Deficits in postural control in individuals with COPD - emerging evidence for an important secondary impairment

Deficit nel controllo posturale in soggetti affetti da BPCO – evidenza emergente di un importante danno secondario

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ABSTRACT
Emerging evidence suggests that individuals with COPD demonstrate reductions in balance control that may be associated with an increased fall risk. The purpose of this review is to: 1) provide a brief overview of balance control and its assessment; 2) review relevant literature describing balance impairment in individuals with COPD; and 3) highlight important areas for future research. The observation of balance deficits and an increased fall risk in patients with COPD suggests the need for including balance assessment and training for patients enrolled in pulmonary rehabilitation who may be vulnerable. Further studies are needed to determine which aspects of balance are affected and to examine the impact of interventions.

Keywords: COPD, falls, postural control, pulmonary rehabilitation.

INTRODUCTION
Chronic obstructive pulmonary disease (COPD) is an inflammatory disorder characterized by progressive airflow limitation [1]. It is one of the most important causes of death in North America and Europe, and is projected to rank third in 2020 in the global burden of disease [2,3]. While treatment of COPD has traditionally focused on lung function, systemic effects of the disease are gaining increased attention. Although reductions in peripheral muscle performance, functional mobility and exercise capacity have been well demonstrated [4,5], emerging evidence suggests that individuals with COPD also demonstrate important deficits in balance control [6-11].
The ability to maintain balance is critical for mobility, avoidance of falls and functional independence in daily living. Balance impairment has been associated with an increased risk of falls and a resulting increase in mortality rate among older adults [12-14]. A large cross-sectional study reported that COPD was second only to osteoarthritis in its association with the number of falls in elderly women [15]. In a recent prospective study, individuals with COPD were found to have a projected annual fall rate of 1.2 falls per person - a substantially higher rate than that previously reported for older adults (incidence rate of 0.24) [16,17]. Furthermore, in this study fallers with COPD showed a greater decline in health-related quality of life scores after 6 months compared to non-fallers [16]. Given the devastating consequences of falls in older adults, an understanding of the balance deficits present in individuals with COPD is essential to guide the development of balance training and fall prevention programs for this population. Therefore, the purpose of this article is to: 1) provide a brief overview of balance control and its assessment; 2) review relevant literature describing balance impairment in individuals with COPD; and 3) highlight important areas for future research.

Balance control and assessment
Successful maintenance of balance, or postural control, requires that the centre of mass (COM) be maintained within the limits of the base of support (BOS) [18]. This is neither a simple nor a fixed task. Rather, the ability to stand upright on two limbs is an extremely complex skill that requires the integration of multiple somatosensory, neuromuscular, as well as central nervous system (CNS) inputs, which must be constantly updated and fine-tuned under an array of situations in everyday life [19]. While the ability to maintain balance during stance is a formidable skill in and of itself, optimal postural control requires centrally initiated dynamic postural adjustments to be made prior to the initiation of voluntary movement (such as taking a step); this must also occur in response to external perturbations which threaten to move the COM outside the BOS and potentially cause a fall [18,20]. Both static (maintaining equilibrium with minimal movement) and dynamic (maintaining equilibrium with moving BOS) postural control are essential to maintain stability and avoid falls [18].

Clinical balance assessment tools are directed to screen for general balance impairments, thereby predicting fall risk [21,22]. For example, the Berg Balance Scale - a widely accepted and psychologically robust clinical measure of balance for older adults - is a 14-item performance based test with predictive validity for determining fall risk [23,24]. Activities such as transfers, reaching, turning around and single legged stance are graded on a scale that ranges from 0 (unable/unsafe) to 4 (independent/efficient/safe), with higher scores indicating greater balance control. Basic functional mobility tests, such as the Timed Up and Go, and measures of balance confidence are also often considered as part of a complete balance assessment as they have been shown to correlate well with standard balance scales and with risk of falls [22,25]. These clinical tools are both discriminative and evaluative; they allow clinicians to identify which patients may benefit from balance retraining and to monitor change in response to interventions.

While functional balance tests are easy to perform and therefore suitable for daily clinical use, laboratory techniques such as electromyography, kinematics and kinetics, provide a continuous evaluation of postural control with a level of precision not accessible in observationally-based clinical assessments [26]. The precision of measurement and closer approximation of the physiologic components engaged in the maintenance of stability are important advantages of including such measurements in a comprehensive evaluation of balance.

