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Original Article

A systematic review on the effect of adding an intervention for balance in pulmonary rehabilitation program of chronic obstructive pulmonary disease patients

Nahid Khan[1, 2], Suresh Mani[1*], Iqbal Alam[3], and Abhinav Jain[4]

[1] *Department of Physiotherapy, School of Allied Medical Sciences, Lovely Professional University, Punjab, 144411 India*

[2] *Department of Physiotherapy, School of Nursing Sciences and Allied Health, Jamia Hamdard, New Delhi, 110062 India*

[3] *Department of Physiology, Hamdard Institute of Medical Sciences and Research, Jamia Hamdard, New Delhi, 110062 India*

[4] *Department of Radio-diagnosis, Hamdard Institute of Medical Sciences and Research, Jamia Hamdard, New Delhi, 110062 India*

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Abstract

Chronic Obstructive Pulmonary Disease (COPD) is a pulmonary condition that also presents with extra pulmonary manifestations. It has been reported that individuals with COPD often experience balance deficits, yet there is a scarcity of literature on balance training for this population, even though the balance deficits can increase the risk of falls and associated morbidity and mortality. The objective of the study was to investigate the effectiveness of balance intervention in addition to a Pulmonary Rehabilitation (PR) program for patients suffering from COPD. We searched the electronic databases PubMed, Cochrane Library, and SCOPUS for randomized controlled trials (RCTs) related to exercise interventions aimed at improving balance in COPD patients from 2001 to 2021. From the database search, a total of 5 RCTs were identified. The findings indicate that PR programs combined with balance training resulted in superior improvements in balance outcome measures compared to PR alone. The combination of Pulmonary Rehabilitation programs and balance training has been shown to be more effective in improving balance for individuals with COPD. However, the long-term effects of this intervention remain unclear.

Keywords: balance, COPD, exercise, pulmonary rehabilitation, falls

1. Introduction

Chronic obstructive pulmonary disease (COPD) is characterized by severe limitation of airflow and respiratory symptoms (Iheanacho, Zhang, King, Rizzo, & Ismaila, 2020). It is projected to become the third leading cause of global disease burden by 2030 (Safiri, 2022). Low to middle income countries bear a higher burden of COPD-associated disability-adjusted life years (McKay, Mahesh, Fordham, & Majeed 2012), with a global prevalence of 4.1% among individuals over 35 years of age (Jirange, Vaishali, Sinha, Bairapareddy, & Alaparthi 2021). In India, the prevalence is even higher at 5%, particularly among smokers, those residing in rural areas, males, individuals with low socioeconomic status, and those using certain types of domestic fuel (McKay *et al.*, 2012). Several factors have been identified as major contributors to

*Corresponding author
Email address: vemsuresh@gmail.com

increased mortality in COPD patients, including lower socioeconomic status, childhood poverty, poor nutritional status, limited education and health literacy, and higher exposure to particulate matter (Abdulsalim *et al.*, 2020). Moreover, COPD imposes a significant economic burden worldwide. The projected cost of COPD on the global economy is estimated to reach $4.326 trillion between 2020 and 2050 (Chen *et al.*, 2023), although the economic impact on India remains largely unknown (Abdulsalim *et al.*, 2020). Notably, COPD ranks second only to osteoarthritis in terms of the prevalence of falls (Jirange *et al.*, 2021). Therefore, COPD poses a substantial global health challenge particularly in low to middle income countries associated with higher number of disability-adjusted life years.

Patients with COPD not only face respiratory challenges but also endure a range of systemic issues. These include cardiovascular co-morbidities, systemic inflammation, peripheral muscle dysfunction, and depression (dos Santos *et al.*, 2022; Rahi *et al.*, 2023; Sweed Khalil, Elganady, & Ali, 2023)r. It is widely acknowledged that COPD significantly impacts the function and structure of skeletal muscles, leading to compromised mobility and balance. In fact, research has demonstrated that COPD patients exhibit poorer postural control and balance compared to non- COPD individuals of the same age. The combination of peripheral muscle atrophy and the natural effects of aging further amplifies the risk of falls and the frequency of falls in COPD patients (Yentes, Liu, Zhang, Markvicka, & Rennard, 2022). Consequently, these individuals experience reduced levels of physical activity, strength, agility, balance, and a loss of functional independence. However, the contribution of the diaphragm muscle in maintaining lumbar spine stability and body balance is unquestionable.

