient and outpatient PR programs. Changes in SPPB subtests were not significantly different between the 2 types of PR programs, except for the change in 4MGS (outpatient=−0.2 [−0.4 to 0] m/s vs. inpatient=0.1 [−0.2 to 0.4] m/s; $P<.001$). However, this difference did not affect the change in SPPB summary score, which was comparable between both groups (table E7, available online only at http://www.archives-pmr.org/).

MID

Because only 5STS and SPPB summary score were responsive to PR, MID estimates were not determined for the balance tests and 4MGS. Using distribution-based techniques, the MID of the 5STS ranged between 2.19-6.33 seconds and between 0.83-0.96 points for the SPPB summary score (table 2).

Furthermore, the change in 6MWT and CAT was not correlated or only weakly correlated with the change in 5STS and SPPB summary score and could therefore not be used as reliable anchors to determine the MIDs (table E8, available online only at http://www.archives-pmr.org/).

Discussion

Generally, the SPPB subtest 5STS and the SPPB summary score are responsive to PR in patients with COPD. In patients with a low performance at baseline, balance tandem and 4MGS are responsive to PR as well. Based on distribution-based calculations, the MID estimates range between 2.19-6.33 seconds for 5STS and 0.83-0.96 points for SPPB summary score.

In accordance with previous studies, 5STS and SPPB summary score were responsive to PR in patients with COPD.[9-11,13] However, the current study did not show an improvement in 4MGS in all patients with COPD as was expected based on previous studies.[10,12] Only LP and MP patients improved their 4MGS. A possible explanation for the decline in 4MGS in the HP group could be a ceiling effect; Kon et al[12] have reported that patients with a better baseline 4MGS were less responsive to PR than patients with a worse baseline 4MGS. Furthermore, only the LP group improved balance tandem time after PR but had a change of 0 (0-10) seconds (or mean change of 3.36±4.96s), which makes the clinical significance of the improvement questionable. No performance group showed an effect of PR in balance side-by-side or semi-tandem. Although balance impairments are common in patients with COPD,[39] most participants were able to complete the balance tests without difficulty. These results imply that standing balance tests are less useful and effective and perhaps not adequality sensitive in evaluating the effectiveness of PR in patients with COPD, suggesting the use of more complex balance tests like Berg Balance Scale or Balance Evaluation Systems Test.[39] Another possible explanation could be the minor focus on balance issues during PR; Marques et al highlighted the value of balance training during PR.[40]

The mean 5STS MID estimates (2.19-6.33s) are larger than the MID estimate by Jones et al (1.7s) in patients with COPD after an 8-week outpatient PR program in the United Kingdom.[13] The current SPPB summary score MID estimates (0.83-0.96 points) are comparable with the study of Perera et al, who reported a small meaningful change of 0.5 points and a substantial change of 1.0 point for SPPB summary scores in older patients.[41] Because the SPPB summary score is reported in whole numbers, it seems reasonable to conclude that an improvement of 1 point on the SPPB summary score can be taken as the MID in patients with COPD after PR. This MID can be interpreted and applied at individual and group levels to determine whether patients improve after PR.

Study limitations

Analyses were performed on a selected population of patients with COPD referred for PR. Including a more diverse group of patients could complicate the interpretation of results and conclusions. These results should be applied with caution in other populations or settings, because differences in interventions, context, and population characteristics are known to influence the response and MID estimates.[42-46] In addition, 86 patients achieved a maximum post-PR SPPB score of 12, which could indicate a ceiling effect.

Table 1 Baseline characteristics of all patients with COPD and after stratification for SPPB summary score

