Exercise-based interventions targeting balance and falls in people with COPD: a systematic review and meta-analysis

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Shareable abstract (@ERSpublications)
There is only weak evidence for exercise-based interventions improving balance in people with COPD to levels that are clinically meaningful, and the effect on falls is unknown. Designing future interventions to include theory-linked BCTs might be useful. https://bit.ly/4cuqDXm

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Abstract

Introduction This review quantifies the mean treatment effect of exercise-based interventions on balance and falls risk in people with COPD.

Methods A structured search strategy (2000–2023) was applied to eight databases to identify studies evaluating the impact of exercise-based interventions ($\geqslant$14 days in duration) on balance or falls in people with COPD. Pooled mean treatment effects (95% confidence intervals (CIs), 95% prediction intervals (PIs)) were calculated for outcomes reported in five or more studies. Inter-individual response variance and the promise of behaviour change techniques (BCTs) were explored.

Results 34 studies (n=1712) were included. There were greater improvements in balance post intervention compared to controls for the Berg Balance Scale (BBS) (mean 2.51, 95% CI 0.22–4.80, 95% PI −4.60–9.63), Timed Up and Go (TUG) test (mean −1.12 s, 95% CI −1.69– −0.55 s, 95% PI −2.78–0.54 s), Single-Leg Stance (SLS) test (mean 3.25 s, 95% CI 2.72–3.77 s, 95% PI 2.64–3.86 s) and Activities-specific Balance Confidence (ABC) scale (mean 8.50%, 95% CI 2.41–14.58%, 95% PI −8.92–25.92%). Effect on falls remains unknown. Treatment effects were larger in male *versus* mixed-sex groups for the ABC scale and SLS test, and in balance training *versus* other exercise-based interventions for the BBS and TUG test. Falls history was not associated with changes in balance. Meta-analysis of individual response variance was not possible and study-level results were inconclusive. Eleven promising BCTs were identified (promise ratio $\geqslant$2).

Conclusion Evidence for the effect of exercise-based interventions eliciting clinically important improvements in balance for people with COPD is weak, but targeted balance training produces the greatest benefits. Future exercise interventions may benefit from inclusion of the identified promising BCTs.

Introduction

A larger proportion of people with COPD experience falls attributable to poor balance compared with healthy older adults (24–30% COPD *versus* 12% non-COPD) [1–3]. Exercise is most often delivered to people with COPD in the form of pulmonary rehabilitation (PR) [4]. Despite the American Thoracic Society and the European Respiratory Society recommending that balance is assessed in people with COPD, balance training as a form of exercise is not routinely included in PR, with the focus being on symptoms of breathlessness [4].

There is a growing body of literature supporting the utility of balance training for people with COPD; however, the conclusions drawn from these studies are limited by small sample sizes ($n \leqslant 50$ in 72% of randomised controlled trials (RCTs) included in a previous review) [5]. A 2020 systematic review of the evidence concluded that exercise, and specifically balance training, had a positive effect on balance in people with COPD [5]. However, a meta-analysis to pool the effect of these studies has not been performed; consequently, the effect of exercise-based interventions on balance and falls remains unclear [5]. Furthermore, research to date has focused on the mean effect of exercise-based interventions for people with COPD, and little attention has been afforded to elucidating how or why interventions are effective or not. Exercise-based interventions are complex and require people to make changes to their behaviour (*e.g.* engaging in prescribed balance training). The Behavior Change Technique Taxonomy v1 (BCTTv1), which comprises 93 hierarchically clustered behaviour change techniques (BCTs), has been recommended as a helpful way to report the active components of behavioural interventions [6].

The main objective of this systematic review with meta-analysis was to quantify the pooled mean treatment effect of exercise-based interventions (including but not limited to PR) on balance and falls risk in people with COPD. In addition, we sought to understand if true inter-individual differences in response to treatment (response heterogeneity) exist [7] and what active ingredients, including BCTs, are associated with improved outcomes.

