Impairments in balance discriminate fallers from non-fallers in COPD

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Summary
Background: Preliminary evidence suggests individuals with COPD exhibit deficits in balance. Further investigation of balance and risk of falls is warranted in these patients. The objective of this study was to determine the clinical measures that discriminate fallers from non-fallers among patients with COPD.

Methods: A cross-sectional study design was used. Subjects > 60 years with COPD attended a single assessment session. A one-year incidence of falls was collected via self-report questionnaire. Risk of falls and balance were determined using the Berg Balance Scale (BBS), Timed Up and Go Test (TUG) and the Activity-Specific Balance Confidence (ABC) Scale. Exercise tolerance was determined from the Six-Minute Walk Test and functional limitation attributable to dyspnea from the Medical Research Council (MRC) dyspnea scale.

Results: Of the 39 COPD subjects (FEV1 = 41.5 ± 17.0% predicted; age: 71.1 ± 6.8 years) who completed the study, 46% (n = 18) reported at least one fall in the preceding year. Significant differences between fallers and non-fallers were found for the ABC (65.8 ± 18.2 vs. 81.7 ± 11.1; p = 0.002), TUG (17.0 ± 4.9 vs. 14.0 ± 3.1 s; p = 0.024), BBS (45.2 ± 5.4 vs. 48.8 ± 5.0; p = 0.042), use of supplemental oxygen (72% vs. 24%; p = 0.002), and MRC dyspnea scale (median 4, range 3 vs. median 3, range 4; p = 0.046).

Conclusions: Patients with COPD fall frequently. Standard clinical balance measures discriminate self-reported fallers from non-fallers. These observations draw attention to an important secondary impairment in COPD.

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**Introduction**

Chronic obstructive pulmonary disease (COPD) is one of the most important causes of death worldwide and is projected to rank third in 2020 in global burden of disease.\(^1\) Although the primary underlying pathophysiology is pulmonary, associated systemic effects of COPD contribute importantly to the symptoms and disability that characterize this condition. Peripheral muscle dysfunction is associated with reduced functional mobility and exercise capacity in COPD.\(^2\) In addition, impaired motor control, reaction time, and dexterity have been reported in individuals with resting hypoxemia.\(^3\) Recent studies have also noted reduced balance and coordination in individuals with COPD relative to healthy controls.\(^4\,\,5\)

Falls have considerable negative consequences for older adults including morbidity, mortality, and loss of autonomy.\(^6\) The presence of chronic disease, multiple medications, impaired mobility and muscle weakness are frequently cited risk factors, and balance impairment is one of the most important predictors of falls in older adults.\(^7\,\,8\) Despite the fact that individuals with COPD possess many of these risk factors, limited information is available regarding balance and falls in this population.\(^9\) Furthermore, the high incidence of osteoporosis in these patients\(^10\) underscores the need for identification of putative risk factors for falls in order to inform the development of both preventive and treatment programs.

The aim of this study was to determine the clinical measures that discriminate between fallers and non-fallers in individuals with COPD. We hypothesized that fallers with COPD would be characterized by impairments in functional balance measures, and greater severity of disease.

**Methods**

**Participants**

Individuals were eligible to participate in this study if they met the following inclusion criteria: (1) physician diagnosis of COPD (FEV\(_1\) < 80% predicted and FEV\(_1\)/FVC < 70% predicted) according to international guidelines \(^11\); (2) age > 60 years; (3) smoking history > 10 pack years; and (4) ability to provide written informed consent. To avoid the potential confounding effect of an exercise training program on fall risk, we recruited patients who had completed less than one week of pulmonary rehabilitation. Individuals with co-morbid conditions likely to jeopardize their safety or influence their balance were excluded. Specifically, exclusion criteria comprised: (1) known cognitive impairment; (2) mechanical ventilation for all or part of the day; (3) neurological or musculoskeletal condition that limited mobility; and (4) symptomatic cardiovascular disease.

**Data collection procedures**

After study approval by the local Research Ethics Board, consecutive patients enrolled in pulmonary rehabilitation programs between March and August 2008 were approached to attend a single assessment session. After obtaining informed consent, measurements of resting lung function, including forced expiratory volume in 1 s (FEV\(_1\)) and carbon monoxide diffusing capacity (D\(_{CO}\)), height, weight and use of supplementary oxygen were retrieved from the patient’s medical chart. All pulmonary function testing was obtained from the same laboratory according to ATS guidelines.\(^12\) Balance testing and questionnaires were administered by the same registered physical therapist, in a quiet laboratory setting. The order of the tests was standardized for all subjects; balance and functional mobility tests were completed first, followed by questionnaires and assessment of exercise capacity. Participants were encouraged to rest as needed throughout the assessment session.

