Title: Five repetition sit to stand test: Responsiveness and minimal important difference in IPF

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Abstract

Background: Standing from a sitting position is an important activity of daily living. The five-repetition sit-to-stand test (5STS) is a simple physical performance test that measures the fastest time taken to stand five times from a chair with arms folded. It can be measured in most healthcare settings, including the home where traditional field walking tests may not be possible. The 5STS has been validated in community-dwelling older adults and people with COPD, but data in idiopathic pulmonary fibrosis (IPF) are limited.

Aims: The aims of this cohort study were to establish the construct validity, responsiveness to pulmonary rehabilitation (PR) and minimal important difference (MID) of the 5STS in IPF.

Methods: In 149 people with IPF, we compared 5STS to measures of lung function, exercise capacity, quadriceps strength, breathlessness and health-related quality of life. Responsiveness and effect sizes were determined by measuring 5STS before and after PR. The MID was estimated using anchor- and distribution-based methods.

Results: The 5STS correlated significantly with incremental shuttle walk test (ISW) (r=-0.55), isometric quadriceps maximum voluntary contract (QMVC) (r=-0.45), Medical Research Council (MRC) score (r=0.40), Chronic Respiratory Questionnaire (CRQ)-Total (r=-0.21) and King's Brief Interstitial Lung Disease-Total (r=-0.21) but not forced vital capacity %predicted or quadriceps 1-repetition maximum (1RM). There was a significant but very weak correlation between change in 5STS and change in MRC (r=0.18), ISW (r=-0.21) and CRQ-Total (r=-0.26) but no significant correlation with change in 1RM (-0.12) or QMVC (r=-0.18). 5STS time improved with PR (median (25th, 75th centile) change: -1.97 (-3.47, -0.62) seconds; p<0.001). The effect size for 5STS was 0.66 and higher than quadriceps 1RM, QMVC and ISW. The mean (range) MID estimate was -1.93 (-1.85 to -2.10) seconds.

Conclusion: In people with IPF, the 5STS is a valid physical performance measure that is responsive to exercise-based interventions and suitable for use in most healthcare settings.

Introduction

Idiopathic pulmonary fibrosis (IPF) is characterised by progressive functional decline [1] including reduced exercise capacity [2], quadriceps strength [3] and walking speed [4]. There is increasing interest in the role of sit-to-stand tests in measuring performance in people living with IPF [5-11] as they are simple and quick to perform, require little space and equipment and the sit-to-stand maneuver is functionally relevant [12]. Sit-to-stand tests are influenced by strength, dynamic balance and cardiorespiratory endurance, and therefore represent overall physical performance rather than muscle strength alone [13]. There are numerous sit-to-stand test protocols including 1-minute sit-to-stand, 30-second sit-to-stand and five-repetition sit-to-stand test (5STS). The most commonly used sit-to-stand test in older adults is the 5STS which involves standing from a chair five times as rapidly as possible in less than 60 seconds without upper limb assistance [12]. As it only involves five maneuvers, it minimises participant burden, which is important in a population characterised by severe dyspnoea, exercise intolerance and lower limb musculoskeletal weakness [1, 14]. The 5STS is a component of several test batteries including the Short Physical Performance Battery [15], Index of Mobility Limitation [16] and Physical Performance Examination of the National Health and Nutrition Examination Survey [17]. Furthermore, it is used as a proxy measure of lower limb strength and physical performance in the European [18] and Asian Working Group for Sarcopenia [19] guidelines respectively.

The majority of literature on 5STS is based on older adults. It has shown to be reliable, valid and responsive to intervention [12] and has been used for multiple purposes including an indicator of lower limb strength [20-22], balance [21, 23, 24], falls risk [25, 26], and measure of disability [27]. Only two studies involving people with interstitial lung disease (ILD) of which IPF was a sub-group (ILD: n= 91 ILD of which n= 28 IPF) have investigated the 5STS [5, 6]. Zamboti and colleagues demonstrated that it has good inter- and intra-rater reliability [6] but there are conflicting data on its relationship with physical performance measures [5, 6]. Therefore, the overall aim of this study was to extend our understanding of the psychometric properties of 5STS in IPF. Specifically, the study objectives were to establish the 1) construct validity of 5STS with measures of lung function, exercise capacity, quadriceps strength, breathlessness and health-related quality of life, 2) responsiveness of 5STS to pulmonary rehabilitation (PR) and 3) estimate the minimal important difference (MID) of 5STS.

Materials and methods

STUDY SUBJECTS

Participants were people with idiopathic pulmonary fibrosis (IPF) who were prospectively and consecutively recruited from the Harefield Pulmonary Rehabilitation Unit, United Kingdom between March 2012 and December 2019. Inclusion criteria were a primary diagnosis of IPF determined by a multidisciplinary team according to international guidelines [1] who were referred to PR; ability to walk 5 metres and provide informed consent. The exclusion criteria were the presence of significant co-morbidities that would affect participants' ability to walk and therefore participate in PR (e.g. leg amputation) or any other conditions that could cause the participant to be unsafe during exercise (e.g. unstable heart condition).

