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Postural control and fear of falling assessment in people with COPD: A systematic review of instruments, ICF linkage and measurement properties

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Abstract/Structured Summary

Objectives: To systematically review the instruments used to assess postural control and fear of falling in people with Chronic Obstructive Pulmonary Disease (COPD), and to synthesize and evaluate their breadth of content and measurement properties.

Data Sources, Study Selection and Data Extraction: This systematic review comprised two phases. Phase 1 aimed to identify the commonly used instruments to assess postural control and fear of falling in the COPD literature. Searches were conducted in eight electronic databases in September 2012. The breadth of content of each instrument was examined based on the International Classification of Functioning, Disability and Health (ICF). In phase 2, a measurement property search filter was adopted and used in four electronic databases to retrieve properties reported in the COPD population. The COSMIN checklist was used to assess the methodological quality of each measurement property reported. Only quantitative studies were included, irrespective of language or publication date. Two independent reviewers performed the selection of articles, the ICF linking process and quality assessment.

Data Synthesis: Seventeen out of 401 publications were eligible in phase 1. Seventeen instruments were identified including 15 for postural control and 2 for fear of falling assessment. The Berg Balance Scale and the Activity-specific Balance Confidence (ABC) scale were the most frequently used instruments to assess postural control and fear of falling respectively. The ICF categories covered varied considerably among instruments. The Balance Evaluation Systems test and ABC presented the greatest breadth of content. Measurement properties reported included criterion predictive validity (4 instruments), construct validity (11 instruments) and responsiveness (1 instrument), with inconsistent findings based on ‘fair’ and ‘poor’ quality studies.

Conclusion: Different instruments with heterogeneous content have been used to assess postural control and fear of falling outcomes. Standardized assessment methods and best evidence on measurement properties is required in the COPD literature.

Key Words: Postural Balance; Fear; Self-Efficacy; Pulmonary Disease, Chronic Obstructive; Outcome Assessment (Health Care).

List of Abbreviations

ABC: activity-specific balance confidence

BBS: berg balance scale

BESTest: balance evaluation systems test

CBMS: community balance and mobility scale

COPD: chronic obstructive pulmonary disease

COSMIN: consensus-based standards for selection of health status measurement instruments

FES: falls efficacy scale

FRT: functional reach test

GOLD: Global Initiative for Chronic Obstructive Lung Disease

ICF: International Classification of Functioning, Disability and Health

OLS: one leg stance

SOT: sensory organization test

SPPB: short physical performance battery

SST: sit-to-stand test

Tinetti: Tinetti balance and gait evaluation

Chronic Obstructive Pulmonary Disease (COPD) represents an important health issue worldwide, with estimates predicting it to be the third leading cause of death by the year 2030.[1] Due to the higher life expectancy observed in developed countries, the proportion of older adults with COPD continues to rise.[2] The multi-system involvement of COPD causes a broad range of functional limitations,[3] and emerging evidence demonstrates that older adults with COPD present with deficits in postural control and increased fear of falling compared to their healthy peers.[4-6] Both impaired postural control and increased fear of falling are established falls risk factors in community dwelling adults without lung disease.[7] The consequences of these factors include activity avoidance, depression, reduced activities of daily living,[8] isolation and decreased health-related quality of life (HRQoL).[9] These are all highly important outcomes frequently targeted for improvement in the management of COPD.[10]

The Clinical Practice Guideline for Prevention of Falls in Older Persons[11] and The Falls Prevention Network in Europe Consensus[12] jointly advocate the use of postural control and fear of falling assessment as screening or evaluative tools in falls prevention programs. However, there is no consensus regarding suitable instruments to assess these outcomes in individuals with COPD.[13] Measurement of postural control is complex and depends on the integration of motor and sensory components.[14] Similarly, fear of falling is measured based on the broad psychology concept of self-efficacy; which refers to individual's perceived confidence to participate in different activities without falling.[15] Due to the complexity involved in the assessment of postural control and fear of falling outcomes, a thorough analysis of the content of available instruments could be useful when selecting suitable instrument to use in COPD populations.

The International Classification of Functioning, Disability and Health (ICF) provides an appropriate framework to identify the domains of functioning and disability addressed by clinical, laboratory and patient-reported outcomes.[16] The ICF linking rules have been developed based on rules from the World Health Organization collaboration project for ICF Core Sets in patients with chronic conditions.[17, 18] Using established linking rules, items of various instruments can be compared according to the ICF categories.[18] In addition, to provide accurate findings regarding the effectiveness of rehabilitation interventions, measurement properties of instruments must be reviewed, particularly previous evidence of reliability, validity and responsiveness.[19] These properties are population-specific, and information must be sought in studies conducted in people with COPD. The consensus-based standards for selection of health status measurement instruments (COSMIN) and its scoring system[20] has been recently developed to standardize the assessment of methodological quality of studies reporting measurement properties.

The aims of this systematic review were: to identify instruments commonly used to assess postural control and fear of falling in patients with COPD, to compare the content of these instruments using the ICF framework, and to synthesize and evaluate the measurement properties reported in the COPD population. Such a review would be valuable for clinicians and researchers to select an appropriate instrument to measure postural control and fear of falling in adults with COPD.

2 METHODS

Prior to conducting this review, the Cochrane Library, the COSMIN list of systematic reviews of measurement properties database, and the International Prospective Register of Systematic Reviews (PROSPERO) were searched by one reviewer (CO) to ensure a similar review or protocol had not been published. Databases were accessed via libraries of The University of Melbourne and Melbourne Health, Australia. No protocol has been previously published for this study.

This review was conducted in two phases and followed the methods suggested for systematic reviews informing rehabilitation practice.[21] Phase 1 identified instruments used to assess postural control and fear of falling in COPD literature. The content of these instruments were then linked to the ICF framework categories. Phase 2 aimed to identify the measurement properties of these instruments reported in the COPD population. Data from retrieved studies were extracted and analyzed using *a priori* developed forms in both phases. The forms were pilot tested before the onset of data extraction, and refinements were performed when necessary. The percentage of agreement and Kappa statistics were calculated as a measure of reliability whenever two reviewers were utilized.[22] All references were stored in Endnote® software, version X5.