Characteristic		Short Physical Performance Battery		
	All Patients With COPD (n=632)	Low-Performance (n=69)	Moderate-Performance (n=300)	High-Performance (n=263)
Age (y)	65±8 (n=632)	69±8*,† (n=69)	66±8 (n=300)	64±8 (n=263)
Sex (male, %)	50 (n=632)	48 (n=69)	50 (n=300)	51 (n=263)
Weight (kg)	72 (60-86) (n=630)	70 (59-90) (n=69)	73 (60-87) (n=298)	70 (60-85) (n=263)
BMI (kg/m^2)	25 (22-30) (n=630)	25 (21-33) (n=69)	26 (22-31) (n=298)	25 (22-29) (n=263)
mMRC score	3 (2-3) (n=631)	4 (3-4)*,† (n=69)	3 (2-3)‡ (n=300)	2 (2-3) (n=262)
mMRC≥2 (% patients)	90 (n=631)	100† (n=69)	93‡ (n=300)	83 (n=262)
CAT score	22±6 (n=593)	25±6*,† (n=62)	22±6‡ (n=283)	20±6 (n=248)
CAT≥18 (% patients)	77 (n=593)	92† (n=62)	79 (n=283)	71 (n=248)
Exacerbations in the past 12 mo: 0/1/2/3/4/>4 (% patients)	18/17/22/14/8/21 (n=627)	7/13/10/22/6/42*,† (n=69)	19/18/21/14/9/19 (n=297)	21/17/26/11/7/18 (n=261)
≥2 exacerbations in the past 12 mo (% patients)	64 (n=627)	80 (n=69)	63 (n=297)	63 (n=261)
Hospitalizations in the past 12 mo: 0/1/2/3/4/>4 (% patients)	53/27/9/6/2/3 (n=630)	37/24/9/16/4/10*,† (n=68)	54/27/11/3/1/4 (n=299)	57/27/6/6/3/1 (n=263)
≥1 hospitalization in the past 12 mo (% patients)	47 (n=630)	63 (n=68)	47 (n=299)	43 (n=263)
CCI (points)	1 (1-2) (n=632)	2 (1-3) (n=69)	1 (1-2) (n=300)	1 (1-2) (n=263)
CCI≥2 (% patients)	45 (n=632)	51 (n=69)	45 (n=300)	44 (n=263)
Long-term O_2 use (yes, % patients)	24 (n=620)	42*,† (n=69)	24 (n=295)	20 (n=256)
GOLD I/II/III/IV (% patients)	9/28/37/26 (n=632)	3/35/27/35 (n=69)	10/27/38/25 (n=300)	8/29/39/24 (n=263)
GOLD A/B/C/D (% patients)	3/24/7/66 (n=625)	0/15/0/85† (n=68)	2/26/5/67 (n=297)	5/24/11/60 (n=260)
FEV_1 (% predicted)	43 (30-62) (n=632)	34 (24-60) (n=69)	42 (30-63) (n=300)	43 (31-63) (n=263)
FEV_1/FVC (%)	35 (27-47) (n=632)	35 (25-48) (n=69)	36 (28-48) (n=300)	35 (27-46) (n=263)
SPPB summary score	9 (8-10) (n=632)	5 (4-6)*,† (n=69)	9 (8-9)‡ (n=300)	10 (10-11) (n=263)
Balance side-by-side (s)	10 (10-10) (n=632)	10 (10-10)*,† (n=69)	10 (10-10) (n=300)	10 (10-10) (n=263)
Balance semi-tandem (s)	10 (10-10) (n=632)	10 (10-10)*,† (n=69)	10 (10-10) (n=300)	10 (10-10) (n=263)
Balance tandem (s)	10 (8-10) (n=632)	0 (0-4)*,† (n=69)	10 (6-10)‡ (n=300)	10 (10-10) (n=263)
4MGS (m/s)	1.0 (0.9-1.2) (n=632)	0.6 (0.5-0.7)*,† (n=69)	1.0 (0.8-1.1)‡ (n=300)	1.2 (1.0-1.3) (n=263)
5STS (s)	16 (14-20) (n=632)	60 (23-60)*,† (n=69)	19 (17-22)‡ (n=300)	14 (12-15) (n=263)

NOTE. Data are presented as mean ± SD, median (Q1 - Q3), or percentages.

Abbreviations: BMI, body mass index; CCI, Charlson Comorbidity Index; FEV_1, forced expiratory volume in the first second; FVC, forced vital capacity; mMRC, modified Medical Research Council.

* Indicates a significant difference after Bonferroni post hoc correction between SPPB summary scores 0-6 and SPPB summary scores 7-9.

† Indicates a significant difference after Bonferroni post hoc correction between SPPB summary scores 0-6 and SPPB summary scores 10-12.

‡ Indicates a significant difference after Bonferroni post hoc correction between SPPB summary scores 7-9 and SPPB summary scores 10-12.