STUDY DESIGN

This observational cohort study was a secondary analysis of two studies approved by West London and London-Riverside Research Ethics Committees and the Health Research Authority (11/LO/1780, 14/LO/2247)) and registered on clinicaltrials.gov (NCT01649193, NCT02530736). All participants provided written informed consent.

Participants underwent an outpatient PR program which was conducted in line with international standards [28]. It comprised two supervised sessions of exercise and education and one unsupervised home-based exercise session per week for eight weeks as previously described [29]. Completion of this program was determined to be attendance of a minimum of eight sessions and the post-PR assessment [14].

STUDY PROCEDURES

5STS was conducted as described by Jones and colleagues [30] using a straight-backed armless, hard seat chair (floor to seat height: 48cm) placed against a wall. Participants sat with their feet flat on the floor and arms across the chest. The assessor demonstrated and instructed the participant to stand up all the way and sit down once without using their arms. The test was terminated if the participant was unable to complete the maneuver independently and the participant categorised as 'unable to complete'. Those able to do the maneuver were asked to stand up all the way and sit down all the way, as fast as possible, five times without using their arms following a demonstration by the assessor. Timing with a stopwatch was started on the command "*go*" and stopped at the end of the completed fifth stand; the time taken was recorded as the participant's score. Participants unable to complete five stands within 60 seconds were categorised as 'unable to complete'. No encouragement was provided during the test, but the assessor counted each successful stand aloud.

5STS, spirometry (pre-PR only), incremental shuttle walk test (ISW) [31], 1-repetition maximum (1RM: double-leg knee extension), isometric quadriceps maximum voluntary contraction (QMVC), King's Brief Interstitial Lung Disease Questionnaire (KBILD) [29], Chronic Respiratory Questionnaires (CRQ) [32] and Medical Research Council Dyspnea Scale (MRC) [33] were completed before and after the PR programme. In addition, at the post-PR assessment patients completed a Global Rating of Change Questionnaire (GRCQ) by responding to this question: "How do you feel your overall condition has changed after rehab?" on a five-point Likert scale ("1: much better" to "5: much worse,"").

ANALYSIS

Baseline characteristics were reported using descriptive statistics (parametric data: mean ± standard deviation (SD)), non-parametric data: median (25^{th}, 75^{th} centile), categorical data: number (percent)). The relationship between 5STS and other outcome measures was analysed using Spearman's Ranks Correlation Co-efficient. Paired t-test (or Wilcoxon signed-rank test for non-parametric data) analysed response to PR. Effect size was calculated using Cohen's d.

We planned to use multiple anchor- and distribution-based approaches to estimate the MID. For anchor-based methods that use linear regression and ROC plots to estimate the MID, the *a priori* criteria for establishing the validity of external anchors were a statistically significant correlation at the 5% level and a correlation coefficient >0.3 [34]. As these criteria were not achieved (online supplement: table S1), we were unable to use this approach. We estimated the MID to be the mean change in 5STS with PR for participants reporting feeling "Much" or "a little better" on the GRCQ. The distribution-based methods used to estimate the MID included 0.5 * SD change [29], minimal detectable change at 95% confidence (MDC_{95}: 1.96 * standard error of the mean * $\sqrt{2}$) [35] and empirical rule effect size (0.08 * 6 * SD change) [36]. Data analyses were performed using GraphPad Prism 9 (GraphPad Software, USA) and SPSS version 26 (IBM, USA). Statistical significance was considered at $p<0.05$.

Results

Of 331 people with IPF referred to Harefield Pulmonary Rehabilitation Unit, 27 declined PR, 18 failed to meet the inclusion criteria (unstable cardiac condition n=8, co-morbidity that limited walking ability n=7, unable to walk 5 meters n=3), 49 declined to participate in the study and 88 did not complete PR (n=21: unwell-respiratory; n=19: unwell-non-respiratory; n=10: family commitments; n=5: deceased; n=33: unable to contact) (figure 1). Data from the remaining 149 participants were analysed.

The baseline characteristics of the cohort are described in table 1. A total of 11 (7%) participants were unable to complete 5STS in 60 seconds and the median (25^{th}, 75^{th} centile) 5STS time for the remaining 138 participants was 11.98 (10.06, 15.77) seconds. The baseline characteristics of participants who completed and did not complete PR are in the online supplement (table S2). Briefly, compared to PR completers, a significantly greater proportion of participants who did not complete PR were unable to complete the 5STS test in 60 seconds (PR completers 7%, PR non-completers 11%; p=0.04) and the median (25^{th}, 75^{th} centile) time taken to complete the maneuver was significantly longer (PR completers was 11.98 (10.06, 15.77) seconds, PR non-completers 13.31 (10.17, 16.02) seconds; p=0.03).

The baseline characteristics according to 5STS completion are in the online supplement (table S3). It was not possible to test for statistical differences between the two groups due to the small number of participants unable to complete the test. However, compared to completers, there was a trend for non-completers to be older, female, prescribed long-term oxygen therapy and have worse breathlessness, exercise capacity, health-related quality of life and isometric maximum quadriceps strength.

