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.

RIASSUNTO

Un'evidenza emergente suggerisce che chi è affetto da BPCO mostra una riduzione nel controllo dell'equilibrio che si può associare ad un maggiore rischio di cadute. Scopo di questa rassegna è: 1) fornire una breve revisione del controllo dell'equilibrio e delle modalità di valutazione; 2) passare in rassegna la letteratura di maggior rilievo che descrive i deficit di equilibrio nei soggetti con BPCO; 3) sottolineare le aree peculiari per le ricerche future. L'osservazione di un deficit di equilibrio e di un maggior rischio di cadute nei pazienti con BPCO suggerisce la necessità di inserire la valutazione dell'equilibrio ed uno specifico training nei pazienti che vengono arruolati in un programma di riabilitazione respiratoria e che si dimostrino a rischio. Ulteriori studi sono necessari per determinare quali aspetti dell'equilibrio siano affetti e per valutare l'impatto degli interventi.

Parole chiave: BPCO, cadute, controllo posturale, riabilitazione respiratoria.

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].

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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 psychometrically 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 I 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 Butcher and colleagues of 30 patients with severe COPD (FEV_1 38% predicted) identified impairments 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 (FEV_1) and consequent reduced physical activity levels in patients with COPD [7]. In a large prospective cohort study, Eisner and colleagues observed that individuals with moderate COPD (FEV_1 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 (FEV_1 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

TABLE I: OVERVIEW OF STUDIES EVALUATING DEFICITS IN POSTURAL CONTROL IN COPD

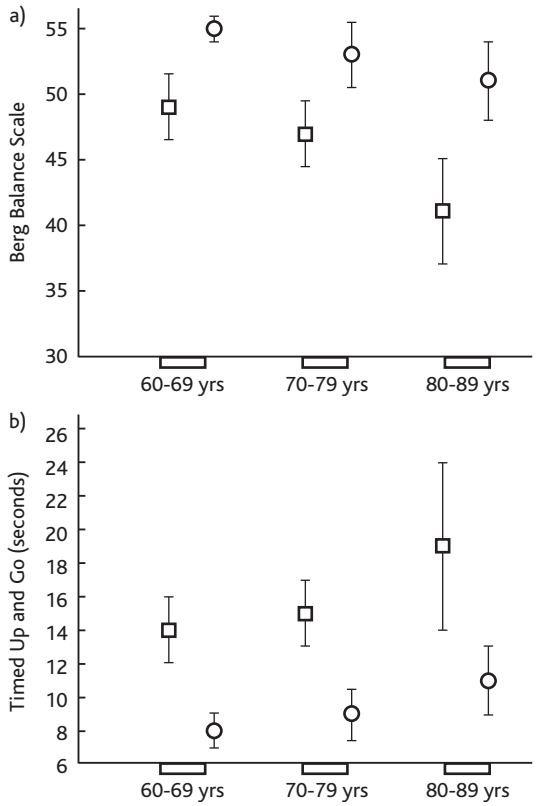
Study	Sample	Key outcomes	Key findings
Grant et al. 1982 [27]	203 patients with advanced hypoxemic COPD (PaO_2 51 mm Hg), age 66 yrs; 74 controls, age 64 yrs.	Measures of coordination from Halstead-Reitan Test Battery including a tactual performance test and the tapping test. Grooved pegboard test.	Impaired perceptual-motor integration, motor dexterity and coordination in COPD vs. controls.
Butcher et al. 2004 [7]	30 COPD (FEV_1 38% predicted), age 71 yrs; 21 controls, age 68 yrs.	Finger-to-nose test Toe Tap Timed Up and Go Posturography Community Balance and Mobility Scale.	Deficits in functional balance and coordination in COPD compared to controls. Increased sway for eyes open, moving platform test.
Eisner et al. 2008 [9]	1,202 COPD (FEV_1 62% predicted), age 58 yrs; 302 age, sex and race matched controls.	Standing balance task from Short Physical Performance Battery. Functional Reach Test.	Poorer performance on standing balance task and functional reach in COPD vs. controls.
Chang et al. 2008 [8]	19 COPD (FEV_1 46% predicted), age 69 yrs.	Timed Up and Go and postural sway in quiet stance following a 6MWT.	Static balance in semi-tandem stance with eyes closed impaired after a sub-maximal exercise test.
Beauchamp et al. 2009 [6]	39 COPD (FEV_1 42% predicted) age 71 yrs.	Berg Balance Scale Timed Up and Go (TUG) and History of Falls.	Worse balance performance on Berg and TUG compared to age-matched reference values. Impaired balance in fallers vs. non-fallers with COPD.
Smith et al. 2010 [11]	12 COPD (FEV_1 33% predicted), age 65 yrs; 12 controls, age 64 yrs.	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.	Reduced balance in mediolateral direction and increased hip motion in COPD vs. controls.
Roig et al. [10]	20 COPD (FEV_1 47% predicted), age 72 yrs; 20 controls, age 68 yrs.	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.	Reduced scores on the SOT and more frequent "falls" in COPD vs. controls. No association between physical activity or muscle strength with balance deficits.