**Measures**

**Self-reported falls**

The questionnaire component of the Elderly Falls Screening Test (EFST) was utilized to establish the number of times each patient had fallen during the preceding 12 months, using the following standard definition: "A fall would be when you find yourself suddenly on the ground, without intending to get there, after you were either in a lying, sitting or standing position."\(^13\) The EFST has been shown to have both criterion and predictive validity in elderly individuals residing in the community.\(^13\)

**Berg Balance Scale (BBS)**

Functional balance was measured using the 14-item BBS.\(^14\) Activities such as transfers, reaching, turning around and single legged stance were graded on a scale ranging from 0 (unable/unsafe) to 4 (independent/efficient/safe), with higher scores indicating greater balance control. The measurement derived using the BBS has demonstrated internal consistency, intra-rater and inter-rater reliability, content validity, construct validity and predictive validity for determining fall risk in older adults.\(^15\) A cut-off score of 46 and below has been identified as a useful score to successfully identify those at risk of falling.\(^16\,\,17\) Age- and gender-specific scores are available in healthy populations.\(^18\)

**Timed Up and Go (TUG)**

The TUG was used to provide a timed measure of balance and functional mobility in our patients.\(^19\) The test requires the patient to rise from a standard armchair, walk 3 m at a comfortable pace, walk back to the chair, and sit down. A practice trial was performed (not recorded) and individuals were permitted to use a gait aid if required. Normative data are available for elderly individuals who reside in the community.\(^18\) The TUG has high intra- and inter-tester reliability and predictive validity for falls in community-living adults.\(^15\,\,19\) A cut-off score of 16 s or more has been shown to predict falls in community-dwelling elderly.\(^20\)

**Activity-specific Balance Confidence (ABC) scale**

The ABC scale requires patients to indicate their confidence in performing 16 activities without losing their balance or becoming unsteady on an 11-point scale (0–100\%). \(^21\) Each item describes a specific activity that requires progressively increased balance control. Greater scores indicate higher balance confidence. The ABC scale has good test–retest...
reliability, internal consistency and predictive capacity for falls in older adults that reside in the community.\textsuperscript{15,21}

### Medical Research Council (MRC) dyspnea scale

The MRC dyspnea scale is a simple and valid method of characterizing patients with COPD in terms of their functional limitation resulting from dyspnea.\textsuperscript{22} The questionnaire comprises five grades (statements) with higher grades indicating greater perceived respiratory disability. Patients were asked to select the statement that best described their limitation.

### Six-minute walk test (6MWT)

The 6MWT is a self-paced test that quantifies functional exercise capacity in terms of the distance walked in 6 min (6MWD).\textsuperscript{23} The test was performed over a 30m level straight course within an enclosed corridor according to the test protocol described by the American Thoracic Society.\textsuperscript{23} During each 6MWT, patients received standardized instructions and encouragement. Two tests were performed to account for possible improvements resulting from familiarization, with the greatest distance recorded. Each 6MWT was separated by a minimum of 30 min.

### Statistical analysis

Statistical analyses were performed using SPSS\textsuperscript{22} (Statistical Package for Social Sciences, version 16.0 for Windows). It was determined that 39 patients were required to yield 80\% power ($\alpha = 0.05$) to detect a difference of 3 points in the BBS between fallers and non-fallers using an independent $t$-test and a standard deviation of 4.\textsuperscript{18} A difference of 3 points was chosen as it has been suggested to represent a clinically important difference for this measure.\textsuperscript{15,24} The assumption of normality was assessed by frequency histograms and box plots as well as statistical methods (Shapiro–Wilks test). For all analyses $p$-values $\leq 0.05$ were considered significant. Fallers were defined as those who reported one or more falls in the past year. Variables in fallers were compared with non-fallers using an independent $t$-test for normally distributed data, the Mann–Whitney $U$-test for non-normally distributed data and ordinal data, and the Chi-Square test for categorical data. A forward step-wise logistic regression was used to determine predictors of falls. Data are expressed as mean $\pm$ standard deviation unless otherwise indicated.