RELATIONSHIP BETWEEN 5STS AND OTHER OUTCOME MEASURES

For measurements taken at baseline, there were weak to moderate significant correlations between 5STS and MRC (r=0.40), QMVC (r=-0.45), ISW (r=-0.55) (figure 2) and significant correlations between 5STS and age (r=0.19), CRQ-Dyspnea (r=-0.21), CRQ-Fatigue (r=-0.18), CRQ-Total (r=-0.21) and KBILD-Total (r=-0.21). There was no significant relationship between 5STS and FVC %predicted (r=-0.08) or 1RM (r=-0.13).

Regarding the correlation between change in outcome measures, there was a significant correlation between change in 5STS and change in MRC (r=0.18), ISW (r=-0.21), CRQ-Dyspnea (r=-0.24), CRQ-Emotion (r=-0.19), CRQ-Mastery (r=0.20) and CRQ-Total (r=-0.26). There was no significant correlation with change in 1RM (-0.12) or QMVC (r=-0.18).

RESPONSE TO PULMONARY REHABILTIATION AND MID ESTIMATION

Following PR, there were significant improvements in the core outcomes of exercise capacity, breathlessness and health-related quality of life as well as quadricep strength (table 2). There was also a significant reduction in time taken to complete 5STS (median (25^{th}, 75^{th} centile) change: -1.97 (-3.47, -0.62) seconds; p<0.001). A total of three out of 11 (27%) participants unable to complete the test pre-PR were able to complete it post-PR. The effect size for 5STS (0.66) was higher than other physical performance measures (1RM: 0.48, QMVC: 0.32, ISW: 0.25). A total of 89% (n=133) of participants reported feeling "much" or "a little" better following PR, whereas 11% % (n=16) reported feeling the "same", "a little worse" or "much worse".

MID estimation

For the anchor-based MID estimate method, the mean change in 5STS in participants reporting feeling "much" or "a little" better on the GRCQ was -2.10 seconds (figure 3). For distribution-based methods, the MID estimates were as follows: 05*SD: -1.93 seconds; $MDC_{95\%}$ -1.85 seconds; empirical rule effect size -1.85 seconds. The mean (range) of MID estimates for 5STS was -1.93 (-1.85 to -2.10) seconds (table 3).

Discussion

This study extends our understanding of the psychometric properties of 5STS in IPF. Construct validity was demonstrated as baseline 5STS shares moderate significant correlations with baseline measures of exercise capacity, isometric maximum quadriceps strength and respiratory disability but not FVC %predicted or isotonic maximum quadriceps strength. There was a significant but very weak correlation between change in 5STS and change in measures of respiratory disability, exercise capacity and health-related quality of life. The 5STS is responsive to PR and 27% of participants who were unable to perform the maneuver at baseline completed it following PR. The MID estimates ranged from -1.93 to -2.10 seconds.

PREVIOUS LITERATURE

Only two small studies involving people with ILD investigated select psychometric properties of 5STS and reported conflicting data [5, 6]. Bloem and colleagues (n=51 of which IPF n=19) reported significant correlations between baseline 5STS and exercise capacity (six-minute walk test distance: 6MWT r=-0.41, p<0.05) but not MRC, FVC %predicted or generic health-related quality of life (Short-form 36 physical and mental components) (r=0.18, r=0.02, r=-0.23, r=-0.09 respectively; all p>0.05) [5]. Zamboti and colleagues (n=40 of which IPF n=28) demonstrated significant relationships with baseline isometric maximum quadriceps strength (r=-0.50, p<0.05) and handgrip force (r=-0.38, p<0.05) but not exercise capacity (6MWT: r=-0.26, p>0.05) [6]. The differences in the results of our research and these studies may be explained by a number of factors. Our study had a significantly larger sample size (n=149) and only included people with IPF which provides more certainty in our results. Furthermore, in order to ensure test validity we followed an established 5STS protocol [12] that involved a standard chair height (seat-height: 48cm) and one test. In contrast, both Bloem and Zamboti and colleagues performed two 5STS tests with the fastest time used in the analysis, and only Bloem and colleagues reported using a standardised chair height (45cm) [5, 6].

In a randomised controlled trial of 34 people with IPF allocated to a 12-week exercise training programme or usual care [10] there was a moderate but non-significant correlation between change in 30-second sit-to-stand test and 6MWT (r=0.41, p=0.12) and no correlation with change in $V0_2$ maximum (r=0.15), FVC %predicted (r=0.09) and health-related quality of life (St. George's Respiratory Questionnaire Total score). Despite using a different sit-to-stand test, these results are similar to our study. A possible explanation for this is that 5STS provides additional information not captured by the other outcome measures, for example, a combination of endurance, balance and function.

