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FACTORS AFFECTING BALANCE IN CHRONIC OBSTRUCTIVE PULMONARY DISEASE

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ABSTRACT

Background: A balance deficit has been identified as an important factor in COPD. Balance being affected in Chronic Obstructive Pulmonary Disease (COPD) is generally accepted. However, determining the cause of impaired balance in COPD patients has not been directly investigated. Thus, this study aimed at finding out the underlying cause of balance deficits in COPD.

Methods: A total of 48 patients(38-male, 10-female) aged 40-65 years, with COPD, diagnosed clinically and by Spirometry were compared with 39 healthy non-COPD controls matched for age, BMI and nationality. The functional balance (Brief-Balance Evaluation Systems Test and Berg Balance Scale), respiratory muscle strength (maximal inspiratory pressure and maximal expiratory pressure), lower limb muscle strength (repeated chair stand test), functional capacity (6-minute walk test) and BODE index were assessed in COPD cases and control group.

Results: A significant difference was observed in all the components between COPD and healthy controls. In moderate COPD a significant corelation was found between brief BES Test & PE max (p=0.017) and in severe COPD a significant corelation was found between brief BES Test & Anterior sway with eye open (p=0.005).

Conclusions: The findings indicate that balance is impaired in COPD which may increase the chances of falls. There is a need for future research to evaluate the role of COPD specific balance training as a comprehensive management of patients with COPD.

Keywords: COPD, Balance, Peripheral muscle strength, respiratory muscle strength, functional capacity, BODE index.

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INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is primarily a pulmonary disease and globally, a principal cause of morbidity and mortality. The disease itself has an economic and social burden that is both substantial and increasing. The growing burden of the disease will be projected as the fourth leading cause of death by the year 2030 [1]. Studies have proved that the overall prevalence of COPD in India is to be 4.36% where the occurrence among males and females was 5.32% and 3.41% respectively [2]. Recently, in past ten years its extra-pulmonary manifestations are increasing and are recognized as contributing to the severity of the disease. It was seen that some of the extra-pulmonary manifestations such as loss of weight, muscle dysfunction (respiratory and peripheral muscles) osteoporosis, cardiovascular diseases, anemia, depression, and anxiety were also present in patients of COPD [3]. Some authors also suggested several factors that have been identified to contribute to peripheral muscle changes including airflow obstruction, disuse, oxidative stress, hypoxia, malnutrition, systemic inflammation, and medication [4].

It was suggested that to maintain postural control in COPD patients, both static and dynamic posture, sensory, musculoskeletal and neural components should work in all together. A study showed deficits in balance or postural control both in static and dynamic postures in COPD. [5] Studies also proposed several mechanisms for a reduced level of postural control and increased fall risk in COPD with decreased level of physical activity [6] peripheral muscle weakness [10] altered trunk muscle mechanics [9] and Somatosensory deficits. [10] Many studies had reported impairment in functional balance, mobility, postural sway [7], functional capacity [11], upper and lower limb muscle strength [5] and static postural control [7] in moderate to severe COPD. [6] Though within the physiotherapy it is yet to find which factor affects the balance primarily to focus on impaired balance-related rehabilitation in patients of COPD.

Thus with this point of view, this paper will discuss the factors affecting balance in patients of a chronic obstructive pulmonary disease so that a COPD specific balance rehabilitation protocol would be designed in future studies.

Therefore, this paper aimed to identify the relationship between balance and respiratory muscle strength, functional capacity, BODE Index, postural control and lower limb muscular strength in COPD patients as compared with age and BMI matched healthy subjects.

METHODOLOGY

The study is a case-control study of nature. The permission to conduct the research was taken from ethical committee of the Indian Spinal Institute Center - Institute of rehabilitation sciences and National institute of tuberculosis and respiratory disease, New Delhi.

A total of 48 COPD patients (38-male, 10-female) aged between 45-65 years, and BMI matched 39 healthy controls were added after meeting the inclusion criteria of diagnosed stable, moderate and severe COPD as per GOLD guidelines updated in 2016 [1], and those who maintained saturation at room air above 90% were included in both groups. Eligible patients were informed and provided with a patient information sheet. Before the baseline evaluation, written consent was taken from the participants. If the participant presented with diagnosed pulmonary conditions other than COPD or any other disease were excluded, other exclusion criteria included were; Patients using invasive & non-invasive mechanical ventilation [2]. Any diagnosed visual or vestibular deficits that could affect postural control. [3] Any participant with dyspnoea at rest. [4] Cognitive impairment. Evaluation of functional balance, postural sway, respiratory muscle strength (PImax & PEmax), and lower limb muscle strength, functional activity, Pulmonary functions and BODE index was done.