The weakness of the diaphragm and intercostal muscles is a well-known issue among patients with COPD. The diaphragm plays a crucial role in both breathing and maintaining proper posture. However, when one of these functions is compromised, it inevitably affects the other. In severe cases of COPD, patients often struggle with regaining balance, which is accompanied by increased activity in the trunk muscles during postural challenges (Stephens *et al.*, 2017). As a result, it has been suggested that the assessment of static and dynamic balance should be an integral part of evaluating COPD patients (Jirange *et al.*, 2021). Moreover, there is an urgent need for research to better understand the effects of a rehabilitation program that incorporates balance training, on functional outcomes and the overall quality of life for individuals with COPD. Therefore, the primary objective of this systematic review is to assess the impact of integrating a balance training protocol into pulmonary rehabilitation (PR) for COPD patients.

2. Methods

2.1 Data sources and searches

The literature search for the present systematic review was conducted by two independent reviewers. Three electronic databases, namely COCHRANE, PubMed and SCOPUS were searched from 2001 to 2021.The MeSH terms for COPD, Balance training and PR were identified and a Boolean algorithm was used for searching the databases.

((((((((((((((chronic obstructive lung disease) OR (chronic obstructive pulmonary diseases)) OR (copd)) OR (chronic obstructive airway disease)) OR (chronic obstructive pulmonary disease)) OR (airflow obstruction, chronic)) OR (airflow obstructions, chronic)) OR (chronic airflow obstructions)) OR (chronic airflow obstruction)) AND (balance)) OR (posture equilibrium)) OR (posture balance)) OR (postural control)) AND (pulmonary rehabilitation)) AND (exercise)) OR (physiotherapy)

2.2 Inclusion and exclusion criteria

RCTs with a balance intervention program added to PR on COPD patients were included in the present systematic review. The language was limited to English. The present systematic review was registered at Prospero (CRD42022326303).

2.3 Study selection

The duplicates from the studies retrieved from electronic database searches were removed. The title of the articles was assessed for inclusion into the study by two reviewers independently (N.K. & S.M.). The full articles were then assessed for eligibility according to the inclusion and exclusion criteria. Disagreements were resolved by another reviewer (A.J.).

2.4 Data extraction

Two reviewers independently extracted the data from the included studies. The data extracted included the demographic details of the subjects including age, severity of COPD, balance measurement, and intervention.

2.5 Quality assessment

The Physiotherapy evidence database (PEDro) Scale was used for the assessment of quality of the included RCT's. Higher scores indicate better quality. A score of less than 3 indicates poor quality, a score of 4-5 indicates fair quality, and a score of 6-10 indicates high quality. The 5 RCT's scores for PEDro ranged from 6-8.

3. Results

A total of 48,513 articles were found in the initial search of the electronic databases. The articles from each database were combined on a MS Excel spreadsheet, from which the duplicates were removed using conditional formatting tool under MS Excel. After removing the duplicates (12,151), the title and abstracts were screened for 36,362 studies. Of these, 36,239 were irrelevant, 60 were not in English and 32 were conference abstracts. Thirty-one full text articles were assessed for eligibility. Of these 31, 18 were irrelevant, 3 had no control group, two were conference abstracts, two had no PR and one was a trial registration. Finally, 5 studies were included in the present systematic review (Figure.1).

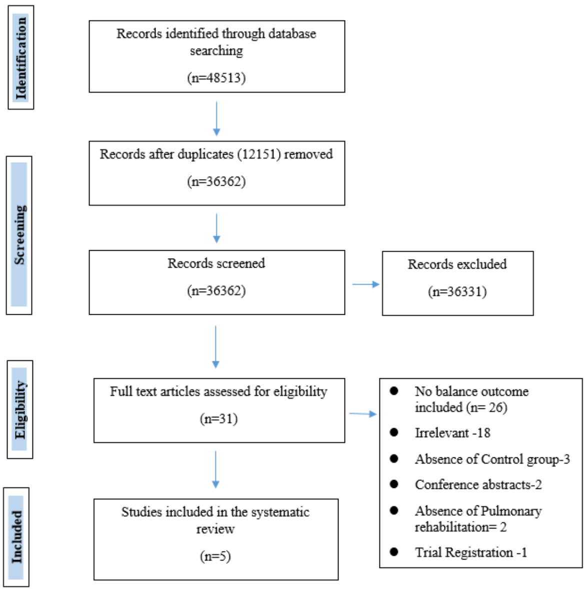

Figure 1. Preferred reporting items for systematic review and meta-analysis (PRISMA) flow diagram

3.1 Risk of bias

The risk of bias was assessed for the included RCT's. Of the 5 RCT's, two had a low risk of overall bias (Gloeckl *et al.*, 2017; M. Beauchamp *et al.*, 2013), whereas the other three had a high risk of bias which is attributed to the lack of blinding of the assessor in one study (Mekki Paillard, Sahli, Tabka & Trabelsi, 2019) and the concealment of allocation sequence and blinding of the outcome assessor (Mkacher, Mekki, Tabka & Trabelsi *et al.*, 2015; Reddy *et al.*, 2021) (Table 6).