This study is the first to investigate the responsiveness of 5STS and estimate the MID in IPF. Vainshelboim and colleagues randomly allocated 34 people with IPF to a 12-week exercise training program or usual care [10]. Although the within-group differences were not reported, there was a significant between-group difference in the 30-second sit-to-stand test favouring the intervention group following the intervention (mean (95% confidence interval (CI)) change: 4.1 (2.3 to 5.9) stands; p<0.001) and at 11 months (mean (95% CI) change: 3 (1 to 6) stands; p<0.05). Previous studies in other chronic respiratory diseases and older people have demonstrated that 5STS is responsive to intervention. Gloeckl and colleagues randomized 72 people with chronic obstructive pulmonary disease (COPD) to a supervised squat exercise program with or without additional whole-body vibration (3-week inpatient programme), and demonstrated significant improvements in the 5STS within both groups but no between-group differences (mean (95% CI) change -1.9 (-4.0 to 0.1), p=0.07) [37]. Jones and colleagues reported a significant reduction in 5STS time following PR (median (25^{th}, 75^{th} centile) change: -1.4 (-3.9, 0.0); p<0.01) and estimated the MID as -1.7 seconds in 239 people with COPD [30]. These results are similar to our study which provides confidence in our data. However, the effect size of 5STS reported by Jones and colleagues was smaller than ours (Jones and colleagues: 0.32 [30], our study: 0.66). This may indicate that 5STS is more responsive in IPF than COPD and requires further investigation.

SIGNIFICANCE OF FINDINGS

Sit-to-stand is a prerequisite to performing other activities such as walking and activities of daily living, and has implications for other outcomes [12]. Accordingly, this renders its measurement and interpretation important for healthcare professionals [12]. 5STS is simple, quick to perform (<2 minutes), requires little equipment (chair with 48cm seat-height and stop-watch) and can be measured in settings with limited space e.g. at the bedside, outpatient clinic, home-setting [12, 30]. We demonstrated that it shares moderate significant correlations with baseline exercise capacity, maximum isometric quadriceps strength and respiratory disability and that failure to complete 5STS was associated with older age and continuous oxygen therapy prescription as well as impaired exercise capacity, quadriceps strength and health-related quality of life. In contrast, there was a very weak but significant correlation with change in 5STS and exercise capacity and no correlation with isometric or isotonic maximum quadriceps strength. All of these outcome measures improved significantly following PR but the effect size was the highest for 5STS. As previously stated, this may indicate that 5STS provides additional information not captured by the other outcome measures, for example, a combination of endurance, balance and function. Accordingly, including the 5STS test as part of a multicomponent, comprehensive assessment, either as part of PR, routine IPF medical appointments, palliative or home-based care may provide additional information to understand the physical condition of individuals with IPF. In addition, 5STS can enable the tailoring of exercise prescriptions in order to provide an individualised programme to maximise benefit.

A recognised limitation of sit-to-stand tests is a floor effect. In our study, 7% (n=11) of participants were unable to perform the test at baseline but 27% (n=3) of this cohort were able to complete it after PR. It is important to note that this is a small number of participants, however, there are no published data in IPF to compare our results.

Compared to other populations, the floor effect appears lower in IPF: COPD: 15% [30], care-home residents 58% [38]. Although our data require corroboration, the floor effect may be less of a concern in IPF cohorts.

Furthermore, we demonstrated that 5STS is responsive to PR and provided the first estimates of the MID in IPF. The capacity of an outcome measure to detect improvement is an important aspect of concurrent validity and is necessary for data interpretation in clinical and research settings [34]. Furthermore, these data may be useful for future trials where 5STS is being considered as an endpoint.

STRENGTHS AND LIMITATIONS

There are several strengths to this study. The participants were diagnosed with IPF by a multidisciplinary team according to international guidance [1] and the PR program was conducted in line with international standards [28]. There are also some limitations. As this study was undertaken in a PR service where full lung function is not measured as part of usual care, we did not measure diffusing capacity of the lung for carbon monoxide. In addition, the service uses ISWT to measure exercise capacity, rather than six-minute walk test (6MWT) or a maximal exercise test on a treadmill or cycle ergometer. Therefore, we are unable to comment on the relationship between 5STS and these outcome measures. However, we have previously demonstrated a strong correlation between ISWT and 6MWT in IPF ($r=0.81$, $p<0.001$) [31]. This indicates that there may also be a strong correlation between 5STS and 6MWT, but this requires investigation. The study did not include a control group, so it is unclear whether the response of 5STS is due to improvement in functional performance or regression to the mean. However, a study of 239 people with COPD demonstrated that 5STS is responsive to PR [30], therefore it is likely that our data reflect improvement in this outcome measure. We did not measure peripheral oxygen desaturation during the 5STS maneuver and are therefore unable to comment on the ability of 5STS to predict exertional hypoxaemia. However, this was not an aim of this study as these data have been reported elsewhere [11, 39]. We did not measure the long-term effect of PR on 5STS nor longitudinal change of 5STS, both of which should be evaluated in future research. It was not possible to use anchor-based methods to determine the MID using linear regression and ROC plots as the a priori criteria for establishing the validity of external anchors (statistically significant correlation at the 5% level and a correlation coefficient >0.3) were not met [34]. Although there is no consensus on the optimal method to determine a MID, a combination of anchor- and distribution-based methods is recommended [34]. Although we used one anchor- and three distribution-based methods, which provides confidence in our results, our data should be corroborated in future research.

In conclusion, the 5STS is a valid assessment tool and is responsive to PR with MID estimates ranging from -1.85 to -2.10 seconds. Although further research is required to corroborate these data 5STS may provide additional information to understand the physical condition of individuals with IPF and may have potential as an endpoint in clinical trials, which should be investigated in future research.