2.1 Phase 1: instrument search and ICF linkage

Search strategies

Eight databases were searched with no dates or language limits (MEDLINE, EMBASE, Web of Science, CINAHL, CENTRAL, PsycINFO, PEDro and OT Seeker). The searches were formulated under the health science librarian guidance and performed on Sept 9th 2012. Reproducible search strategies were customized for each database. A list of free-text terms related to 'postural control', 'fear of falling' and 'falls' was created and combined with 'chronic obstructive pulmonary disease'. Where possible, the controlled vocabulary of each database was used to incorporate all relevant subheadings (i.e. MeSH headings and EMTREE). In addition, the synonyms recommended by each specific thesaurus were used for the searches available only in free-text terms. Falls-related terms were included in this review to identify articles that might have included postural control or fear of falling assessment as a fall predictor. Free-text terms related to specific assessment instruments were also included; these terms were selected from a list of outcomes measures identified in a previous systematic review of balance training in the elderly,[23] from the American Physical Therapy Association Catalog of Tests,[24] and the Australian Physiotherapy Association Neurology Special Group Handbook.[25] Appendix 1 outlines the search strategy developed fort MEDLINE (Web of KnowledgeSM).

Eligibility Criteria

After removing the duplicates, two independent reviewers (CO, KM) screened titles and abstracts followed by the full-text review using unblinded electronic forms. Studies were included if the following criteria were present: (1) quantitative study design; (2) performed in the COPD population with established clinical diagnosis according to the guidelines of the global strategy for the diagnosis, management and prevention of COPD (GOLD);[26] (3) used instruments with face validity to assess postural control or fear of falling as primary or secondary outcomes. The instruments identified should have demonstrated face validity according to the following definitions:

Postural control: "The act of maintaining, achieving or restoring a state of balance during any posture or activity".[27]

Fear of falling: based on the operational definition of fear as "low perceived self-efficacy or confidence at avoiding falls".[15]

Papers were excluded if they: (1) were case studies, conference abstracts, protocols or review articles; or (2) had used instruments conceptualized to assess walking distance or mobility. Any disagreement about inclusion was resolved by consensus. No publication date or language restrictions were imposed. Papers published in a language other than English were included provided the abstract was written in English and postural control or fear of falling outcome measures were identified in the abstract. Reference lists of the included articles were hand searched to identify additional eligible studies.

Data extraction

Study characteristics were extracted by one review author (CO) and checked by the second reviewer (KM). First, information was extracted on: (1) publication information and (2) instruments characteristics. Secondly, the breadth of content of each instrument was compared using the ICF linking rules by two independent reviewers (CO, AL). The ICF framework is a comprehensive classification system that uses standardized terms related to components of health at both, individual and population level. The classification has two parts, each containing specific lists. The first part classifies functioning and disability and encompasses the lists: body function (b), structures (s), and activity and participation (d). The second part covers contextual factors and consists of the environmental factors (e) list. For the purpose of this review only the first part was used. Each list has a correspondent letter (b, s, d and e) followed by a numeric code which relates to a hierarchical level. As an example, 'activity and participation' list (d) would provide 'mobility' (d4) as a first level, 'maintaining a body position' (d415) as the second level, and 'maintaining a standing position' (d4153) as the third level. The items of each postural control or fear of falling instrument were linked to the most precise ICF level. Measures that aimed to assess general physical functioning were included in the review if at least 50% of the total score were assigned to postural control assessment. This percentage has been used in previous systematic review where the outcome under investigation is one component of the whole composite assessed by the instrument.[28]

2.3 Phase 2: measurement properties and quality assessment

Search strategies

Customized searches were carried out in MEDLINE, EMBASE, CINAHL and Web of Science (Web of Knowledge[SM]) on Oct 3rd 2012 using a validated sensitive search filter (sensitivity 97.4%; precision 4.4%) for finding studies on measurement properties of instruments in a defined population.[29] The full search strategy used for MEDLINE is described in Appendix 2. No publication date or language restrictions were imposed on the searches.

Eligibility Criteria

The selection of articles was performed by two independent reviewers (CO, CG) using similar methods to phase 1. Studies were included if: (1) the population studied comprised at least 80% of people with COPD, and (2) reported information regarding one or more measurement properties (reliability, intra/inter-rater; measurement error; criterion validity, concurrent/predictive; construct validity, hypothesis testing; or responsiveness). The Effect Size Index[30] was used to calculate measurement responsiveness. Effect Size Indices of 0.2, 0.5, and 0.8 have been interpreted according to Cohen et al to represent small, moderate and large responsiveness to change, respectively.[31] Information about the same properties was sought in the articles included in phase 1. Conference abstracts were excluded due to inability to evaluate the quality score.

Data extraction and quality assessment

Two independent reviewers (CO, CG), with prior experience using the COSMIN checklist,[20] evaluated the quality of studies. The checklist is a validated tool that comprises 10 sections, each one scoring the quality of one measurement property. Four sections, not related to population-specific information, were not relevant for the purpose of this review (internal consistency, content, structural and cross-cultural validities). Each section contains 5 to 18 items that are individually scored based on a 4-point scale (excellent, good, fair or poor). As an example in the criterion validity section, item 3 is scored based on the sample size utilized (excellent, n= or >100; good, n=50-99; fair, n=30-49; and poor, n<30). An overall quality score for each measurement property is obtained by using the lowest score recorded among the items, as recommended.[20]

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3 RESULTS

3.1 Phase 1: Instrument search and ICF linkage

The study selection process is summarized in Figure 1. Nineteen eligible studies were initially included. Two studies were excluded after full-text review due to absence of postural control or fear of falling assessment (1 study)[32] and protocol article (1 study).[33] Percentage of agreement for titles and abstracts screening was 99%, Kappa = 0.89 and for full-text review was 89%, Kappa = 0.88. The majority (n=10) of articles were published between 2010 and 2012. Nine clinical and six laboratory-based instruments were identified for postural control and two for fear of falling assessment. Postural control was assessed using clinical instruments in 76% (n=13) of the articles and was the primary outcome in 52% (n=9). A combined assessment approach (clinical and laboratory-based assessments) was used in 29% (n=5) of the studies. Observational study design was predominant (94%, n=16). Characteristics of the identified instruments are shown in Table 1.