3.2 Participant characteristics

There was a total of 351 participants, of which 182 were in the intervention group and 169 were in the control group. The age range was 58.3 to 67.1 years for the intervention group and 59.5 to 71.9 years for the control group (Table. 2). Two of the randomized controlled trials mentioned the recruitment of subjects from the inpatient PR program (Gloeckl *et al.*, 2017; M. Beauchamp *et al.*, 2013). Three of the studies included patients with a history of falls in last 5 years or a recent near fall (Table 1).

Table 1. Characteristics of the included randomized controlled trials

Author	Population	Duration of the study (weeks)	Total No. of sessions	Duration of session (min)	Protocol		Outcome	Adverse event
					Intervention	Control		
Reddy *et al.* (2021)	COPD (Stage II)	8	24	15-20	Balance training + PR	PR	Improved balance	Not reported
Mekki *et al.* (2018)	COPD	24	72	20	NMES + PR	PR	Improved walking tolerance and balance	Not reported
Gloeckl *et al.* (2017)	COPD (Stage III – IV)	3	9	8	Squat training with WBVT + PR	PR	Improved balance	None
Mkacher *et al.* (2015)	COPD	24	72	30	Balance training + PR	PR	Improved balance	Not reported
Beauchamp *et al.* (2013)	COPD (Stage II-III)	6	18	30	Balance training + PR	PR	Improved balance	Not reported

PR= Pulmonary Rehabilitation; NMES = Neuromuscular electrical stimulation; WBVT= Whole body vibration therapy

Table 2. Characteristics of age, gender, BMI, FEV1, 6MWT and dropouts in the included randomized controlled trials

Author	Setting	Age in years (mean ± SD)		Male Gender (Percentage)		BMI (kg/m^2)		FEV$_1$ (% predicted)		6 MWD (minutes)		Dropouts (number)	
		I	C	I	C	I	C	I	C	I	C	I	C
Reddy *et al.* (2021)	Outpatient	52.53 ± 3.98	52.1 ± 4.59	78.7%	82.2%	NR	NR	67.2 ± 22.3	69.6 ± 23.7	303.0 ± 15.5	309.7 ± 15.8	2	6
Mekki *et al.* (2018)	Outpatient	59.6 ± 4.8	59.5 ± 3.1	100%	100%	25.6 ± 0.7	25.6 ± 0.5	57.7 ± 14.4	57.1 ± 10.2	503.0 ± 29.0	503.0 ± 31.0	5	10
Gloeckl *et al.* (2017)	Inpatient	65 ± 8	63 ± 9	73%	62%	25.2 ± 5.2	25.6 ± 6.3	33.6 ± 8.5	36.6 ± 11.7	335.0 ± 107.0	350.0 ± 104.0	8	5
Mkacher *et al.* (2015)	Outpatient	58.3 ± 4.3	61.2 ± 3.2	NR	NR	24.1 ± 3.8	25.2 ± 2.6	39.4 ± 10.3	38.6 ± 8.6	446.0 ± 23.0	448.0 ± 23.0	0	0
Beauchamp *et al.* (2013)	Inpatient	67.1 ± 9.4	71.9 ± 4.9	33%	44%	27.2 ± 9.3	23.9 ± 6.5	39.9 ± 13.2	35.4 ± 17.5	NR	NR	2	1

I= Intervention group, C= Control group, NR= Not Reported

3.3 Exercise training programs

The exercise training programs have been summarized in Table 1. Balance training programs were similar in two studies. The balance training included stance and gait exercise with progression to difficult tasks. Another study which included exercises administered weight shifting, tandem walking, single leg standing, stand up and sit down, and standing on a wobble board (Reddy *et al.*, 2021). One RCT used Neuromuscular electrical stimulation (NMES) whereas another study utilised squat training with WBVT for balance training program. The duration of intervention was from 3 to 24 weeks. The patient details, study protocols and results of between group and within group analyses are depicted in Tables 3, 4 and 5.