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Competing interests:

- PT, SP, GE, TJ, CMN report no competing interests.
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Table 1: Baseline characteristics (n=149)

Variable	Baseline
Sex (Male: n (%))	109 (73%)
Age (years)	73 ± 8
FVC (L)	2.28 ± 0.80
FVC (%predicted)	71.7 ± 21.3
BMI (kg/m^2)	27.4 ± 5.1
COPD (n (%))	11 (7%)
Pulmonary hypertension (n (%))	12 (8%)
Ischemic heart disease (n (%))	26 (17%)
Musculoskeletal disease (n (%))	46 (31%)
Nintedanib (n (%))	9 (6%)
Pirfenidone (n (%))	23 (15%)
Smoking history (n (%))	
Never smokers	75 (50%)
Former smokers	73 (49%)
Current smokers	1 (1%)
Long-term oxygen therapy (n (%))	14 (9%)
Ambulatory oxygen therapy (n (%))	17 (11%)
MRC	3 ± 1
Five-repetition sit-to-stand (seconds)*	11.98 (10.06, 15.77)
1 repetition maximum (kg)	34 (20, 45)
QMVC Peak (kg)	27 (19, 35)
ISW (m)	276 ± 168
CRQ Dyspnea	16 ± 6
CRQ Fatigue	14 ± 5
CRQ Emotion	33 ± 9
CRQ Mastery	19 ± 6
CRQ Total	82 ± 22
KBILD Psychological	57 ± 16
KBILD Breathlessness and activity	42 (33, 50)
KBILD Chest Symptoms	64 ± 20
KBILD Total	55 (49, 62)

Data reported as mean ± standard deviation, median (25th, 75th centile), number (percentage).

*n=142 as 11 participants were unable to complete the 5STS test at baseline.

Abbreviations: BMI: Body Mass Index; COPD: Chronic Obstructive Pulmonary Disease; CRQ: Chronic Respiratory Questionnaire; FVC: Forced Vital Capacity; ISW: Incremental Shuttle Walk Test; KBILD: King's Brief Interstitial Lung Disease; MRC: Medical Research Council Dyspnea Score; QMVC: Quadriceps Maximum Voluntary Contraction.

Table 2. Response to pulmonary rehabilitation (n=149)

Variable	**Baseline**	**Response to PR**	**p-value**	**Cohen's d**
MRC	3 ± 1	-0.7 (-0.8, -0.5)	<0.001	0.63
5STS (seconds)*	11.98 (10.06, 15.77)	-1.97 (-3.47, -0.62)	<0.001	0.66
1 repetition maximum (kg)	34 (20, 45)	11 (6, 22)	<0.001	0.48
QMVC Peak (kg)	27.20 (19.36, 34.74)	1.58 (-1.28, 4.17)	0.03	0.32
ISW (m)	276 ± 168	46 (34 to 58)	<0.001	0.25
CRQ Dyspnea	16 ± 6	4.4 (3.3-5.4)	<0.001	0.68
CRQ Fatigue	14 ± 5	2.0 (1.3-2.7)	<0.001	0.41
CRQ Emotion	33 ± 9	2.4 (1.3-3.5)	<0.001	0.28
CRQ Mastery	19 ± 6	1.2 (0.4-2.0)	<0.01	0.23
CRQ Total	82 ± 22	10.0 (7.0 -13.0)	<0.001	0.47
KBILD Psychological	57 ± 16	6.1 (3.4-8.8)	<0.001	0.09
KBILD Breathlessness and activity	41.9 (33.1, 50.2)	4.70 (-1.1, 12.5)	<0.001	0.35
KBILD Chest symptoms	64 ± 20	6.1 (2.2-10.0)	<0.01	0.27
KBILD Total	54.8 (49, 61.8)	4.0 (-1.1, 8.7)	<0.001	0.47

Data reported as mean ± standard deviation, median (25th, 75th centile), mean (95% confidence interval) change, median (25th, 75th centile) change, number (percent).

*n=142 as 11 participants were unable to complete the 5STS test at baseline.

Abbreviations: BMI: Body Mass Index; CRQ: Chronic Respiratory Questionnaire; ISW: Incremental Shuttle Walk Test; KBILD: King's Brief Interstitial Lung Disease; MRC: Medical Research Council Dyspnea Score; QMVC: Quadriceps Maximum Volitional Contraction.

Table 3. MID estimates of 5STS

Method	**MID estimate (seconds)**
Anchor-based method	
GRCQ	-2.10
Distribution-based methods	
0.5 * standard deviation	-1.93
Minimal detectable change at 95% confidence	-1.85
Empirical rule effect size	-1.85
Mean of all estimates	**-1.93**

Abbreviations: 5STS: Five-Repetition Sit-to-stand Test; GRCQ: Global Rating of Change Questionnaire; MID: Minimal Important Difference.