Methods

This review protocol was registered on PROSPERO in August 2021 (CRD42021262626) and adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [8].

Six members of a support group for people with chronic breathlessness, Breathe Easy (Darlington, UK), were consulted about the concept of the review and interpretation of findings.

Search strategy and study selection

A structured search strategy was developed in collaboration with an information specialist in August 2021 and was updated in January 2023. It consisted of key words (including proximity searching) combined with MeSH headings. The search strategy (supplement 1) was applied to the following databases: MEDLINE, AMED, Web of Science, Embase, CINAHL, PEDro, EThOS and the Cochrane Library. The search was supplemented with hand and citation searching.

Inclusion criteria were informed by the PICOS framework as follows. The population (P) comprised adults (⩾18 years) with a confirmed diagnosis of COPD, including those post-acute exacerbation and in a stable state. The intervention (I) comprised exercise-based interventions (⩾14 days in duration, with or without explicit balance content), inclusive of PR and those delivered alongside adjunctive therapies (*e.g.* whole bodyweight vibration). The primary end-point was defined as immediately post the intervention period. The comparator (C), where applicable, included usual care or a comparator intervention. The outcomes (O) were balance or falls. The study design (S) included RCTs, pilot RCTs, non-RCTs and prospective single group pre–post studies. The search results were limited to the year 2000 onwards, which coincided with the publication date of the British Thoracic Society statement on PR [9].

Two reviewer pairs (KJL and SLH or KJL and CFJ) independently screened the titles and abstracts of articles returned by the search for eligibility. The same pair of reviewers independently reviewed full-text articles using a study selection form. Any disagreements were resolved by discussion.

Data extraction and risk of bias assessment

A data extraction form was designed and refined using five included studies. Data extracted were study characteristics, participant characteristics according to PROGRESS-PLUS [10] and disease-related factors (*e.g.* severity of COPD and any comorbidities). Any analyses examining equity effects (*i.e.* impact of individual participant characteristics, according to PROGRESS-PLUS, on the effect of an intervention) were included in data extraction [11, 12]. Details of interventions were extracted with reference to the TIDieR checklist [13].

Mean treatment effects (intervention minus control) were extracted from the mean change between baseline and follow-up along with the corresponding standard deviation (SD). Where change scores were not reported (mean±SD), they were calculated from the f-ratio, using the t-ratio to derive the standard error (SE). If no information on mean change was reported/available, post intervention-only units were extracted.

Two reviewer pairs (SLH and DF or SLH and KJL) independently coded the presence of theory-linked BCTs for patient and interventionist training interventions reported in studies using the BCTTv1 [6]. One coder (DF) was an experienced coder and provided guidance. SLH and KJL accessed BCT coding training *via* the BCT taxonomy website (www.bct-taxonomy.com) [14].

SLH and KJL independently assessed treatment fidelity using a treatment fidelity assessment template [15] and implementation strategies using Expert Recommendations for Implementing Change (ERIC) [16].

Methodological risk of bias was independently assessed and reported in accordance with the Cochrane Handbook [17]. Reviewer pairs performed the quality assessment using the Risk of Bias 2 (RoB 2) for RCTs (SLH and KJL) and Risk of Bias In Non-randomised Studies – of Interventions (ROBINS-I) tool for non-RCTs (JE and SS) [18, 19]. A Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach was used to summarise the quality of evidence for outcomes included in the meta-analysis.

Data analysis and synthesis

Statistical analyses were executed using random effects restricted maximum-likelihood models in Stata and R (v4.3.0, www.r-project.org; metafor v4.2.0) [20].