3.4 Baseline characteristics

No difference between the two groups for baseline characteristics and outcomes was observed in four of the 5 RCT's (Beauchamp *et al.*, 2013; Gloeckl *et al.*, 2017; Mekki *et al.*, 2019; Mkacher *et al.*, 2015). In one study there was no difference in the mean age of the participants of the two groups but the baseline measures for Timed up and go test (TUG) (p <0.004) and Activity specific Balance confidence scale (ABC) (p<0.039) were statistically different between the two groups (Reddy *et al.*, 2021).

3.5 Change of balance in PR protocol alone

Table 3 shows the details of balance training, and its outcome. The improvement for balance in the PR only group for Berg Balance scale (BBS) (p<0.001(Mekki *et al.*, 2019) and p<0.000 (Reddy *et al.*, 2021) was reported in only two studies. A change of more than or equal to 4 points represents a Minimal detectable change (MDC) in the elderly patients with baseline scores in the range of 45-56 points (Beauchamp *et al.*, 2013). Beauchamp *et al.* reported a mean change of 1.6±3.9 in the control group for BBS. Improved TUG scores were reported in three studies (p<0.05 (Mkacher *et al.*, 2015), p<0.001 (Mekki *et al.*, 2019) and p<0.000 (Reddy *et al.*, 2021). A test duration of more than 16 seconds or more predicts falls in the elderly population, though in a study the mean value for TUG was 14.3 ±0.6 at baseline and 11.8± 0.6 post intervention, with statistically significant difference (p<0.001) (Mekki *et al.*, 2019). TUG score was 15.3±1.1 at

Table 3. The details of balance training program protocol, outcome measures and results

Author	Type of exercise	Time / Session	Frequency	Training duration	Balance measure	Main results
Reddy *et al.*, (2021)	Balance training: weight shifting, stand up & sit down, tandem walking, single leg stand, standing on wobble board Endurance & Strength training Breathing exercise	15 mins / 60 mins	3 times / week 3 times / week	8 weeks	BBS * TUG * SLST* ABC* EFST*	Balance training with conventional PR improves balance, 6 MWT and HRQOL in moderate COPD
Mekki *et al.*, (2018)	Endurance & Strength training NMES	45 mins / 20 mins	3 times / week	24 weeks	TUG (-3)* BBS (9.2)* COP (mediolateral) (-27.5)* COP (anteroposterior) (-5.5)* COP area (-60.8)*	NMES with PR significantly improved walking tolerance and balance as compared to PR only
Gloeckl *et al.*, (2017)	Squat exercises on side alternating vibration platform Endurance & Strength training	8 mins / 15 min	3 times / week 5 times / week	3 Weeks	Romberg stance /eye closed APL (76) Semi tandem stance/ eyes closed APL (-348)* Semi tandem stance/ eyes open APL (-78)* One leg stance/ Eyes open APL (-187)*	WBVT with PR improves balance and muscle power in COPD
Mkacher *et al.*, (2015)	Stance exercise, Transition exercise, Gait exercise, Functional strengthening, Breathing exercise, Supervised exercise training for PR	30 mins	3 times / week	6 months	Significant between group difference for TUG, Tinetti, BBS, ABC (p<0.01)	Balance training with PR significantly improved balance in COPD
Beauchamp *et al.*, (2013)	Endurance exercise Breathing exercise Balance training: Stance, transition, gait, functional strengthening,Self-management education	20-30 mins 30 mins 30 mins	5 times / week Everyday 3 times / week	6 weeks	BBS (5.4)* Bestest (9.6)* ABS (9) NS	Balance training with PR significantly improved balance, self-reported physical function, lower extremity muscle strength compared to PR only

*: Statistically significant difference between experimental and control group; NS= Non-significant; BBS= Berg Balance scale; TUG= Timed up and go test; ABC= Activity Balance confidence scale; EFST= Elderly falls screening test; SLST= Single leg stance test; BESTest= The Balance evaluation systems test; COP= Center of pressure; APL= Absolute path length (mm)

baseline and improved to 13.2±1.5 (p<0.05) in another study (Mkacher *et al.*, 2015). In the third study that measured TUG score, the baseline reading was 16.27±1.07 which improved to 14.40±0.81 (p< 0.000) (Reddy *et al.*, 2021).

Improvements for centre of pressure (COP) displacement in mediolateral direction (eyes open) (p<0.05), COP (eyes open) (p<0.001) and COP area (eyes closed) (p<0.001) were observed in one study (Mekki *et al.*, 2019). No statistically significant improvements in the control group were reported in any of the balance tests in another study (Gloeckl *et al.*, 2017) (Table 5).