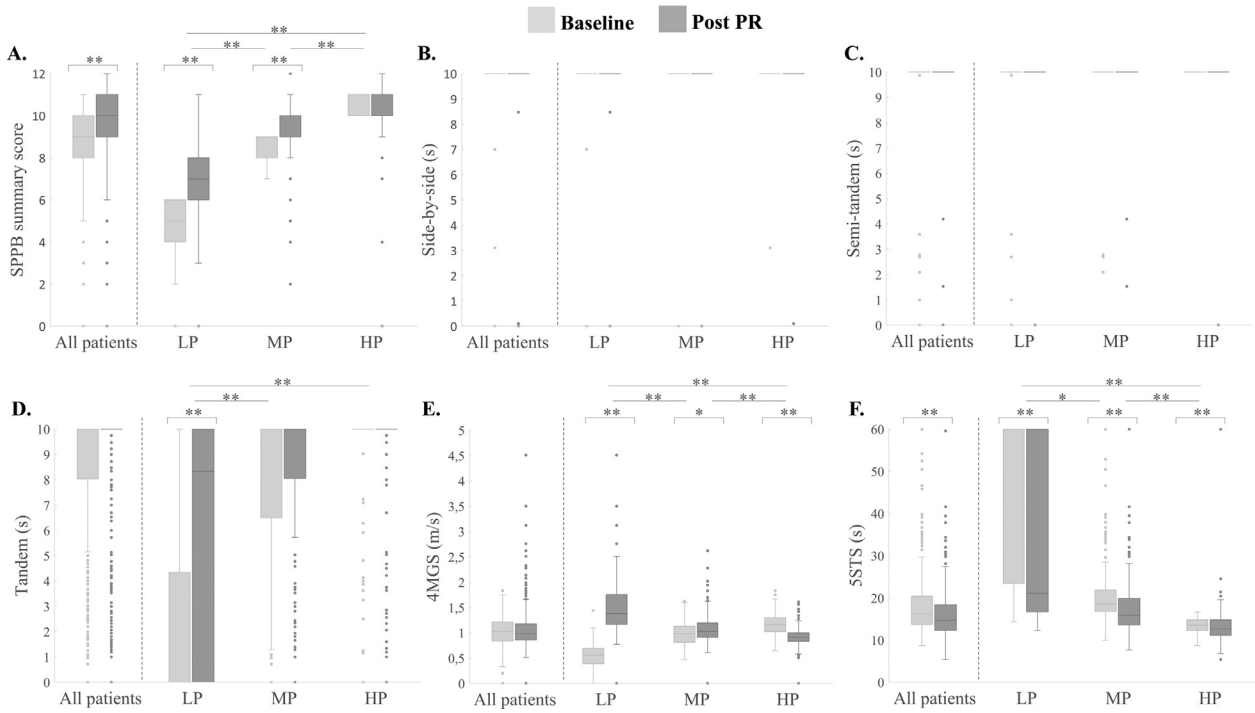

Fig 1 Box plots of the baseline and post-PR (A) SPPB summary score, (B) balance side-by-side, (C) semi-tandem, (D) tandem, (E) 4MGS, and (F) 5STS for all patients and the LP, MP, and HP group. *Indicates a significant difference at $P<.01$; **indicates a significant difference at $P<.001$. The boxes in (B) and (C) are displayed as lines at the top because almost all patients maintained the balance side-by-side and semi-tandem positions for the maximum of 10 seconds.

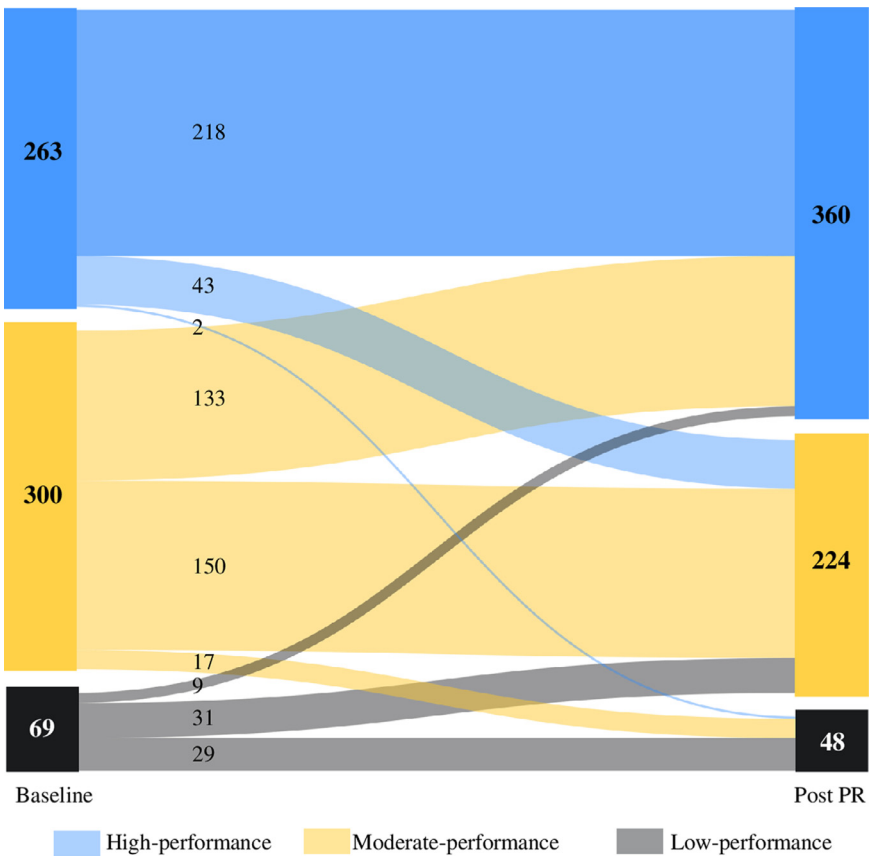

Fig 2 Sankey diagram depicting the flow and distribution of the SPPB summary score for the different performance groups at baseline and post-PR.