Pooled treatment effects (mean, 95% confidence intervals (CIs) and 95% prediction intervals (PIs) (using t and SE)) were calculated for balance outcomes reported in five or more studies [21]. PIs convey how the effect size varies across studies. This is important because although an intervention may on average have a moderate clinical impact for all studies, the impact may be large in some studies while being trivial in others [22]. A mixed approach, as described above, was used to calculate the mean treatment effect (intervention minus control) in each study together with its SE. An attempt was made to query a data reporting error in one study; however, no response was received [23] and data were taken on face value.

Random effects meta-analyses were undertaken using the Hartung and Knapp approach [24]. The Tau statistic was used to quantify between-study heterogeneity [25]. The probability that the mean treatment effect in a future study would exceed the minimal clinically important difference (MCID) (or minimal detectable change when MCID was not available) was calculated using estimated effect size, Tau, SE and t [26, 27].

Exploratory meta-regression was undertaken to quantify the extent to which sex, falls history and treatment type were associated with differences in changes in balance. A funnel plot was used to assess small study bias (publication bias) for outcomes reported in ⩾10 studies included in the meta-analysis [28]. The Eggers statistical test for funnel plot asymmetry was also performed.

A planned meta-analysis of the variance in individual response was not possible owing to the limited number of studies reporting the SD of the change scores. Imputation using the correlation coefficient was deemed inappropriate [29]. Instead, where possible, inter-individual differences were reported at the study level using the SD of change ($\mathrm{SD}_{\mathrm{change}}$) after adjusting for random within-subject variability using the equation $\sqrt{(\mathrm{SD}^{2\ \mathrm{intervention}} - \mathrm{SD}^{2\ \mathrm{control}})}$ and its 95% CIs. The 95% CIs were constructed from the derived SE for the true individual response variance, relaxing the zero bound on variances. The SE for the true individual response variance was derived from the SD of the change scores in each group and their degrees of freedom [7, 30, 31]. In one instance [32], the SD was derived from the interquartile range (IQR), based on a normal distribution and using a corrected denominator for small sample sizes (Q3−Q1)/1.24 [33].

The association of BCTs within exercise-based interventions with improvements in balance outcomes was explored by first grouping interventions into three levels of promise (very, quite and none) according to statistically significant within-group or between-group changes in balance. Second, a promise ratio was calculated by summing up the very or quite promising interventions featuring a specific BCT and dividing this by the number of non-promising interventions featuring the same BCT. BCTs with a promise ratio of ⩾2 were classified as promising [34, 35].

Results

Initial searches returned 2880 results, of which 1306 were duplicates. Titles and abstracts were screened, generating 1574 unique articles. A total of 75 full-text articles were assessed for eligibility (with no additional titles identified by citation searching) and 34 were included in the review (figure 1). Study characteristics and intervention details are reported in tables 1 and 2. While all studies reported age and most reported sex, other equity characteristics, defined according to PROGRESS-PLUS (*e.g.* ethnicity,