### Results

#### Subjects

Thirty-nine patients ($FEV_1 = 41.5 \pm 17.0\%$ predicted; age $71.1 \pm 6.8$ years) completed the study. Their characteristics are summarized in Table 1. Eighteen patients (46\%) reported at least one fall in the preceding year; with 5 patients (13\%) reporting 2 or more falls. Of the 18 patients who used supplementary oxygen, 12 (67\%) were on long-term oxygen therapy. To facilitate interpretation of the clinical measures of balance and functional mobility in patients with COPD, Fig. 1 shows the mean BBS and TUG scores against those derived in a sample of healthy elderly individuals,\textsuperscript{18} separated for each decade of life. Fifteen patients (38\%) achieved a score $\leq 46$ for the BBS and 14 patients (36\%) demonstrated scores $\geq$ the 16-s cut-off for predicting falls with the TUG. No differences in any measures were observed for gender ($p > 0.05$).

#### Comparison of fallers and non-fallers

In order to examine our a-priori hypotheses, we compared measures of functional balance and disease severity between fallers (defined as patients with one or more self-reported falls in the preceding 12 months) and non-fallers (Table 2). Although multiple comparisons were made, pre-established hypotheses precluded the need for adjustments for type I errors.\textsuperscript{22} In support of the first hypothesis (i.e., impaired balance in fallers), significant differences were demonstrated between fallers and non-fallers for the ABC ($t$-test, $p = 0.002$), TUG ($t$-test, $p = 0.024$), and BBS ($t$-test, $p = 0.042$). With respect to our second hypothesis (i.e., greater disease severity in fallers), use of supplemental oxygen (chi-square, $p = 0.002$) and MRC dyspnea scale (Mann–Whitney $U$-test, $p = 0.046$) distinguished fallers from non-fallers. However, no differences were observed between the two groups in $FEV_1$, $DlCO$, or 6MWD ($p > 0.05$). Note, the mean difference in 6MWD between the groups (49 m) approached the minimally clinically important difference for this measure.\textsuperscript{22} There was no difference between groups based on gender ($p > 0.05$), though, not surprisingly, age was greater in fallers compared to non-fallers ($73.3 \pm 6.9$ vs. $69.0 \pm 6.1$, $p = 0.047$).

An exploratory, forward, step-wise logistic regression was used to identify the variables that predicted falls. Variables included those from Table 2 with probability

\begin{table}[	extit{Table 1}]
\centering
\begin{tabular}{|l|l|}
\hline
\textbf{Variable} & \textbf{Result} \\
\hline
Men/Women (n) & 18/21 \\
Supplemental oxygen (n,\%) & 18, 46\% \\
Age (yrs) & 71.1 $\pm$ 6.8 \\
\textbf{FEV_1 (L)} & 0.9 $\pm$ 0.4 \\
\textbf{FEV_1 (%predicted)} & 41.5 $\pm$ 17.0 \\
\textbf{FVC (L)} & 2.4 $\pm$ 0.8 \\
\textbf{FVC (%predicted)} & 77.0 $\pm$ 17.0 \\
\textbf{DlCO (ml/min/mmHg)} & 9.8 $\pm$ 4.5 \\
\textbf{DlCO (%predicted)} & 51.0 $\pm$ 21.2 \\
MRC dyspnea scale & median 3, IQR 3 \\
\textbf{6MWD (m)} & 303.3 $\pm$ 114.9 \\
\textbf{Body Mass Index (kg/m^2)} & 25.7 $\pm$ 9.5 \\
\textbf{ABC score} & 74.4 $\pm$ 16.6 \\
\textbf{BBS score} & 47.1 $\pm$ 5.4 \\
\textbf{TUG (sec)} & 15.4 $\pm$ 4.3 \\
\hline
\end{tabular}
\caption{Subject characteristics ($n = 39$).}
\end{table}
values of \( p < 0.05 \) (ABC, TUG, BBS, supplemental oxygen and MRC). ABC \( (p = 0.033, \text{odds ratio } 0.94) \) and use of supplemental oxygen \( (p = 0.027, \text{odds ratio } 5.83) \) were retained as independent predictors of falls.

Post hoc analysis

Given the finding that oxygen use was a predictor of falls, we conducted a post hoc analysis to explore differences in clinical measures of balance and mobility with patients classified according to their use of supplemental oxygen (Table 3). There were significant differences for the TUG \( (t\text{-test, } p < 0.001) \), ABC \( (t\text{-test, } p = 0.019) \), BBS \( (t\text{-test, } p = 0.028) \), and 6MWD \( (t\text{-test, } p = 0.037) \) between patients using supplemental oxygen and those who did not. No differences were observed between the two groups in measures of lung function or age.