Figure legends:

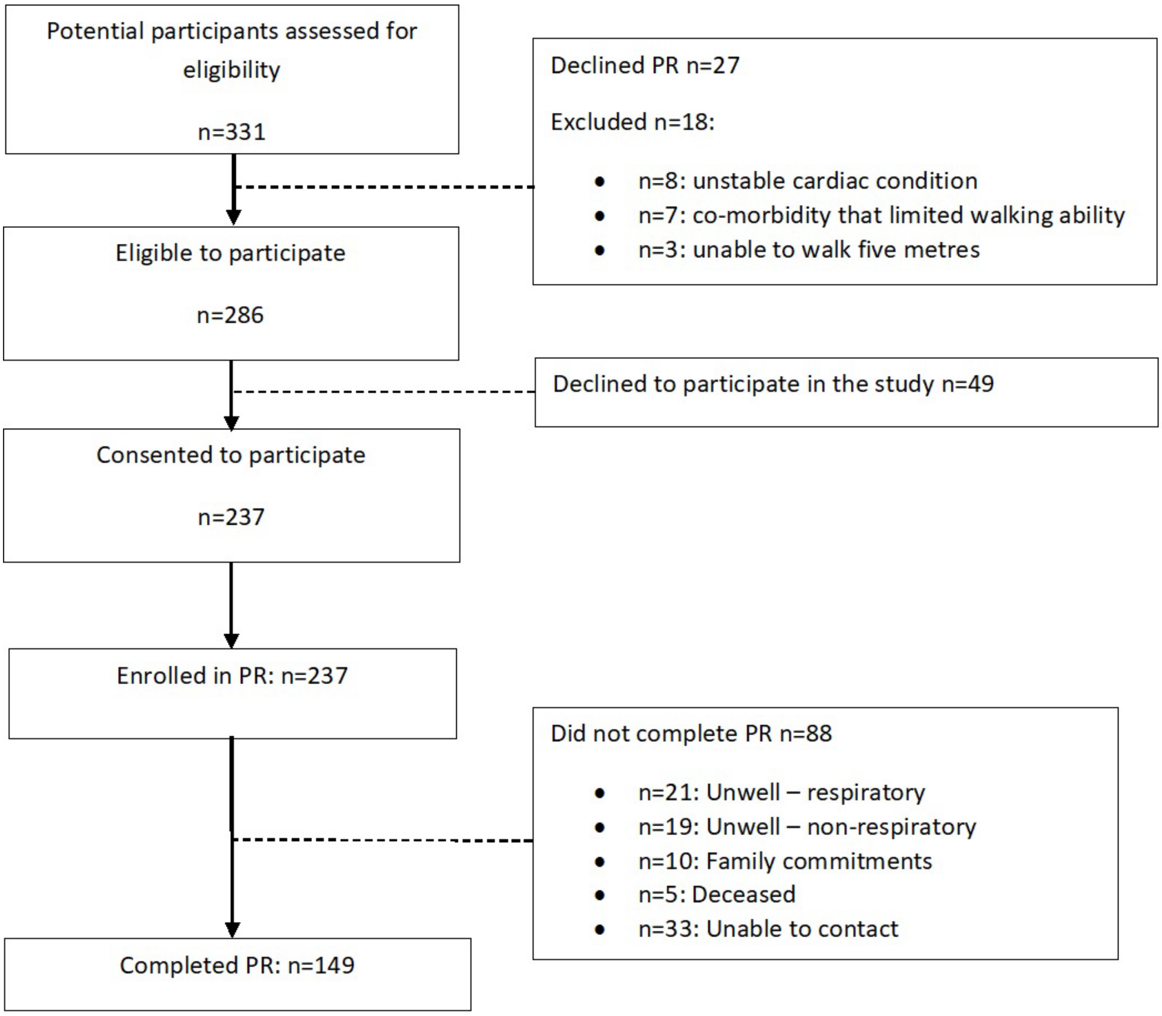

Figure 1. Study flow diagram

Abbreviations: PR: Pulmonary Rehabilitation.