Pulmonary function results were obtained through Spirometry followed by evaluation of respiratory muscle strength using pressure manometer in both COPD and controls. Each subject underwent a clinical balance performance test and test for lower limb muscle strength. Postural sway and functional capacity were measured by sway meter and six-minute walk test respectively.

Clinical balance measures

Clinical balance tests included the Brief- Balance Evaluation Systems Test (Brief-BESTest) and Berg Balance Scale (BBS). The Brief-BESTest was created from 6 items of the BESTest, 1 from each section, with 2 items (single-leg stance and functional forward reach) being scored bilaterally, resulting in an 8-item test. Brief- BESTest is defined by Timed "Up & Go test, push & release laterally, closed eye standing on foam, strength of hip abductor, functional reach and one-leg stance. Items are scored from 0 to 3, and the scores are summed to obtain a total score out of a possible maximum score of 24 points. Higher scores indicate better balance performance. Brief-BESTest demonstrated reliability comparable to that of the Mini-BESTest and potentially superior sensitivity while requiring half the items of the Mini-BESTest and representing all theoretically based sections of the original BESTest.[12] Berg balance scale (BBS) was developed to measure balance among older people with impairment in balance function by assessing the performance of functional tasks. It is a valid instrument used for evaluation of the effectiveness of an intervention and quantitative descriptions of function in clinical practice and research. The BBS consisted of 14 items that are scored on an ordinal scale of 0 to 4. A score of 0 is given if the participants are unable to do the task, and a score of 4 is given if the participants are able to complete the task. The maximum total score on the test is 56. The items vary from simple mobility tasks to complex ones. Time taken to complete the test is 15- 20 minutes. Individuals who score 41 -56 have low fall risk; 21-40 have medium fall risk and 0 -20 have high fall risk. [13]

Lower limb muscle strength

The test used of lower limb muscle strength was repeated chair stand test (number of sit-to-stands the subject can

complete in 30 s) was used as a measure of lower body strength. [14]

Postural sway

Sway meter was constructed with a 40-centimetre rod attached to a belt. One end is attached to anterior superior iliac spine and other to the pen which rests on a horizontal place at the level of anterior superior iliac spine. The sway meter was placed posterior to the subject so that the vision could be excluded. Subjects were asked to stand on the paper sheet with footprints. The distance between two feet would be around three inches. The graph sheet was placed behind the subject. The graph was levelled in such a way; the rod was maintained in horizontal position. The individuals were standing straight with their hands by their sides. The duration of each trial was 30 seconds. A starting point was marked on the graph sheet. The subjects were allowed to take rest of 5-10 seconds, after each trial. A total of six trials were done. The first three trials were done with eyes open and then three trials with eyes closed. The maximum duration of all trials was 6-7 minutes. A maximum deviation out of the trials was taken for analysis. [15]

Respiratory muscle strength testing

Maximal inspiratory pressure (PImax) and the maximal expiratory pressure (PEmax) measures the respiratory muscle strength. The PImax reflects the strength of the diaphragm and other inspiratory muscles, while the PEmax reflects the strength of the abdominal muscles & other expiratory muscles. [16]

Pulmonary functional test (PFT)

Spirometry was done to evaluate pulmonary function testing. To determine whether the patient has lung problems or not, PFT is performed which measures lung capacities. For spirometry, forced vital capacity (FVC) was measured by having the patient, after inspiring maximally, expire as forcefully and rapidly as possible into a Spirometer for a minimum of 6 seconds. After 3 acceptable FVC maneuvers have been obtained, the maneuvers with largest sum of FVC and forced expiratory volume at 1 s (FEV1) was selected for interpretation. [17]

Functional capacity

The six-minute walk test is being simple, valid, self-paced test to assess the submaximal level of functional capacity and is better tolerated & more representative of the activity of daily living. It requires 30 meter corridor for its implementation. Patients are instructed to rest 10 minutes before the test. Variables such as age, height, weight blood pressure, heart rate, respiratory rate, Sp02, dyspnea, and fatigue are measured before the test start, immediately after the test and after 5 minutes. [18]