Discussion

This is the first study to demonstrate differences in balance, functional mobility and balance confidence between fallers and non-fallers in patients with COPD. The novel findings of this study are: (i) standard clinical measures of functional balance, the BBS and TUG, discriminated between fallers and non-fallers; (ii) impaired balance confidence and the use of supplemental oxygen were significant predictors of falls in this population; and (iii) falls and balance impairments are commonly observed in COPD. Moreover, the results of this work demonstrated that impairments in balance and functional mobility were significantly worse in patients who were prescribed supplementary oxygen compared to those without the requirement for oxygen. These findings highlight the importance of assessing and treating balance in patients with COPD as part of their comprehensive management.

Compared with non-fallers, scores on the BBS and TUG in fallers were 3.5 points lower, and 3.1 s longer, respectively, indicative of clinically relevant deficits in measures of balance and functional mobility in patients with COPD who fall.\(^{15,24,27}\) These deficits are of similar magnitude to previously reported differences in BBS and TUG scores between fallers and non-fallers in other chronic disease populations with established fall risk, such as Parkinson’s and Multiple Sclerosis.\(^{28,29}\) In addition, fallers with COPD in this study achieved mean scores on the BBS and TUG that were consistent with previously established cut-off values\(^{16,17,20}\) for risk of falls for healthy elderly, however,

\[
\text{Table 2: Clinical measures in fallers and non-fallers with COPD.}
\]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Fallers ((n = 18))</th>
<th>Non-fallers ((n = 21))</th>
<th>Mean difference</th>
<th>95% Confidence interval</th>
<th>( p)-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC score</td>
<td>65.8 ± 18.2</td>
<td>81.7 ± 11.1</td>
<td>-15.9</td>
<td>-25.5 to -6.3</td>
<td>0.002*</td>
</tr>
<tr>
<td>O2</td>
<td>( n = 13, 72% )</td>
<td>( n = 5, 24% )</td>
<td>n/a</td>
<td>n/a</td>
<td>0.002*</td>
</tr>
<tr>
<td>TUG (s)</td>
<td>17.0 ± 4.9</td>
<td>14.0 ± 3.1</td>
<td>3.1</td>
<td>0.4 – 5.7</td>
<td>0.024*</td>
</tr>
<tr>
<td>BBS score</td>
<td>45.2 ± 5.4</td>
<td>48.8 ± 5.0</td>
<td>-3.5</td>
<td>-7.0 to -0.2</td>
<td>0.042*</td>
</tr>
<tr>
<td>MRC dyspnea scale</td>
<td>median 4, IQR 3</td>
<td>median 3, IQR 2</td>
<td>n/a</td>
<td>n/a</td>
<td>0.046*</td>
</tr>
<tr>
<td>6MWD (m)</td>
<td>278.4 ± 125.7</td>
<td>327.5 ± 100.1</td>
<td>-49.0</td>
<td>-124.0 to 25.9</td>
<td>0.192</td>
</tr>
<tr>
<td>FEV(_1) (%)</td>
<td>42.7 ± 15.8</td>
<td>40.6 ± 18.4</td>
<td>2.1</td>
<td>-9.0 to 13.2</td>
<td>0.704</td>
</tr>
<tr>
<td>( D_1O_2 ) (%)</td>
<td>50.1 ± 23.9</td>
<td>51.8 ± 19.1</td>
<td>-1.8</td>
<td>-17.2 to 13.7</td>
<td>0.818</td>
</tr>
</tbody>
</table>

Note: values are mean ± SD, unless otherwise indicated.

Abbreviations: ABC, Activity-specific Balance Confidence scale; TUG, Timed Up and Go test; BBS, Berg Balance Scale; MRC, Medical Research Council; IQR, inter-quartile range; 6MWD, six-minute walking distance; FEV\(_1\), forced expiratory volume in 1 s; and \( D_1O_2 \), carbon monoxide diffusing capacity.

\(^*\)Significant at \( p < 0.05 \).
use of these cut-off values for predicting falls in COPD require further validation using prospective studies. Although limited in the COPD literature, there is increasing recognition of balance deficits in this population. Recent work has shown reduced balance and coordination in patients with COPD compared to controls,4 as well as acute deficits in static balance following field-based exercise testing.3 The current study extends previous observations by considering the frequency of self-reported falls and by using the BBS (a widely used clinical balance tool) to assess functional balance. While current clinical practice guidelines for COPD focus on lower extremity conditioning,30 there are no specific recommendations regarding balance training and fall prevention strategies. Recent surveys on pulmonary rehabilitation practices in Canada and in the UK, found that less than 10% of outpatient programs used the TUG for assessing functional mobility.31,32 Given the high observed incidence of falls in COPD, a balance assessment should be part of pulmonary rehabilitation, especially in patients using supplementary oxygen or with low balance confidence.