Balance impairment in COPD
There is increasing interest in examining deficits in postural control among individuals with COPD. Table 1 provides an overview of these studies. The first investigation in this area was conducted by Grant and colleagues, who reported that nearly half of a sample of 203 older individuals with advanced COPD exhibited deficits in motor speed, strength and coordination, compared to controls [27]. The authors also reported impairments in higher cognitive functions and complex perceptual-motor integration which were attributed to cerebral hypoxia associated with their COPD. More recently, a study by Butter and colleagues of 30 patients with severe COPD (FEV1 38% predicted) identified differences in functional balance as measured by the Community Balance and Mobility Scale and the Timed Up and Go test, as well as increased postural sway, compared to aged matched healthy controls. In this study, it was suggested that balance and coordination deficits correlated with measures of severity of airflow obstruction (FEV1) and consequent reduction in physical activity levels in patients with COPD [7]. In a large prospective cohort study, Eisner and colleagues observed that individuals with moderate COPD (FEV1 62% predicted; n = 1202) performed significantly worse on two tests of functional balance (Functional Reach Test and a tandem stance task) as compared with 302 healthy age-, sex- and race-matched controls [9]. Two studies have considered the influence of fatigue on laboratory measures of static balance in patients with moderate to severe COPD. Chang and colleagues investigated static postural control following sub-maximal exercise in 19 COPD (FEV1 46% predicted) subjects [8]. The authors reported that in the absence of visual input patients with COPD demonstrated impaired static postural control (i.e. increased sway) following a six-minute walk test. It was hypothesized that the increased postural sway following exercise was related to decreased peripheral muscle strength and endurance as well as to the increase in ventilation...
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Smith et al. compared postural sway as well as lumbar spine and hip movement in 12 people with severe COPD (FEV₁ 33% predicted) with 12 healthy controls, before and after participation in upper limb exercise. Those with COPD demonstrated increased mediolateral sway and angular motion of the hip compared to healthy controls. This finding has important implications, as mediolateral displacement is closely related to falls in older adults [28]. This mediolateral displacement was reported to further increase after upper limb exercise, a finding attributed to the impact of trunk muscles on balance and respiration [11].

Recent work has also considered the influence of balance on fall risk in COPD. We investigated clinical measures of balance and the retrospective incidence of falls in 39 older adults with COPD (FEV₁ 42% predicted) [6]. We noted that 46% (n = 18) of subjects reported at least one fall in the preceding year and that performance on clinical balance tests (Berg Balance Scale and Timed Up and Go) discriminated between self-reported fallers and non-fallers. Balance confidence and use of supplemental oxygen were found to be independent predictors of falls in these patients. Similar to previous work, when compared to reference values matched for each decade of life [29], subjects with COPD (n = 39) exhibited reduced scores on clinical tests of balance (Figure 1). In another study, Roig et al. compared measures of postural control and fall risk in 20 elderly COPD patients (FEV₁ 47% predicted) with 20 healthy, age-matched controls [10]. Participants stood on a force plate in a visual surround system and were challenged to stay upright under increasingly challenging conditions; both the force plate and the visual background were manipulated in order to assess the contribution of the vestibular, somatosensory and visual sensory systems to postural stability (Sensory Organization Test). Individuals with COPD experienced more frequent “falls” (defined as when a subject needed to take a step or touch the background to regain balance) and exhibited marked deficits in postural control, compared to controls. Of interest, the authors did not observe an association between muscle weakness or the level of physical activity and deficits in postural control. These studies suggest that deficits in balance consti-

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample</th>
<th>Key outcomes</th>
<th>Key findings</th>
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<tr>
<td>Grant et al. 1982 [27]</td>
<td>203 patients with advanced hypoxemic COPD (PaO₂ 51 mm Hg), age 66 yrs; 74 controls, age 64 yrs.</td>
<td>Measures of coordination from Halstead-Reitan Test Battery including a tactual performance test and the tapping test. Grooved pegboard test.</td>
<td>Impaired perceptual-motor integration, motor dexterity and coordination in COPD vs. controls.</td>
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<tr>
<td>Butcher et al. 2004 [7]</td>
<td>30 COPD (FEV₁ 38% predicted), age 71 yrs; 21 controls, age 68 yrs.</td>
<td>Finger-to-nose test Toe Tap Timed Up and Go Posturography Community Balance and Mobility Scale.</td>
<td>Deficits in functional balance and coordination in COPD compared to controls. Increased sway for eyes open, moving platform test.</td>
</tr>
<tr>
<td>Chang et al. 2008 [8]</td>
<td>19 COPD (FEV₁ 46% predicted), age 69 yrs.</td>
<td>Timed Up and Go and postural sway in quiet stance following a 6MWT.</td>
<td>Static balance in semi-tandem stance with eyes closed impaired after a sub-maximal exercise test.</td>
</tr>
<tr>
<td>Smith et al. 2010 [11]</td>
<td>12 COPD (FEV₁ 33% predicted), age 65 yrs; 12 controls, age 64 yrs.</td>
<td>Center of pressure displacement using a force plate. Angular motion of hip and lumbar spine. Tests repeated before and after an upper limb exercise task.</td>
<td>Reduced balance in mediolateral direction and increased hip motion in COPD vs. controls.</td>
</tr>
<tr>
<td>Roig et al. [10]</td>
<td>20 COPD (FEV₁ 47% predicted), age 72 yrs; 20 controls, age 68 yrs.</td>
<td>Postural sway and number of “falls” using the Sensory Organization Test (SOT) to assess balance on a moving force plate and visual surround system. Physical Activity Scale for the Elderly. Knee extensor muscle torque.</td>
<td>Reduced scores on the SOT and more frequent “falls” in COPD vs. controls. No association between physical activity or muscle strength with balance deficits.</td>
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An important secondary impairment in individuals with COPD. Abnormal balance was identified from both clinical and laboratory measures in individuals with varying degrees of COPD severity. It is likely that the observed balance deficits may contribute to the increased risk of falling in this population.

