

BALANCE TRAINING COMBINED WITH PULMONARY REHABILITATION IMPROVES POSTURAL BALANCE IN CHRONIC OBSTRUCTIVE PULMONARY DISEASE: SYSTEMATIC REVIEW AND META-ANALYSIS

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Highlights: (1) Therapeutic interventions added to PR have the potential to improve balance. (2) Adding balance training to postural rehabilitation improves postural balance. (3) NMES promotes increased in peripheral muscle strength and functional capacity. (4) Currently, there is low certainty of the evidence for clinical decision-making.

PRE-PROOF

(as accepted)

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ABSTRACT

Objective: To synthesize the effects of different exercise-based therapeutic interventions on the outcomes postural balance, occurrence of falls, peripheral muscle strength and functional capacity in patients with chronic obstructive pulmonary disease (COPD). **Methods:** The search was carried out in the following databases: MEDLINE (PubMed), EMBASE, PEDro, CENTRAL, CINAHL, and LILACS until January 2025. Two reviewers independently performed selection, data extraction, and risk-of-bias assessment of the studies (Cochrane Handbook) and quality-of-evidence assessment (GRADE). **Results:** Seventeen randomized clinical trials met the eligibility criteria (n=859 patients). The addition of balance training (BT) to pulmonary rehabilitation (PR) resulted in a significant improvement in balance (MD 4.02 points; 95% CI 0.78-7.27) compared with conventional PR. The vibration platform and neuromuscular electrical stimulation (NMES) also improved balance. NMES in PR increased peripheral muscle strength (MD 36.3 N, 95% CI 15.0-57.6) and functional capacity (MD 40.91 m, 95% CI 21.17-60.65). **Conclusion:** This systematic review and meta-analysis suggest that therapeutic interventions such as ET, vibration platform therapy, or NMES added to PR have the potential to improve balance in COPD. Despite these promising findings, larger, low-bias studies are needed.

Keywords: Pulmonary Disease, Chronic Obstructive; Postural Balance; Exercise; Rehabilitation; Meta-Analysis.

PROSPERO: CRD42021251585.

Introduction

Currently, chronic obstructive pulmonary disease (COPD) is the third most frequent cause of death in the world, surpassing lower respiratory tract infections¹. In 2019, the global prevalence of COPD was estimated at 10.3%, representing 391.9 million cases in subjects aged 30 to 79 years, being one of the main causes of chronic hospitalization and consequently a growing challenge for public health². It is important to highlight that the prevalence and impact of this pathology probably do not reflect reality due to frequent underdiagnosis³.

The primary pathophysiology of COPD involves damage to the respiratory system,

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resulting from an abnormal pulmonary inflammatory response that clinically culminates in persistent and progressive airflow limitation¹. However, because it is a complex and heterogeneous disease, several extrapulmonary manifestations are evident, including peripheral muscle dysfunction, functional limitations, and reduced quality of life (QoL)⁴⁻⁶. Furthermore, balance deficits have emerged as a significant deficit secondary to COPD⁷⁻⁸. This premise is supported by systematic reviews demonstrating a clinically significant reduction in balance in these patients, which contributes to the occurrence of falls⁹⁻¹⁰. However, even with robust evidence, the use of therapeutic interventions to improve balance is not addressed in statements on pulmonary rehabilitation (PR)¹¹.

Systematic reviews have been developed to summarize the available evidence on various therapeutic strategies to improve postural balance in subjects with COPD and to guide clinical practice. In this sense, Delbressine et al. (2020) were pioneers in systematically reviewing the literature and suggesting that exercise-based interventions have the potential to improve balance in patients with COPD¹². Other previous reviews suggest that rehabilitation, balance training as part of the PR program, Tai Chi, and cycling exercises may be effective in improving the balance of these patients¹³⁻¹⁴. However, in general, important limitations were observed in these reviews, such as restricted search strategies and the inclusion of studies whose design did not exclusively encompass randomized clinical trials (RCT), language restriction, outcomes limited to postural balance and risk of falls, and the meta-analysis performed considered only the common assessment instruments used and not the different interventions of the studies¹³⁻¹⁴.

Given the above and the fact that the mechanisms underlying impaired postural balance in COPD are not yet fully understood, which can make it difficult to identify effective therapeutic approaches, a systematic review encompassing diverse non-pharmacological interventions is necessary to provide evidence for clinical rehabilitation practice. Thus, the following research question was defined: Can patients with COPD benefit from exercise-based therapeutic interventions, compared to any control group, in terms of postural balance, fall occurrence, peripheral muscle strength, and functional capacity immediately after the intervention?

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Methods

This systematic review and meta-analysis were conducted in accordance with the Systematic Reviews and Meta-Analyses (PRISMA) Statement¹⁵. The study protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) - CRD42021251585.

Research strategy and selection criteria

A comprehensive literature search was conducted in the following electronic databases: MEDLINE (PubMed), EMBASE, Physiotherapy Evidence Database (PEDro), Cochrane Central Register of Controlled Trials (CENTRAL), Cumulative Index to Nursing and Allied Health Literature (CINAHL) and Latin American and Caribbean Health Sciences Literature Database (LILACS) were used to identify literature related to the research question from the databases' inception until January 2025. Manual searches were conducted in the reference lists of previous systematic reviews on this topic and in any trials included in the review. The search had no restrictions regarding the year or language of publication. The detailed search strategies used in the aforementioned databases are presented in Appendix 1.

Eligibility criteria

Potentially eligible studies were included in the review after title and abstract analysis by two independent and previously trained reviewers (T.D.S. and A.B.) (Kappa=0.90). The following criteria were considered, based on the PICOS acronym: P (population): adult subjects with a clinical and spirometric diagnosis of COPD¹⁶; I (intervention): exercise-based therapeutic interventions (such as strength training, resistance training, balance training, whole-body vibration, postural retraining, neuromuscular electrical stimulation – NMES, aerobic exercises, plyometrics, among others), provided that they presented at least one measure related to the outcome of postural balance or occurrence of falls; C (comparator): any control or placebo group; O (outcomes): postural balance and occurrence of falls (primary outcomes), muscle strength, and functional capacity (secondary outcomes) and S (study design): RCTs or RCT crossover. Discrepancies between the two reviewers were discussed and resolved with the assistance of a third reviewer (I.M.A.).

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The final decision regarding the inclusion of the article was based on the independent full reading of the potentially relevant or uncertain studies by the same reviewers. The following exclusion criteria were considered: absence of at least one validated instrument to measure postural balance or the occurrence of falls after the intervention, evaluation of psychosocial outcomes, duplicate studies (repeated in different databases or doubly published in different journals and/or at different times by the authors), and availability of only conference proceedings.

It is noteworthy that the primary outcome measures included postural balance and falls, while the secondary outcomes included peripheral muscle strength and functional capacity.

Data extraction

Two reviewers (T.D.S. and A.B.), independently, using a standardized form, collected the following data from the included articles: publication details, methodology, outcomes, sample characteristics, interventions (type of therapeutic interventions, frequency, duration, progression method, combination of these or isolated use, and information about the comparison group), outcome measures (adverse effects), results, and conclusions obtained. The corresponding authors of articles with insufficient data were contacted to determine if this data could be provided. For a coherent presentation of the results, the articles were grouped by therapeutic intervention and assessment instrument.

Risk of bias assessment

The risk of bias was assessed by both independent reviewers (T.D.S. and A.B.) (Kappa=0.90) using RoB 2, a Cochrane Collaboration risk of bias tool revised for randomized studies¹⁷. In this study, five domains are considered: bias arising from the randomization process, bias due to deviations from planned interventions, bias due to the absence of outcome data, bias in the measurement of outcomes, and bias in the selection of the reported outcome. These domains were classified as low risk of bias, some concern, or high risk of bias.

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Quality of evidence assessment

The Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) method was used by two independent reviewers (T.D.S. and A.B.) to assess the quality of evidence for each outcome, based on five factors: risk of bias, inconsistency, indirect evidence, imprecision, and other considerations¹⁸. Quality was reduced by one level for each unmet factor, resulting in four levels: high, moderate, low, or very low. The evaluation was carried out using the online tool (<https://www.gradepro.org/>). In this review, to assess the quality of evidence, we only considered outcomes and exercise-based therapeutic interventions for which a meta-analysis was possible.

Statistical analysis

Data analysis was performed in accordance with Cochrane statistical guidelines using Review Manager software (RevMan version 5.4; Cochrane Collaboration, Copenhagen, Denmark) to perform meta-analysis of those outcomes for which the data allowed¹⁹. Considering the other cases, descriptive statistics were used. To quantify the effect of continuous outcomes, results are presented as the difference in means (MD) with 95% confidence intervals. The statistical heterogeneity among studies was assessed using the inconsistency statistic (I^2), with values of 25%, 50%, and 75% considered indicative of low, moderate, and high heterogeneity, respectively. The random effects model was used in all analyses. A value of $p \leq 0.05$ was considered statistically significant. The data were analyzed by intervention, assessment instrument, and outcome. Furthermore, the study results were compared with the previously established minimum clinically important difference (MCID) for postural balance outcomes in COPD patients (Berg Balance Scale – BBS, Activities-specific Balance Confidence – ABC, Timed Up and Go – TUG). Balance Evaluation Systems Test (BESTest)²⁰, peripheral muscle strength (30-second Sit-to-Stand Test – 30-second SST, maximum voluntary contraction – MVC, and one repetition maximum test – 1RM)²¹⁻²², and functional capacity (Six-Minute Walk Test – 6MWT)²³.