The number of items and time to undertake the full assessment varied among instruments. Multi-item scales assessing different components of balance impairment were more frequently used (n=11, 68%) compared to single-item instruments. Berg Balance Scale (BBS)[4, 5, 34, 35] and Short Physical Performance Battery (SPPB)[36-39] were the most frequent used instruments to assess postural control (4 studies), followed by Functional Reach Test (FRT)[37, 38] and One Leg Stance (OLS)[40, 41] (2 studies). Among laboratory-based instruments, there was no similarity between assessment methods and heterogeneous protocol designs were identified. The Activity-specific Balance Confidence (ABC)[5, 10, 34, 35] scale was the most frequently used for fear of falling assessment (4 studies).

During the ICF linking process the Kappa statistics was calculated based on the third hierarchical level. The percentage of agreement between the two reviewers was 85%, Kappa = 0.75. In total, 112 items were linked to ICF categories. Seven items (6%) could not be linked, and were classified as 'not covered by ICF'.[18] Full description of ICF linkage is available in Supplement 1. Six postural control instruments (4 clinical) consider categories from 'body function' (b) and 'body structures' (s) lists (Table 2). The Balance Evaluation Systems Test (BESTest) covered the majority of categories and was also the most comprehensive clinical instrument across the ICF framework. In the 'activity and participation' (d) list, the BBS covered nine 'mobility' (d4) categories, followed by the Community Balance and Mobility Scale (CBMS) and BESTest both covering seven items. The subcategory 'maintaining a standing position' (d4154), related to a more static evaluation of postural control, was considered by the majority of clinical instruments (n=12); and dynamic balance was mostly assessed using stepping ability evaluation, subcategory 'climbing' (d4551). Tasks that required more complex postural control such as: 'jumping' (d4552) and 'walking around obstacles' (d4503), were considered only by the BESTest and the CBMS (Table 3). Amongst laboratory-based instruments, the Sensory Organisation Test (SOT) and the Perturbation-Evoked Reactions assessment were the only instruments linked to the 'body function' (b) and 'body structures' (s) lists (Table 2). The subcategory 'maintain a standing position' (d4152) was the most frequently covered by laboratory-based instruments. Fear of falling instruments considered distinct ICF subcategories. Only 'reaching' (d4452) and 'moving around within home' (d4601) were alike.

Overall, the ABC items predominantly considered the category ‘mobility’ (d4) (90%), whereas the Falls Efficacy Scale (FES) considered the categories ‘self-care’ (d5) and ‘domestic-life’ (d6) (66%) (Table 4).

3.2 Phase 2: measurement properties and quality assessment

The sensitive search for measurement properties identified three articles, which did not meet the inclusion criteria after consensus between the two reviewers (CO, CG). Therefore, measurement properties were extracted in more detail from articles previously included in phase 1. Twelve studies reported measurement properties of 11 instruments in COPD (1 fear of falling). Studies which published data from the same series of patients were included, provided that the measurement property identified had not been reported in the previous articles. Importantly, not only statistically significant measurement properties were extracted, to avoid selective outcome reporting bias. Four authors were contacted for additional unpublished information and two responded.[35, 42] The majority of studies (n=7, 58%) included patients with severe COPD, GOLD stage 3,[26] with a median (range) sample size of 37 (12-1.202). The measurement properties reported for each instrument are summarized in Table 5 and available information on interpretability of the results presented in Supplement 2.

No study has investigated reliability or measurement error of postural control or fear of falling assessment instruments in patients with COPD. Assessments were longitudinally repeated in three studies: postural control assessment after a pulmonary rehabilitation program[35] and 2-year follow-up period,[38] and fear of falling after 6-month follow-up.[10] Properties reported were: criterion-predictive validity (n=3, 15%), construct validity (n=12, 70%) and responsiveness (n=1, 5%). The COSMIN quality assessment was performed by two independent reviews (CO, CG) achieving a percentage agreement of 94%, Kappa=0.86. Overall, the studies scored ‘fair’ or 'poor' for the measurement properties evaluated. The worst scored area amongst studies was design requirements (sample size and lack of *a priori* hypotheses).

Properties of postural control instruments

The criterion-predictive validity of postural control instruments was investigated in two studies. In one study, the BBS predictive validity for falls could not be confirmed.[34] In the second study,[38] the FRT and the SPPB demonstrated predictive validity for increased risk of disability in a 2-year follow-up period.

Overall, evidence of construct validity was supported in relationships reported between postural control performance and common COPD outcome measures: pulmonary function, index of disease severity, muscle strength, exercise capacity and physical activity. Associations between postural control and pulmonary function parameters were explored in two studies. Moderate to good relationships (.50>r>.75)[43] between CBMS scores, peak sway and sway index in posturography were found with pulmonary function parameters.[40] Decrement in forced expiratory volume in one second was also identified as a risk factor for a poor performance in the SPPB.[39] Construct validity of the Sit-to-Stand test (SST) and balance section of the Tinetti scale was demonstrated by moderate to excellent relationships (r>.50) with the body-mass index, airflow obstruction, dyspnea, and exercise capacity (BODE) index for COPD;[44] which is an index assessed according to values of body mass index, percent predicted values for forced expiratory volume in one second, modified Medical Research Council dyspnea scale and the distance walked in six minutes, respectively.[45] The BESTest and BBS presented fair to moderate relationships (.25>r>.50) with peripheral muscle strength measures,[5] however, associations between postural control and muscle strength were not confirmed in two other studies.[4, 42] A moderate to good relationship between BBS and exercise capacity was found in one study[4] and higher SPPB scores were associated with greater distance walked in the six-minute walk test.[39] The BESTest and BBS demonstrated fair to moderate relationship (.25>r>.50) with physical activity levels,[5] however, no associations were found between performance in the SOT and similar physical activity measures.[42] In accordance with the previously formulated hypothesis, only the BBS and CBMS had evidence of construct validity. Discriminative validity was demonstrated by the BBS between COPD fallers and non-fallers; and by the BBS and the CBMS between oxygen users and non-users.[34, 40]

Responsiveness of BBS was reported in one study following a pulmonary rehabilitation program (Effect size 0.38; mean change score 2.8, 95%CI 1.7 - 3.8).[35] Using the construct approach, a fair to modedrate relationship between change in BBS scores and total score on the Chronic Respiratory Disease Questionnaire of quality-of-life was found.