BODE Index

BODE Index consists of four components that include body mass index (BMI), degree of airflow obstruction as measured by FEV1(O), dyspnea measured by MRC dyspnea scale (D) and exercise capacity measured by six-minute walk distance (E). These variables are incorporated into a multidimensional scale ranged from 0 (least risk) to 10 (highest risk). [19]

Statistical analysis

The statistical package SPSS version 20, Microsoft Excel 2007 was used to analyze the data where mean and standard deviation was derived. Independent sample t-tests were used to determine between-group differences for continuous variables. The data was grouped according to age into two groups consisting of patient aged between 40-55 years and 56-65 years old. The COPD group was also analysed into two groups - moderate and severe. Pearson's coefficient of correlation was used to determine the relationship between variables in COPD, moderate and severe groups. A probability level, $P < 0.05$ was used as the criterion for statistical significance.

RESULTS

A total number of 48 patients with moderate to severe COPD and 39 aged, BMI matched healthy controls were recruited in the study as per the inclusion and exclusion criteria. The baseline characteristics of both groups are provided in Table 1. The mean age in COPD was 55.39±6.50 years (range 40-65) and in control was 52.92±5.80 years (range 45-65) at p= 0.07. Compared with moderate COPD, the severe COPD group showed significant expiratory airflow limitation (p= 0.01) consistent with GOLD (Global initiative for chronic obstructive lung disease) guidelines updated, 2016. The healthy control subjects had normal spirometry and were well matched for age, height, weight, and BMI, which were found to be non-significant.

Table 1: Demographic details of COPD and Control group.

Characteristics	COPD N=48	Controls N=39	p-value
Age (years)	55.39±6.50	52.92±5.80	0.068
Height (cm)	160.47±7.43	160.00±8.23	0.77
Weight (kg)	56.52±8.97	58.94±9.28	0.22
BMI (kg/m^2)	21.86±2.54	22.92±2.37	0.05
	Moderate	Severe	
FEV_1% predicted	61.60±8.72	41.40±5.36	0.01*
FEV_1/FVC Observed	58.68±6.06	49.60±9.48	0.01*

* Level of significance < 0.05

Comparison between COPD and Control group regarding various parameters

Results from the clinical balance tests, functional capacity, respiratory muscle strength, postural sway, lower limb muscle strength, and BODE index are shown in table 2. Among COPD, lower Brief-BESTest and BBS scores, reduced six-minute walk distance, respiratory muscle strength, lower limb muscle strength, and increased BODE index were significant compared to the controls (all p= 0.01). There was no difference between groups in all components of postural sway except lateral sway with eye closed (p= 0.01)

Table 2: Comparison between COPD and Control group regarding various parameters

Variables	COPD N= 48	Range	Controls N= 39	Range	t-value	p-value
Brief-BESTest	17.60± 3.91	5 - 24 (19)	23.23± 0.84	21 - 24 (3)	-9.67	0.01*
BBS	53.29± 2.12	43 - 56 (13)	55.53± .68	53- 56 (3)	-6.9	0.01*
SMWD	388.95± 51.22	280 - 500 (220)	474.97± 58.49	367 - 600 (233)	-7.2	0.01*
PImax	71.33± 26.92	19 - 150 (131)	94.56± 20.86	42 - 148 (106)	-4.5	0.01*
PEMax	61.54± 20.90	22 - 134 (112)	78.94± 18.05	47 - 131 (84)	-4.16	0.01*
AEO	1.24± 0.62	0 - 2.70 (2.70)	1.02± 0.55	0 - 2.70 (2.70)	1.74	0.08
PEO	0.93± 0.65	0 - 2.60 (2.60)	0.83± 0.48	0 - 2.40 (2.40)	0.8	0.42
LEO	1.43± 0.63	.40 - 3.00 (2.60)	1.29± 0.74	.20 - 3.70 (3.50)	0.93	0.35
AEC	1.37± 0.65	0 - 3.10 (3.10)	1.09± 0.64	0 - 3.20 (3.20)	1.97	0.052
PEC	1.13± 0.60	.10 - 2.70 (2.60)	1.08± 0.60	.20 - 2.80 (2.60)	0.31	0.75
LEC	2.11± 0.96	.50 - 5.60 (5.10)	1.16± 0.60	.40 - 3 (2.60)	5.58	0.01*
LLMS	12.31± 1.89	9 - 17 (8)	15.87± 2.35	11 - 21 (10)	-7.64	0.01*
BODE Index	2.60± 1.36	0 - 5 (5)	0.64± 0.66	0 - 2 (2)	8.75	0.01*

* Level of significance < 0.05

Comparison between COPD and Control group regarding sub-component score of Brief-BESTest

Results from the sub-components of Brief-BESTest are shown in table 3. Among COPD biomechanical constraints, Stability limits, Transitions, Reactive postural responses, Sensory orientation, and Stability of gait were significantly lower compared to the controls (all p< 0.01).