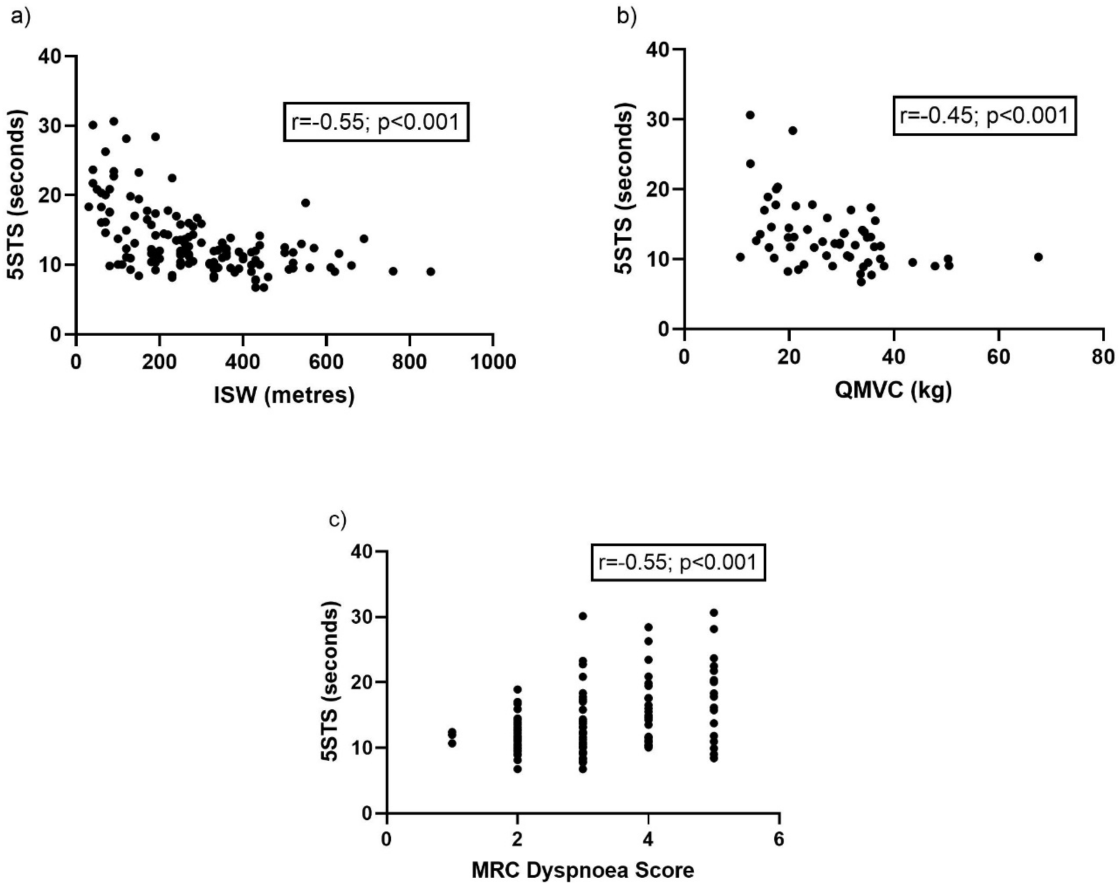

Figure 2. Correlation between baseline 5STS and a) ISW, b) QMVC and c) MRC

Abbreviations: 5STS: Five-Repetition Sit-to-stand Test; ISW: Incremental Shuttle Walk Test; MRC: Medical Research Council; QMVC: Quadriceps Maximum Voluntary Contraction.

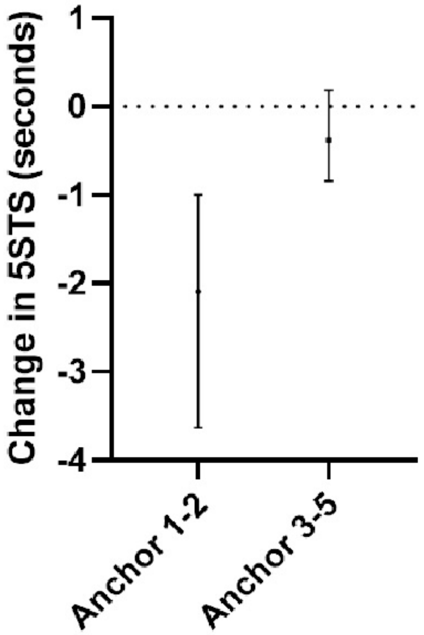

Figure 3. Mean (95% confidence interval) change in 5STS following PR according to response to the Global Rating of Change Questionnaire. Anchor 1-2: “Much” or “a little” better; Anchor 3-5: “Same”, “a little worse”, “much worse”.

Abbreviations: 5STS: Five-Repetition Sit-to-stand Test.

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Online supplement

Five repetition sit to stand test: Responsiveness and minimal important difference in IPF

Table S1. Correlation between change in 5STS and change in other outcomes

Variable	r-value (p-value)
Δ MRC	0.18 (0.03)
Δ 1 Repetition Max (kg) (n=68)	-0.12 (0.33)
Δ QMVC Peak (kg) (n=44)	-0.18 (0.29)
Δ ISW (m)	-0.21 (0.01)
Δ CRQ Dyspnoea	-0.24 (<0.01)
Δ CRQ Fatigue	-0.16 (0.07)
Δ CRQ Emotion	-0.19 (0.03)
Δ CRQ Mastery	-0.20 (0.02)
Δ CRQ Total	-0.26 (<0.01)
Δ KBILD Psychological	-0.16 (0.13)
Δ KBILD Breathlessness and activity	-0.12 (0.25)
Δ KBILD Chest Symptoms	-0.07 (0.50)
Δ KBILD Total	-0.13 (0.21)

Data reported as r-value (p-value).

Abbreviations: 5STS: Five-Repetition Sit to Stand Test; BMI: Body Mass Index; CRQ: Chronic Respiratory Questionnaire; ISW: Incremental Shuttle Walk Test; KBILD: King's Brief Interstitial Lung Disease; MRC: Medical Research Council Dyspnoea Score; QMVC: Quadriceps Maximum Volitional Contraction.