In this study, oxygen usage both discriminated between fallers and non-fallers, and was a predictor of falls in patients with COPD. Our post hoc analysis indicated that impairments in balance and functional mobility, including TUG, were significantly greater in patients who used supplemental oxygen. In contrast, Butler et al. found no differences in TUG between oxygen users and non-users, after controlling for FEV1.4 The reason for this discordance might relate to the differences in methodologies used to measure TUG between the studies. Specifically, Butler reported using the fastest of three recorded trials,4 whereas our investigation utilized the second trial of walking at a “normal walking pace” as outlined by the developers.19 In addition, our study noted reduced 6MWD in patients with oxygen compared to those without oxygen. As the 6MWD is a surrogate marker for time spent walking during daily life in COPD,33 it might be that oxygen users were more sedentary, leading to greater impairments in balance. The previous report of an association between oxygen use and low physical activity supports this contention.44 Other possible explanations for the relationship between falls and oxygen use include decreased motor coordination from cerebral hypoxemia,3 and the potential physical hazard from ambulatory oxygen equipment.

Balance confidence, or balance self-efficacy, also discriminated fallers from non-fallers and was found to be a predictor of falls in patients with COPD. Fear of falling is increasingly recognized as an important public health concern in older adults with and without a history of falls.35 The cross-sectional design of our study prevents us from establishing whether impaired balance confidence was a risk factor or a response to a fall. Nevertheless, the ABC scale has merit as a simple assessment tool to identify those patients with COPD at risk of falls. Further, interventions aimed at targeting fear of falls have been shown to be effective in older adults36 and may be worthwhile in COPD.

Fallers with COPD in this study were characterized by greater functional limitations than non-fallers (MRC 4 vs. MRC 3) and lower 6MWD. Although the latter did not reach statistical significance, the actual difference (49 m 95% CI: −124.0 to 25.9) approached the minimal clinically significant change of 54 m for the 6MWT.26 As such, the 6MWT may prove useful as a tool to guide fall risk assessment in patients with COPD, however, future work is required to determine if a suitable threshold can be determined for predicting falls in these patients. Interestingly, while use of supplemental oxygen distinguished fallers from non-fallers, FEV1 and DCO CO did not. These findings suggest that increased fall risk in patients with COPD is more closely related to the disability resulting from the disease rather than the primary impairment in lung function.

In addition to the significant differences in BBS and TUG scores between fallers and non-fallers, individuals with COPD, as a group, exhibited lower BBS and TUG scores (Fig. 1) relative to age-matched reference values established in older adults functioning independently in the community.18 In fact, over 35% of our total sample achieved scores below the established cut-offs for risk of falls for the BBS and TUG.16,17,20 These observations are consistent with the report by Butler and colleagues of impaired balance and coordination in individuals with COPD compared with healthy controls.4 However, both the current findings and the results by Butler and colleagues are limited by lack of ability to control for activity levels. It is, therefore, difficult to determine if the reductions in balance noted in patients with COPD relate to a systemic manifestation of the disease itself or to reduced activity levels as a consequence of progressive lung disease. Future studies are needed in which balance and falls in COPD are considered in light of levels of physical activity.
Certain limitations must be considered when interpreting the results of this study. Our small sample size limits the generalizability of our results to the COPD population and reduces the reliability of our logistic regression. However, the study was powered to detect a three-point difference in the BBS (power = 0.8). The one-year history of falls described by 46% of our patients was high when referenced against large epidemiological studies reporting retrospective fall incidence between 28 and 35% among community-residing older adults. Larger, prospective studies will yield more precise estimates of fall incidence as they eliminate recall bias which may underestimate the true incidence. Nevertheless, the high number of falls in our sample underscores the need to better define this important issue within the context of other risk factors including vision, cognitive function, demographic and environmental factors, medications, physical activity, and muscle strength. In addition, while the primary aim of the current study was to identify factors that characterized fallers in a cohort of patients with COPD, future work would benefit from use of age-matched controls to determine if these factors differ in healthy elderly.

In summary, this study has shown that simple clinical measures of balance can discriminate between fallers and non-fallers with COPD. Patients using supplementary oxygen and those with reduced balance confidence appear to be at particular risk of falling. These findings highlight the importance of an increased risk of falling in COPD and suggest the need for including balance assessment and training, as well as fall prevention strategies within the framework of pulmonary rehabilitation. Future research is warranted to explore the mechanism underlying the observed balance deficits in this population.

Conflict of interest statement

The authors have no conflict of interest.

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