3.6 Improvement in balance in PR along with balance training protocol

Two studies reported a statistically significant improvement for BBS where the score improved from 45.3±1.1 to 54.6±2.9 (p<0.01) (Mkacher *et al.*, 2015) and from 40.12±1.67 to 46.1±1.38 (p<0.000) (Reddy *et al.*, 2021). Statistically, non-significant mean change of 7±5.5 was reported for BBS in one study (Beauchamp *et al.*, 2013). A statistically significant improvement in TUG score was also reported in one study (p<0.05) (Mkacher *et al.*, 2015). NMES with PR resulted in a mean change of 9.2±2.1 (p<0.001) for BBS score and -3±1 (p<0.001) for TUG score. A statistically significant improvement (p<0.001) was also observed for COP displacement in mediolateral direction, anteroposterior direction and COP (Mekki *et al.*, 2019). WBVT with PR led to statistically significant improvements for Romberg stance (eyes closed) APL (P<0.029), semi tandem stance (eyes closed) APL (p<0.001), semi tandem stance (eyes open) APL (p<0.005), and one leg (eyes open) APL (p<0.012) (Gloeckl *et al.*, 2017) (Table 4).

3.7 Statistical methods employed in the included articles

Gloeckl *et al.*, reported the results as mean±SD and proportions (%). Results were analysed on STATISTICA 13 (StatSoft Tulsa, OK) by one of the authors. They used Repeated measures Anova and students t-test (paired and unpaired). The tests were two tailed and a p-value <0.05 was considered significant (Gloeckl *et al.*, 2017). Reddy *et al.*, analysed the data on Windows IBM SPSS Statistics, Version 25.0.0. Descriptive statistical analysis was depicted as mean±SD and p-values <0.05 were considered significant. For the within group analysis paired t-test and Wilcoxon signed rank test were used, and for between group comparison independent t-test and Mann-Whitney U-test were used (Reddy *et al.*, 2021). Mkacher *et al.* tested for normality using Kolmogorov- Smirnov test. Descriptive statistical analysis was depicted as mean±SD and p-values <0.05 were considered significant. 2 tailed unpaired t-test was used to analyse the difference between the two groups at baseline and at 6 months after rehabilitation. Within group analysis for both the groups was done by 2 tailed paired t-test. The data were analysed by using STATISCA (Statistica Kernel version10, Stat Soft, France) (Mkacher *et al.*, 2015). Mekki *et al*, analysed the data by using Statistica (Version 6, Statsoft, Inc, Tulsa, OK). For data normality they also used Kolmogorov-Smirnov test. Descriptive statistical analysis was depicted as mean±SD and p-values <0.05 were considered significant. Patient characteristics were compared between the two groups with independent t-test. Two-way analysis of variance was used to compare the primary and secondary outcomes. Static balance parameter was compared using three-way ANOVA. Post hoc analysis (Tukey) was conducted to test the differences among means (Mekki *et al.*, 2019).

Table 4. Results of between group analysis (expressed as mean difference)

Author	BBS (points)	TUG (seconds)	Other measures	
Reddy *et al.*, (2021)	-22.55%**	-46.46%**	SLST	-52.69%**
			ABC	13.89%**
Mekki *et al.*, (2018)	**	*	COP ML-EO	**
			COP ML-EC	**
			COP AP- EO	**
			COP AP- EC	**
			COP Area – EO	**
			COP Area – EC	**
Gloeckl *et al.*, (2017)	NR	NR	Romberg stance / EC EC APL (mm)	-76 (-202-30) NS
			Semi tandem stance/ EC APL (mm)	-348 (-504 to -193)**
			Semi tandem stance/ EO APL (mm)	-78 (-155 to -1)*
			One leg stance/ EO APL (mm)	-187 (-327 to -48) **
Mkacher *et al.*, (2015)	**	**	Tinetti Score	**
			ABC (%)	**
			UST (seconds)	*
Beauchamp *et al.*, (2013)	5.4 (2.1-8.6)*	NA	BESTest	9.6(3.9-15.3)**
			ABC (%)	9(-5.2-23.3) NS
			PF-10	13.1(3-23.2)*
			Chair stand	3.3(0.6-6)*

** = p<0.01, *= p<0.05. NA = Not applicable, NS = Not significant, NR= Not Reported,
BESTest= The Balance evaluation systems test; SLST= Single leg stance test; ABC= Activity Balance confidence scale; COP ML-EO= Center of pressure displacement in mediolateral direction (mm) with eyes open; COP ML-EC= Center of pressure displacement in mediolateral direction (mm) with eyes closed; COP AP- EO= Center of pressure displacement in anteroposterior direction (mm) with eyes open; COP AP- EC= Center of pressure displacement in anteroposterior direction (mm) with eyes closed; COP Area – EO= Center of pressure area (mm^2) with eyes open; COP Area – EC= Center of pressure area (mm^2) with eyes closed