Properties of fear of falling instruments

Criterion-predictive validity of ABC for falls was confirmed in one study.[34] The scale also presented construct validity in differentiating COPD fallers from non-fallers based on the previously established hypothesis (discriminative validity).[34] No additional data were available on measurement properties of fear of falling instruments in COPD (Table 5).

4 DISCUSSION

In this systematic review, the ICF linkages and measurement properties of 15 postural control assessment instruments and two fear of falling questionnaires were synthesized and evaluated from 17 studies in COPD. The relatively large number of measurement instruments utilized highlights the apparent lack of agreement on how to best assess these outcomes in this population. Diversity was seen in the range of ICF categories covered by the postural control and fear of falling instruments. Limited information was found to establish the measurement properties of the identified instruments in the COPD literature. The available evidence is based on 'fair' to 'poor' quality studies, using COSMIN as a surrogate measure of quality assessment in studies not primarily designed to evaluate measurement properties. The results of this review provides useful information for clinicians and researchers to compare the content and utility of postural control and fear of falling measures, assists in the selection of the most suitable instruments, and identifies directions for future research to support evidence-based recommendations in the evaluation of these outcomes in people with COPD.

Assessment Instruments

To date, no standardized assessment instrument for postural control or fear of falling has been established for people with COPD.[46] Phase 1 of this review identified studies in the COPD literature that utilized a wide range of clinical, laboratory-based and self-reported instruments. The BBS was the most commonly used instrument. Initially developed to assess balance in the elderly, the BBS score is based on ordinal ratings of the performance of 14 test items specifically related to postural control constructs linked to maintaining and changing a range of basic body positions.[47] Single task instruments such as the Functional Reach Test and One Leg Stance were also employed in the COPD literature.[37, 38, 40, 41] Although limited in evaluating a single postural control activity, the burden of assessment of these instruments is low, making them a feasible choice in COPD studies with large sample sizes compared to longer, more comprehensive instruments.[37, 38]

More comprehensive instruments were identified which have subscales in addition to the total score. These subscales evaluate a range of activities linked to the ICF mobility category such as gait variables and walking ability; instruments with subscales included the Tinetti scale[44] and the SPPB.[36-39] The use of such instruments, with additional subscales, deserves special consideration when used to evaluate postural control in people with COPD. If a less complex postural adjustment is required, an overestimation of the total score could be found amongst individuals with high levels of physical functioning. On the other hand, if the tasks required are limited by a compromised respiratory capacity, a lower score can be expected which may not necessarily relate to a poor balance performance. Therefore, if postural control is the main outcome under investigation in a COPD population, these instruments with extra subscales may not be suitable.

Furthermore, more comprehensive instruments can evaluate postural control performance in specific situations that might be related to increased risk of falling in COPD. For instance, the evaluation of dual task performance could be of clinical utility in a subgroup of people with

COPD who must contend with prescribed portable oxygen therapy.[48] However, to date no study has established the use of portable oxygen as an environmental falls risk factor.

Seven studies used laboratory-based assessments employing six different instruments with varied assessment protocols; hence, these data could not be pooled in order to make general statements and recommendations. Laboratory-based instruments may be more sensitive and specific in detecting the population-specific factors that may alter postural control in adults with COPD;[6, 42] however, similar to the single task clinical instruments, the majority of reviewed laboratory studies were confined to the evaluation of a single static postural control task. The evaluation of postural control response using single task instruments could limit the responsiveness and external validity relating to balance and mobility activities in the community. Also, due to the higher cost of the laboratory measures, they have limited utility in a clinical setting.

Two self-report questionnaires were cited in the COPD literature to evaluate fear of falling, the ABC [5, 10, 34, 35] and the FES.[49] Assessment of fear of falling amongst adults with COPD may be useful in identifying those individuals with physical activity restriction due to the inability to abide fearful situations.

Breadth of content – ICF Classification

To the authors knowledge this is the second review which has aimed to compare the breadth of content of outcome measures in COPD. Another review has examined the content of COPD-specific health-related quality of life questionnaires using the ICF.[50] The use of the ICF linking process summarized the major differences and similarities between instruments to provide a comprehensive and helpful overview of instruments frequently used in rehabilitation practice. Difficulties were encountered in assigning ICF codes to the meaningful concepts within the instruments in only 6% of items. The meaningful concepts that could not be linked to an ICF category referred only to highly specific concepts/tasks such as, 'centre of mass' in the BESTest or 'lateral dodging' in the CBMS. These findings confirmed the comprehensiveness and utility of the ICF framework in examining the breadth of content of the instruments examined in this review.

Within the *body functions and body structures* lists, six instruments had items linked to ICF categories. The BESTest was the most comprehensive clinical instrument incorporating items related to motor and sensory components of postural control. Despite the promising breadth of content, the BESTest has been only used once in COPD.[5] Similarly, one study used the SOT.[42] The SOT was the only laboratory-based instrument covering the categories 'seeing' (b210), 'vestibular' (b235), and 'proprioceptive functions' (b260). Considering that most systemic alterations related to COPD are unlikely to have a direct effect on these body functions, it is not surprising that use of SOT in the COPD literature was uncommon. However, the use of these comprehensive instruments in assessing different aspects of postural control should be encouraged in future research, as the mechanisms responsible for a poor balance performance in COPD still require investigation.[13]

Within the *activity and participation* list, items from the 'mobility' (d4) category were considered most frequently, reflecting the importance of normal postural control to increase mobility. This finding suggests that postural control assessment should to be considered as part of the general physical function evaluation in COPD. The BBS covered the majority of 'mobility' sub-categories; this may explain its frequent use in the COPD literature. The BESTest and CBMS covered an equivalent number of categories; however, the categories addressed by the CBMS demanded more complex levels of postural control such as 'running' (d4552) and 'jumping' (d4553). The use of scales which demand more complex postural control should be considered when assessing adults with COPD in high levels of physical functioning. In addition, these scales could discriminate/evaluate impairments in higher level areas of physical function that could negatively impact on community integration or identify potential deficits as falls risk factors. As expected, single-item instruments such as FRT and SST covered a limited number of ICF categories. Similarly, most of the reviewed laboratory-based instruments considered only a single ICF category, 'maintaining a standing position' (d4154). Given this specificity of focus, these single ICF category instruments may need to be combined with additional measurement instruments to detect changes in performance associated with interventions aiming to improve broader aspects of postural control in research and clinical practice.