following exertion. Smith et al. compared postural sway as well as lumbar spine and hip movement in 12 people with severe COPD (FEV_1 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 (FEV_1 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 (FEV_1 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-

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.



From [6], with permission.

tute 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

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

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

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.

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References

1. Ries AL, Bauldoff GS, Carlin BW, Casaburi R, Emery CF, Mahler DA, Make B, Rochester CL, Zuwallack R, Herrerias C. Pulmonary Rehabilitation: Joint ACCP/AACVPR Evidence-Based Clinical Practice Guidelines. Chest 2007;131(5 Suppl):4S-42S.
2. Lopez AD, Shibuya K, Rao C, Mathers CD, Hansell AL, Held LS, Schmid V, Buist S. Chronic obstructive pulmonary disease: current burden and future projections. Eur Respir J 2006;27:397-412.
3. Global Strategy for the Diagnosis, Management and Prevention of COPD. 2007 [cited 2008 11/05]; http://www.goldcopd.org.
4. Skeletal muscle dysfunction in chronic obstructive pulmonary disease. A statement of the American Thoracic Society and European Respiratory Society. Am J Respir Crit Care Med 1999;159:S1-40.
5. Maltais F, LeBlanc P, Jobin J, Casaburi R. Peripheral muscle dysfunction in chronic obstructive pulmonary disease. Clin Chest Med 2000;21:665-677.
6. Beauchamp MK, Hill K, Goldstein RS, Janaudis-Ferreira T, Brooks D. Impairments in balance discriminate fallers from non-fallers in COPD. Respir Med 2009;103:1885-1891.
7. Butcher SJ, Meshke JM, Sheppard MS. Reductions in functional balance, coordination, and mobility measures among patients with stable chronic obstructive pulmonary disease. J Cardiopulm Rehabil 2004;24:274-280.
8. Chang AT, Seale H, Walsh J, Brauer SG. Static balance is affected following an exercise task in chronic obstructive pulmonary disease. J Cardiopulm Rehabil Prev 2008;28:142-145.
9. Eisner MD, Blanc PD, Yelin EH, Sidney S, Katz PP, Ackerson L, Lathon P, Tolstykh I, Omachi T, Byl N, Iribarren C. COPD as a systemic disease: impact on physical functional limitations. Am J Med 2008;121:789-796.
10. Roig M, Eng J, MacIntyre D, et al. Postural control is impaired in people with COPD: an observational study. Physiotherapy Canada In press.
11. Smith MD, Chang AT, Seale HE, Walsh JR, Hodges PW. Balance is impaired in people with chronic obstructive pulmonary disease. Gait Posture 2010;31:456-460.
12. Guideline for the prevention of falls in older persons. American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopaedic Surgeons Panel on Falls Prevention. J Am Geriatr Soc 2001;49:664-672.
13. Bueno-Cavanillas A, Padilla-Ruiz F, Jimenez-Moleon JJ, Peinado-Alonso CA, Gálvez-Vargas R. Risk factors in falls among the elderly according to extrinsic and intrinsic precipitating causes. Eur J Epidemiol 2000;16:849-859.