Table S2: Baseline characteristics of participants who completed (n=149) and did not complete pulmonary rehabilitation (n=88)

Variable	**PR completers (n=149)**	**PR non-completers (n=88)**	**p-value**
Sex (Male: n (%))	109 (73%)	62 (71%)	0.45
Age (years)	73 ± 8	72 ± 9	0.68
FVC (L)	2.28 ± 0.80	2.09 ± 0.78	0.03
FVC (%predicted)	71.7 ± 21.3	62.3 ± 23.5	0.02
BMI (kg/m^2)	27.4 ± 5.1	28.1 ± 4.9	0.41
COPD (n (%))	11 (7%)	7 (8%)	0.53
Pulmonary hypertension (n (%))	12 (8%)	7 (8%)	0.72
Ischemic heart disease (n (%))	26 (17%)	17 (19%)	0.66
Musculoskeletal disease (n (%))	46 (31%)	46 (31%)	
Nintedanib (n (%))	9 (6%)	4 (5%)	0.47
Pirfenidone (n (%))	23 (15%)	14 (16%)	0.32
Smoking history (n (%))			
Never smokers	75 (50%)	35 (40%)	0.06
Former smokers	73 (49%)	53 (60%)	
Current smokers	1 (1%)	0 (0%)	
Long-term oxygen therapy (n (%))	14 (9%)	15 (17%)	0.03
Ambulatory oxygen therapy (n (%))	17 (11%)	19 (21%)	0.02
MRC	3 ± 1	4 ± 1	0.02
Five-repetition sit-to-stand (seconds)	11.98 (10.06, 15.77)*	13.31 (10.17, 16.02)†	0.03
1 repetition maximum (kg)	34 (20, 45)	34 (20, 45)	0.03
QMVC Peak (kg)	27 (19, 35)	27 (19, 35)	0.02
ISW (m)	276 ± 168	143 ± 87	<0.01
CRQ Dyspnea	16 ± 6	14 ± 5	0.07
CRQ Fatigue	14 ± 5	11 ± 5	0.03
CRQ Emotion	33 ± 9	29 ± 7	0.02
CRQ Mastery	19 ± 6	15 ± 8	0.02
CRQ Total	82 ± 22	69 ± 20	0.01
KBILD Psychological	57 ± 16	60 ± 18	0.04
KBILD Breathlessness and activity	42 (33, 50)	46 (35, 52)	0.03
KBILD Chest Symptoms	64 ± 20	69 ± 23	0.02
KBILD Total	55 (49, 62)	61 (53, 69)	0.01

Data reported as mean ± standard deviation, median (25th, 75th centile), number (percentage).

*n=142 as 11 participants were unable to complete the 5STS test at baseline.

† n=78 as 10 participants were unable to complete the 5STS test at baseline.

Abbreviations: BMI: Body Mass Index; COPD: Chronic Obstructive Pulmonary Disease; CRQ: Chronic Respiratory Questionnaire; FVC: Forced Vital Capacity; ISW: Incremental Shuttle Walk Test; KBILD: King's Brief Interstitial Lung Disease; MRC: Medical Research Council Dyspnea Score; PR: Pulmonary Rehabilitation; QMVC: Quadriceps Maximum Voluntary Contraction.

Table S3. Comparison of baseline characteristics between participants that completed and failed 5STS test

Variable	Completed 5STS (n=138)	Failed 5STS (n=11)
Sex (Male: n (%))	103 (75%)	6 (55%)
Age (years)	73 (8)	77 (7)
FVC (L)	2.27 (0.80)	2.34 (0.80)
FVC (%predicted)	71.3 (21.1)	76.7 (23.7)
BMI (kg/m^2)	27.3 (5.0)	30.0 (6.6)
COPD (n (%))	10 (7%)	1 (9%)
Pulmonary hypertension (n (%))	11 (8%)	1 (9%)
Ischemic heart disease (n (%))	26 (18%)	1 (9%)
Nintedanib (n (%))	9 (7%)	0 (0%)
Pirfenidone (n (%))	23 (17%)	0 (0%)
Smoking history (n (%))		
Never smokers	64 (46%)	11 (100%)
Former smokers	73 (53%)	0 (0%)
Current smokers	1 (1%)	0 (0%)
Long-term oxygen therapy (n (%))	12 (9%)	2 (18%)
Ambulatory oxygen therapy (n (%))	17 (12%)	0 (0%)
MRC	3 (1)	4 (1)
1 Repetition Max (kg) (n=70)	34 (20, 45) (n=70)	No data
QMVC Peak (kg) (n=64)	28 (10, 35) (n=58)	21 (17, 28) (n=6)
ISW (m)	288 (166)	106 (89)
CRQ Dyspnoea	16 (6)	13 (6)
CRQ Fatigue	15 (5)	12 (6)
CRQ Emotion	33 (9)	32 (11)
CRQ Mastery	19 (6)	19 (6)
CRQ Total	82 (22)	76 (24)
KBILD Psychological	57 (16)	62 (28)
KBILD Breathlessness and activity	42 (33, 50)	39 (23, 48)
KBILD Chest Symptoms	64 (19)	65 (26)
KBILD Total	55 (49, 62)	55 (15)

Data reported as mean (standard deviation), median (25th, 75th centile), number (percentage).

Abbreviations: 5STS: Five-Repetition Sit to Stand Test; BMI: Body Mass Index; COPD: Chronic Obstructive Pulmonary Disease; CRQ: Chronic Respiratory Questionnaire; FVC: Forced Vital Capacity; ISW: Incremental Shuttle Walk Test; KBILD: King's Brief Interstitial Lung Disease; MRC: Medical Research Council Dyspnoea Score; QMVC: Quadriceps Maximum Voluntary Contraction.