The two reviewed fear of falling instruments addressed distinct ICF categories linked to confidence in postural control during everyday activities. While the FES covered more individual ICF categories (Table 4), the ABC covered additional outdoor mobility activities. This difference in targeted ICF activity categories may explain the greater reported capacity of the

ABC to discriminate older adults fallers from non-fallers.[51] It is therefore important to clarify that comparisons of the breadth of content cannot substitute for a thorough study of the characteristics and measurement properties of a given instrument specific to the targeted population.

Measurement properties

The majority of measurement properties identified for the instruments presented in this review have not been established specifically to application in a COPD population; either because there was no information available, the information was insufficient, or because evidence was only available from 'fair' and 'poor' quality studies. No reliability studies had been completed with a COPD population to permit interpretation of change in postural control or fear of falling over time, as result of disease progression or response to treatment. *Criterion-predictive* validity was confirmed only for FRT and SPPB in predicting increased risk of disability.[38] One retrospective study found the BBS did not predict falls.[34] Given the importance of postural control measures for future falls,[7] the analysis of their predictive ability using prospective data in COPD should be a priority. *Responsiveness* of BBS was only investigated after pulmonary rehabilitation[35] and demonstrated a small to moderate effect size;[31] evidence for this property is yet to be determined for the majority of instruments identified. As there is limited evidence currently available, recommendations about which test would be most sensitive in detecting change in postural control after an intervention cannot be made from this review. Although none of the instruments included reported evidence addressing all relevant measurement properties specific to application in COPD, evidence was most comprehensive for the *construct validity* of the BBS and BESTest in patients with COPD, GOLD stage 3. These instruments appear to be the best choices for use in clinical practice until further research is completed. The ABC scale was the only fear of falling assessment instrument with demonstrated *construct* and *criterion-predictive* validity for falls.

Although the measurement properties of many of the instruments identified in this review have been reported for the elderly, these findings may not be generalizable to the assessment of the general COPD population. Either because varying levels of COPD severity (GOLD 1-4) were included in the selected studies, or there were limited number of studies addressing measurement properties of a particular instrument. Fatigue,[52] muscle strength,[5] poor exercise capacity[4] and altered trunk muscle biomechanics[6] are important balance-related factors that could modify the reliability and responsiveness of instruments in COPD. Moreover, balance measures specifically designed for the elderly population (>65 years old) could have limited utility in those diagnosed with COPD in their early 60's or at a younger age, in whom a higher level of physical functioning is expected. The CBMS and the BESTest have applicability to younger populations and could be the better choice for use in this subgroup of people with COPD until further research is conducted. It is therefore important that future research establish the measurement properties of postural control and fear of falling instruments specific to application in people with COPD with varying levels of disease severity and physical functioning.

Study Limitations

The risk for selection bias was minimized in this review by using two independent reviewers to screen articles in both phases of the search. Publication bias may have affected the study internal validity; however, non-significant findings regarding the measurement properties were also extracted to avoid selective reporting among the included studies. The analysis of breadth of content using the ICF framework may have been affected either because there was a lack of specific categories or items addressing similar tasks were grouped in the same ICF category. However, only 6% of the total items could not be linked, demonstrating the appropriateness of ICF in examining the breadth of content of these instruments. In addition, the items and new concepts not linked may also be considered for inclusion in future ICF updates. The final COSMIN rating applied in phase 2 was determined using the lowest score rather than the average rating as recommended,[20] this approach may have underestimated the final quality score reported. The COSMIN scoring system was designed to evaluate studies on measurement properties and none of the studies included in this review had evaluation of a measurement property as its primary aim; this may also have influenced the low COSMIN final score observed. However, the COSMIN checklist is the only user-friendly tool currently available to evaluate and quantify the methodological quality of studies included in systematic reviews of measurement properties.

5 CONCLUSIONS

Research in postural control and fear of falling in people with COPD is relatively recent. The results of this systematic review demonstrate that there is no standardized method established to assess these outcomes and the breadth of content varied considerably among instruments currently used. The content description and measurement properties presented in this systematic review should enable the choice of an appropriate instrument by clinicians and researchers. To date, the BBS and the BESTest appear to be the recommended instruments to assess postural control in clinical practice based on their content and validity; and the use of the CBMS and BESTest should be considered for high functioning individuals with COPD. The ABC and the FES have been used to evaluate fear of falling in COPD, however, these scales present different breadth of content according to the ICF and evidence for their measurement properties is still insufficient. Further research designed to address the measurement properties of postural control and fear of falling outcomes is needed before additional recommendations can be made; particularly studies to investigate responsiveness after interventions and predictive validity for future falls in COPD.

Conflict of interest statement

There are no financial interests from the authors, which could create potential conflict of interest regarding this work.

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Ethics Approval

Ethics approval was not required for this review

Suppliers list

None

List of Figures legend

Figure 1: Phase 1 - Flow diagram of instrument selection process.

Abbreviations: EMBASE: Excerpta Medica Database; Web of Sc:, Web of Science (Web of knowledge[SM]); CINAHL: Cumulative Index to Nursing and Allied Health Literature; CENTRAL: Cochrane Central Register of Controlled Trials; PEDRO: Physiotherapy Evidence Database; OTSeeker: Occupational Therapy Systematic Evaluation of Evidence.