Table 2 Distribution-based methods to estimate the minimal important difference in 5STS and SPPB summary score in patients with COPD

Method	Formula	5STS (s)	SPPB Summary Score (Points)
SEM	$SD_{baseline} \times \sqrt{1 - ICC}$	2.19	0.83
Empirical rule effect size	$0.08 \times 6 \times SD_{delta}$	4.05	0.86
Cohen's effect size	$0.5 \times SD_{delta}$	4.22	0.89
$0.5*SD_{baseline}$	$0.5 \times SD_{baseline}$	6.33	0.96
MID range		2.19-6.33	0.83-0.96

Inpatient and outpatient PR programs were combined in the analyses performed in this study. Although the Δ SPPB summary score was comparable between groups, differences were found in other attributes, which partly may be explained by differences at baseline. Indeed, patients with the most severe limitations participated in the inpatient program. Furthermore, due to the retrospective design, it was not possible to regain details of the actual content of the program.

Despite the intent to use anchor- and distribution-based methods to calculate MID estimates, only distribution-based calculations could be performed. Therefore, the obtained MIDs provide no clinical significance but statistical significance only. It is highly recommended that multiple anchor-based approaches be used in future MID estimations, such as the incremental shuttle walk test or patient's self-reported improvement, which were used in previous studies.[12,13,41]

Conclusions

The SPPB subtest 5STS and summary score are both responsive to PR in patients with COPD after PR. The balance tandem test and 4MGS are only responsive to PR in patients with COPD with a low performance at baseline. Based on distribution-based calculations, an MID estimate of 1 point for the SPPB summary score is recommended in patients with COPD. Future research is needed to confirm MID estimates for the SPPB in different centers using anchor-based methods as well.

Suppliers

a. MasterScreen PFT/Body, Jaeger.
b. Lunar iDXA, DEXAtech Benelux BV.
c. Ergoselect, Ergoline.
d. Biodex Multi-joint System 3; Biometrics Motion B.V.
e. SPSS, version 25.0; IBM.

Keywords

Minimal important difference; Pulmonary disease, chronic obstructive; Physical functional performance; Rehabilitation

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Table E1 The scoring system of the standing balance tests, 4MGS and 5STS.

Scores	Balance Side-by-Side Test (s)	Balance Semi-Tandem Test (s)	Balance Tandem Test (s)	4MGS (s)	5STS (s)
4				<4.82	<11.20
3				4.82−6.20	11.20−13.69
2			10.00	6.21−8.70	13.70−16.69
1	10.00	10.00	3.00-9.99	>8.70	16.70−60.00
0	<10.00	<10.00	<3.00	Unable	Unable (>60.00)

Abbreviations: 4MGS, 4-m gait speed; 5STS, 5-repetition sit-to-stand.

Table E2 Differences in baseline characteristics between included and excluded patients.

	Included (n=632)	Excluded (n=321)	*P* Value
Age (years)	65±8 (n=632)	65±9 (n=321)	0.154
Gender (male, %)	50 (n=632)	54 (n=321)	0.373
Weight (kg)	72 (60-86) (n=630)	73 (60-86) (n=298)	0.968
BMI (kg/m^2)	25 (22-30) (n=630)	25 (22-30) (n=298)	0.791
mMRC score	3 (2-3) (n=631)	2 (2-3) (n=321)	0.282
mMRC≥2 (% patients)	90 (n=631)	82 (n=321)	0.002
CAT score	22±6 (n=593)	21±7 (n=300)	0.383
CAT≥18 (% patients)	77 (n=594)	72 (n=300)	0.100
Exacerbations in the past 12 months (0/1/2/3/4/>4, % patients)	18/17/22/14/8/21 (n=627)	23/16/16/13/8/24 (n=321)	0.258
≥2 exacerbations in the past 12 months (% patients)	64 (n=627)	62 (n=321)	0.434
Hospitalizations in the past 12 months (0/1/2/3/4/>4, % patients)	53/27/9/6/2/3 (n=630)	61/22/9/6/2/0 (n=299)	0.295
≥1 hospitalization in the past 12 months (% patients)	47 (n=630)	39 (n=299)	0.064
CCI (points)	1 (1-2) (n=632)	1 (1-2) (n=321)	0.280
CCI≥2 (% patients)	45 (n=632)	42 (n=321)	0.370
Long-term O_2 use (yes, % patients)	24 (n=620)	19 (n=316)	0.115
GOLD I/II/III/IV (% patients)	9/28/37/26 (n=632)	10/27/41/22 (n=320)	0.555
GOLD A/B/C/D (% patients)	3/24/7/66 (n=625)	10/28/8/54 (n=297)	0.008
FEV_1 (% predicted)	43 (30-62) (n=632)	43 (32-59) (n=320)	0.691
FEV_1/FVC (%)	35 (27-47) (n=632)	34 (28-48) (n=320)	0.842