Table 3: Comparison between COPD and Control group regarding sub-component score of Brief-BESTest

Variables	COPD N= 48	Range	Controls N= 39	Range	t-value	p-value
Boimechenical Constraints	1.6± 0.89	0 - 3 (3)	2.92± 0.27	2 - 3 (1)	-9.70	0.01*
Stability Limits	2.29± 0.50	1 - 3 (2)	2.64± 0.49	2 - 3 (1)	-3.28	0.01*
Left Transition	2.13± 0.82	0 - 3 (3)	2.92± 0.27	2 - 3 (1)	-6.37	0.01*
Right Transition	2.15± 0.80	0 - 3 (3)	2.95± 0.22	2 - 3 (1)	-6.65	0.01*
Left Reactive Postural Response	2.52± 0.71	0 - 3 (3)	2.97± 0.16	2 - 3 (1)	-4.27	0.01*
Right Reactive Postural Response	2.42± 0.77	0 - 3 (3)	2.9± 0.31	2 - 3 (1)	-3.97	0.01*
Sensory Orientation	2.35± 0.64	0 - 3 (3)	2.92± 0.27	2 - 3 (1)	-5.61	0.01*
Stability in Gait	2.15± 0.95	0 - 3 (3)	3± 0.00	3 - 3 (1)	-6.26	0.01*

* Level of significance < 0.05

Comparison between COPD and Control Group in the age of 40-55 years

Results from the clinical balance tests, functional capacity, respiratory muscle strength, postural sway, lower limb muscle strength, and BODE index are shown in table 4. Among COPD of age 40-55 years, lower Brief-BESTest and BBS score, reduced six-minute walk distance, lower limb muscle strength and increased BODE index were significant compared to the controls (all p≤ 0.01). Respiratory muscle strength was also reduced in COPD compared with controls (p≤ 0.02). There was no difference between groups in all the components of postural sway except lateral sway with eyes closed (p= 0.001).

Table 4: Comparison between COPD and Control Group in the age of 40-55 years

Variables	COPD N= 22	Range	Controls N= 23	Range	t-value	p-value
Brief-BESTest	18.59± 2.87	11 - 24 (13)	23.47± 0.79	21 - 24 (3)	-7.7	0.01*
BBS	53.40± 1.68	49 - 56 (7)	55.65± 0.57	54 - 56 (2)	-5.93	0.01*
SMWD	401.50± 54.77	280 - 500 (220)	490.82± 62.80	367 - 600 (233)	-5.09	0.01*
PImax	78.45± 27.99	41 - 150 (109)	94.39± 17.58	57 - 136 (79)	-2.29	0.02*
PEMax	60.27± 22.74	33 - 134 (101)	81.78± 19.54	55 - 131 (76)	-3.39	0.001*
AEO	1.00± 0.60	0 - 2.30 (2.30)	0.97± 0.51	0 - 2.70 (2.70)	0.15	0.87
PEO	1.02± 0.56	0 - 2.40 (2.40)	0.77± 0.49	0 - 1.90 (1.90)	1.57	0.12
LEO	1.54± 0.60	.40 - 2.60 (2.20)	1.23± 0.71	.30 - .70 (3.40)	1.54	0.13
AEC	1.25± 0.59	0 - 2.10 (2.10)	1.07± 0.68	.30 - 3.20 (2.90)	0.89	0.37
PEC	1.11± 0.64	.10 - 2.70 (2.60)	1.10± 0.59	.20 - 2.80 (2.60)	0.02	0.97
LEC	2.10± 1.09	.50 - 5.60 (5.10)	1.16± 0.56	.40 - 2.60 (2.20)	3.6	0.001*
LLMS	12.40± 1.94	9 - 17 (8)	16.17± 2.44	12 - 21 (9)	-5.73	0.01*
BODE Index	2.50± 1.56	0 - 5 (5)	0.47± 0.66	0 - 2 (2)	5.59	0.01*

* Level of significance < 0.05

Comparison between COPD and Control Group in the age of 56-65 years

Results from the clinical balance tests, functional capacity, and respiratory muscle strength, postural sway, lower limb muscle strength, and BODE index are shown in table 5. Among COPD of age 56-65 years, lower Brief-BESTest and BBS score, reduced six-minute walk distance, increased lateral sway with eyes closed, reduced lower limb muscle strength and increased BODE index was significant compared to the controls (all p≤0.01). Respiratory muscle strength was also reduced in COPD compared with controls (p≤ 0.04).There was no difference between groups in all the components of postural sway except lateral sway with eyes closed (p= 0.001).