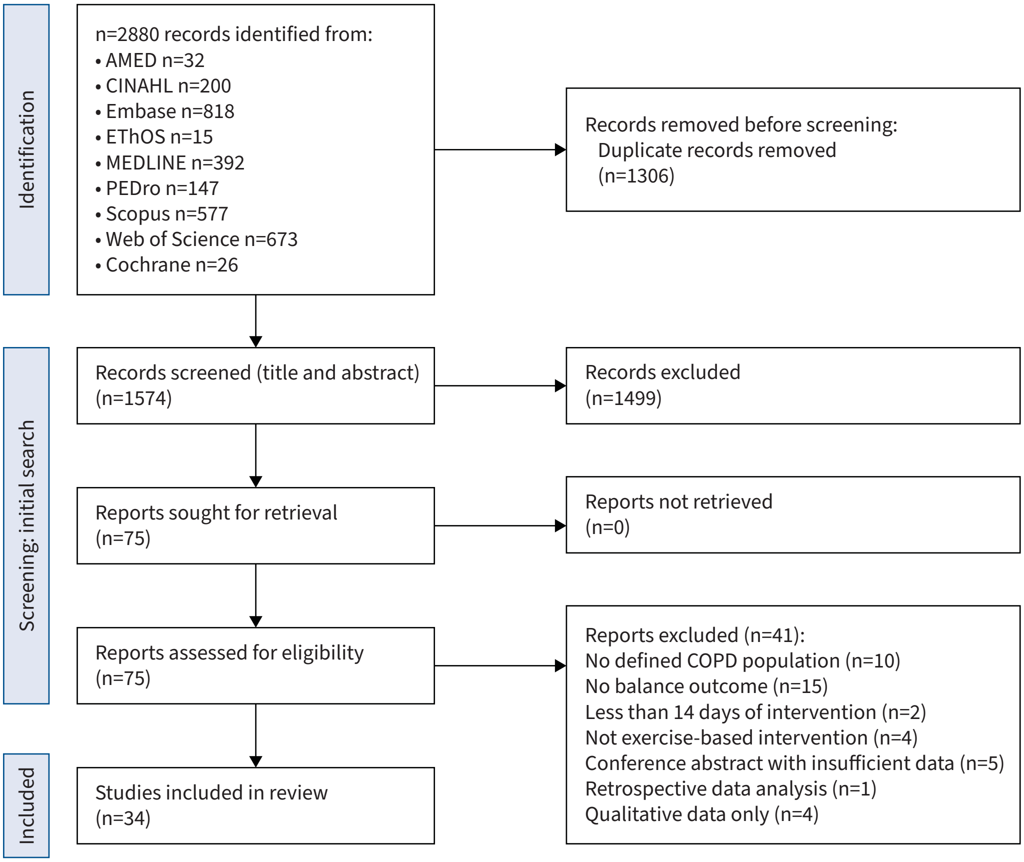


FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flow diagram.

socioeconomic status) were not reported and no studies investigated the impact of characteristics on the intervention effect.

A summary of risk of bias assessment is presented in figure 2. A GRADE summary of the quality of evidence is presented for the outcomes included in the meta-analysis (supplement 2). The certainty of evidence was downgraded for all outcomes (Berg Balance Scale (BBS), Timed Up and Go (TUG) test, Single-Leg Stance (SLS) test and Activities-specific Balance Confidence (ABC) scale). Risk of bias and imprecision were both downgraded by one, resulting in a low certainty of evidence, and inconsistency was downgraded by one for the ABC scale, resulting in a very low certainty of evidence for this outcome.

Meta-analysis

Meta-analysis was possible for the following balance outcomes (figure 3): BBS (nine studies), TUG test (10 studies), SLS test (six studies) and ABC scale (six studies). The pooled mean treatment effect indicates greater improvement in the intervention group compared to the control for the BBS total score (n=446) (mean 2.51, 95% CI 0.22–4.80, 95% PI −4.60–9.63, p=0.04), TUG duration (n=470) (mean −1.12 s, 95% CI −1.69– −0.55 s, 95% PI −2.78–0.54 s, p=0.002), SLS duration (n=303) (mean 3.25 s, 95% CI 2.72–3.77 s, 95% PI 2.64–3.86 s, p=0.001) and ABC score (n=332) (mean 8.50%, 95% CI 2.41–14.58%, 95% PI −8.92–25.92%, p=0.02). The probability that the mean treatment effect in a future study would exceed the MCID (or minimal detectable change for SLS) was 46% for the BBS (>3), 43% for TUG test (<−1.5 s), 30% for the SLS test (>4 s) and 40% for the ABC scale (>13%) [62, 68, 69].

Studies reporting balance outcomes that could not be pooled for meta-analysis (n=9 non-RCT and n=13 RCTs) are summarised narratively [23, 36–41, 43, 44, 46, 47, 50, 51, 54, 59, 60, 62–67].