Table 5. Results of within group analysis (expressed as mean change)

Author	BBS (points)		TUG (seconds)		Other outcome measures	I	C
	I	C	I	C			
Reddy *et al.*, (2021)	14.9%**	11.9%**	-25.26%**	-11.49%**	SLST	45.2%**	27.26%**
					ABC	8.97%**	3.7%**
Mekki *et al.*, (2018)	9.2±2.1**	8.4±3.7**	-3±1**	-2±1.2**	COP ML-EO	-27.5±6.2**	-4.2±7.7*
					COP ML-EC	-37.4±9**	-3.3±4.3 NS
					COP AP- EO	-5.5±14.4**	-0.8±21.3NS
					COP AP- EC	-13.6±13.7**	-4.4±6.5 NS
					COP Area – EO	-60.8±9.3**	-13.1±9.6 **
					COP Area – EC	-52.8±14**	-20.4±14.7**
Gloeckl *et al.*, (2017)	NR	NR	NR	NR	Romberg stance / eye closed APL (mm)	-92(-174 to -10)*	-16(-99 to 66)
					Semi tandem stance / eyes closed APL (mm)	-272(-382 to -162)**	67(-45 to 179)
					Semi tandem stance / eyes open APL (mm)	-78 (-133 to -23)**	0(-54 to 54)
					One leg stance / eyes open APL (mm)	-124(-221 to -27)*	55 (-43 to 153)
Mkacher *et al.*, (2015)	**	NS	**	*	Tinetti Score	*	NS
					ABC (%)	**	*
					UST (seconds)	**	*
Beauchamp *et al.*, (2013)	7±5.5	1.6±3.9 NS	NA	NA	BESTest	15.6±2.4	6±5.5
					ABC	22±22.3	13±19.5
					PF-10	18.7±13.2	5.6±16.7
					Chair stand	6.2±4	2.9±3.6

**=p<0.01 *= p<0.05, NA= Not applicable, NS= Not significant, NR= Not Reported, I= Intervention group; C= Control group;
ABC = Activity Balance confidence scale; UST = Unipedal stance test; BESTest = The Balance evaluation systems test;
PF-10 = Physical function subscale of the 36-itemShort form Health survey; APL: Absolute path length
COP ML-EO = Center of pressure displacement in mediolateral direction (mm) with eyes open
COP ML-EC = Center of pressure displacement in mediolateral direction (mm) with eyes closed
COP AP- EO = Center of pressure displacement in anteroposterior direction (mm) with eyes open
COP AP- EC = Center of pressure displacement in anteroposterior direction (mm) with eyes closed
COP Area – EO = Center of pressure area (mm^2) with eyes open
COP Area – EC = Center of pressure area (mm^2) with eyes closed

Table 6. PEDro Scoring of included studies

	Reddy	Mekki	Gloeckle	Mkacher	Beauchamp
Eligibility criteria were specified	Yes	Yes	Yes	Yes	Yes
- Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)	1	1	1	1	1
- Allocation was concealed		1	1	0	1
- The groups were similar at baseline regarding the most important prognostic indicators	1	1	1	1	1
- There was blinding of all subjects	0	0	0	0	1
- There was blinding of all therapists who administered the therapy	0		0	0	0
- There was blinding of all assessors who measured at least one key outcome	0	0	1	0	1
- Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	1	0	1	1	0
- All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"	1	1	1	1	1
- The results of between-group statistical comparisons are reported for at least one key outcome	1	1	1	1	1
- The study provides both point measures and measures of variability for at least one key outcome	1	1	1	1	1
Total	6	6	8	6	8

Beauchamp *et al.* analysed data by SAS, version 9.2 (SAS Institute Inc). Shapiro-Wilks test and frequency histograms were used to evaluate the distribution of data. Between group analysis for baseline data was done using independent Student's t-test or the Mann-Whitney U-test (Beauchamp *et al.*, 2013).

4. Discussion

The objective of this systematic review was to understand the impact of incorporating a balance training protocol into PR programs for enhancing balance in patients with COPD. The findings of this review indicate that the inclusion of a specific balance training protocol in PR programs leads to significant improvements in balance among COPD patients. While the control group also demonstrated some improvements in balance outcome measures, the intervention group experienced a greater magnitude of improvement. It is worth noting that the available literature on this topic is limited; however, the RCTs included in this review provide evidence that COPD patients derive benefits from the addition of balance training to their PR protocols. The methodological quality of the reviewed articles ranged from 6 to 8, indicating a good overall quality. However, it is important to highlight that three out of the five RCTs included in this review exhibited a high risk of bias. This high risk was primarily attributed to the lack of assessor's blinding and inadequate allocation concealment.

