Original Article:

Submaximal Exercise Task Post Clinical Balance in COPD Patients and its Correlation with Quadriceps Girth, Body Mass Index and Disease Severity

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Abstract

Purpose: To study and compare the effect of submaximal exercise on static and dynamic balance in patients with severe and moderate chronic obstructive pulmonary disease (COPD) and correlation of the balance impairments with disease severity, quadriceps girth and body mass index (BMI).

Methods: A sample of convenience of 45 middle aged participants (mean age 53.47 ± SD 4.775), including 15 with severe COPD, 15 with moderate COPD who were not undergoing pulmonary rehabilitation program and 15 healthy controls were included. The subjects performed Timed Up and Go Test (TUG) for dynamic balance and quiet standing to assess postural sway using sway meter with eyes closed and opened in narrow, semi tandem and tandem stance for 30 seconds. The balance variables were then correlated to forced expiratory volume in one second (FEV1), quadriceps girth and body mass index. Significance was set at alpha less than 0.05.

Results: when compared to healthy controls, significant differences were found in postural sway in all the stances in severe COPD patients, and in semi tandem and tandem stances in moderate COPD patients. TUG test significantly differed in both severe and moderate COPD (p=0.0001) and no difference between severe and moderate COPD TUG test was found. Moderate negative correlation was found between FEV1 and postural away in few stances whereas no correlation was found with quadriceps girth and BMI of COPD patients.

Conclusion: Static as well as dynamic balance are affected in COPD patients with postural sway affected more in severe COPD than moderate COPD leading to functional disability and risk of falls which increases with increase in age. Balance alterations can be moderately correlated to FEV1.

Keywords*: Chronic Obstructive Pulmonary Disease, submaximal exercise, state and dynamic balance, anteroposterior sway, mediolateral sway, total sway, Timed Up and Go test, Quadriceps girth, Body Mass Index, FEV1.*

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Introduction

The detriments of peripheral muscle weakness have been noted in chronic obstructive pulmonary disease (COPD) along with hypoxia and hypercapnia, due to systemic manifestations. This extra pulmonary manifestation of has found to be associated with reduced functional mobility and exercise tolerance and deficits in

simple motor movement[1,2]. Thus, along with exertional dyspnea being the main factor for functional limitation peripheral muscle strength also contributes for the same, lower limb being more affected than upper limb[1]. Quadriceps myopathy is the most recognized characters of COPD coma resulting to two functional dysfunction which is a result of systemic inflammatory response and inactivity[3,4]. some studies have shown that myopathy is known to contribute to neurological abnormalities in patient in critical care unit and also that hypoxia effects motor coordination and postural control at high altitude and does they may have a similar effect in patient with hypoxic COPD[1,5,6].

Balance is an important component for performing activities of daily life and for being functionally independent. Recent evidences have stated that balance impairment is observed in elder COPD patients. Even balance assessment proved effective in the fallers from non-fallers in elder COPD. Evidence have stated that static balance is affected serious stable COPD following submaximal exercise task. But no studies have been performed to know the differences between moderate and severe COPD and how far quadriceps girth which has found to be reduced in COPD patients due to god resets myopathy is related to balance. Few researchers have studied the effect of body mass index BMI on postal balance but not in BD population. The aim of this study is to compare static and dynamic balance of senior and moderate COPD patients and to correlate it with quadriceps girth, BMI and forced expiratory volume in one second (FEVI) in middle age see OPD so that some of the aging effects on balance can be excluded and balance impairments can be well associated with the disease condition.

Methods

45 participants falling in the age group of 45 to 60 years (mean age 53.47+- SD 4.775) were recruited including 15 with stable severe COPD (mean FEVI =41.27), 15 stable moderate COPD mean FEVI= 68.33) and 15 healthy controls from the outpatient department of Lala Ram Swaroop TB and Respiratory Medicine Institute. Patients were excluded if they had a history of major exacerbation in past one month. Major orthopedics condition, mobility limiting arthritis, neuromuscular condition[1,7], unstable angina, myocardial infarction and hypertension[8], any pain (either localized or general) or any conditions affecting low back or lower limb[7], cognitive impairment[1], vestibular disorders[1,7], tuberculosis, other lung diseases other than COPD[1,7]. A through explanation of the procedure was performed and possible risks and benefits were explained. Written informed consent was obtained from each participant, with ethical clearance from the Research Ethical Committee of Lala Ram Swaroop Institute of TB and Respiratory Care, New Delhi.