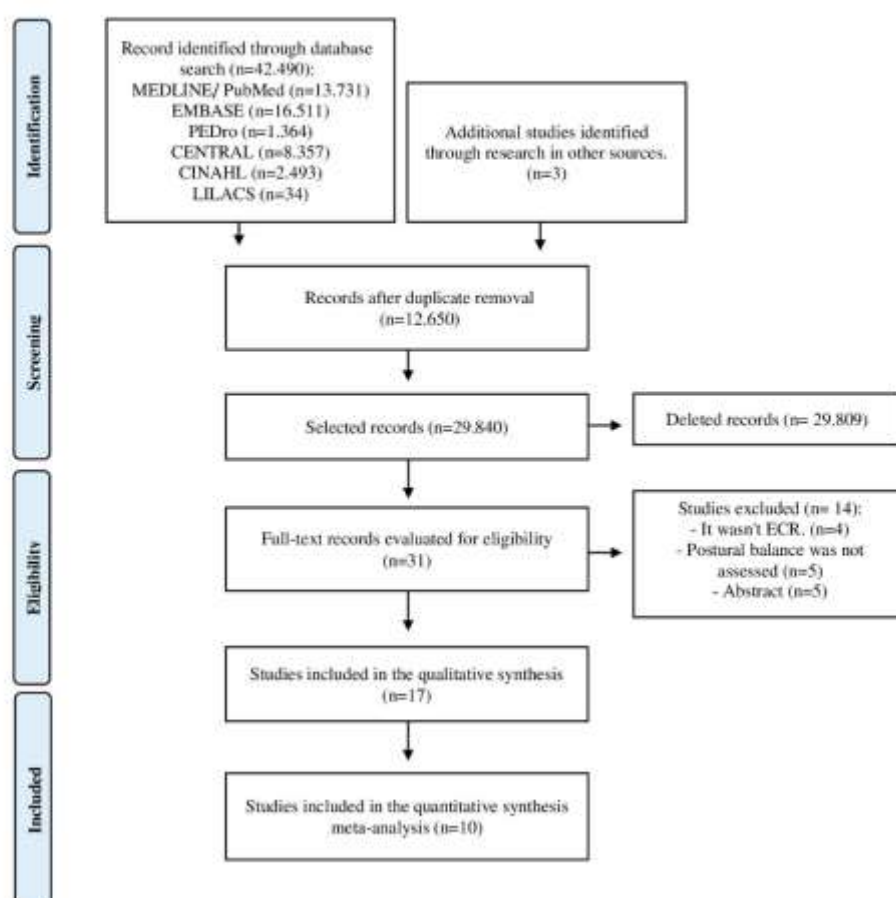
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Results

Selection of studies

The search strategy identified 42,490 potentially relevant studies. Following the steps of excluding duplicates and screening titles and abstracts, 31 full-text articles were selected for a detailed review. At the end of the systematic review, 17 studies were included. The flowchart summarizes the study selection process and the reasons for exclusions (Figure 1).

Figure 1. PRISMA flow diagram



Source: The authors

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Characteristics of the studies

The main characteristics of the studies included in this systematic review are presented in Table 1. 859 patients with stable COPD and 58 in exacerbation were included; of these, in ten studies, the patients presented, on average, moderate COPD²⁶⁻³⁵, in six severe COPD³⁶⁻⁴¹ and in one study, the pulmonary function values are not detailed⁴². Most studies were conducted with a relatively small sample size (<50 patients per group), with only Reddy et al. (2021) having a sample of 128 patients²⁷.

The interventions used were varied, such as balance training (n=328; 63.8±4.6 years)^{26-28,36-37}, vibration platform (n=209; 62.9±5.8 years)^{29,38-38,42}, NMES (n=87; 61.0±4.5 years)³⁰⁻³¹ and other interventions, which included combined training, aerobic exercise, aquatic exercise, Sun-style t'ai chi, virtual reality, or inspiratory muscle training (IMT) (n=293; 66.4±5.8 years)^{32-35, 40-41}. In some studies (n=11; 64.7%), the aforementioned interventions were added to conventional PR programs^{26-28,30-31,35-39,42}. These interventions did not result in adverse events, however not all studies reported this aspect^{28-29,32-34,37-40}.

Regarding balance training, exercises such as transition, gait, functional strengthening, and support were frequently included, with each session lasting predominantly 30 minutes, encompassing 18 to 72 sessions, three times a week^{26-28, 36-39}. Considering the vibration platform in all studies, dynamic squat exercises were described, lasting 8 to 30 minutes and performed 2 to 5 times a week^{29,38-38,42}. The NMES was performed similarly across studies regarding the protocol used and the duration of the sessions³⁰⁻³¹. Finally, the other interventions used different protocols, showing wide variation between studies in relation to the therapeutic resource used and the duration of the sessions^{32-35,40-41}.

Postural balance was measured using different clinical and laboratory tests, among which the most frequently used included the BBS^{26-27,29-31,36-37,41} and the TUG^{27-29,30-31,35-36,41}.

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Table 1 - Characteristics of the studies included in the systematic review

Author, Year, Country	Sample characteristics	Groups	Age (years)	FEV ₁ (% predicted)	Duration, Frequency, Total	Training program
Balance training						
Mkacher et al. 2015 ³⁶ Tunísia	Stable COPD (n=68)	IG: BT + PR CG: PR	58.3±4.3 61.2±3.2	39.4±10.3 38.6±8.6	BT: 30 minutes, 3 days/week 24 weeks. PR: 3 days/week, 2 times a day, for 24 weeks.	BT: Supportive exercises, transition, gait training, and functional strengthening. RP: supervised physical training, breathing exercises, education, and psychological and social support.
Mounir et al. 2019 ²⁶ Egito	Stable COPD (n=48)	IG: BT + PR CG: PR	63.1±1.7 62.4±1.6	63.6±5.6 61.6±8.5	BT: 25-30 min., 3 days/week 8 weeks. PR: 25-30 min., 3 days/week 8 weeks.	BT: Functional strengthening, posture exercises, transition and gait training. PR: Endurance training (60-80% of MV obtained in the 6MWT), upper and lower limb strength training (3 sets of 8 repetitions) 50-75% 1MR and daily breathing exercises.
Beauchamp et al. 2013 ³⁷ Canadá	Stable COPD (n=36)	IG: BT + PR CG: PR	71.9±4.9 67.1±9.4	39.9±13.2 35.4±17.5	BT: 30 minutes, 3 days/week 6 weeks. PR: 5 days/week, 6 weeks.	BT: Support, transition, gait, and strengthening exercises. Progression: more challenging conditions. PR: Supervised exercise, breathing exercises, self- management education, psychological and social support.
Reddy et al. 2021 Índia ²⁷	Stable COPD (n=128)	IG: BT + PR CG: PR	52.5±3.9 52.1±4.6	67.2±22.3 69.6±23.7	BT: 15-20 min., 3 days/week 8 weeks. PR: 60 minutes, 3 days/week 8 weeks.	BT: Weight transfer, standing and sitting without support, walking in a straight line, single-leg standing; weight distribution and postural alignment of the trunk in a swinging plank. PR: Endurance exercises (5-6 Borg walks), strengthening exercises (10-15 repetitions, increasing load and number of sets), breathing exercises, relaxation, education, and psychological support.
Chuatrakoon et al. 2022 ²⁸ Tailândia	Stable COPD (n=48)	IG: BT + PR home CG: PR home	74.5±5.3 75.4±6.8	62.9±17.4 53.3±17.7	BT: 20 minutes, 3 days/week 8 weeks. PR: 45 minutes, 3 days/week 8 weeks.	BT: Posture exercises (different support bases and surfaces), walking, and functional exercises. Training progression: reducing hand support and increasing the number of repetitions. PR: Breathing exercises, stretching, muscle strengthening (2 sets of 10 repetitions, load based on the 10MR test; with increasing number of sets and repetitions), endurance exercises (walking 3-4 Borg scales for 15 min., with increasing duration) and education.

Vibrating platform

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Spielmanns et al. 2016 ²⁹ Alemanha	Stable COPD (n=27)	IG: Vibrating platform	69.0 (65.3-73.0)	63,0 (39-71)	Vibrating platform: 30 minutes, 2 days/week for 12 weeks.	Vibrating platform: Warm-up, vibration platform (15 min.): Isometric squat position, performed for 3 x 2 min., 6 to 10 Hz, displacement of 4 to 6 mm (first 4 weeks). Progression: exercise duration and vibration frequency and cool-down. Calisthenic training: In combination with relaxation and breathing exercises.
		CG: Calisthenic training	70.0 (66-78)	52.0 (43-73)	Calisthenic training: 30 min., 2 dias/semana 12 semanas.	
Gloeckl et al. 2017 ³⁸ Alemanha	Stable COPD (n=74)	IG: Vibrating platform + PR	65.0±8.0	33.6±8.5	Vibrating platform: 8 minutes/session 3 days/week, 12 weeks. PR: 5 days/week, 12 weeks.	Vibrating platform: Squat exercise (4 sets of 2 min. duration) high frequencies (24 to 26 Hz), 5 mm displacement. Squat exercise (4 sets of 2 min. duration) on a normal floor. PR: Endurance training (cycling at 60% of peak power) and strength training (15-20 repetitions of large muscle groups).
		CG: Squat (floor)+ PR	63.0±9.0	36.6±11.7		
Gloeckl et al. 2021 ³⁹ Alemanha	Stable COPD (n=48)	IG: BT on the vibration platform + PR	65.0±7.0	36.2±8.4	PR: 6 days/week 12 weeks. BT on the vibration platform: 20 min., 3 days/week 12 weeks.	PR: multimodal e multidisciplinar abrangente. BT on the vibration platform: Alternating lateral vibration platform, 5 to 26 Hz and peak-to-peak displacement of 4-5 mm. Dynamic squat exercises, dynamic heel raises, and static unilateral posture. BT conventional: Same description as above. Progression: addition of more challenging conditions.
		CG: BT conventional + PR	66.0±8.0	38.0±6.3		
Ezzat et al. 2021 ⁴² Egito	Stable COPD (n=60)	IG: vibration platform + PR	52.5±4.4	-	Vibrating platform: 3 days/week, 12 weeks. PR: 3 days/week, 12 weeks.	Vibrating platform: Static squat (knees slightly bent - 3 sets of 3 min., totaling 9 min.), on a vibration platform, 25-35 Hz, and 6 mm displacement. PR: Breathing exercises and a home program (20-30 minute walk and incentive spirometry).
		CG: PR	51.9±4.6			
NMES						
Mekki et al. 2018 ³⁰ Tunisia	Stable COPD (n=45)	IG: NMES+PR	59.6±4.8	57.7±14.4	NMES: 20 min. (each leg) 3 days/week, 24 weeks.	NMES: Quadriceps femoris, triceps surae, and hamstring muscles. Parameters: 400 μs, 50 Hz, 15 to 60 mA, 5 s ON and 15 s OFF (3rd month) and 10 s ON and 30 s OFF (after). PR: Warm-up, endurance training (ergometer, target heart rate of 60%-70% of the maximum heart rate of the 6MWT), strengthening (2 sets of 10 repetitions for upper and lower limbs, 50%-85% of the 10MR test) and cool-down.
		CG: PR	59.5±3.1	57.1±10.2	PR: 80 minutes, 3 days/week, 24 weeks.	