Three non-RCTs used the BBS [54, 64, 66]. Improvements were observed after a 6-month home-based falls prevention programme (mean±SD pre 49.3±5.9, 6-month post 51.8±5.0, p=0.02) [54] and following an 8-week

TABLE 1 Study characteristics

First author, year [ref.]	Setting	Population													
		Age (years)		BMI (kg·m^{-2})		Sex (% male)		FEV$_1$ (% predicted)		6MWD (m)		Dropouts (n)		Subjects (n)	
		I	C	I	C	I	C	I	C	I	C	I	C	I	C
Randomised controlled trials															
Acheche, 2020 [36]	NR	63±4	62±6	24.09±5.97	25.14±5.68	100	100	54.13±19.85	54.80±15.74	418±105	427±61	3	4	22	20
Beauchamp, 2013 [37]	Inpatient	72±5	67±9	27.2±9.3	23.9±6.5	33	44	39.90±13.2	35.40±17.5	NR	NR	2	1	19	17
de Castro, 2020 [38]	Outpatient	65±7	66±8	25.3±5.1	26.0±5.2	NR	NR	36.2±8.4	38.0±6.3	349±68	360±73	4	5	24	24
Gloeckl, 2017 [39]	Inpatient	65±8	63±9	25.2±5.2	25.6±6.3	73	62	33.6±8.5	36.6±11.7	335±107	350±104	8	5	37	37
Gloeckl, 2021 [40]	Inpatient	65±7	66±8	25.3±5.1	26.0±5.2	NR	NR	36.2±8.4	38.0±6.3	349±68	360±73	4	5	24	24
Leung, 2013 [41]	Outpatient	73±8	73±7	27.8±4.3	27.2±4.8	65 (whole cohort)		55.6±15.5	62.7±16.0	NR	NR	3	1	19	19
Marques, 2015 [42]	Outpatient	69±7	66±13	27.2±4.6	28.9±5.5	81.8	50	67±22.4	74.3±21.7	410±60	397±122	6	8	22	20
Mekki, 2019 [23]	Outpatient	60±5	60±3	25.6±0.7	25.6±0.5	100	100	57.7±14.4	57.1±10.2	503±29	503±31	5	10	25	20
Mkacher, 2015 [43]	Outpatient	58±4	61±3	24.1±3.8	25.2±2.6	100	100	39.4±10.3	38.6±8.6	446±23	448±23	0	0	35	33
Mounir, 2019 [44]	NR	63±2	62±2	24.85±2.22	24.95±2.38	100	100	63.62±5.64	61.58±8.51	296±42	370±51	NR	NR	24	24
Rinaldo, 2017 [45]	Outpatient	66±5	66±4	29.9±4.4	28.4±5.7	100	100	72.2±18.8	60.1±24.3	519±72	455±110	2	2	12	12
Spielmanns, 2017 [32]	NR	69 (65–73)	70 (66–78)	27.2 (24.6–34)	30.6 (29–32.5)	50	53.8	63.0 (39.3–71)	52.0 (43–73)	507 (440–595)	490 (410–608)	1	1	15	14
Reddy, 2020 [46]	NR	55±3	55±5	NR	NR	80	70	NR	NR	332+7	311±16	NR	NR	10	10
Reddy, 2021 [47]	NR	53±4	52±5	NR	NR	78.78	82.25	67.2±22.3	69.6±23.7	303±16	310±16	NR	NR	66	62
Charususin, 2021 [48]	Outpatient	66±8	69±5	25.4±4.5	21.4±4.6	71.4	71.4	51.2±17.4	61.6±30.1	335±107	290±96	0	0	7	7
Chuatrakoon, 2022 [49]	Home based	75±5	75±7	19.4±3.5	17.9±4.0	83	50	62.9±17.4	53.3±17.7	298±37	236±104	0	0	24	24
Ezzat, 2021 [50]	NR	52±5	52±5	29.98±2.95	30.32±3.66	56.7	56.7	NR	NR	NR	NR	NR	NR	30	30
Kaya, 2023 [51]	Home based	65±6	65±9	25.14±3.73	25.94±4.26	83.3	83.3	NR	NR	469±99	439±112	0	0	12	12
Lopez-Lopez, 2021 [52]	Inpatient	GEG 75±7 FEG 76±9	71±9	GEG 25.41±4.88 FEG 23.65±6.25	26.29±3.69	GEG 92.3 FEG 85.7	93.3	NR	NR	NR	NR	0	0	GEG 13 FEG 14	16
Tounsi, 2021 [53]	NR	62±5	63±4	23.13±4.37	23.41±5.19	100	100	37±7	39±9	426±91	428±129	0±1 stopped intervention	0±2 stopped intervention	17	18