Data is presented as mean ± SD, median (Q1 − Q3), or percentages. Abbreviations: BMI, body mass index; CAT, COPD Assessment Test; CCI, Charlson Comorbidity Index; FEV_1, forced expiratory volume in the first second; FVC, forced vital capacity; GOLD, Global Initiative for Chronic Obstructive Lung Disease; mMRC, modified Medical Research Council.

Table E3 Differences in baseline characteristics between patients following an in- and outpatient program.

	Inpatient (n=387)	Outpatient (n=238)	*P* Value
Age (years)	66±8 (n=387)	65±8 (n=238)	0.252
Gender (male, %)	45 (n=387)	59 (n=238)	0.001
Weight (kg)	71 (59-86) (n=386)	75 (62-88) (n=237)	0.081
BMI (kg/m^2)	25 (21-31) (n=386)	25 (22-30) (n=237)	0.575
mMRC score	3 (2-4) (n=387)	2 (2-3) (n=237)	<0.001
mMRC≥2 (% patients)	95 (n=387)	80 (n=237)	0.002
CAT score	23±6 (n=364)	19±6 (n=223)	<0.001
CAT≥18 (% patients)	87 (n=364)	60 (n=223)	<0.001
Exacerbations in the past 12 months (0/1/2/3/4/>4, % patients)	14/15/22/15/9/25 (n=385)	26/20/22/12/6/14 (n=235)	<0.001
≥2 exacerbations in the past 12 months (% patients)	71 (n=385)	54 (n=235)	<0.001
Hospitalizations in the past 12 months (0/1/2/3/4/>4, % patients)	48/27/10/7/3/5 (n=386)	63/26/5/3/2/1 (n=237)	<0.001
≥1 hospitalization in the past 12 months (% patients)	52 (n=386)	37 (n=237)	<0.001
CCI (points)	1 (1-2) (n=387)	1 (1-2) (n=238)	0.972
CCI≥2 (% patients)	45 (n=387)	46 (n=238)	0.741
Long-term O_2 use (yes, % patients)	33 (n=379)	10 (n=234)	<0.001
GOLD I/II/III/IV (% patients)	6/23/39/32 (n=387)	13/37/35/15 (n=238)	<0.001
GOLD A/B/C/D (% patients)	1/21/4/74 (n=384)	8/29/12/51 (n=234)	<0.001
FEV_1 (% predicted)	38 (28-54) (n=387)	51 (38-70) (n=238)	<0.001
FEV_1/FVC (%)	33 (26-46) (n=387)	39 (31-50) (n=238)	<0.001

Data is presented as mean ± SD, median (Q1 − Q3), or percentages. Abbreviations: BMI, body mass index; CAT, COPD Assessment Test; CCI, Charlson Comorbidity Index; FEV_1, forced expiratory volume in the first second; FVC, forced vital capacity; GOLD, Global Initiative for Chronic Obstructive Lung Disease; mMRC, modified Medical Research Council.

Table E4 Baseline, post and delta (post minus baseline) pulmonary rehabilitation data of all patients with COPD.

	Baseline	Post PR	Delta	*P* Value
	Symptom burden and health status			
mMRC score	3 (2-3) (n=591)	2 (1-2) (n=591)	-1 (-1-0) (n=591)	<0.001
mMRC≥2 (% patients)	89 (n=591)	64 (n=591)	-25 (n=591)	<0.001
CAT score	22±6 (n=560)	19±7 (n=560)	-3±6 (n=560)	<0.001
CAT≥18 (% patients)	77 (n=560)	58 (n=560)	-19 (n=560)	<0.001
	Body composition			
FFM index	16.5±2.5 (n=620)	17.0±2.4 (n=620)	0.4±0.6 (n=620)	<0.001
FFM legs (kg)	15.1 (12.1−17.7) (n=621)	15.5 (12.7−18.3) (n=621)	0.5 (0.0-1.1) (n=621)	<0.001
	Emotional status			
HADS anxiety score	7 (4-10) (n=557)	6 (3-9) (n=557)	-1 (-3-1) (n=557)	<0.001
HADS anxiety≥10 (% patients)	28 (n=557)	22 (n=557)	-6 (n=557)	0.001
HADS depression score	7 (4-10) (n=557)	5 (3-8) (n=557)	-1 (-3-0) (n=557)	<0.001
HADS depression≥10 (% patients)	30 (n=557)	16 (n=557)	-14 (n=557)	<0.001
	Physical status			
6MWD (m)	370±109 (n=618)	391±109 (n=618)	22±56 (n=618)	<0.001
CWRT TTE (s)	230 (166-329) (n=546)	328 (215-660) (n=546)	112 (14-347) (n=546)	<0.001
Isokinetic quadriceps peak torque (Nm)	82 (60-105) (n=456)	89 (70-115) (n=456)	9 (2-17) (n=456)	<0.001
Isokinetic quadriceps peak torque (% predicted)	61 (47-72) (n=456)	69 (56-80) (n=456)	7 (2-13) (n=456)	<0.001
Isokinetic quadriceps total work (J)	1389 (994-1836) (n=456)	1676 (1248-2109) (n=456)	247 (107-418) (n=456)	<0.001