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Acheche et al. 2020 ³¹ Tunísia	Stable COPD (n=42)	IG: NMES+PR (Endurance + Strength Training)	63.0±4.0	54.1±19.8	Endurance training: 45 min. Strength training: 20 min. NMES: 20 min, 3 days/week 24 weeks.	Endurance training: warm-up, walking on an ergometer (60-70% of maximum heart rate achieved at the end of the 6MWT, interval training). Strength training: 50% of 1MR increment to 80% 1MR (2 sets of 8-10 repetitions). NMES: 16 bipolar, rectangular, self-adhesive electrodes (both legs), quadriceps femoris, calf and vastus lateralis muscles. Parameters: 50 Hz; 400 µs; 15-20 mA and duty cycle of 10/30 s.
		CG: PR (Endurance + Strength Training)	62.0±6.0	54.8±15.7		

Other interventions

Rinaldo et al. 2017 ³² Itália	Stable COPD (n=24)	IG: Endurance training + strength training= CT	66.2±4.2	60.1±24.3	CT: 60 minutes, 3 days/week 14 weeks. PAE: 60 min., 3 days/week Supervised (1-5 sessions) after gradual reduction of supervision, 14 weeks.	Endurance training: cycling, walking on a treadmill or upper limb ergometer (3 to 4 on the Borg scale). Strength training: 4 sets for lower limbs (leg press and knee extension), upper limbs (chest and shoulders) and trunk (abdominal crunches with free weights and back extension), 50 and 80% 1MR. Load adjusted according to 1RM. PAE: Aerobic exercise, flexibility and balance exercises (3 to 4 on the modified Borg scale), Nordic walking or weightless circuit training (e.g., squats) 10-15 repetitions.
		CG: PAE	66.1±4.5	72.2±18.8		
Torres-Sánchez et al. 2017 ⁴⁰ Espanha	Exacerbated COPD hospital (n=58)	IG: Medical care + aerobics	75.65±6.25	42.3±10.6	Day 2 from admission to hospital discharge. Duration depends on length of stay.	Standard medical and pharmacological care. Intervention: cycling with a pedal exerciser (activity interrupted at level 6 on the Borg scale). Increased resistance daily.
		CG: Medical care	72.12±8.19	39.1±12.2		
de Castro et al. 2020 ³³ Brasil	Stable COPD (n=31)	IG: <i>Water group</i>	65.0±8.0	51.0±15.0	Water group e Land group: 60 minutes, 3 days/week, 14 weeks.	Water group: warm-up, endurance cycling (75% of 6MWT VM, Modified Borg scale 4-6), strengthening (quadriceps) and (biceps and triceps) (70% of 1MR, adding 14% to match the weight used (GC)) and stretching. Land group: warm-up, endurance (75% of 6MWT VM) and cycling (60% of maximum workload), strengthening of lower limbs (quadriceps) and upper limbs (biceps and triceps) (70% 1MR, Modified Borg scale 4-6) and overall stretching.
		CG: <i>Land group</i>	64.0±8.0	49.0±17.0		

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Leung et al. 2013 ³⁴ Austrália	Stable COPD (n=42)	IG: <i>Short-form Sun-style t'ai chi + home exercises</i> CG: Medical care	73.0±8.0	59.0±16.0	Short-form Sun-style t'ai chi: 60 min, 12 weeks.	Short-form Sun-style t'ai chi: start with 2-3 “forms” per week, completing all 21 by week 8. Intensity 3 on the modified Borg scale (using wrist weights between 0.5 and 1.5 kg if necessary). Home exercises: t'ai chi training booklet and DVD.
Rutkowski et al. 2020 ³⁵ Polônia	Stable COPD (n=106)	PR + endurance exercise PR+VR+ endurance exercise	62.1±2.9 60.6±4.3 60.4±4.2	65.4±24.0 60.5±16.2 69.2±23.6	PR: 15-30 minutes, once a day, 5 days a week, for 2 weeks. Exercício de endurance: 20-30 minutes, 5 days a week. Virtual reality: 20 minutes, 5 days a week.	PR: Physical conditioning exercises, coordination and balance, stretching, breathing exercises, walking, HB and relaxation. Endurance exercise: cycle ergometer (training heart rate based on equation). The percentage values were 70% (GOLD II) and 60% (GOLD III). Virtual reality: console (Xbox 360®), motion sensor (Kinect®) and projector with speakers. 4 Minigames: Rafting, cross-country racing, hitting a ball towards a player and mountain wagon ride.
Tounsi et al. 2021 ⁴¹ Tunísia	Stable COPD (n=32)	PR+VR IG: Resistance training + IMT CG: Resistance training	62.0±5.0 63.0±4.0	37.0±7.0 39.0±9.0	Resistance training: 30 min., 3 days/week, 8 weeks. IMT: Once a day; 7 days a week, 8 weeks.	Resistance training: supervised aerobic exercise on a treadmill (60-80% of the MV obtained in the 6MWT) and stretching. IMT: Two sets of 30 breaths (4 to 5 min/set) with 5 to 10 min of rest. The respiratory resistance load was set at 50% of the initial MIPmax and then increased by 10% every two weeks. Part of the training was supervised and part was performed at home.

Source: The authors

Legend: FEV₁: forced expiratory volume in the first second; COPD: chronic obstructive pulmonary disease; IG: intervention group; CG: control group; BT: balance training; PR: pulmonary rehabilitation; AS: average speed; 6MWT: six-minute walk test; 1MR: one repetition maximum; 10MR: ten repetition maximum; NMES: neuromuscular electrical stimulation; HR: heart rate; CT: combined training; EDU: Physical activity education; VR: virtual reality; BH: bronchial hygiene; GOLD: Global Initiative for Chronic Obstructive Lung Disease. IMT: inspiratory muscle training.

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Effects of interventions on postural balance

Balance training

Considering the five studies that used the addition of balance training in PR compared to conventional PR, four used the BBS^{26-27,36-37}. The mean difference in BBS was 4.02 points (95% CI 0.78 to 7.27; $I^2 = 97\%$; $p=0.02$; $n=280$), significantly favoring the addition of balance training (Figure 2.2.1 A). Four studies used the ABC instrument to assess the level of confidence in performing specific activities without loss of balance, whose findings demonstrate no significant difference between the groups when balance training was added to the PR (MD= 9.34; 95% CI -0.98 to 19.66; $I^2 = 98\%$; $p=0.08$; $n=280$)^{27-28,36-37}.

Additionally, three studies used the TUG, demonstrating that balance training in PR was able to provide improvement in dynamic postural balance, evidenced by the reduction in the execution time of the aforementioned test (MD=-2.19; 95% CI -2.86 to -1.52; $I^2 = 65\%$; $p<0.001$; $n=244$)^{27-28,36}. Two other studies using the BESTest instrument also suggest an improvement in this outcome when this intervention is added to PR (MD=7.83; 95% CI 0.13 to 15.52; $I^2 = 80\%$; $p=0.05$; $n=84$)^{26,37}. The single-leg stance test was also one of the instruments used in two studies that demonstrated a significant increase in test execution time after balance training in the PR (MD=3.47; 95% CI=2.52 to 4.42; $I^2 = 59\%$; $p<0.001$; $n=196$)²⁷⁻³⁶. MCID was exceeded in all studies for the BBS, TUG, and BESTest clinical tests^{26-28,36-37}. However, on the ABC scale, MCID was not achieved in two studies²⁷⁻²⁸.

Vibration platform

The addition of the vibration platform in a PR program provided a significant reduction in *absolute path length* (APL) on the force platform during the *Semi Tandem* posture with eyes closed (MD=-250.33; 95% CI= -416.77 to -83.89; $I^2 = 65\%$; $p=0.003$; $n=122$) (figure 2.2.1 B), *One-Leg* posture with eyes open (MD=-164.67; 95% CI= -257.07 to -72.28; $I^2 = 0\%$; $p<0.001$; $n=122$) and during the Romberg posture with eyes closed (MD=-78.16; 95% CI= -137.11 to -19.15; $I^2 = 0\%$; $p=0.009$; $n=122$)³⁸⁻³⁹. The *semi-tandem* posture with eyes open was also evaluated in the study by Gloeckl et al. (2017) (Table 2)³⁸. Furthermore, two other studies added a vibration platform to PR. Still, they used different instruments to assess balance, with Spielmanns et al. (2016) employing the BBS and the single-leg stance test, and Ezzat et al.

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(2021) using computerized dynamic posturography (Table 2)^{29,42}. It is important to highlight that for the BBS, used in the study by Spielmanns et al. (2016), the MCID was not exceeded²⁹.