Measurement:

The pre exercise baseline measurement of breathlessness using Brogs Dyspnoea scale, baseline oxygen saturation and baseline heart rate was measured after enrolling the participant in the study. Quadriceps girth was also measured prior to the test using cloth measuring tape taking lateral joint as a point from which girth was measured at two different levels 10 cm and 20 cm for both the limbs[9]. Static balance was measured by assessing postural sway in the three validated stances, narrow, semitandem and tandem[10] i.e. with increasing level of difficulty, with both eyes open and eyes closed using an instrument called "Swaymeter". It consists of a pair of graduated ruler's oriented perpendicular to each other and fixed upon a stand. It measures the displacement of the body at the level of the waist in anteroposterior, mediolateral direction and total sway in all the stances with the increasing level of their difficulty through the pen attached to a stand together, which is fixed with a belt[11]. Patient were asked to stand for 30 seconds in narrow stance with both the feet together, semi tandem stance with the big toe of one foot placed at the side of the heel of the other foot and tandem stance with the big toe of one foot touching the heel of the foot placed ahead of it.

TUG test was performed to assess dynamic balance as well as functional mobility. Subjects were instructed to start by sitting on a chair, which was kept constant (46cm) for all the patients and on the word go to stand up, walk 3m, turn around, walk back to the chair, and sit down. Time was calculated from the time the pelvis was lifted to the time it was placed back on the chair. For older adults, completing the task in 7 to 9 seconds is low risk of hampered dynamic balance which may lead to falls, moderate risk in 10 to 12 seconds, and high risk

in 13 seconds or more[12]. The order of balance measures was randomized full stop the measurements obtained through the procedure was then correlated to quadriceps girth, FEVI and body mass index of the patients with COPD in order to obtain the relationship between balance and these variables.

Statistical Analysis

Analysis was performed using SPSS software version 15.0. the paired t test was applied for within subject dependent variable. As multiple groups were taken, a post hoc analysis was performed using tukey test to compare the difference between each reading. An alpha value of 5% was set for finding the significant difference. Pearson's r correlation analysis was used to determine the correlation of quadriceps girth, BMI and FEVI with static and dynamic balance.

Results

The demographic characteristics of the patients are presented in table 1. All three groups did not differ significantly with respect to age. The Spirometry results showed significant difference in FEV1 among all the three groups. Dyspnea increased on 20 point Borg scale to 10.78 +-2.476 post task as compared to pre task mean rating of 8.84 +- 2.335.

Table 1: demographic data of the participants

Variable	Severe COPD	Moderate COPD	Healthy Control	Total
Age, Yrs	54.87 ± 4.984	53.27 ± 4.480	51.85 ± 5.04	53.47 ± 4.775
BMI	19.3 ± 1.70	18.97 ± 2.374	24.76 ± 2.421	21.573 ± 3.494
QG	31.93 ± 1.981	33.73 ± 3.081	40.85 ± 1.908	35.6 ± 4.658
FEV1 % predicted	41.27 ± 6.33	68.33 ± 8.764	95 ± 5.099	67.51 ± 23.6

Effect of exercise on TUG test:

Significant differences was found between severe and healthy control (p =0.0001) and between moderate and healthy controls (p =0.0001). No difference was found in tea UG performance between severe and moderate COPD (p=0.4).

Effect of exercise on postural sway:

Table 2: Post Hoc Tukey Analysis results severe COPD to healthy controls in marrow, semitandem and tandem stance in eyes closed AP, ML and total sway.