4.1 Balance training protocol

Subject with COPD often experience balance issues and increased risk of fall due to loss of skeletal muscle mass and impaired function of diaphragm. The etiology of balance impairment in COPD patients appears to be multifactorial, involving environmental, patient, and activity-related factors. These factors include exacerbation, systemic inflammation, malnutrition, and hypoxemia-associated changes in muscle structure and function (Tudorache *et al.*, 2015; Vardar-Yagli *et al.*, 2019). As the disease severity increases, there is a loss of muscle mass in the thigh, leading to decreased exercise endurance, fatigue, and dyspnea even with minimal exertion. Consequently, this population becomes more susceptible to falls (Tudorache *et al.*, 2015). Additionally, the bronchitic phenotype has been reported to have a higher risk of falls compared to the emphysematous phenotype (Voica *et al.*, 2016). Furthermore, COPD has a significant impact on the structure and functioning of the diaphragm, leading to a decrease in diaphragmatic excursion. This, in turn, affects respiration and balance in individuals with COPD (Bradley & Esformes, 2014). These factors include impaired balance recovery reaction to external perturbations, ineffective balance receptors, integrators and effectors, and decreased muscle strength, and impaired neuro-muscular excitability. On the other hand, the improvement in balance measures has been attributed to increased muscle strength, improved functioning of the vestibular system, and enhanced neuromuscular excitability. However, the rationale for selecting different balance interventions highlights a literature gap. Several studies have hypothesized various factors contributing to impaired balance in COPD patients (Beauchamp *et al.*, 2013; Gloeckl *et al.*, 2017; Mekki *et al.*, 2019; Mkacher *et al.*, 2015; Reddy *et al.*, 2021).. Therefore, it is crucial to develop treatment strategies that consider the multifactorial causes of COPD, in order to design an effective balance training protocol for patients.

4.2 Session and Intervention duration

The duration of individual balance training sessions varied significantly, ranging from 8 minutes to 30 minutes. This variation can be attributed to the different training protocols employed. Randomized controlled trials (RCTs) that included exercise training for balance tended to have longer session durations, while studies incorporating neuromuscular electrical stimulation (NMES) and whole-body vibration training (WBVT) had comparatively shorter with durations of 20 minutes and 8 minutes, respectively. On the other hand, the duration of the intervention ranged from 3 to 24 weeks across the included studies. Notably, two studies were conducted over a period of 24 weeks (Mekki *et al.*, 2019; Mkacher *et al.*, 2015), while one study lasted for 8 weeks (Reddy *et al.*, 2021), another for 6 weeks (Beauchamp *et al.*, 2013), and one for 3 weeks (Gloeckl *et al.*, 2017). In all the included studies, balance training sessions were conducted three times per week. It is worth mentioning that the duration of exercise was kept consistent between the control and experimental groups, except for one study (Reddy *et al.*, 2021). This variation in intervention duration sheds light on the existing gap in the literature regarding the balance training component for patients with chronic obstructive pulmonary disease (COPD). It is crucial to address this gap in order to enhance our understanding of the optimal duration for balance training interventions in COPD patients. By conducting further research in this area, we can develop more effective and tailored interventions that can improve the balance and overall well-being of individuals with COPD.

4.3 The Impact of different stages of COPD

Among the studies analyzed, two studies focused on patients with moderate to severe COPD, while one study mentioned the inclusion of patients with moderate COPD severity (Beauchamp *et al.*, 2013). The remaining two studies did not specify the severity of COPD. Notably, none of the studies reported any adverse events, indicating that the protocols were well tolerated by the COPD patients. Although four studies mentioned dropouts, these were unrelated to the study protocols (Beauchamp *et al.*, 2013; Gloeckl *et al.*, 2017; Mkacher *et al.*, 2015; Reddy *et al.*, 2021). It is important to note that the generalizability of the findings is limited due to the absence of participants from different COPD grades. Consequently, it is not possible to estimate any potential association between COPD severity and balance. Furthermore, the impact of gender on balance impairment or improvement following intervention was not reported, highlighting a gap in the existing literature.