Neuromuscular electrical stimulation (NMES)

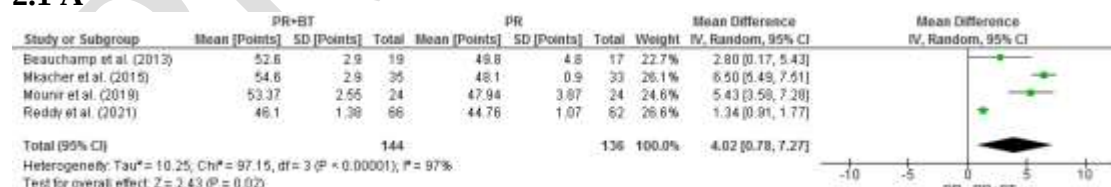
Two studies investigated the effects of adding NMES to a PR³⁰⁻³¹ program, whose results demonstrated a significant reduction in the execution time of the TUG (MD=-0.60; 95% CI=-0.87 to -0.33; I^2 =0%; p <0.0001; n =87) (figure 2.2.1 C). Similarly, on the strength platform, under open and closed eyes conditions, respectively, the variables COPap (MD=-8.04; 95% CI= -13.80 to -2.29; I^2 =0%; p =0.006; MD=-9.67; 95% CI= -17.15 to -2.20; I^2 = 0%; p =0.01), and COPml (MD=-18.16; 95% CI=-24.72 to -11.59; I^2 =43%; p <0.00001; MD=-22.58; 95% CI= -41.68 to -3.48; I^2 =95%; p =0.02) also showed a significant reduction. However, there was no significant increase in the score obtained in the BBS (MD=-0.16; 95% CI=-2.61 to 2.29; I^2 =93%; p =0.90). The MCID limits for TUG and BBS were exceeded.

Other interventions

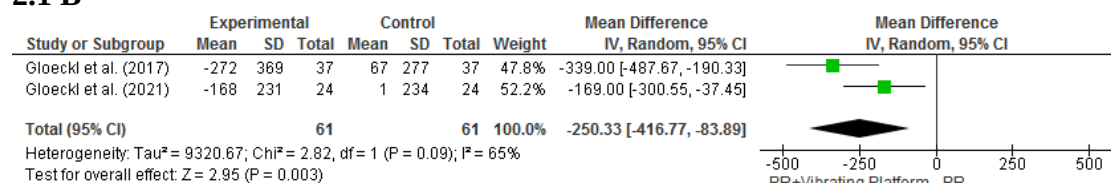
Other studies have used different interventions to investigate the effects on postural balance; the results are described in detail in Table 2. MCID was reached for TUG^{33,41}, but not for BBS and ABC⁴¹.

Figure 2 – Effects of different interventions on postural balance, peripheral muscle strength, and functional capacity in COPD.

2.1 A

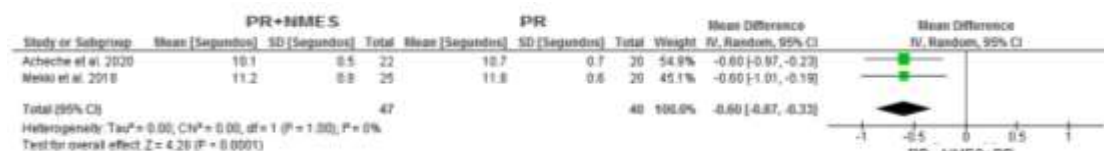


2.1 B

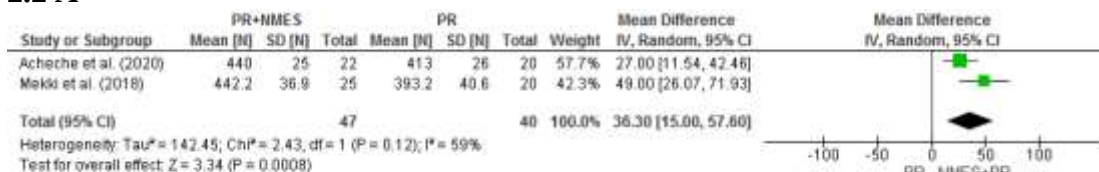


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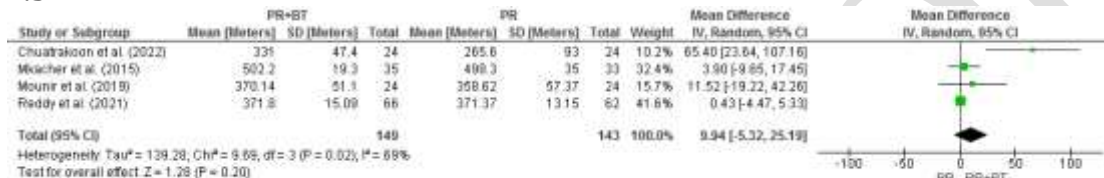
2.1 C



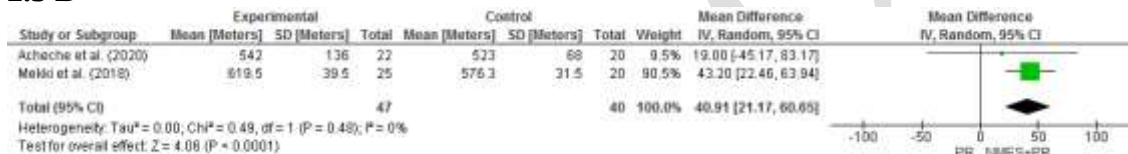
2.2 A



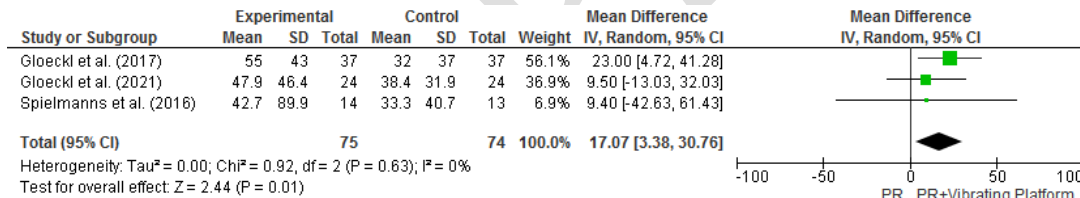
2.3 A



2.3 B



2.3 C



Source: The authors

2.1 Postural balance: **A)** Balance training (Berg Balance Scale); **B)** Vibration platform (strength platform – Semi Tandem posture - eyes closed); **C)** Neuromuscular electrical stimulation (Timed Up and Go). **2.2 Peripheral muscle strength:** **A)** Neuromuscular electrical stimulation (maximum voluntary contraction). **2.3 Functional capacity:** **A)** Balance training (six-minute walk test); **B)** Neuromuscular electrical stimulation (six-minute walk test); **C)** Vibration platform (six-minute walk test).

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Table 2 – Extraction of results regarding postural balance

Author	Sample	Instruments	IG vs CG
Whole-Body Vibration Trainin			
Gloeckl et al. 2017 ³⁸	IG: 37 CG:37	Power platform - Semi-tandem stance (eyes open) (mm) IG: -78.0±151.0*; CG: 0±173.0*	Significant reduction in favor of IG (p=0.046)
Spielmanns et al. 2016 ²⁹	IG: 14 CG:13	BBS (scores): IG: 54.0 (49.3-55.0) vs 55.0 (52.3-56.0); CG: 50.0 (47.0-51.0) vs 51.0 (47.0-52.0) Single-leg stance test (sec.): IG: 3.9 (1.7-7.5) vs 6.4 (3.2-18.3); CG: 3.6 (2.5-5.2) vs 3.0 (2.6-5.5)	BBS no significant difference (p=0.370); Unipodal stance test no significant difference (p=0.070).
Ezzat et al. 2021 ⁴²	IG: 30 CG:30	Computerized dynamic posturography: Antero-posterior stability: IG: 2.5±0.5 vs 1.9±0.4; CG: 2.2±0.8 vs 2.1±0.5 Mid-Lateral Stability: IG: 2.5±0.7 vs 2.0±0.4; CG: 2.7± 0.7 vs 2.7± 0.8 Overall Stability: IG: 3.4±0.6 vs 2.4±0.4; CG: 3.4±0.8 vs 3.3±0.8	Significant reduction in anteroposterior stability index (p=0.038), mediolateral stability index (p=0.001) and overall stability index (p=0.001) resulting in improved postural sway.
Other interventions			
Rinaldo et al. 2017 ³²	IG: 12 CG: 12	OLS (1 min.): IG: 47.7±48.2 vs 107.2±22.3; CG: 72.5±47.6 vs 104.6±33.8	No significant difference (p=0.482)
Torres-Sánchez et al. 2017 ⁴⁰	IG: 29 CG: 29	OLS (seg.): Right leg: IG: 4.0±6.8 vs 11.6±10.7; CG: 5.2±7.5 vs 2.5±7.5 Left leg: IG: 2.9±5.2 vs 9.5±10.6; GC: 3.6±4.9 vs 0.7±7.1	Increase in the right leg favoring GI (p=0.013) and no significant difference in the left leg (p=0.059)
de Castro et al. 2020 ³³	IG: 14 CG: 17	Force platform COP displacement area (cm2) - Feet hip-width apart Eyes open: IG: 2.8 (1.2 to 5.9) vs 3.1 (1.5 to 5.6); CG: 2.5 (1.7 to 4.5) vs 2.9 (2.2 to 4.1) Eyes closed: IG: 3.7 (1.3 to 8.3) vs 3.2 (1.4 to 5.6); CG: 3.2 (1.7 to 4.2) vs 3.3 (2.4 to 4.1) COP displacement area (cm2) – Short base	No significant difference for any of the variables related to postural balance (p>0.05)

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IG: 7.8 (4.0 to 9.7) vs 6.9 (5.2 to 11.2); CG: 5.9 (4.5 to 6.7) vs 5.8 (5.0 a 7.0)

OLS (seg.)[#]:

IG: 12.6±4.6 vs 14.0±6.7; CG: 11.6±4.1 vs 12.3±2.7

TUG (seg.):

IG: 10.0±1.5 vs 9.0±1.4; CG: 10.0±1.9 vs 9.0±2.1

Leung et al. 2013
34

IG: 19
CG: 19

Functional reach (cm):

IG: 30.1±8.0 vs 34.7±7.0; CG: 9.4±8.0 vs 28.7±8.0

Body sway:

Side by side stand (AP-mm):

IG: 23.2±12.0 vs 18.4±7.0; CG: 21.7±7.0 vs 23.2±8.0

Side by side stand (ML-mm):

IG: 30.3±13.0 vs 17.6±7.0; CG: 25.6±12.0 vs 26.4±12.0

Semi-tandem stand (AP-mm):

IG: 29.0±10.0 vs 21.8±6.0; CG: 24.6±13.0 vs 28.7±17.0

Semi-tandem stand (ML-mm):

IG: 38.6±18.0 vs 25.8±10.0; CG: 29.1±12.0 vs 32.6±12.0

Significant reduction in ML (-13.4 (-20-7)) and AP (-6.3 (-10-2)) oscillation in the side-by-side stand posture and ML (-12.4 (-21-3)) in the semi-tandem stand posture. Significant improvement in functional reach distance (5.4 (3-8)).