Table 5: Comparison between COPD and Control Group in the age of 56-65 years

Variables	COPD N= 26	Range	Controls N= 16	Range	t-value	p-value
Brief-BESTest	16.76± 4.51	5 - 23 (18)	22.87± 0.80	22 - 24 (2)	-6.73	0.01*
BBS	53.19± 2.46	43 - 56 (13)	55.37± 0.80	53 - 56 (3)	-4.16	0.001*
SMWD	378.34± 46.44	300 - 480 (180)	452.18± 44.07	375 - 515 (140)	-5.16	0.01*
PImax	65.30± 24.94	19 - 123 (104)	94.81± 25.47	42 - 148 (106)	-3.67	0.001*
PEMax	62.61± 19.61	22 - 96 (74)	74.87± 15.34	47 - 112 (65)	-2.25	0.04*
AEO	1.45± 0.56	.70 - 2.70 (2)	1.09± 0.60	.20 - 2.40 (2.20)	1.95	0.058
PEO	0.86± 0.73	0 - 2.60 (2.60)	0.91± 0.46	.20 - 2.40 (2.20)	-0.27	0.78
LEO	1.34± 0.65	.40 - 3 (2.60)	1.38± 0.81	.20 - 3.50 (3.30)	-0.17	0.86
AEC	1.48± 0.69	.20 - 3.10 (2.90)	1.12± 0.61	0 - 1.90 (1.90)	1.67	0.1
PEC	1.14± 0.58	.30 - 2.40 (2.10)	1.06± 0.62	.20 - 2 (1.80)	0.44	0.66
LEC	2.11± 0.86	.60 - 3.90 (3.30)	1.16± 0.67	.40 - 3 (2.60)	3.98	0.001*
LLMS	12.23± 1.88	9 - 16 (7)	15.43± 2.22	11 - 18 (7)	-4.81	0.01*
BODE Index	2.69± 1.19	1 - 5 (4)	0.87± 0.61	0 - 2 (2)	6.48	0.01*

* Level of significance < 0.05

Comparison between Moderate COPD and Control group

Results from the clinical balance tests, functional capacity, respiratory muscle strength, postural sway, lower limb muscle strength and BODE index are shown in table 6. Among moderate COPD, Lower Brief-BESTest and BBS score, reduced six-minute walk distance, respiratory muscle strength, lower limb muscle strength, and increased BODE index was significant compared to the controls (all p= 0.01). There was no difference between groups in all components of postural sway except lateral sway with eye closed (p= 0.01)

Table 6: Comparison between Moderate COPD and Control group

Variables	Moderate N= 25	Range	Controls N= 39	Range	t-value	p-value
Brief-BESTest	18.36± 4.08	5 - 24 (19)	23.23± 0.84	21 - 24 (3)	-5.88	0.01*
BBS	53.24± 2.57	43 - 56 (13)	55.54± 0.68	53 - 56 (3)	-4.37	0.01*
SMWD	400.52± 49.95	310 - 500 (190)	474.97± 58.49	367 - 600 (233)	-5.43	0.01*
PImax	74.12± 32.05	35 - 150 (115)	94.56± 20.86	42 - 148 (106)	-2.82	0.01*
PEMax	63.68± 23.49	22 - 134 (112)	78.95± 18.05	47 - 131 (84)	-2.76	0.01*
AEO	1.21± 0.59	.10 - 2.70 (2.60)	1.03± 0.55	0 - 2.70 (2.70)	1.29	0.20
PEO	0.95± 0.73	0 - 2.60 (2.60)	0.84± 0.48	0 - 2.40 (2.40)	0.74	0.46
LEO	1.49± 0.63	.50 - 3 (2.50)	1.29± 0.75	.20 - 3.70 (3.50)	1.07	0.29
AEC	1.33± 0.66	.20 - 3.10 (2.90)	1.10± 0.65	0 - 3.20 (3.20)	1.40	0.17
PEC	1.13± 0.62	.10 - 2.40 (2.30)	1.09± 0.60	.20 - 2.80 (2.60)	0.25	0.81
LEC	2.23± 1.03	.60 - 5.60 (5)	1.16± 0.61	.40 - 3 (2.60)	4.69	0.01*
LLMS	12.32± 2.04	9 - 17 (8)	15.87± 2.35	11 - 21 (10)	-6.40	0.01*
BODE Index	1.84± 1.07	0 - 4 (4)	0.64± 0.67	0 - 2 (2)	5.02	0.01*