4.4 Assessment tools of balance

Balance was assessed through a variety of methods, including functional balance tests, fear of falling evaluations, and laboratory-based balance approaches. In terms of functional balance tests, four studies utilized the BBS (Beauchamp *et al.*, 2013; Gloeckl *et al.*, 2017; Mkacher *et al.*, 2015; Reddy *et al.*, 2021). Additionally, three studies employed the TUG test to assess balance (Mkacher *et al.*, 2015; Reddy *et al.*, 2021) Other tests used in individual studies included the single leg stance test (Reddy *et al.*, 2021), the unipedal stand test (Mkacher *et al.,* 2015), the chair stand for lower body strength functional assessment (Beauchamp *et al.*, 2013), and the Sit to Stand test on a force platform (Gloeckl *et al.*, 2017). A systematic review reported that TUG, BBS, and Balance evaluation – systems test (BESTest) were found to be effective in assessing balance in COPD patients (Beauchamp, 2018), with documented construct validity and inter-rater and intra-rater reliability in this population (Beauchamp, 2018). Fear of falling was measured using the ABC scale in three of the included studies (Beauchamp *et al.*, 2013; Mkacher *et al.*, 2015; Reddy *et al.*, 2021). The laboratory balance approach was utilized in two studies, with one study employing the 2-legged jump test on a force platform and measuring anterior-posterior load (Gloeckl *et al.*, 2017), and another study measuring COP displacement (Mekki *et al.*, 2019). Overall, these assessments provide a comprehensive understanding of balance in COPD patients, with a range of tests and measures employed to ensure accuracy and reliability.

4.5 Impact of adding a balance training protocol to pulmonary protocol for improving balance in patients with COPD

The included RCTs in this review strongly support the anticipation that addition of a specific component for balance training to the PR program leads to significant improvements in balance outcome measures within the intervention group, with statistically significant differences observed between the intervention and control groups. Integrating balance training into Pulmonary Rehabilitation program reduces the increased risk of falls in COPD patients (Beauchamp *et al.*, 2013). In addition, the PR-only group of the two included RCT's also demonstrated improvement in BBS scores (Mkacher *et al.*, 2015; Reddy *et al.*, 2021). While two studies reported a statistically significant improvement ($p<0.01$), the remaining studies did not yield statistically significant results (Beauchamp *et al.*, 2013). These findings highlight the superior balance enhancement achieved by the PR group with the inclusion of a balance intervention. The findings highlight the significant improvements in balance outcome measures, lower limb muscle strength, walking endurance, and maximal voluntary contractions. Such research adds more effective and comprehensive approach to managing COPD, ultimately leading to better outcomes and improved well-being for patients. Therefore, incorporation of a balance training protocol into PR yields substantial improvements in balance.

4.6 Strength and limitations

There are several limitations in the current systematic review that need to be addressed. Firstly, it is important to note that only five RCTs were included in this review. While this provides a starting point, it is crucial to acknowledge that the majority of studies on COPD patients primarily focus on respiratory symptoms. As a result, there is a scarcity of published studies on balance intervention in this population. Furthermore, it is worth mentioning that the included studies had relatively small sample sizes. Although all of these studies provided a rationale for their sample size calculations, it is important to consider the implications of this limitation. Additionally, the severity of COPD in these studies was limited to moderate to severe cases, with two studies failing to mention the specific grade of COPD. This lack of information makes it challenging to generalize the findings to a broader population. Another noteworthy limitation is that one of the studies did not have similar groups at baseline. This discrepancy raises concerns about the validity of the results and the potential impact on the overall conclusions drawn from the review. Additionally, two of the studies included participants from inpatient PR, which may introduce bias and limit the generalizability of the findings to other settings. Furthermore, none of the included studies conducted a long-term follow-up, which is essential for assessing the sustainability of any interventions or treatments. This absence of long-term data hinders our ability to fully understand the impact of balance training interventions on COPD patients. Therefore, future studies should aim to address these limitations and further explore the potential benefits of balance training in COPD population.

5. Conclusions

PR has proven to enhance balance outcomes in patients with COPD. However, when a balance training program is added to PR, the results for balance in COPD patients are even more remarkable. Designing a tailored rehabilitation protocol that specifically targets the factors contributing to balance deficits is crucial. Yet, there is still much work to be done in understanding the mechanisms that impact balance in this population, in order to determine the most effective interventions. Unfortunately, there is a scarcity of studies focusing on balance training interventions and limited data on the long-term effects of such interventions on balance in COPD patients. This review emphasizes the existing imbalance in COPD patients and the potential for improvement through various rehabilitation strategies. It is imperative that the available balance assessments and interventions be incorporated into international guidelines for COPD care.

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