Data is presented as mean ± SD, median (Q1 − Q3), or percentages. Abbreviations: CAT, COPD Assessment Test; CWRT, Constant Work Rate Test; FFM, Fat-free mass; HADS, Hospital Anxiety and Depression Scale; mMRC, modified Medical Research Council; TTE, Time-To-Exhaustion; 6MWD, 6-Minute Walk Test distance.

Table E5 Baseline, post and delta (post minus baseline) pulmonary rehabilitation data of the LP, MP and HP group.

	Low-Performance (n=69)			Moderate-Performance (n=300)			High-Performance (n=263)		
	Baseline	Post PR	Delta	Baseline	Post PR	Delta	Baseline	Post PR	Delta
				Symptom burden and health status					
mMRC score	4 (3-4) (n=63)	2 (2-3)** (n=63)	-1 (-2-0) (n=63)	3 (2-3) (n=278)	2 (1-2)** (n=278)	-1(-1-0) (n=278)	2 (2-3) (n=250)	2 (1-2)** (n=250)	-1 (-1-0) (n=250)
mMRC≥2 (% patients)	100 (n=63)	91 (n=63)	-9 [a,b] (n=63)	92 (n=278)	67** (n=278)	-25 [c] (n=278)	83 (n=250)	54** (n=250)	-29 (n=250)
CAT score	25±6 (n=57)	22±6** (n=57)	-3±5 (n=57)	22±6 (n=266)	19±7** (n=266)	-3±6 (n=266)	20±6 (n=237)	18±7** (n=237)	-2±6 (n=237)
CAT≥18 (% patients)	91 (n=57)	79 (n=57)	-12 (n=57)	79 (n=266)	60** (n=266)	-19 (n=266)	70 (n=237)	50** (n=237)	-20 (n=237)
				Body composition					
FFM index	16.6±2.7 (n=68)	17.0±2.5* (n=68)	0.4±0.9 (n=68)	16.5±2.6 (n=293)	17.0±2.5** (n=293)	0.5±0.7 (n=293)	16.5±2.4 (n=259)	16.9± 2.3** (n=259)	0.4±0.5 (n=259)
FFM legs (kg)	14.4 (11.7-17.5) (n=68)	14.9 (12.2-17.3)* (n=68)	0.5 (-0.0-1.2) (n=68)	15.0 (12.0-17.7) (n=294)	15.4 (12.6-18.2)** (n=294)	0.5 (-0.1-1.1) (n=294)	15.3 (12.3-17.9) (n=259)	15.8 (12.8-18.6)** (n=259)	0.5 (0.2-1.1) (n=259)
				Emotional status					
HADS anxiety score	9 (6-13) (n=55)	7 (5-11) (n=55)	-2 (-4-2) (n=55)	8 (5-10) (n=265)	6 (4-9)** (n=265)	-2 (-3-1) (n=265)	7 (4-9) (n=237)	5 (3-9)** (n=237)	-2 (-3-1) (n=237)
HADS anxiety≥10 (% patients)	47 (n=55)	33 (n=55)	-14 (n=55)	29 (n=265)	23 (n=265)	-6 (n=265)	23 (n=237)	18 (n=237)	-5 (n=237)

(*continued on next page*)

Table E5 (*Continued*)