* Level of significance < 0.05

Comparison between Severe COPD and Control group

Results from the clinical balance tests, functional capacity, respiratory muscle strength, postural sway, lower limb muscle strength and BODE index are shown in table 7. Among severe COPD, Lower Brief-BESTest and BBS score, reduced six-minute walk distance, respiratory muscle strength, lower limb muscle strength, and increased BODE index was significant compared to the controls (all p= 0.01). There was no difference between groups in all components of postural sway except lateral sway with eye closed (p= 0.01)

Table 7: Comparison between Severe COPD and Control group

Variables	Severe N= 23	Range	Controls N= 39	Range	t-value	p-value
Brief-BESTest	16.78± 3.64	7 - 22 (15)	23.23± 0.84	21 - 24 (3)	-8.35	0.01*
BBS	53.35± 1.56	49 - 56 (7)	55.54± 0.68	53 - 56 (3)	-6.40	0.01*
SMWD	376.39± 50.67	280 - 480 (200)	474.97± 58.49	367 - 600 (233)	-6.98	0.01*
PImax	68.30± 20.23	19 - 101 (82)	94.56± 20.86	42 - 148 (106)	-4.88	0.01*
PEMax	59.22± 17.92	34 - 96 (62)	78.95± 18.05	47 - 131 (84)	-4.17	0.01*
AEO	1.29± 0.66	0 - 2.40 (2.40)	1.03± 0.55	0 - 2.70 (2.70)	1.67	0.10
PEO	0.93± 0.58	0 - 2.40 (2.40)	0.84± 0.48	0 - 2.40 (2.40)	0.66	0.51
LEO	1.37± 0.64	.40 - 2.60 (2.20)	1.29± 0.75	.20 - 3.70 (3.50)	0.42	0.67
AEC	1.42± 0.67	0 - 2.60 (2.60)	1.10± 0.65	0 - 3.20 (3.20)	1.88	0.06
PEC	1.13± 0.60	.30 - 2.70 (2.40)	1.09± 0.60	.20 - 2.80 (2.60)	0.28	0.78
LEC	1.99± 0.91	.50 - 3.90 (3.40)	1.16± 0.61	.40 - 3 (2.60)	3.88	0.01*
LLMS	12.30± 1.77	9 - 15 (6)	15.87± 2.35	11 - 21 (10)	-6.76	0.01*
BODE Index	3.43± 1.16	2 - 5 (3)	0.64± 0.67	0 - 2 (2)	10.55	0.01*

* Level of significance < 0.05

In COPD

There was a positive correlation found between Brief-BESTest and FVC% predicted (r= 0.286, p= 0.049). Brief-BESTest was also found to be negatively correlated with anterior

sway with eyes open (r= -0.347, p= 0.016) and posterior sway with eyes open (r= -0.306, p= 0.035). There exists a strong positive correlation between BBS and Brief-BEST-est (r= 0.631, p= 0.01). Anterior sway with eyes open was observed to be positively correlated with age (r= 0.367, p= 0.010). Posterior sway with eyes open showed a negative correlation with PEmax (r= -0.294, p= 0.042). Lateral sway with eyes open showed positive correlation with FVC % predicted (r= 0.319, p= 0.027) and negative correlation with FEV1/FVC ratio observed (r= -0.295, p= 0.042). A significant negative correlation was observed between six minute walk distance and age (r=-0.361, p= 0.012) and there also exists a significant positive correlation between six minute walk distance and FEV1/FVC ratio observed (r= 0.325, p= 0.024). Lower limb muscle strength was observed to be positively correlated with PImax (r= 0.512, p= 0.01) and PEmax (r= 0.514, p= 0.01) shown in table 8