Variables	Sev- con	Variables	Sev- con	Variables	Sev- con
	P		P		P
Prenarrowecap	0.043*	Prenarrowecml	0.154	Prenarrowectt	0.078
postnarrowecap	0.010*	Postnarrowecml	0.001*	Postnarrowectt	0.0001*

Presemitanecap	0.042*	Presemitanecml	0.005*	Presemitanectt	0.006*
Postsemitanecap	0.0001*	Postsemitanecml	0.0001*	Postsemitanectt	0.010*
Pretandemecap	0.018*	Pretandemecml	0.0001*	Pretandemectt	0.039*
posttandemecap	0.0001*	Posttandemecml	0.0001*	posttandemectt	0.000*

Sev- severe COPD; cont- healthy controls; ec- eyes closed; eo- eyes open;
Semitan-semitandem stance; ap – anteroposterior sway; ml- mediolateral sway

Eyes open:

Mean increase in anterior posterior by 1.05, mediolateral (ML) by 2.15cm as well as total sway by 3.22 cm was found in narrow stance in severe COPD patients. Mediolateral as well as total sway was found to be affected in all the remaining stances in COPD patients given in table 2, 3, 4, 5. Mediolateral (p=0.0001) and total sway was found to be affected in moderate COPD patients in tandem stance (p=0.024). Healthy controls also show significant difference in mediolateral sway (p=0.004) and total sway (p=0.02) in tandem stance.

Eyes closed:

According to the post hoc tukey analysis, severe COPD patients showed increase anteroposterior sway, medial lateral sway and total sway in all narrow, tandem and semi tandem stances as compared to healthy controls (table 2, 3, 4, 5). However moderate COPD patients showed increased mediolateral sway in semi tandem stance (p=0.003) and anteroposterior sway (p=0.001) and mediolateral sway in tandem stance (p=0.0001) significant difference in total sway in tandem stance (p=0.0001) was also found in moderate COPD patients.

Table 3: Narrow Stance

	Severe		**Moderate**		**Healthy**	
	Pre	**post**	**Pre**	**post**	**pre**	**post**
Eyes Open Total Sway	5cm	9cm	4.7cm	5cm	4cm	4cm
Eyes Closed AP Sway	3.7cm	4cm	3.0cm	3.7cm	3 cm	3cm
Eyes Open in AP Sway	3.0cm	4.0 cm	2.5cm	3.7cm	2cm	2cm
Eyes Open in ML Sway	3.2cm	4.0cm	2.7cm	3.6cm	1.8cm	1.8cm
Eyes Closed ML Sway	2.5cm	3.8cm	2.5cm	2.7cm	1.0cm	1.5cm

Table 4: Semi tandem Stance						
	Severe		Moderate		Healthy	
	pre	post	pre	post	pre	post
Eyes Open Total Sway	9cm	10cm	6.0cm	8.2cm	5.2cm	5.8cm
Eyes Closed AP Sway	8.7cm	9.5cm	7.0cm	8.0cm	6 cm	6cm
Eyes Open in AP Sway	4.0cm	4.5 cm	3.5cm	4.5cm	3cm	3.5cm
Eyes Open in ML Sway	5.2cm	6.0cm	3.7cm	4.5cm	3.5cm	3.5cm
Eyes Closed ML Sway	9.0cm	1.0cm	8.0cm	9.0cm	5.0cm	5.0cm
Eyes Closed in Total Sway	11cm	19.5cm	10cm	16cm	9.0cm	9.4cm

Table 5: Tandem Stance						
	Severe		Moderate		Healthy	
	pre	post	pre	post	pre	post
Eyes Open Total Sway	15cm	19cm	16cm	18cm	10.2cm	10.8cm
Eyes Open in AP Sway	4.8cm	5.5 cm	5.0cm	6.0cm	3.5cm	3.5cm
Eyes Open in ML Sway	8.2cm	10cm	7.7cm	8.5cm	6.5cm	6.5cm
Eyes Closed in Total Sway	21cm	22cm	18cm	20.2cm	10cm	10cm

Correlation analysis:

Pearson's correlation showed moderate negative correlation was obtained FEV1 and postural sway in four stances ML sway in eyes open (r= -0.473,p ,=0.008) and closed (r =-0.394, p =0.03) in narrow stance, semi tandem and tandem stance (r= -522, p=0.003). Correlation analysis was done within 30 COPD patients. No significant correlation was obtained between quadriceps girth, BMI and balance.