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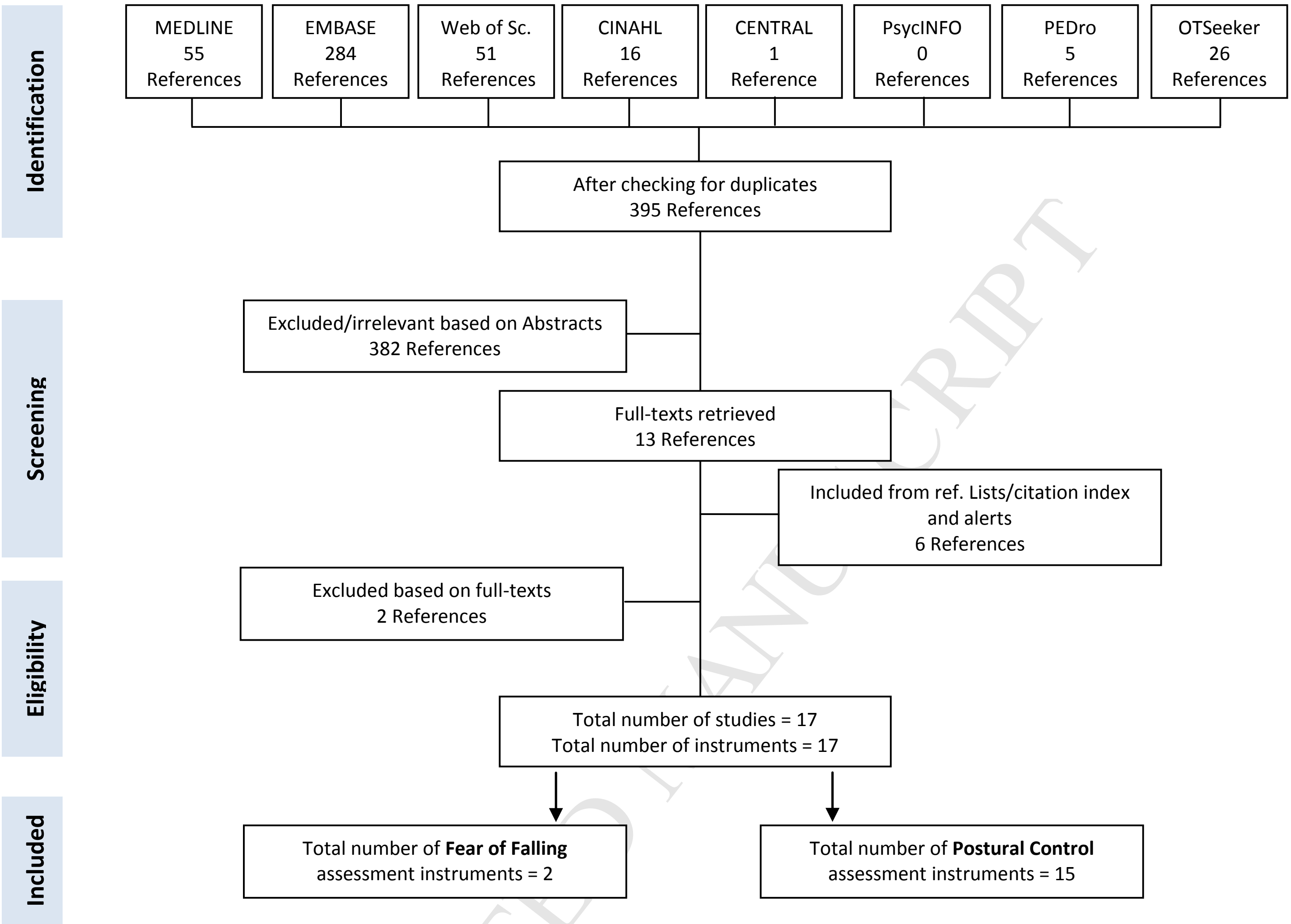
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EMBASE 284 References
Web of Sc. 51 References
CINAHL 16 References
CENTRAL 1 Reference
PsycINFO 0 References
PEDro 5 References
OTSeeker 26 References
After checking for duplicates 395 References
Excluded/irrelevant based on Abstracts 382 References
Full-texts retrieved 13 References
Included from ref. Lists/citation index and alerts 6 References
Excluded based on full-texts 2 References
Total number of studies = 17
Total number of instruments = 17
Total number of Fear of Falling assessment instruments = 2
Total number of Postural Control assessment instruments = 15

Table 1-Description of instruments used to assess postural control or fear of falling in COPD

Outcome measure	Applicability	Frequency of use	Number of items	Number of tasks or response options	Scoring algorithm	Completion time	Free copy available
Postural control	**Clinical**						
	BBS	4	14	5	Total score	15-20 min	Yes
	BESTest	1	27	4	6 subscales and total score	40 min	No
	CBMS	1	13	6	Total score	30-60 min	Yes
	FRT	2	1	1	cm	1-5 min	Yes
	OLS	2	1	1	sec	10 – 60 sec	Yes
	SPPB	4	5	5	3 subscales and total score	10-15 min	Yes
	SST	1	1	1	Number of repetitions	1 min	Yes
	Step test	1	1	1	Number of steps/15 sec	5 min or less	Yes
	Tinetti	1	9	2-3	2 subscales (balance and gait) and total score	10-15 min	Yes
	Laboratory						
	FP	2	V	V	Displacement (mm)	V	-
	PER	1	V	V	Time (ms) and amplitude (mm)	V	-
	Posturography	1	V	V	Displacement (cm and %)	V	-
	SOT	1	6	6 tasks and composite	Total score	NR	-
	Stabilometer	1	V	V	Displacement (cm)	V	-
	Swaymeter	1	V	V	Displacement (mm)	V	-
Fear of Falling	**Self-reported**						
	ABC	4	16	11	Total score	10 min	Yes
	FES(S)	1	10	10	Total Score	10 min	Yes

Abbreviations: FES(S): Falls efficacy scale (Swedish Version); FP: Force Platform (Centre of Pressure analysis); NR: not reported; PER: Perturbation-evoked reactions; V: variable, depends on the study protocol design; -:not applicable.

Table 2–ICF linkages with 'body function' (b) and 'body structures' (s) lists.

Instruments		Body function and body structures list												
			b Body Functions											s Body structures
			b 210 Seeing functions	b 235 Vestibular function	b 260 Proprioceptive function	b 280 Sensation of pain	b 710 Mobility of join functions	b 730 Muscle power functions	b 740 Muscle endurance functions	b 750 Motor reflex functions		b 755 Involuntary movement reaction functions	b 760 Control of voluntary movement functions	s 750 Structure of lower extremity
		Number of items covered		b2351 Vestibular function of balance		b 28015 Pain in lower limb	b 7101 Mobility of several joints	b 7300 Power of isolated muscles and muscle groups	b 7401 Endurance of muscle groups		b 7502 Reflexes generated by other exteroceptive stimuli		b 7601 Control of complex voluntary movements	s 7502 Structure of ankle and foot
Postural Control														
Clinical														
	BBS	1	√											
	BESTest	10	√		√	√	√	√	√		√	√	√	√
	CBMS	1											√	
	Tinetti	1	√								√			
Laboratory	PER	1								√				
	SOT	3	√	√	√									

Abbreviations:PER: Perturbation-evoked reactions

Table 3–ICF linkage with 'activities and participation' (d) list; category mobility (d4)/d410-d469.