Table 8: Correlation of variables in COPD

		FEV_1%	PImax	AEO	PEO	LEO	BriefBEST	LLMS	SMWD	BODE	BBS
Age	Pearson Correlation	-.286*	-.241	.367*	-.211	-.110	-.234	-.173	-.361*	.222	-.095
	Sig. (2-tailed)	.049	.099	.010	.150	.456	.109	.240	.012	.130	.521
BMI	Pearson Correlation	-.037	.434**	.159	.043	.116	-.048	.109	-.016	-.281	-.009
	Sig. (2-tailed)	.805	.002	.281	.770	.431	.747	.459	.917	.053	.950
FVC%	Pearson Correlation	.696**	.178	-.101	.114	.319*	.286*	-.093	.027	-.326*	.079
	Sig. (2-tailed)	.000	.227	.493	.440	.027	.049	.529	.857	.024	.591
FEV_1%	Pearson Correlation	1	-.020	-.031	.004	.066	.186	-.090	.223	-.633**	-.058
	Sig. (2-tailed)		.894	.833	.978	.654	.205	.544	.128	.000	.694
FEV_1/FVC	Pearson Correlation		-.188	.057	-.081	-.295*	-.034	-.010	.325*	-.555**	-.120
	Sig. (2-tailed)		.200	.702	.586	.042	.818	.946	.024	.000	.415
MEF_{50}%	Pearson Correlation		-.079	.040	-.067	-.079	.094	-.078	.282	-.567**	-.062
	Sig. (2-tailed)		.594	.787	.649	.591	.525	.597	.052	.000	.675
PImax	Pearson Correlation		1	.005	-.032	.191	.188	.512**	.330*	-.172	.147
	Sig. (2-tailed)			.974	.832	.194	.201	.000	.022	.243	.317
PEmax	Pearson Correlation			.221	-.294*	.210	.221	.514**	.284	-.172	.220
	Sig. (2-tailed)			.132	.042	.152	.132	.000	.051	.242	.133
AEO	Pearson Correlation			1	-.078	.319*	-.347*	.032	-.117	.035	-.066
	Sig. (2-tailed)				.600	.027	.016	.828	.429	.811	.657
PEO	Pearson Correlation				1	.018	-.306*	-.196	-.064	-.023	-.100
	Sig. (2-tailed)					.901	.035	.182	.663	.874	.501
BriefBEST	Pearson Correlation						1	.204	.255	-.221	.631**
	Sig. (2-tailed)							.165	.080	.131	.000
LLMS	Pearson Correlation							1	.569**	-.099	.056
	Sig. (2-tailed)								.000	.501	.704
SMWD	Pearson Correlation								1	-.534**	.014
	Sig. (2-tailed)									.000	.926

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

In Moderate COPD

A significantly large positive correlation was observed between Brief-BESTest and PEmax (r= 0.472, p= 0.017). BBS showed a significant positive correlation with Brief-BESTest (r= 0.568, p= 0.003). Six minute walk distance showed a negative correlation with age (r= -0.430, p= 0.032) and significantly large positive correlation with PImax (r= 0.488, p= 0.013), PEmax (r= 0.556, p= 0.004) and lower limb muscle strength (r= 0.664, p= 0.01). Lower limb muscle strength was observed to be positively correlated with PImax (r= 0.571, p= 0.003) and PEmax (r= 0.728, p= 0.001). A significant negative correlation was observed between PImax and age (r= -0.464, p= 0.020) and positive correlation was observed between PImax and BMI (r= 0.518, p= .008). Shown in table 9.

Table 9: Correlation of variables in moderate COPD

		PImax	Brief BEST	LLMS	SMWD	BODE	BBS
Age	Correlation Coefficient	-.464*	-.044	-.276	-.430*	.314	-.039
	Sig. (2-tailed)	.020	.836	.181	.032	.126	.854
BMI	Correlation Coefficient	.518**	.196	.138	.282	-.588**	.065
	Sig. (2-tailed)	.008	.347	.511	.172	.002	.759
PImax	Correlation Coefficient	1.000	.083	.571**	.488*	-.227	.080
	Sig. (2-tailed)		.692	.003	.013	.275	.704
PEmax	Correlation Coefficient		.472*	.728**	.556**	-.206	.317
	Sig. (2-tailed)		.017	.000	.004	.323	.122
Brief BEST	Correlation Coefficient		1.000	.128	.261	-.354	.568**
	Sig. (2-tailed)			.541	.207	.082	.003
SMWD	Correlation Coefficient			0.664	1.000	-.450*	-.080
	Sig. (2-tailed)			.000		.024	.703

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

In Severe COPD

Brief-BESTest showed a significant negative correlation with anterior sway with eyes open (r= -0.569, p= 0.005). Anterior sway with eyes open showed a positive correlation with age (r= 0.430, p= 0.040). Lateral sway with eyes open was observed to be negatively correlated with FEV1/FVC ratio observed (r= -0.579, p= 0.004). A significant positive correlation was observed between lateral sway with eyes closed and BMI (r= 0.429, p= 0.041). Six-minute walk distance was observed to be positively correlated with MEF50 % predicted (r= 0.462, p= 0.027 and lower limb muscle strength (r= 0.561, p= 0.005). Shown in table 10.