Discussion

The purpose of this study was to assess and compare the effects of submaximal exercise task on postural balance, including both static and dynamic balance in COPD patients as compared to healthy controls in the middle aged individuals and to correlate the balance with FEV1, Quadriceps girth and Body Mass Index. The results found significant differences in dynamic balance of severe and moderate as compared to healthy individuals. Total postural sway was found to be affected from normal to challenging stances in severe COPD patients whereas mediolateral sway was only found to be affected in moderate COPD in challenging stances like semi tandem and tandem with more significant differences found in eyes closed stances than eyes open ones. Moderate negative correlation was found between FEV1 and postural sway in four of the total stances indicating inverse relationship between FEV1 and postural sway. This study was design to compare the balance between moderate and severe COPD in middle age population so that some of the effects of aging on

balance which is usually found above 60 years, based on the evidences[13–16], can be excluded.

Simple inexpensive, reliable and valid test like TUG test[7,17–19] for dynamic balance and postural sway through sway meter[7,11,20] were used to assess balance which can be easily and economically available and used in clinical settings. The alteration in balance as interpreted from the study, can be considered as a consequence of either muscle fatigue which would have occurred due to an exercise task[7,21,22]. Increase in sway especially mediolateral has been reported in challenging positions in normal individual[7], however according to the findings of this study COPD were found to have alterations in balance in even in normal narrow stance and less challenging semi tandem stance as well as showed increased time to complete TUG test. One of the reasons for this may be Quadriceps myopathy since noticeable decreased girth was found in both severe and moderate COPD as compared to healthy controls. Evidence have stated that weak quadriceps muscle is related to postural imbalance and leads to increase postural sway which poses the risk of falls[13,20]. But since the fatigue and muscle strength was not assessed in this study, and no significant correlation was obtained between girth and balance, it cannot be clearly explained from this point of view.

After contributing factor for an altered balance can be breathlessness since evidences have stead that hypoxia can lead to altered postural balance[5,6]. According to Killian and Campbell[23], as COPD progresses, respiratory muscles have to generate increased pressures to maintain an adequate ventilatory thresh hold resulting in increased dyspnea. Few evidences have shown that myopathy is known to contribute to neurological abnormalities in patient in critical care units and you have stated that hypoxia effects motor coordination and postural control at high altitudes and does they may have a similar effect in patient with hypoxic COPD[1,5,6]. Even the disease severity it was found to be significantly correlated to postural sway in few variables in this study and evidences signifies the relationship between disease severity and postural balance[1,24]. More clear results would have obtained if large sample size was taken for correlation. Does the reason for altered postural control in COPD can be thought to be related to disease severity as well as consequences of pulmonary and systemic manifestation in leading to hypoxia and quadriceps myopathy which needs to be further assessed using reliable and accurate measures.

Balance impairment: risk of fall and disability.

Studies have reported that increased CWE is associated with increased fall risk in an individual[13,25]. Maki and lagoie et al has stated that increased lateral sway is the single best predictor of future following risk in his study on elder population[16,26]. However peterka et al in his study of subjects ranging from 7 to 81 years stated that patient greater than 55 years shows significant greater and posterior sway which poses them to risk of fall[14]. Similar findings were found by laughton et al[26,27] who stated that followers displayed increased a peace way full stop in the study done by Angela at al and Scott et al in COPD patients increased mediolateral and total survey was demonstrated which was considered to hamper the activities of daily life of PD patients and causes them to the risk of falls[1,7]. Beauchamp et al performed a study to discriminate followers from no followers in using balance measures and found that followers have altered static and dynamic balance the current study supports these findings indicating functional this ability and risk of falls are associated with COPD which increases with CVR 80 of the disease[25]. Thus the key findings of this study show that severe COPD patients are more affected and have greater balance impairments than moderate COPD patients as compared to healthy controls this can hamper their functional activities and can lead to functional disability. Even moderate see OPD faces balance issues not as significant as severe ones, but are post to risk of falls and functional ability to sense lateral balance is found to be affected during challenging activities. TUG test that assess dynamic or walking balance was found to be significantly affected in both the groups and was falling in the range of high risk of fallers with a mean of greater than 16 seconds for both groups[28]. This altered dynamic balance reflects a reduced ability while maintaining a standing posture and while performing a potentially destabilizing and challenging activities[11].