14. Wild D, Nayak US, Isaacs B. Prognosis of falls in old people at home. J Epidemiol Community Health 1981;35:200-204.
15. Lawlor DA, Patel R, Ebrahim S. Association between falls in elderly women and chronic diseases and drug use: cross sectional study. BMJ 2003;327:712-717.
16. Roig M, Eng JJ, Macintyre DL, Road JD, Fitzgerald JM, Burns J, Reid WD. Falls in people with chronic obstructive pulmonary disease: An observational cohort study. Respir Med 2010; [Epub ahead of print].
17. O'Loughlin JL, Boivin JF, Robitaille Y, Suissa S. Falls among the elderly: distinguishing indoor and outdoor risk factors in Canada. J Epidemiol Community Health 1994;48:488-489.
18. Shumway-Cook A, Woollacott M. Motor Control Translating Research into Clinical Practice. Philadelphia: Lippincott Williams and Wilkins, 2007, 3rd ed.
19. Maki BE, McIlroy WE. Control of rapid limb movements for balance recovery: age-related changes and implications for fall prevention. Age Ageing 2006;35(Suppl.2):ii12-ii18.
20. Horak F, Macpherson J. Postural orientation and equilibrium. In: Smith J, ed. Handbook of Physiology. Exercise. Regulation and Integration of Multiple Systems. New York: Oxford, 1996:255-292.
21. Berg KO, Wood-Dauphinee SL, Williams JI, Maki B. Measuring balance in the elderly: validation of an instrument. Can J Public Health 1992;83(Suppl 2):S7-11.
22. Lajoie Y, Gallagher SP. Predicting falls within the elderly community: comparison of postural sway, reaction time, the Berg balance scale and the Activities-specific Balance Confidence (ABC) scale for comparing fallers and non-fallers. Arch Gerontol Geriatr 2004;38:11-26.
23. Finch E, Brooks D, Stratford P, Mayo NE. Physical rehabilitation outcome measures: a guide to enhanced clinical-decision-making. Hamilton: Canadian Physiotherapy Association. 2002;320. 2nd ed.
24. Tyson SF, Connell LA. How to measure balance in clinical practice. A systematic review of the psychometrics and clinical utility of measures of balance activity for neurological conditions. Clin Rehabil 2009;23:824-840.
25. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991;39:142-148.
26. Alexander N. Using technology-based techniques to assess postural control and gait in older adults. Clin Geriatr Med 1996;12:725-744.
27. Grant I, Heaton RK, McSweeny AJ, Adams KM, Timms RM. Neuropsychologic findings in hypoxemic chronic obstructive pulmonary disease. Arch Intern Med 1982;142:1470-6.
28. Maki BE, Holliday PJ, Topper AK. A prospective study of postural balance and risk of falling in an ambulatory and independent elderly population. J Gerontol 1994;49:M72-84.
29. Steffen TM, Hacker TA, Mollinger L. Age- and gender-related test performance in community-dwelling elderly people: Six-Minute Walk Test, Berg Balance Scale, Timed Up & Go Test, and gait speeds. Phys Ther 2002;82:128-37.
30. Roig M, Eng JJ, Road JD, Reid WD. Falls in patients with chronic obstructive pulmonary disease: a call for further research. Respir Med 2009;103:1257-1269.
31. Beauchamp MK, O'Hoski S, Goldstein RS, Brooks D. Effect of pulmonary rehabilitation on balance in persons with chronic obstructive pulmonary disease. Arch Phys Med Rehabil 2010;91:1460-1465.