Rutkowski et al. 2020
35

G1: 34
G2: 38
G3: 34

TUG (seg.):

G1: 6.6 (6.0-6.7) vs 6.2 (5.9-6.5); G2: 6.0 (5.7-6.3) vs 5.3 (4.9-5.6);
G3: 5.8 (5.5-6.2) vs 5.5 (5.1-5.8)

Significant reduction G2 vs G1: p=0.000
No significant difference G1 vs G3: p=0.133

Tounsi et al. 2021
41

IG: 16
CG: 16

EEB (scores):

IG: 47.7±2.7 vs 52.3±2.5; CG: 47.2±4.5 vs 49.1±4.6

TUG (seg.):

IG: 9.3±1.4 vs 8.4±1.4; CG: 9.3±1.1 vs 9.0±1.0

OLS (seg.):

IG: 38.9±23.1 vs 46±25.6; CG: 38.0±27.1 vs 39.6±27.8

ABC (%):

IG: 75.7±10.0 vs 88.0±9.5; CG: 75.1±12.5 vs 80.3±12.5

Significant increase in EEB in favor of GI (p=0.019).
Significant increase in ABC in favor of GI (p=0.014).
No significant difference for TUG and OLS (p>0.05).

Source: The authors

Values presented for pre- and post-intervention periods, expressed as mean ± standard deviation or median (interquartile range). GI: intervention group; CG: control group; BBS: Berg Balance Scale; OLS: One-legged stance; TUG: Timed up And Go; COP: center of pressure; AP: anteroposterior; ML: mediolateral; G1: Pulmonary rehabilitation including endurance exercise; G2: Pulmonary rehabilitation including endurance exercise and virtual reality; G3: PR including virtual reality; ABC: Activities-specific Balance Confidence. [#] Four subjects were unable to complete the OLS test; *Difference between the means.

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Effects of interventions on fall risk assessment

Falls were not reported individually as an outcome in any of the 17 studies included in this review. However, the assessment of fall risk was considered by Reddy et al. (2021) through the Elderly Falls Screening Test (considers history of falls, injuries resulting from falls, and gait speed and Chuatrakoon et al. (2022) through Physiological Profile Assessment (evaluates physiological deficiencies that contribute to falls, which include: visual contrast sensitivity, proprioception, quadriceps muscle strength, hand reaction time, and postural sway)²⁷⁻²⁸. In both studies, the addition of balance training to PR significantly reduced the risk of falls compared with conventional PR ($p=0.000$; $p=0.01$)²⁷⁻²⁸. Mkacher et al. (2015) demonstrated a significant increase in the score obtained on the Tinetti Test (which assesses the risk of falling in two domains: balance and gait), indicating a reduction in the risk of falling after balance training in addition to PR ($p<0.01$)³⁶.

Effects of interventions on peripheral muscle strength

Balance training

Of the five studies investigating the effects of balance training in a rehabilitation program, only Beauchamp et al. (2013) included peripheral muscle strength as an outcome (Table 3, supplementary material). In the aforementioned study, the MCID was exceeded³⁷. However, in the study by Chuatrakoon et al. (2022), quadriceps muscle strength is one of the items that make up the Physiological Profile Assessment; however, this did not show a significant difference after the intervention between the groups ($p=0.53$)²⁸.

Vibration platform

Two studies evaluated the effects of a vibration platform in a PR program on peripheral muscle strength but found no significant difference compared with conventional PR (MD=4.90; 95% CI=-7.84 to 17.64; $I^2=0$ %; $p=0.45$; $n=122$)³⁸⁻³⁹. Spielmanns et al. (2016) observed a significant increase in peripheral muscle strength with the leg press peak force in the vibration platform group compared to calisthenic training (Table 3, supplementary material)²⁹.

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Neuromuscular electrical stimulation

Two studies, which used NMES in a PR program, reported the assessment of muscle strength using the MVC of the quadriceps femoris muscle³⁰⁻³¹. The mean difference in MVC of the quadriceps muscle was 36.3 N (95% CI = 15.0 to 57.6; $I^2 = 59\%$; $p = 0.0008$; $n = 87$), significantly favoring the addition of the aforementioned intervention (Figure 2.2.2 A) and exceeding the MCID.

Other interventions

Of the six studies that used different therapeutic interventions, five describe their effects on peripheral muscle strength^{32-35,40} (Table 3, supplementary material). In only one study, the 1MR test, the MCID was exceeded³².

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Table 3. Extraction of results related to peripheral muscle strength

Author	Sample	Instruments	IG vs CG
Treino de equilíbrio			
Beauchamp et al. 2013 ³⁷	IG: 19 CG: 17	STS 30 sec. (repetitions): IG: 6.6±4.6 vs 12.7±3.3; CG: 7.0±5.0 vs 10.0 ± 3.9	Increase in favor of IG (p=0.020)
Whole-Body Vibration Training			
Spielmanns et al. 2016 ²⁹	IG: 14 CG: 13	Peak force of the leg press (Kg): IG: 92.0 (66.7-138.0) vs 123.0 (93.3-166.7); CG: 130.0 (112.0-142.0) vs 127.5 (115.0-153.8)	Increase in favor of IG (p=0.001)
Gloeckl et al. 2021 ³⁹	IG: 24 CG: 24	Countermovement jump [W/Kg]: IG: 2.3 (1.1-3.4)* CG: -0.1 (-0.9-0.8)*	Increase in favor of IG (p=0.001)
Other interventions			
Rinaldo et al. 2017 ³²	IG: 12 CG: 12	1MR – Bench press and leg extension (kg): Supine (kg): IG: 41.1±8.9 vs 50.0±8.8; CG: 57.8±15.1 vs 54.3±13.9 Leg extension (kg): IG: 59.2±18.2 vs 65.8±24.0; CG: 64.1±21.8 vs 65.6±20.4	Increase in favor of the IG: Supine and Leg Extension (p<0.05)
Torres-Sánchez et al. 2017 ⁴⁰	IG: 29 CG: 29	Dynamometry (N): IG: 103.6±11.4 vs 114.0± 37.3; CG: 101.5±13.5 vs 86.3±40.2	Increase in favor of the IG (p=0.028)
de Castro et al. 2020 ³³	IG: 14 CG: 17	Dynamometry (N): IG: 87.0±30.0 vs 103.0±37.0; CG: 73.0±23.0 vs 84.0±20.0 IG: 87.0±33.0 vs 96.0±31.0; CG: 68.0±22.0 vs 75.0±185.0	No significant difference: p=0.430 e p=0.620
Leung et al. 2013 ³⁴	IG: 19 CG: 19	Isokinetic strength of the quadriceps (N): Right: IG: 119.0±51.0 vs 136.0±54.0; CG: 143.0±50.0 vs 136.0±47.0 Left: IG: 123.0±46.0 vs 139.0 ± 50.0; CG: 153.0±50.0 vs 151.0±46.0	Increase in favor of the IG
Rutkowski et al. 2020 ³⁵	G1: 34 G2: 38	Push-up (repetition): G1: 18.9 (17.9-20.1) vs 20.3 (19.2-21.4);	Increase G2 vs G1: <i>Arm curl</i>

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G3: 34	G2: 18.7 (17.7-19.7) vs 21.9 (20.9-23.0); G3: 21 (19.9-22.1) vs 25.6 (24.6-26.7); STS 30 sec. (repetitions): G1: 14.8 (13.6-15.9) vs 15.6 (14.5-16.7) G2: 14.6 (13.5-15.7) vs 16.9 (15.8-17.9) G3: 16.4 (15.2-17.5) vs 18.9 (17.8-20.1)	(p<0.003) e TSL (p<0.008) Increase G3 vs G1: <i>Arm curl</i> (p <0.000) e TSL (p <0.001)
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Source: The authors

Values presented for pre- and post-intervention periods, expressed as mean $\pm$ standard deviation or median (interquartile range). IG: Intervention group; CG: Control group; SST: 30-second sit-to-stand test; 1MR: Maximum repetition; G1: Pulmonary rehabilitation including endurance exercise; G2: Pulmonary rehabilitation including endurance exercise and virtual reality; G3: PR including virtual reality. *Difference between means.

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Effects of interventions on functional capacity

Balance training

Regarding functional capacity, assessed in four studies^{26-28,36}, the addition of balance training in PR did not promote a significant difference (MD=9.94; 95% CI=-5.32 to 25.19; $I^2=69\%$; $p=0.20$; $n=292$) (Figure 2.2.3 A). However, it reached MCID. It is pertinent to note that Beauchamp et al. (2013) report only that MCID was obtained for the intervention and control groups³⁷.

Vibration platform

Three of the studies that used the vibration platform in a PR program compared to conventional PR assessed functional capacity using the 6MWT^{29,38,39}. The mean difference in distance covered during the 6MWT was 17.07 meters (95% CI = 3.38 to 30.76; $I^2 = 0$; $p = 0.01$; $n = 149$), significantly favoring the addition of the vibration platform and exceeding the MCID (Figure 2.2.3 B).

Neuromuscular electrical stimulation

The addition of NMES in a PR program significantly increased the distance covered in the 6MWT by 40.91 meters (95% CI = 21.17 to 60.65; $I^2 = 0\%$; $p < 0.0001$, $n = 87$), exceeding the MCID³⁰⁻³¹ (Figure 2.2.3 C).

Other interventions

The six studies that used different interventions assessed functional capacity as the outcome, and in most of these ($n=4$; 66.7%) there was no significant difference after the intervention (Table 4, supplementary material)^{32-35,40-41}. In four of these studies, considering the 6MWT, the MCID was achieved, as reported in Rinaldo et al. (2017) (endurance + resistance exercises), by Castro et al. (2020) (Land group), Rutkowski et al. (2020) (G2: PR + endurance exercise + virtual reality and G3: PR + virtual reality and Tounsi et al. (2021) (endurance training + IMT)^{32-34,41}.