Limitations:

Use of force plates to record center of pressure excursions or posturography techniques can give more accurate result for the assessment of balance since the

readings obtained from Swaymeter was more manual though it has been validated against force plates[8]. Small sample size and convenient sampling used was another limitation in the study.

Future studies can be done correlating quadriceps strength and endurance in COPD patients with balance. Balance impairment was only assessed in this study, but the time for which these balance alteration remains following an exercise task can be assessed in future research which can help in exercise prescription. Further research can be done to assess the effect of balance training in COPD.

Conclusion

Static as well as dynamic balance are affected in COPD patients with postural sway affected from normal to challenging stances in severe COPD patients. Moderate COPD patients also faces balance deficits but in more challenging and destabilizing conditions as compared to severe ones. Thus balance impairments should be assessed while enrolling the COPD patient pulmonary rehabilitation program to control the factors like disability, falls etc. associated with balance deficits. Balance alterations may be inversely related to FEV1.

Informed patient consent: Participants recruited in the study signed the informed patient consent forms, and these forms are secured securely at the site of the study.

Author's contribution: All the authors led to the creation and design of the study. All the authors read and approved the final manuscript for publication.

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References

1. Butcher SJ, Meshke JM, Sheppard MS. Reductions in functional balance, coordination, and mobility measures among patients with stable chronic obstructive pulmonary disease. *J Cardpulm Rehabil*. 2004;24(4):274-280. doi:10.1097/00008483-200407000-00013
2. Bernard S, LeBlanc P, Whittom F, et al. Peripheral muscle weakness in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med*. 1998;158(2):629-634. doi:10.1164/ajrccm.158.2.9711023
3. Polkey M. Peripheral muscle weakness in COPD: where does it come from? *Thorax*. 2003;58(9):741-742. doi:10.1136/thorax.58.9.741
4. Debigaré R, Maltais F. The major limitation to exercise performance in COPD is lower limb muscle dysfunction. *J Appl Physiol Bethesda Md 1985*. 2008;105(2):751-753; discussion 755-757. doi:10.1152/japplphysiol.90336.2008a
5. Fraser WD, Eastman DE, Paul MA, Porlier JA. Decrement in postural control during mild hypobaric hypoxia. *Aviat Space Environ Med*. 1987;58(8):768-772.
6. Nordahl SH, Aasen T, Owe JO, Molvaer OI. Effects of hypobaric hypoxia on postural control. *Aviat Space Environ Med*. 1998;69(6):590-595.
7. 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(2):142-145. doi:10.1097/01.HCR.0000314209.17300.cc
8. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS statement: guidelines for the six-minute walk test. *Am J Respir Crit Care Med*. 2002;166(1):111-117. doi:10.1164/ajrccm.166.1.at1102
9. Reina-Bueno M, Lafuente-Sotillos G, Castillo-Lopez JM, Gomez-Aguilar E, Munuera-Martinez PV. Radiographic Assessment of Lower-Limb Discrepancy. *J Am Podiatr Med Assoc*. 2017;107(5):393-398. doi:10.7547/15-204
10. Freeman EE, Broman AT, Turano KA, West SK, SEE Project. Motion-detection threshold and measures of balance in older adults: the SEE Project. *Invest Ophthalmol Vis Sci*. 2008;49(12):5257-5263. doi:10.1167/iovs.07-1106
11. Hinman RS, Bennell KL, Metcalf BR, Crossley KM. Balance impairments in individuals with symptomatic knee osteoarthritis: a comparison with matched controls using clinical tests. *Rheumatol Oxf Engl*. 2002;41(12):1388-1394. doi:10.1093/