Instruments		Activities and participation list	d 410 Changing basic body position					d 415 Maintaining a body position		d 420 Transfering oneself		d 440 Fine hand use		d 445 Hand and arm use	d 450 Walking				d 455 Moving around		
		Number of categories covered	d 4101 Squatting	d 4103 Sitting	d 4104 Standing	d 4105 Bending	d 4106 Shifting the body's centre of gravity	d 4153 Maintaining a sitting position	d 4154 Maintaining a standing position	d 4200 Transferring oneself while sitting	d 4201 Transferring oneself while lying	d 4400 Picking up	d 4401 Grasping	d 4452 Reaching		d 4500 Walking short distances	d 4502 Walking on different	d 4503 Walking around obstacles	d 4551 Climbing	d4552 Running	d 4553 Jumping
Postural Control																					
Clinical	BBS	9		√	√		√	√	√	√		√	√	√					√		
	BESTest	7			√	√			√					√		√		√	√		
	CBMS	7	√						√						√	√			√	√	√
	FRT	1												√							
	OLS	1							√												
	SPPB	4		√	√				√							√					
	SST	2		√	√																
	Step test	1																	√		
	Tinetti	5		√	√		√	√	√												
Laboratory	FP	1							√												
	PER	1							√												
	Posturography	1							√												
	SOT	1							√												
	Stabilometer	1							√												
	Swaymeter	1							√												
Fear of Falling																					
Self-reported	ABC	6		√		√								√			√	√	√		
	FES*	3								√	√			√							

**Note: for the purpose of generalisability of the results, only items from the original version of FES were classified. Abbreviations: FP: Force Platform (Centre of Pressure analysis); PER: Perturbation-evoked reactions; Step test (15cm)*

Table 4–ICF linkages with 'activities and participation' (d) list; categories: mobility (d4)/ d470-d499, self-care (d5) and domestic life (d6).

Instruments			Activities and participation list									
			d 470 Using transportation	d 450 Washing oneself	d 460 Moving around in different locations		d 510 Washing oneself	d 520 Caring for body parts	d 530 Toileting	d 540 Dressing	d 630 Preparing meals	d 640 Doing housework
		Number of items covered	d 4701 Using private motorized transportation	d 5101 Washing whole body	d 4601 Moving around within home	d 4602 Moving around outside the home and other buildings	d 5101 Washing whole body				d 6300 Preparing simple meals	d 6402 Cleaning living area
Fear of Falling Self-reported	ABC	4	√		√	√						√
	FES*	6			√		√	√	√	√	√	

**Note: for the purpose of generalisability of the results, only items from the original version of FES were classified.*

Table 5–Criterion-predictive, construct validity and responsiveness of instruments.

Instruments	Author, yr	COPD severity (FEV_1%/GOLD stage)*	Type of validity	COSMIN	Comparable variable	Comparator OM or predicted outcome	Validation results
Clinical							
BBS	Beauchamp MK, 2009	41.5±17.0/GOLD 3, n=39	Construct/ Crit-predictive	Fair/ Fair	Total score	1 BBS scores could discriminate between fallers and non-fallers 2 Falls predictor (retrospective)	1 p=.042 2 not a predictor
	Beauchamp MK, 2010	46.3±22.3/GOLD 3, n=29	Construct/ Responsiveness	Poor/ Poor	Change in BBS score after PRP	1 Baseline BBS 2 Change CRQ overall scores post PRP 3 Change CRQ dyspnea post PRP 4 Change 6MWT post PRP	1 r=.60, p=.001 2 r=.40, p=.05 3 no relationship 4 no relationship
	Ozalevli S, 2011	43.5±6.0/GOLD 3, n=36	Construct	Poor	Total score	1 Frequency of falls (times/year) 2 Frequency of tripping (times/year) 3 6MWT 4 SaO_2 (%) post 6MWT 5 Dyspnea post 6MWT 6 Leg fatigue post 6MWT 7 PaO_2(%) 8 FEV1, FVC and FEVV1/FVC 9 KE strength (MMT)	1 r=-.63, p<.001 2 r=-.46, p<.001 3 r=.61, p<.001 4 r=.30, p<.05 5 r=.42, p<.05 6 r=.38, p<.05 7 r=.28, p<.05 8 r<.17, p>.05 9 r=.23, p>.05
	Beauchamp MK, 2012	39.4±16.3/GOLD 3, n=37	Construct	Fair	Total score	1 PASE 2 KF strength (Nm/kg) 3 DF strength (Nm/kg)	1 r=.41, p=.007 2 r=.28, p=.046 3 r=.31, p<.05
BESTest	Beauchamp MK, 2012	39.4±16.3/GOLD 3, n=37	Construct	Fair	Total score (a) BESTest Biomechanics (b) BESTest Transitions (c) BESTest Reactive (d) BESTest Sensory (e) BESTest Gait (f)	1 (a)PASE 2 (b) PASE 3 (c) PASE 4 (d) PASE 5 (a)KF strength (Nm/kg) 6 (a)KE strength (Nm/kg) 7 (b) KE strength (Nm/kg) 8 (c) KF strength (Nm/kg) 9 (d) DF strength (Nm/kg) 10 (a)PF strength (Nm/kg) 11 (e) KE strength (Nm/kg) 12 (e) KF strength (Nm/kg) 13 (e) DF strength (Nm/kg) 14 (f) KE strength (Nm/kg) 15 (f) KF strength (Nm/kg) 16 (a) KF and PASE	1 r=.40, p=.008 2 r=.30, p<.05 3 r=.32, p<.05 4 r=.45, p<.01 5 r=.43, p=.004 6 r=.42, p=.005 7 r=.28, p<.05 8 r=.33, p<.05 9 r=.29, p<.05 10 r=.06, p>.05 11 r=.34, p<.05 12 r=.41, p<.01 13 r=.32, p<.05 14 r=.41, p<.01 15 r=.41, p<.01 16 independently associated with BESTest score(p=.008 and p=.033 respectively)
CBMS	Butcher S J, 2004	45.7±3.73/GOLD 3, n=15 oxygen non-users; and 29.87±3.73/GOLD 4, n=15 oxygen users	Construct	Fair	Total score	1 FEV_1 2 FVC 3 PEF 4 Different between oxygen users and non-users	1 r=.58, p<.05 2 r=.61, p<.05 3 r=.59, p<.05 4 p<.05