Continued

TABLE 1 Continued

First author, year [ref.]	Setting	Population													
		Age (years)		BMI (kg·m^{-2})		Sex (% male)		FEV$_1$ (% predicted)		6MWD (m)		Dropouts (n)		Subjects (n)	
		I	C	I	C	I	C	I	C	I	C	I	C	I	C
Non-randomised controlled trials															
Beauchamp, 2021 [54]	Home based	74±6		26.2±9.9		36.2		40.5±13.8		319±109		11		36	
Beauchamp, 2010 [55]	Inpatient	70±10		29.2±7.8		58.6		46.3±22.3		295±92		4		29	
Harrison, 2019 [56]	Inpatient	69±10		29.7±9.9		53		38.2±14.7		NR		During PR: 8 Post PR: 5 Post 3-month FU: 6 Post 6-month FU: 5		Post PR Ax: 32 3-month Ax: 17 6-month Ax: 11 12-month Ax: 6	
Harrison, 2015 [57]	In and outpatient	73±6		28±8		42.1		41±16		NR		9		19	
Jacome and Marques 2014 [58]	Outpatient	68±10		28.7±5.0		59.3		83.8±6.4		432±76		4		29	
Lui, 2019 [59]	In and outpatient	62±8		26.9±5.2		56.8		55.9±19.7		512±67		0		44	
Marques, 2015 [60]	Outpatient	68±12		28.4±6.0		59.1		72.2±22.3		376±95		12		22	
Marques, 2015 [61]	Outpatient	70±8		NR		77.8		69±25		394±46		1		9	
Mesquita, 2016 total group [62]	In and outpatient	64±9		26.2±5.8		55		49±20		430±120		92		378	
Minet, 2015 [63]	Home based	69±9		23.0±5.0		13.5		27.1±12.5		NR		13		50	
Ozsoy, 2021 [64]	NR	78 (72–85)	75.0 (70.0–79.0)	24.9 (24.1–29.4)	27.1 (24.3–28.8)	58	57	57.2±12.2	101.3±26.5	350 (280–394)	455 (359–490)	3	2	22	23
Pichon, 2012 [65]	Inpatient	68±8		26.3±5.8		64.7		40.8±13.8		327±100		2		17	
Wshah, 2019 [66]	Outpatient	73±8		26.6±4.3		30		43.2±18.8		339±74		1		23	
Berriet, 2022 [67]	Inpatient	4±9		26.75±5.8		63.5		42.2±17.1		387±113		8		82	

Data are presented as mean±SD or median (interquartile range), unless otherwise indicated. BMI: body mass index; FEV$_1$: forced expiratory volume in 1 s; 6MWD: 6-min walk distance at baseline; I: intervention; C: control; NR: not reported; FEG: functional electrostimulation group; GEG: global exercise group; PR: pulmonary rehabilitation; FU: follow-up; Ax: assessment.