Table 10: Correlation of variables in Severe COPD

		BMI	AEO	LEO	LEC	Brief BEST	SMWD	BODE
Age	Correlation Coefficient	.647**	.430*	.059	.277	-.251	-.142	-.332
	Sig. (2-tailed)	.001	.040	.791	.201	.248	.517	.122
BMI	Correlation Coefficient	1.000	.395	.237	.429*	-.322	-.329	-.223
	Sig. (2-tailed)		.062	.277	.041	.134	.125	.307
FEV_1/FVC	Correlation Coefficient		.101	-.579**	.190	-.153	.276	-.460*
	Sig. (2-tailed)		.645	.004	.384	.486	.203	.027
MEF_{50}%	Correlation Coefficient		-.141	-.393	.266	.097	.462*	-.369
	Sig. (2-tailed)		.522	.064	.221	.660	.027	.083
AEO	Correlation Coefficient		1.000	.357	.160	-.569**	-.124	-.126
	Sig. (2-tailed)			.094	.465	.005	.573	.568
LLMS	Correlation Coefficient						.561**	-.090
	Sig. (2-tailed)						.005	.683
SMWD	Correlation Coefficient						1.000	-.497*
	Sig. (2-tailed)							.016

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

DISCUSSION

Balance deficits are growing recognized as an important physical functional limitation in COPD. COPD being a pulmonary disease thus, factors affecting balance needs to be studied. So this study was prospectively conducted to understand the relationship between balance, pulmonary functions, functional capacity, and postural sway and to identify the factors which are affecting the balance in COPD.

The study showed a significant difference in the balance scores of COPD and healthy controls. There was a significant change observed in BriefBest and BBS scores in our study. When the COPD sample was divided as per severity into moderate and severe, similar results were observed (Table 6, 7). The results of our study are consistent with that of Butcher et al. 2004, Chang et al. 2008, Beauchamp et al. 2009, Smith et al. 2010, Roig et al. 2009, and Singh et al. 2014.

Another finding of this study was a significant difference in lateral sway with eyes closed between COPD and controls measured by sway meter. When the COPD sample was divided as per severity into moderate and severe, similar results were observed (Table 6, 7). The result of this study was

similar to study conducted by Chang et al. 2008 and Smith et al. 2010 on COPD where sway was measured using sway meter and force plate respectively.

Combining the observations of the study it is evident that the severity of disease is an important factor for balance deficits in COPD. In combination with all results, the severity of disease has a relation with balance deficits in COPD patients. The results are first of its kind to show the direct relation between disease severity and balance deficits in COPD which was not observed in previous work done by Beauchamp et al. 2012, Naz et al. 2013, Xavier et al. 2017. [31, 32]

Our study unlike the previous work done to elicit the factors affecting balance in COPD did not show any relation with lower limb strength, physical capacity, and dyspnoea. The possible reasons would be that both lower limb strength and physical capacity were performance-based tests in the current work and not the laboratory-based methods which could not elicit the relation with balance deficits. Postural sway is affected by lower limb strength, and it showed relation with balance deficits which is indicative of the lower limb strength influencing balance in COPD.

The results of the current study do give strong evidence of balance deficits being present in COPD and being affected with severity of disease. Thus, assessment of balance deficits needs to be an integral part of rehabilitation of COPD patients.

CONCLUSION

Impaired balance is an important & modifiable secondary impairment seen in an increased risk of fall. It has been noted when compared with age, BMI matched control subjects, and individuals with COPD have reduced performance in all subcomponents of balance. These deficiencies in balance are associated with poor functional capacity levels and lower extremity muscle weakness. Given the association between impaired balance and increased risk of falls a detailed balance evaluation should be offered to individuals at risk. There is a clear need for future research to evaluate the role of COPD specific balance training as part of comprehensive management of patients with COPD.

Limitations of the study

The clinical measure was used for assessing balance & lower limb strength in COPD as well as in controls. For measuring postural sway other objective methods can be used like force plate, posturography or Sensory Organization Test which is more specific.

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