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Table 4. Extraction of results in relation to functional capacity

Author	Sample	Test	IG with regard to CG:
Outras intervenções			
Rinaldo et al. 2017 ³²	IG: 12 CG: 12	6MWT (m): IG: 455.0±110.0 vs 480.0±121.0; CG: 519.0±72.0 vs 540.0±48.0	No difference between the groups (p=0.094)
Torres-Sánchez et al. 2017 ⁴⁰	IG: 29 CG: 29	SST 30 seg. (repetições) IG: 8.7±4.6 vs 13.7±4.8; GC: 9.7±6.2 vs 9.1±3.2	No significant difference between the groups (p=0.409)
de Castro et al. 2020 ³³	IG: 14 CG: 17	6MWT (m): IG: 496.0±68.0 vs 527.0±83.0; CG: 487.0±56.0 vs 532.0±71.0	No significant difference between the groups (p=0.440)
Leung et al. 2013 ³⁴	IG: 19 CG: 19	ISWT (m): IG: 349.0±136.0 vs 388.0±135.0; 402.0±179.0 vs 386.0±169.0 ESWT (s): GI: 467.0±276.0 vs 803.0±364.0; 442.0±334.0 vs 430.0± 383.0	Significant increase in ESWT (348 (186–510))
Rutkowski et al. 2020 ³⁵	G1: 34 G2: 38 G3: 34	6MWT (m): G1: 492.1 (479.4-504.7) vs 508.3 (495.6-520.9) G2: 471.5 (459.6-48.5) vs 510.6 (498.7-522.6) G3: 487.9 (475.3-500.2) vs 523.4 (510.8-536.0)	G2 vs G1: p=0.011 G1 vs G3: p= 0.031
Tounsi et al. 2021 ⁴¹	IG: 16 CG: 16	6MWT (m): GI: 426.3±90.7 vs 468.6±98.2 GC: 428.2±12 vs 457.9±130.6	No significant difference (p=0.926)

Source: The authors

Values presented for pre- and post-intervention periods, expressed as mean ± standard deviation or median (interquartile range). IG: intervention group; CG: control group; 6MWT: six-minute walk test; SST: 30-second sit-to-stand test; ISWT: Incremental shuttle walk test; ESWT: endurance shuttle walk test; G1: pulmonary rehabilitation including endurance exercise; G2: pulmonary rehabilitation including endurance exercise and virtual reality; G3: PR including virtual reality.

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Analysis of the risk of bias

The final risk of bias assessment, according to RoB2, for the studies included in this review is presented in Figure 3. Of the 17 studies, only 7 showed a low risk of bias for all domains assessed^{26,28,34-35,37,40-41}. In 5 studies, a high risk of bias was observed due to the absence of outcome data, particularly due to loss to follow-up (approximately 15% of the sample)^{30-31,38-39}. The lack of detailed information in the studies stands out, raising concerns across different areas. Based on the GRADE approach, the level of evidence in synthesis was low or very low (Table 5).

Figure 3. Risk of bias in the studies included in the systematic review and meta-analysis.

	Acheche et al. (2020)	Beauchamp et al. (2013)	Chuattakoon et al. (2022)	de Castro et al. (2020)	Ezzat et al. (2021)	Globeck et al. (2017)	Globeck et al. (2021)	Leung et al. (2013)	Mekki et al. (2018)	Mkacher et al. (2015)	Mounir et al. (2019)	Reddy et al. (2021)	Rinaldo et al. (2017)	Rutkowski et al. (2020)	Speilmann et al. (2016)	Torres-Sánchez et al. (2016)	Tounsi et al. (2021)
Bias resulting from the randomization process	+	+	+	+	?	+	+	+	+	+	+	+	+	+	+	+	+
Bias due to deviations from planned interventions	+	+	+	+	?	+	+	+	+	+	+	+	+	+	+	+	+
Bias due to the absence of outcome data	+	+	+	+	?	+	+	+	+	+	+	+	+	+	+	+	+
Bias in the maintenance of outcomes	+	+	+	+	?	+	+	+	+	+	+	+	+	+	+	+	+
Bias in the selection of the reported study.	+	+	+	+	?	+	+	+	+	+	+	+	+	+	+	+	+

■ Low risk of bias
 ■ Some concerns
 ■ High risk of bias

Source: The author

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Table 5. Quality of evidence from the studies included in the meta-analysis.

Assessment of certainty							Number of patients		Effect	Certainty
Number of studies	Study design	Risk of bias	Inconsistency	Indirect evidence	Imprecision	Other considerations	BT + PR	PR	Absolute (CI 95%)	
Postural balance (assessed with: BBS (0-56 points))										
4	RTC	Serious ^a	Serious ^b	Don't worry	Serious ^c	No	144	136	MD= 4.02 (0.78 to 7.27)	⊕○○○
Postural balance (assessed with: ABC (0-100%))										
4	RTC	Serious ^a	Serious ^b	Don't worry	Serious ^c	No	144	136	MD= 9.34 (-0.98 to 19.66)	⊕○○○
Postural balance (assessed with: TUG (seconds))										
3	RTC	Serious ^a	Don't worry	Don't worry	Serious ^c	No	125	119	MD= -2.19 (-2.86 to -1.52)	⊕⊕○○
Postural balance (assessed with: BESTest (score))										
2	RTC	Don't worry ^a	Serious ^b	Don't worry	Serious ^c	No	43	41	MD= 7.83 (0.13 to 15.52)	⊕⊕○○
Postural balance (assessed with: Single-leg stance test (seconds))										
2	RTC	Serious ^a	Don't worry	Don't worry	Serious ^c	No	101	95	MD= 3.47 (2.52 to 4.42)	⊕⊕○○
Functional capacity (assessed with: Six-minute walk test (meters))										
4	RTC	Serious ^a	Serious ^b	Don't worry	Serious ^c	No	149	143	MD= 9.94 (-5.32 a 25.19)	⊕○○○
Number of studies	Study design	Risk of bias	Inconsistency	Indirect evidence	Imprecision	Other considerations	Vibrating platform + PR	PR	Absolute (CI 95%)	Certainty
Postural balance (assessed with: Force platform (Semi Tandem Postural - Eyes closed - APL - mm))										
2	RTC	Serious ^d	Don't worry	Don't worry	Serious ^c	No	61	61	MD= -250.33 (-416.77 to -83.89)	⊕⊕○○
Postural balance (assessed with: Force platform (One-Leg posture - eyes open - APL - mm))										
2	RTC	Serious ^d	Don't worry	Don't worry	Serious ^c	No	61	61	MD= -164.67 (-257.07 to -72.28)	⊕⊕○○
Postural balance (assessed with: Force platform (Romberg posture - eyes closed - APL - mm))										
2	RTC	Serious ^d	Don't worry	Don't worry	Serious ^c	No	61	61	MD=- 78.16 (-137.11 a -19.15)	⊕⊕○○
Muscle strength (assessed with: Knee extension (N))										
2	RTC	Serious ^d	Don't worry	Don't worry	Serious ^c	No	61	61	MD= 4.9 (-7.84 a 17.64)	⊕⊕○○
Functional capacity (assessed with: (Six-minute walk test (m))										

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2	RTC	Serious ^d	Don't worry	Don't worry	Serious ^c	No	61	61	MD 17.07 (3.38 a 30.,76)	⊕⊕○○
Number of studies	Study design	Risk of bias	Inconsistency	Indirect evidence	Imprecision	Other considerations	NMES	PR	Absolute (CI 95%)	Certainty
Postural balance (assessed using: TUG (seconds))										
2	RTC	Serious ^a	Don't worry	Don't worry	Serious ^c	No	47	40	MD=- 0.6 (-0.87 to - 0.33)	⊕⊕○○
Postural balance (assessed using: force platform (COPap – eyes open – mm))										
2	RTC	Serious ^a	Don't worry	Don't worry	Serious ^c	No	47	40	MD= - 8.04 (-13.8 to -2.29)	⊕⊕○○
Postural balance (assessed using: force platform (COPap – eyes closed – mm))										
2	RTC	Serious ^a	Don't worry	Don't worry	Serious ^c	No	47	40	MD= - 9.67 (-17.15 to - 2.2)	⊕⊕○○
Postural balance (assessed using: force platform (COPml – eyes open – mm))										
2	RTC	Serious ^a	Don't worry	Don't worry	Serious ^c	No	47	40	MD=- 18.16 (-24.72 to - 11.59)	⊕⊕○○
Postural balance (assessed using: force platform (COPml – eyes closed – mm))										
2	RTC	Serious ^a	Serious ^b	Don't worry	Serious ^c	No	47	40	MD=- 22.58 (-41.68 to -3.48)	⊕○○○
Postural balance (assessed using: EEB (0–56 points))										
2	RTC	Serious ^a	Serious ^b	Don't worry	Serious ^c	No	47	40	MD=- 0.16 (-2,61 to 2.29)	⊕○○○
Peripheral muscle strength (assessed via: Maximal voluntary contraction of the quadriceps (N))										
2	RTC	Serious ^a	Don't worry	Don't worry	Serious ^b	No	47	40	MD= 36.3 (15.0 to 57.6)	⊕⊕○○
Functional capacity (assessed using: Six-minute walk test (m))										
2	RTC	Serious ^a	Don't worry	Don't worry	Serious ^b	No	47	40	MD= 40.91 (21.17 to 60.65)	⊕⊕○○

Source: The authors

^a There are studies classified according to the risk of bias as "Some concerns" in several areas.^b There was inconsistency between the studies.^c The total number of participants in this comparison is less than the ideal size. ^d Bias due to the absence of outcome data (loss to follow-up). Legend: BT: Balance training; PR: pulmonary rehabilitation; CI: confidence interval; BBS: Berg Balance Scale; RCT: randomized clinical trial; MD: Mean difference ABC: Activities-specific Balance Confidence; TUG: Timed up and go; BESTest: Balance Evaluation Systems Test; APL: absolute path length; NMES: neuromuscular electrical stimulation; COPap: amplitude of displacement of the center of pressure in the anteroposterior direction; COPml: Amplitude of displacement of the center of pressure in the mediolateral direction; ⊕○○○: Very low certainty; ⊕⊕○○: Low certainty.