	Low-Performance (n=69)			Moderate-Performance (n=300)			High-Performance (n=263)		
	Baseline	Post PR	Delta	Baseline	Post PR	Delta	Baseline	Post PR	Delta
HADS depression score	10 (5-13) (n=55)	8 (4-10)** (n=55)	-2 (-5-1) (n=55)	7 (5-10) (n=265)	6 (4-9)** (n=265)	-1 (-3-1) (n=265)	6 (4-9) (n=237)	5 (2-8)** (n=237)	-1 (-3-0) (n=237)
HADS depression≥10 (% patients)	56 (n=55)	26** (n=55)	-30 [a,b] (n=55)	29 (n=265)	18** (n=265)	-11 (n=265)	25 (n=237)	12** (n=237)	-13 (n=237)
				Physical status					
6MWD (m)	213±84 (n=65)	260±110** (n=65)	47±78 [a,b] (n=65)	356±91 (n=294)	380±94** (n=294)	24±53 (n=294)	425±89 (n=259)	437±94** (n=259)	12±49 (n=259)
CWRT TTE (s)	148 (104-260) (n=40)	300 (175-656)** (n=40)	156 (16-383) (n=40)	217 (159-314) (n=261)	313 (215-635)** (n=261)	108 (15-304) (n=261)	251 (189-344) (n=245)	390 (230-763)** (n=245)	112 (6-435) (n=245)
Isokinetic quadriceps peak torque (Nm)	52 (41-78) (n=38)	63 (52-80)* (n=38)	8 (-1-18) (n=38)	76 (59-101) (n=206)	87 (67-114)** (n=206)	9 (3-17) (n=206)	88 (69-111) (n=212)	97 (80-118)** (n=212)	9 (2-17) (n=212)
Isokinetic quadriceps peak torque (% predicted)	45 (34-62) (n=38)	52 (44-65)* (n=38)	8 (0-13) (n=38)	58 (43-70) (n=206)	65 (52-80)** (n=206)	7 (2-13) (n=206)	65 (52-74) (n=212)	73 (61-82)** (n=212)	6 (2-13) (n=212)
Isokinetic quadriceps total work (J)	791 (569-1138) (n=38)	1115 (857-1372)** (n=38)	248 (-26-488) (n = 38)	1313 (914-1808) (n=206)	1577 (1156-2016)** (n=206)	258 (95-433) (n=206)	1555 (1179-1928) (n=212)	1789 (1492-2245)** (n=212)	236 (112-412) (n=212)

Data is presented as mean ± SD, median (Q1 — Q3), or percentages.
* indicates a significant difference between baseline and post PR of p<0.01,
** indicates a significant difference between baseline and Post PR of p<0.001.
[a] indicates a significant difference after Bonferroni post-hoc correction between the delta's SPPB summary scores 0-6 and SPPB summary scores 7-9.
[b] indicates a significant difference after Bonferroni post-hoc correction between the delta's of SPPB summary scores 0-6 and SPPB summary scores 10-12.
[c] indicates a significant difference after Bonferroni post-hoc correction between the delta's of SPPB summary scores 7-9 and SPPB summary scores 10-12.
Abbreviations: CAT, COPD Assessment Test; CWRT, Constant Work Rate Test; FFM, Fat-free mass; HADS, Hospital Anxiety and Depression Scale; mMRC, modified Medical Research Council; TTE, Time-To-Exhaustion; 6MWD, 6-Minute Walk Test distance.

Table E6 Baseline, post and delta (post minus baseline) pulmonary rehabilitation data of patient following an in- or outpatient program.