rheumatology/41.12.1388

12. Kear BM, Guck TP, McGaha AL. Timed Up and Go (TUG) Test: Normative Reference Values for Ages 20 to 59 Years and Relationships With Physical and Mental Health Risk Factors. *J Prim Care Community Health*. 2017;8(1):9-13. doi:10.1177/2150131916659282
13. Hytönen M, Pyykkö I, Aalto H, Starck J. Postural control and age. *Acta Otolaryngol (Stockh)*. 1993;113(2):119-122. doi:10.3109/00016489309135778
14. Talbot LA, Musiol RJ, Witham EK, Metter EJ. Falls in young, middle-aged and older community dwelling adults: perceived cause, environmental factors and injury. *BMC Public Health*. 2005;5:86. doi:10.1186/1471-2458-5-86
15. Davis A, McMahon CM, Pichora-Fuller KM, et al. Aging and Hearing Health: The Life-course Approach. *The Gerontologist*. 2016;56 Suppl 2:S256-267. doi:10.1093/geront/gnw033
16. 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(2):M72-84. doi:10.1093/geronj/49.2.m72
17. Cattaneo D, Regola A, Meotti M. Validity of six balance disorders scales in persons with multiple sclerosis. *Disabil Rehabil*. 2006;28(12):789-795. doi:10.1080/09638280500404289
18. Chaabene H, Negra Y, Capranica L, et al. Validity and Reliability of a New Test of Planned Agility in Elite Taekwondo Athletes. *J Strength Cond Res*. 2018;32(9):2542-2547. doi:10.1519/JSC.0000000000002325
19. Thrane G, Joakimsen RM, Thornquist E. The association between timed up and go test and history of falls: the Tromsø study. *BMC Geriatr*. 2007;7:1. doi:10.1186/1471-2318-7-1
20. Sturnieks DL, Tiedemann A, Chapman K, Munro B, Murray SM, Lord SR. Physiological risk factors for falls in older people with lower limb arthritis. *J Rheumatol*. 2004;31(11):2272-2279.
21. Helbostad JL, Sturnieks DL, Menant J, Delbaere K, Lord SR, Pijnappels M. Consequences of lower extremity and trunk muscle fatigue on balance and functional tasks in older people: A systematic literature review. *BMC Geriatr*. 2010;10:56. doi:10.1186/1471-2318-10-56
22. Gribble PA, Hertel J. Effect of lower-extremity muscle fatigue on postural control. *Arch Phys Med Rehabil*. 2004;85(4):589-592. doi:10.1016/j.apmr.2003.06.031
23. Hassan B, Mockett S, Doherty M. Static postural sway, proprioception, and maximal voluntary quadriceps contraction in patients with knee osteoarthritis and normal control subjects. *Ann Rheum Dis*. 2001;60(6):612-618. doi:10.1136/ard.60.6.612
24. Kearon MC, Summers E, Jones NL, Campbell EJ, Killian KJ. Effort and dyspnoea during work of varying intensity and duration. *Eur Respir J*. 1991;4(8):917-925.
25. 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(12):1885-1891. doi:10.1016/j.rmed.2009.06.008
26. Laughton CA, Slavin M, Katdare K, et al. Aging, muscle activity, and balance control: physiologic changes associated with balance impairment. *Gait Posture*. 2003;18(2):101-108. doi:10.1016/s0966-6362(02)00200-x
27. 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(1):11-26. doi:10.1016/s0167-4943(03)00082-7
28. Bradley PS, Olsen PD, Portas MD. The effect of static, ballistic, and proprioceptive neuromuscular facilitation stretching on vertical jump performance. *J Strength Cond Res*. 2007;21(1):223-226. doi:10.1519/00124278-200702000-00040