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Discussion

This is the first systematic review with meta-analysis to evaluate the effects of different exercise-based therapeutic interventions on postural balance, fall incidence, peripheral muscle strength, and functional capacity in patients with COPD. The main findings indicate that adding balance training to postural rehabilitation resulted in significant improvement in postural balance, as measured by the BBS, BESTest, single-leg stance test, and TUG. The addition of the vibration platform to the PR promoted a significant reduction in postural sway (strength platform) and an increase in functional capacity. The use of NMES in a rehabilitation program has resulted in improved outcomes in postural balance (TUG and strength platform), peripheral muscle strength (MVC of the quadriceps femoris muscle), and functional capacity. Overall, the results demonstrated low to very low-quality evidence regarding the inclusion of balance training, vibration platforms, or NMES in PR for patients with COPD.

Considering that balance disorders are an important secondary manifestation of COPD⁸, different therapeutic interventions were identified in this review as proposed in the literature with the potential to improve this outcome. Among these, specific balance training was frequently included as part of PR, generally consisting of functional strengthening, posture, transition, and gait training exercises^{26-28,36-37}. The meta-analysis of this review demonstrated that adding balance training to PR resulted in significant increases of 4.02 points in BBS, 3.47 seconds in the single-leg stance test, and 7.83 points in BESTest compared to conventional PR. Furthermore, there was a significant reduction of 2.19 seconds in the TUG execution time. For the BBS, TUG, and BESTest tests, in addition to statistical significance, clinical relevance (MCID exceeded) was also demonstrated. Despite a statistically significant effect, the certainty of the evidence was classified as very low and low due to risk of bias across several domains, inconsistencies between studies, and a small sample size. Therefore, the results should be interpreted with caution, limiting the strength of clinical recommendations. Our results are consistent with the findings of two other systematic reviews, whose analyses were descriptive, suggesting that balance training performed in PR has a beneficial effect on balance in patients with COPD^{11,13}. However, some factors should be highlighted that may have contributed to a reduction in the quality of the evidence and, thus, decreased confidence in the accuracy of the results. Regarding these factors, the studies overall had a small sample size (an average of 33

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patients per group). Inconsistencies were also observed, which may be due to high heterogeneity in session duration, variation in total intervention time, and differences in the methodological quality of the underlying studies. Furthermore, two studies did not present important information for three of the five domains evaluated and were therefore classified as having a high risk of bias.

The vibration platform features a recent therapeutic modality in which, during movement, oscillatory vibrations are generated, stimulating muscle spindles and alpha motor neurons and, through the stretch reflex, producing muscle contractions³⁸. Given the potential benefits, this resource has been used in patients with COPD. As observed in this meta-analysis, adding a vibration platform to postural resuscitation significantly reduced postural sway across different postures. However, the evidence is of low quality, which reduces confidence in the results. Explanations for the reduced quality include the high risk of bias due to the absence of outcome data and the imprecision from the small sample size (average of 31 patients per group). Furthermore, it is important to note that only two studies could be included in the meta-analysis due to the different assessment instruments used. Similarly, Ezzat et al. (2021) demonstrated a significant reduction in postural sway (dynamic posturography) after the aforementioned intervention compared to conventional PR⁴². However, in the study by Spielmanns et al. (2016), there was no significant difference in the BBS or the single-leg stance test. Furthermore, there was no clinical relevance for BBS.²⁹ Some relevant factors to be considered in light of these discrepancies in results include: variable amplitude and frequency of vibration, which influence the intensity of the movement, weekly frequency, and total number of sessions.

NMES was another potentially valuable intervention strategy used in some of the studies to improve postural balance³⁰⁻³¹. The studies included in this review presented similar NMES protocols, which included: a high frequency of 50 Hz (aiming to recruit type II glycolytic fibers and thus confer an increase in strength); a pulse duration of 400 μ s (to obtain a motor response at the expense of small amplitude), and a duty cycle of 10/30 s (to minimize muscle fatigue)⁴³⁻⁴⁴. However, the intensity used varies between studies, influencing the number of motor units recruited. Therefore, it is suggested that the addition of NMES to PR resulted in a significant reduction in TUG (0.60 seconds) and postural sway (eyes open COPap conditions). 8.04 mm; COPml: 18.16 mm and closed COPap: 9.67 mm; COPml: 22.58 mm).

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The TUG test showed clinical relevance. However, the studies included in the meta-analysis provided low-quality evidence, downgraded due to the risk of bias (loss to follow-up) and imprecision (mean of 22 patients per group)³⁰⁻³¹.

Other therapeutic modalities adjunctive to conventional treatment used in the studies included in this review, suggestive of promoting significant improvement in postural balance in patients with COPD, included aerobic exercise⁴⁰, Short-form Sun-style t'ai chi³⁴, virtual reality,³⁵ and IMT⁴¹. However, due to the wide variety of interventions, their heterogeneity, and the limited number of studies, comparing the protocols used becomes unfeasible. Furthermore, clinical relevance was observed only when using one of the tests to assess postural balance (TUG)^{33,41}. Given that the possible underlying mechanisms of balance alterations in COPD are multifactorial¹⁴, investigating therapeutic interventions that could act on these mechanisms becomes relevant. Therefore, more RCTs are needed to make the evidence viable, which remains inconclusive.

Balance changes contribute to an increased risk and prevalence of falls⁴⁵, which consequently can result in increased mortality in subjects with COPD⁴⁶. Based on this premise, improving balance and preventing falls should become priority goals in the treatment of these patients. Despite this emerging interest, unlike the American Geriatrics Society, which recommends balance training as a component of multifactorial interventions for fall prevention in community-dwelling older adults, international PR statements do not address interventions to improve balance outcomes and consequently reduce falls^{10,47}. In this review, falls were defined as the primary outcome because they are a hard, clinically relevant outcome. However, none of the included studies reported this event directly or individually, highlighting a significant gap in the literature and limiting the immediate clinical relevance of our findings. However, balance training combined with PR significantly reduced the risk of falls, as assessed by different instruments, compared to conventional PR. This finding should be interpreted with caution, as the quality of the available evidence is very low to low. It is important to highlight that the lack of a standardized definition of falls and the use of different assessment instruments across studies can contribute to misinterpretation of data and the number of falls reported, resulting in epidemiological inaccuracy⁴⁵. Furthermore, improvements in postural balance measures do not necessarily translate into an effective reduction in the occurrence (frequency)

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of falls. We observed that many studies in the literature use the term "risk of falls." In this sense, RCTs that consider the outcome of falls (frequency) are necessary given their clinical relevance.

Reduced muscle strength, physical activity, and exercise capacity, which contribute to impaired QoL, are particularly relevant among the various factors that contribute to balance impairment in patients with COPD^{8,14,48}. Therefore, since these outcomes have implications for clinical practice, they were considered in this review. In this meta-analysis, the addition of NMES to PR increased peripheral muscle strength (36.3 N) and functional capacity (40.9 m) compared with conventional PR³⁰⁻³¹. In addition to statistical significance, clinical relevance was observed. However, the quality of the evidence is low, due to the risk of bias (loss to follow-up) and imprecision. Similar to what was observed in this study, a meta-analysis conducted by Hill et al. (2018) found that NMES applied concomitantly with conventional physical training significantly improved functional capacity; however, the findings regarding peripheral muscle strength were uncertain⁴⁹. These conflicting results regarding muscle strength are likely due to our review including only studies that reported at least one measure of postural balance or the occurrence of falls (primary outcome), which certainly restricted the number of studies included.

Additionally, considering the vibration platform therapeutic modality, its concomitant use with PR resulted in an increase of 17.07 m in the distance covered during the 6MWT, but without a difference in peripheral muscle strength. This analysis presented low-quality evidence due to risk of bias and imprecision. Our findings are consistent with those observed in the systematic review and meta-analysis (8 RCTs, n=365 patients) conducted by Zhou et al. (2018), in which the vibration platform demonstrated beneficial effects on functional capacity, showing a significant and clinical difference⁵⁰. The physiological mechanisms that may explain the aforementioned result may stem from increased neuromuscular activity, improved blood circulation, and relief of clinical symptoms⁵¹⁻⁵².

Regarding the secondary outcomes of this review, balance training in combination with PR did not promote statistically significant changes in functional capacity (6MWT) compared with PR alone. However, there was clinical relevance. Factors such as risk of bias, inconsistency, and imprecision may have contributed to the reduction in the quality and reliability of this evidence. It is noteworthy that no systematic reviews in the literature have

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been conducted in patients with COPD to investigate the effects of this intervention on functional capacity. However, considering such an outcome is potentially relevant, as reduced exercise capacity may be associated with impaired balance in these patients⁸. We identified that few studies evaluated peripheral muscle strength³⁷, whose results suggest a significant difference in favor of adding balance training in PR and exceeded the MCID.

Different clinical, laboratory, and self-reported assessment instruments were used to quantify postural balance. The diversity in the use of these instruments suggests a lack of consensus on which is the most appropriate for evaluating this outcome in patients with COPD¹¹. In this review, we identified that most of the included studies used the BBS and/or TUG as assessment instruments^{26-31,33,37,41}. Our result was consistent with that observed in a systematic review of the measurement properties of instruments that assessed balance in patients with COPD⁵³. Regarding BBS, studies demonstrate adequate responsiveness to PR, association with other assessment instruments, and the defined MCID²⁰. However, its use should be recommended in subjects with lower balance ability, due to the possible ceiling effect⁵³⁻⁵⁴. The TUG test has been reported as sensitive and specific in identifying patients with a history of falls in the past year and in detecting changes in postural balance after PR⁵⁵⁻⁵⁶. However, it is suggested that the TUG be performed primarily in subjects with better mobility and balance⁵⁵⁻⁵⁶. Therefore, standardization in the use of assessment instruments is crucial to enable comparisons between studies, and thus allow the identification of effective therapeutic approaches in postural balance.