Areas for future research
The underlying mechanisms for reduced postural control in individuals with COPD remain unclear. Many hypotheses have been proposed, including decreased levels of physical activity [6,7], peripheral muscle weakness [6], altered trunk muscle mechanics [11], hypoxemia [27] and somatosensory deficits [30]. These ideas present clinician investigators with exciting scientific opportunities. In addition, while there is increasing evidence that individuals with COPD exhibit impairments in postural control, a detailed assessment of the systems responsible for these deficits is lacking in the literature.

The American Geriatrics Society recommends exercise with balance training as an essential component of any multifactorial falls intervention strategy for older adults at risk of falling [12]. While the exercise component of pulmonary rehabilitation is considered the cornerstone of rehabilitation, it is predominately targeted to train peripheral muscles. Balance training and fall prevention strategies are not included in international guidelines for pulmonary rehabilitation and very few programs include any standardized balance assessment [1]. In 29 subjects with COPD, a conventional pulmonary exercise rehabilitation program, in the absence of any specific balance training, resulted in only minor improvements in balance and no effect on balance confidence (Table II) [31]. Therefore, a more tailored intervention designed to improve balance and reduce risk of falls in the populations at risk would be a welcome addition to pulmonary rehabilitation.

CONCLUSION

In summary, there is a growing body of evidence to suggest that balance impairments are of significant concern for individuals with COPD. These findings

![FIGURE I: A COMPARISON BETWEEN A) BERG BALANCE SCALE SCORES AND B) TIMED UP AND GO SCORES IN SUBJECTS WITH COPD (○) AND REFERENCE VALUES FROM HEALTHY ELDERLY (□) FOR EACH DECADE OF LIFE. REFERENCE DATA FROM STEFFEN ET AL. [29] WHERE MEAN AND 95% CONFIDENCE INTERVALS WERE REPORTED FOR MALES AND FEMALES FOR EACH DECADE OF LIFE RANGING FROM 60-90 YEARS.]

![TABLE II: EFFECT OF A CONVENTIONAL PULMONARY REHABILITATION PROGRAM ON BALANCE, EXERCISE TOLERANCE AND HEALTH-RELATED QUALITY OF LIFE*]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-rehabilitation</th>
<th>Post-rehabilitation</th>
<th>Mean change</th>
<th>95% Confidence interval</th>
</tr>
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<tbody>
<tr>
<td>BBS score</td>
<td>46.9 ± 7.0</td>
<td>49.6 ± 5.7</td>
<td>2.8 ± 2.8</td>
<td>1.7 to 3.8</td>
</tr>
<tr>
<td>TUG score (sec)</td>
<td>15.7 ± 5.3</td>
<td>14.2 ± 4.5</td>
<td>-1.5 ± 2.4</td>
<td>-2.4 to -0.5</td>
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<tr>
<td>ABC scale</td>
<td>74.3 ± 17.0</td>
<td>79.1 ± 16.0</td>
<td>4.8 ± 15.4</td>
<td>-1.0 to 10.7</td>
</tr>
<tr>
<td>6MWT distance (m)</td>
<td>303.4 ± 84.2</td>
<td>355.8 ± 92.0</td>
<td>52.5 ± 54.0</td>
<td>31.1 to 73.9</td>
</tr>
<tr>
<td>CRQ-dyspnea</td>
<td>3.0 ± 1.1</td>
<td>4.6 ± 1.3</td>
<td>1.5 ± 1.4</td>
<td>1.0 to 2.1</td>
</tr>
<tr>
<td>CRQ-total</td>
<td>3.8 ± 1.0</td>
<td>5.2 ± 0.9</td>
<td>1.4 ± 1.0</td>
<td>1.0 to 1.8</td>
</tr>
</tbody>
</table>

Definition of abbreviations: 6MWT, Six-minute walk test; ABC, Activities-specific Balance Confidence; BBS, Berg Balance Scale; CRQ, Chronic Respiratory Questionnaire; TUG, Timed Up and Go.

Values are mean ± SD unless otherwise indicated.

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highlight the importance of an increased risk of falling in COPD and suggest the need for including a balance assessment for patients enrolled in pulmonary rehabilitation, with focused balance training for those at risk. Fall prevention strategies should also be taught as part of the patient education-self management program. An improved understanding of the mechanisms that underlie the observed balance deficits in COPD and the most effective interventions for improving balance will likely reduce the healthcare resource utilization associated with repeated falls as well as improve health related quality of life for our patients with COPD.

CONFLICT OF INTEREST STATEMENT: None of the authors has any conflict of interest to declare in relation to the subject matter of this manuscript.

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