FRT	Eisner MD, 2008[39]	62.0±23.0/GOLD1-4, n=1202	Construct	Good	Total score	1 FEV_1	1 no relationship
	Eisner MD, 2011	63.0/GOLD 2, n=777	Construct/ Crit-predictive	Fair/ Poor	Lowest quartile of the distribution of SPPB scores	1 Valued Life Activities scale – secondary risk of disability: development of a new one or more activity that cannot be performed in 2 years follow-up period.	1 OR 2.22; 95% CI: 1.7 to 3.88
SPPB	Eisner MD, 2007	57.9±22.6/GOLD 2, n=355	Construct	Fair	Total score	1 Higher SAD 2 Lean/fat ratio 3 Obese BMI 4 Higher fat mass	1 Lower SPPB scores in men (-0.067, 95% CI: -0.13 to 0.00) and women (-0.097, 95% CI: -0.015 to -0.047) 2 Lower SPPB scores in women (0.52, 95% CI: 0.24 to 0.80) 3 Lower SPPB scores in women (-1.00, 95% CI: -1.61 to -0.40) 4 Greater risk of poor SPPB in women (-0.037 points per 1 kg increment; 95% CI -0.053 to -0.020)
	Eisner MD, 2008[39]	62.0±23.0/GOLD1-4, n=1202	Construct	Good	Lowest quartile of the distribution of SPPB scores (a) Tandem stand component of SPPB (b)	1 (a) FEV_1 (per liter decrement) 2 (a) 6MWT 3 (b) FEV_1	1 Greater risk of "poor" SPPB score; (OR 1.5, 95% CI:1.2 to 1.9, p<.001) 2 Higher SPPB score associated with greater distance in 6MWT (35meters per 1-point increment, 95% CI: 28 to 42) 3 no relationship
	Eisner MD, 2011	63.0/GOLD 2, n=777	Construct/ Crit-predictive	Fair/ Poor	Lowest quartile of the distribution of SPPB scores	1 Valued Life Activities scale – primary risk of disability: 3.3% increase from baseline in 2 years follow-up period (n=1051) 2 Valued Life Activities scale – secondary risk of disability: development of a new one or more activity that cannot be performed in 2 years follow-up period (n=777)	1 OR 2.57; 95% CI: 1.65 to 4.01 2 OR 3.20; 95% CI: 1.76 to 5.81
	Singer J, 2011	median(25^{th}, 75^{th} percentile): 52.7(38.8-67.4)/GOLD1-4, n=828	Construct	Fair	Lowest quintile of the distribution of SPPB (poor lower extremity function)	1(a) Decrease quadriceps muscle strength (lb of force) 2 (b) Lower MIP (cm H_2O)	1 (a) Higher risk of poor lower extremity function in men (OR 1.32, 95% Ci: 1.11 to 1.57; p=.001) and women (OR 1.87, 95% CI: 1.54 to 2.27; p<.001) 2 (b) Higher risk of poor lower extremity function in women (OR 1.18, 95% CI: 1.00 to 1.39; p=.04) 3 (b) No association in men
SST	Rocco CCm, 2011	39.8±8.9/GOLD 3, n=22	Construct	Poor	Total score	1 BODE index	1 r=.59, p<.05
Tinetti	Rocco CCm, 2011	39.8±8.9/GOLD 3, n=22	Construct	Poor	Total score	1 BODE index	1 r=.78, p<.05

Laboratory							
FP	Rocco CCm, 2011	39.8±8.9/GOLD 3, n=22	Construct	Poor	AP displacement, cm (a) LL displacement, cm (b)	1 BODE index	1 (a) r=.11, p=NS 2 (b) r=.06, p=NS
Posturography	Butcher S J, 2004	45.7±3.73/GOLD 3, n=15 oxygen non-users; and 29.87±3.73/GOLD 4, n=15 oxygen users	Construct	Fair	Peak sway in eyes open with AP platform tilt (a) Sway index in eyes open with platform tilt (b)	1 (a) FEV_1 2 (a) FVC 3 (a) PEF 4 (b) FEV_1 5 (b) FVC 6 (b) PEF	1 r=.41, p<.05 2 r=.27, p NS 3 r=.52, p<.05 4 r=.47, p<.05 5 r=.45, p<.05 6 r=.44, p<.05
SOT	Roig M, 2011	46.7±13.0/GOLD 3, n=20	Construct	Poor	Composite equilibrium score, individual SOT conditions, or specific systems.	1 KE peak torque 2 PASE	1 no association 2 no association
Fear of Falling							
Self-reported							
ABC	Beauchamp MK, 2009	41.5±17.0/GOLD 3, n=39	Construct/ Crit-Predictive	Fair/ Fair	Total score	1 ABC score could discriminate between fallers and non-fallers 2. Falls predictor (retrospective)	1. p=.002 2. OR 0.94, p=.033
	Roig M, 2010	46.4±21.6/GOLD 3, n=101	Construct	Fair	Total score	1 Falls incidence	1 r=-0.17, p=.1

**COPD severity given in percentage of predicted of FEV_1 and as GOLD stages. no relationship: lack of relationship was found and r values are not provided in the text. Abbreviations: 6MWT: six-minute walk test; BMI: body mass index; BODE: Body-Mass Index, Airflow Obstruction, Dyspnea, and Exercise Capacity index; CRQ: Chronic Respiratory Questionnaire; CI :confidence interval; DF: ankle dorsiflexor; FEV_1: forced expiratory volume in 1 second; FP: Force Platform (Centre of Pressure analysis); FVC: forced vital capacity; KE: knee extensor; KF: knee flexor; MIP: Maximum inspiratory pressure; OM: outcome measure; OR odds ratio; PaO_2: partial pressure of oxygen in arterial blood; PASE: Physical Activity Scale for the Elderly; PEF: peak expiratory flow; PRP: pulmonary rehabilitation program; pt: participant; PF: Plantar flexors; SAD: sagittal abdominal diameter; SaO_2: saturation level of oxygen in hemoglobin in arterial blood.*