This review considered different exercise-based therapeutic interventions with the potential to improve postural balance in clinical practice for patients with COPD, with a view to presenting an overview of the evidence to support the personalization of the intervention, including postural rehabilitation. A sensitive and comprehensive search strategy was conducted across six databases, with no language or publication year restrictions. All the steps that make up the methodology were executed independently by two evaluators. Furthermore, we used the revised Cochrane Collaboration risk of bias tool for randomized controlled trials (RoB2) and carefully assessed the quality of evidence according to the GRADE approach. However, given the heterogeneity of the interventions, it is pertinent to highlight the limitation in the external validity of our findings, as the physiological and clinical principles of each therapeutic modality

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are distinct, which may limit the generalizability of the results. Furthermore, certain limitations should be considered when interpreting the results of this review. First, it was only possible to include a small number of studies in the meta-analysis due to different assessment instruments and, mainly, the limited number of studies on therapeutic approaches, which may have contributed to considerable statistical heterogeneity. However, it is known that balance, as a relevant outcome of different interventions in COPD, is still an emerging topic¹³. Second, the sample size of the studies was relatively small. However, it should be noted that the number of COPD patients participating in PR is extremely low, as, in general, the included studies added another intervention to these programs⁵⁷. Third, it was not possible to use the quality of evidence assessment (GRADE) for all outcomes and interventions presented, as more than one study was needed to assess the reliability of the results¹⁸. Fourth, a considerable portion of the studies presented a risk of bias (high or some concern) for some of the domains evaluated.

Despite the limitations listed above, our findings are relevant to clinical practice, as they highlight the potential benefits of adding balance training to PR, making it an easy-to-implement modality with no additional cost. Furthermore, we synthesized the available evidence on the improvement of postural balance in patients with COPD across different therapeutic modalities, which may help guide more individualized rehabilitation strategies in clinical practice.

Conclusion

Therapeutic interventions such as balance training, vibration platform, or NMES, when added to postural rehabilitation, improved postural balance outcomes in patients with COPD. Despite these promising findings, the quality of the evidence is low to very low. Therefore, caution is advised when interpreting these results. NMES as part of PR increases peripheral muscle strength and functional capacity, and the vibration platform also enhances functional capacity; however, this evidence is limited due to its low quality. In light of the above, based on the available evidence from RCTs, there is no robust evidence to support a clinical decision. High-quality RCTs are needed to support systematic reviews, thereby enabling more conclusive results. In this regard, our research group conducted an RCT, the study protocol of which was recently published⁵⁸. Future research should investigate the effectiveness of therapeutic interventions on the outcome of fall occurrence.

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Supplementary material

Strategies

Medline

1. randomized controlled trial.pt.
2. controlled clinical trial.pt.
3. comparative study.pt.
4. clinical trial.pt.
5. randomized.ab.
6. placebo.ab,ti.
7. drug therapy.fs.
8. randomly.ab,ti.
9. trial.ab,ti.
10. groups.ab,ti.
11. or/1-10
12. (animals not (humans and animals)).sh.
13. 11 not 12
14. Lung Diseases, Obstructive/
15. exp Pulmonary Disease, Chronic Obstructive/
16. emphysema\$.tw.
17. (chronic\$ adj3 bronchiti\$).tw.
18. (obstruct\$ adj3 (pulmonary or lung\$ or airway\$ or airflow\$ or bronch\$ or respirat\$)).tw.
19. (COPD or AECOPD or AECB).tw.
20. or/14-19
21. Physical Therapy Modalities/
22. exp Physical Fitness/
23. exp Physical endurance/
24. exp Exercise Therapy/
25. Physical Exertion/
26. exp Exercise Test/
27. exp Exercise/
28. ((pulmonary or respiratory) adj3 rehabilitation\$).ti,ab.
29. exercis\$.ti,ab.
30. (physical\$ adj3 (activit\$ or train\$ or fitness\$ or therap\$)).ti,ab.
31. interval train\$.ti,ab.
32. exp Postural Balance/
33. Musculoskeletal Equilibrium/ or Posture/
34. (balance or functional reach or sway).tw.
35. (postur\$ adj3 (stability or instability)).tw.
36. posturograph\$.tw.
37. (cent\$3 adj (pressure or mass)).tw.
38. Accidental Falls/
39. (falls or faller*1).tw.
40. or/21-39
41. 11 AND 20 AND 40

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Physiotherapy Evidence Database (PEDro)

Abstract & Title: Physical Therapy Modalities, Physical Fitness, Exercise Therapy, Physical Exertion, Pulmonary rehabilitation, Physical Exercise, exercise-based interventions, Exercise Training, Postural Balance, pressure center, center of mass, Falls

AND

Body Part: Chest

AND

Topic: Chronic respiratory disease

AND

Method: Clinical trial

CENTRAL

1- Physical Therapy Modalities OR Physical Fitness OR Physical endurance OR Exercise Therapy OR Physical Exertion OR Exercise Test OR Exercise OR Pulmonary rehabilitation OR Physical Exercise OR exercise-based interventions OR Exercise Training OR Postural Balance OR pressure center OR center of mass OR Accidental Falls OR Falls

2- Lung Diseases, Obstructive OR Pulmonary Disease, Chronic Obstructive OR Chronic Obstructive Pulmonary Disease OR emphysema OR COPD OR COAD OR AECOPD OR AECB OR Chronic Obstructive Airway Disease OR Chronic Obstructive Lung Disease OR Airflow Obstruction, Chronic OR Chronic Airflow Obstructions OR Obstructive Lung Disease OR Emphysema OR Bronchitis Chronic OR Chronic Bronchitis OR Chronic Airflow Limitation OR Chronic respiratory disease

#1 AND #2

CINAHL

1-(MH "Clinical Trials+") OR "randomi?ed controlled trial*" OR clinical W3 trial OR double-blind OR single-blind OR triple-blind OR (MH "Placebo Effect") OR (MH "Placebos") OR placebo* OR random* OR (MH "Random Sample") OR (MH "Study Design+") OR latin square OR (MH "Comparative Studies") OR (MH "Evaluation Research+") OR (MH "Prospective Studies+") OR follow-up stud* OR followup stud* OR control* OR prospectiv* OR volunteer*

2-(MH "Pulmonary Disease, Chronic Obstructive") OR Lung Diseases, Obstructive OR Chronic Obstructive Pulmonary Disease OR emphysema OR COPD OR COAD OR AECOPD OR AECB OR Chronic Obstructive Airway Disease OR Chronic Obstructive Lung Disease OR Airflow Obstruction, Chronic OR Chronic Airflow Obstructions OR Obstructive Lung Disease OR Emphysema OR Bronchitis Chronic OR Chronic Bronchitis OR Chronic Airflow Limitation OR Chronic respiratory disease

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3-(MH “Physical Therapy Modalities”) OR Physical Fitness OR Physical endurance OR (MH “Exercise Therapy”) OR exercise training modality OR Physical Exertion OR Exercise Test OR (MH “Exercise”) OR Exercise, Physical OR Physical Exercise OR (MH “Rehabilitation”) OR Pulmonary rehabilitation OR Physical Exercise OR exercise-based interventions OR Exercise Training OR (MH “Postural Balance”) OR pressure center OR center of mass OR (MH “Accidental Falls”) OR Falls

1 AND 2 AND 3

LILACS

Pulmonary Disease, Chronic Obstructive OR Lung Diseases, Obstructive OR Chronic Obstructive Pulmonary Disease OR emphysema OR COPD OR COAD OR AECOPD OR AECB OR Chronic Obstructive Airway Disease OR Chronic Obstructive Lung Disease OR Airflow Obstruction, Chronic OR Chronic Airflow Obstructions OR Obstructive Lung Disease OR Emphysema OR Bronchitis Chronic OR Chronic Bronchitis OR Chronic Airflow Limitation OR Chronic respiratory disease AND Physical Therapy Modalities OR Physical Fitness OR Physical endurance OR Exercise Therapy OR exercise training modality OR Physical Exertion OR Exercise Test OR Exercise OR Exercise, Physical OR Physical Exercise OR Rehabilitation OR Pulmonary rehabilitation OR Physical Exercise OR exercise-based interventions OR Exercise Training OR Postural Balance OR pressure center OR center of mass OR Accidental Falls OR Falls

EMBASE

1- 'Clinical Article' OR 'Clinical Study' OR 'Clinical Trial' OR 'Controlled Study' OR 'Randomized Controlled Trial' OR 'Major Clinical Study' OR 'Double Blind Procedure' OR 'Multicenter Study' OR 'Single Blind Procedure' OR 'Phase 3 Clinical Trial' OR 'Phase 4' OR 'Clinical Trial' OR 'crossover procedure' OR 'placebo'

2- 'Pulmonary Disease, Chronic Obstructive' OR 'Lung Diseases, Obstructive' OR 'Chronic Obstructive Pulmonary Disease'/exp OR 'emphysema' OR 'COPD' OR 'COAD' OR 'AECOPD' OR 'AECB' OR 'Chronic Obstructive Airway Disease' OR 'Chronic Obstructive Lung Disease' OR 'Airflow Obstruction, Chronic' OR 'Chronic Airflow Obstructions' OR 'Obstructive Lung Disease' OR 'Emphysema' OR 'Bronchitis Chronic' OR 'Chronic Bronchitis' OR 'Chronic Airflow Limitation' OR 'Chronic respiratory disease'

3- 'Physical Therapy Modalities'/exp OR 'Physical Fitness' OR 'Physical endurance' OR 'Exercise Therapy'/exp OR 'Exercise Training Modality'/exp OR 'Physical Exertion'/exp OR 'Exercise Test' OR 'Exercise'/exp OR Exercise, Physical OR 'physical exercise'/exp OR 'Rehabilitation' OR 'Pulmonary Rehabilitation'/exp OR 'Physical Exercise' OR 'exercise-based interventions' OR 'Exercise Training' OR 'Postural Balance'/exp OR 'pressure center' OR 'center of mass' OR 'Accidental Falls' OR 'Falls'

#1 AND #2 AND #3