	Inpatient (n=384)			Outpatient (n=238)			Differences in Delta's
	Baseline	Post PR	Delta	Baseline	Post PR	Delta	*P* Value
			Symptom burden and health status				
mMRC score	3 (2-4) (n=363)	2 (1-3)** (n=363)	-1 (-2-0) (n=363)	2 (2-3) (n=222)	2 (1-2)** (n=222)	0 (-1-0) (n=222)	<0.001
mMRC≥2 (% patients)	95 (n=363)	70** (n=363)	-25 (n=363)	79 (n=222)	54** (n=222)	-25 (n=278)	0.805
CAT score	23±6 (n=347)	20±6** (n=347)	-3±6 (n=347)	19±6 (n=208)	17±7* (n=208)	-1±6 (n=208)	<0.001
CAT≥18 (% patients)	87 (n=347)	66** (n=347)	-21 (n=347)	59 (n=208)	45** (n=208)	-14 (n=208)	0.133
			Body composition				
FFM index	16.3±2.5 (n=378)	16.8±24** (n=378)	0.5±0.7 (n=378)	17.0±2.5 (n=235)	17.3±2.5** (n=235)	0.3±0.5 (n=235)	0.004
FFM legs (kg)	14.5 (11.8-17.0) (n=379)	15.0 (12.4-17.4)** (n=379)	0.6 (0.1-1.1) (n=379)	16.0 (13.1-18.8) (n=235)	16.4 (13.4-19.3)** (n=235)	0.5 (0-0.9) (n=235)	0.271
			Emotional status				
HADS anxiety score	8 (5-11) (n=345)	6 (4-9)** (n=345)	-1 (-3-1) (n=345)	6 (3-8) (n=208)	5 (3-8) (n=208)	-1 (-2-1) (n=208)	0.001
HADS anxiety ≥10 (% patients)	34 (n=345)	24** (n=345)	-10 (n=345)	19 (n=208)	18 (n=208)	-1 (n=208)	0.017
HADS depression score	8 (5-11) (n=345)	6 (3-9)** (n=345)	-2 (-4-0) (n=345)	6 (4-9) (n=208)	5 (3-7)** (n=208)	-1 (-2-1) (n=208)	<0.001
HADS depression≥10 (% patients)	37 (n=345)	18** (n=345)	-15 (n=345)	18 (n=208)	13 (n=208)	-5 (n=208)	<0.001
			Physical status				
6MWD (m)	332±102 (n=377)	358±106** (n=377)	26±59 (n=377)	432±88 (n=234)	444±92** (n=234)	13±47 (n=234)	0.002
CWRT TTE (s)	201 (148-300) (n=312)	318 (212-654)** (n=312)	126 (34-398) (n=312)	272 (197-378) (n=227)	349 (217-676)** (n=227)	77 (-24-272) (n=227)	0.001
Isokinetic quadriceps peak torque (Nm)	74 (55-94) (n=268)	84 (65-105)** (n=268)	9 (3-18) (n=268)	92 (73-120) (n=183)	102 (83-129)** (n=183)	8 (2-17) (n=183)	0.729
Isokinetic quadriceps peak torque (% predicted)	57 (42-69) (n=268)	65 (51-77)** (n=268)	7 (2-13) (n=268)	67 (55-77) (n=183)	74 (62-83)** (n=183)	6 (1-12) (n=183)	0.284
Isokinetic quadriceps total work (J)	1202 (872-1586) (n=268)	1492 (1108-1889)** (n=268)	250 (92-437) (n=268)	1638 (1306-2194) (n=183)	1863 (1530-2402)** (n=183)	234 (119-383) (n=183)	0.764

Data is presented as mean ± SD, median (Q1 — Q3), or percentages.
* indicates a significant difference between baseline and post PR of p<0.01,
** indicates a significant difference between baseline and Post PR of p<0.001.Abbreviations: CAT, COPD Assessment Test; CWRT, Constant Work Rate Test; FFM, Fat-free mass; HADS, Hospital Anxiety and Depression Scale; mMRC, modified Medical Research Council; TTE, Time-To-Exhaustion; 6MWD, 6-Minute Walk Test distance.

Table E7 Baseline, post PR and delta (post PR minus baseline) data of the SPPB subtests and summary score in patient following an in- or outpatient program.

	Inpatient (n = 387)			Outpatient (n = 238)			Differences in Delta's
	Baseline	Post PR	Delta	Baseline	Post PR	Delta	*P* Value
Side-by-side (s)	10 (10-10)	10 (10-10)	0 (0-0)	10 (10-10)	10 (10-10)	0 (0-0)	0.823
Semi-tandem (s)	10 (10-10)	10 (10-10)	0 (0-0)	10 (10-10)	10 (10-10)	0 (0-0)	0.723
Tandem (s)	10 (7-10)	10 (8-10)	0 (0-0)	10 (10-10)	10 (10-10)*	0 (0-0)	0.144
4MGS (m/s)	1.0 (0.8-1.1)	1.1 (0.9-1.3)**	0.1 (-0.2-0.4)	1.1 (1.0-1.3)	0.9 (0.8-1.0)**	-0.2 (-0.4-0)	<0.001
5STS (s)	17 (14-23)	16 (13-20)**	-1 (-4-1)	15 (13-18)	13 (11-16)**	-1 (-4-0)	0.256
SPPB summary score	9 (8-10)	9 (8-10)**	0 (0-2)	10 (9-11)	10 (9-11)**	1 (0-2)	0.092

Data is presented as median (Q1 — Q3).
* indicates a significant difference between baseline and post PR of p<0.01,
** indicates a significant difference between baseline and Post PR of p<0.001.Abbreviations: 4MGS: 4-meter gait speed, 5STS: 5-repetition sit-to-stand, SPPB: Short Physical Performance Battery.

Table E8 Correlations between change in CAT score and 6MWT (m) with the change in 5STS and SPPB summary score for patients with COPD.

	ΔCAT score		Δ6MWT (m)	
	Correlation Coefficient	*P* Value	Correlation Coefficient	*P* Value
Δ5STS (s)	0.084	0.047	-0.120	0.003
ΔSPPB summary score	-0.151	<0.001	0.183	<0.001

Abbreviations: CAT, COPD Assessment Test; SPPB, short physical performance battery; 5STS, 5-repetition sit-to-stand; 6MWT, 6-minute walk test