TABLE 2 Study interventions

First author, year [ref.]	Total duration (weeks)	Total sessions (n)	Session duration (mins)	Total duration (n × duration)	Exercise intervention	Control	Adverse events	Fidelity check	Balance outcomes used
Randomised controlled trials									
Acheche, 2020 [36]	24	72	85	6120	Endurance and resistance training with NMES	Endurance and resistance training	NR	NR	BBS, TUG posturography
Beauchamp, 2013 [37]	6	18	30	540	PR with balance training	PR	None	Pilot tested trial on 2 patients	BBS, BESTest
de Castro, 2020 [38]	12	36	60	3780	Water-based endurance and resistance training	Land-based endurance and resistance training	None	NR	TUG, posturography
Gloeckl, 2017 [39]	3	9	60	540	PR with WBVT	PR	None	NR	Posturography
Gloeckl, 2021 [40]	3	9	20	180	PR with balance training on WBVT	Balance exercises on a balance board alongside standard PR	None	NR	Posturography
Leung, 2013 [41]	12	24	60 (+30 unsupervised at home)	1440 supervised 1800 unsupervised	Short-form Sun-style Tai Chi	Usual care no exercise training	None	NR	Body sway
Marques, 2015b [42]	12	36	60	2160	Family-based PR with balance training	PR	NR	NR	TUG
Mekki, 2019 [23]	24	72	20	1440	PR with NMES	PR	NR	NR	BBS, TUG, posturography
Mkacher, 2015 [43]	24	72	30	2106	PR with balance training	PR	NR	NR	BBS, TUG, Tinetti, SLS
Mounir, 2019 [44]	8	24	30	720	PR with balance training, plus 30 min daily home breathing exercise programme	PR	NR	NR	BBS, BESTest
Rinaldo, 2017 [45]	28	84	60	5040	Physical activity education	Endurance and resistance training	None	NR	SLS
Spielmanns, 2017 [32]	12	24	30	720	3×2 min isometric squat on WBVT	Calisthenics training, relaxation and breathing exercises	None	NR	BBS, SLS
Reddy, 2020 [46]	8	24	20	480	PR plus balance training	PR	NR	NR	BBS, TUG, SLS, ABC, EFST
Reddy, 2021 [47]	8	24	20	480	PR plus balance training	PR	NR	NR	BBS, TUG, SLS
Charususin, 2021 [48]	8	16	60	960	Water-based exercise training	Land-based exercise training	NR	NR	TUG

Continued

TABLE 2 Continued

First author, year [ref.]	Total duration (weeks)	Total sessions (n)	Session duration (mins)	Total duration (n × duration)	Exercise intervention	Control	Adverse events	Fidelity check	Balance outcomes used
Chuatrakoon, 2022 [49]	8	24	65	1560	Home-based PR plus balance training	Home-based PR	None	NR	TUG
Ezzat, 2021 [50]	12	NR	NR (20–30 walking but no details of other activities)	NR	WBVT-based exercise programme	Traditional PT (breathing exercises, home exercises and walking)	NR	NR	Posturography
Kaya, 2023 [51]	8	16	45	720	Creative dance-based exercise with chest PT	Walking programme with chest PT	NR	NR	Posturography
Lopez-Lopez, 2021 [52]	NR (dependent on LOS)	NR	40 (general)	NR	Standard medical treatment (pharmacological) plus global exercise (breathing and limb exercises) or NMES	Standard medical treatment (pharmacological)	None	NR	SLS
Tounsi, 2021 [53]	8	24	Treadmill training: 30 ISMT: ∼10	1280	ISMT plus endurance training	Endurance training	NR	NR	BBS, TUG, ABC, SLS
Non-randomised studies									
Beauchamp, 2021 [54]	26	78	40	3120	Home-based balance training with physiotherapist home visits, then online video and DVD video recording support with bimonthly PT telephone support calls		One fall, trip over exercise equipment, rib fracture and shoulder soft tissue injury	None	BBS, BESTest, ABC, falls diaries and fall history
Beauchamp, 2010 [55]	6	NR	Endurance training: 20–30 Strength training: NR Breathing and stretching exercises: 30	NR	PR		NR	None	BBS, TUG
Harrison, 2019 [56]	6	42	60	2520	PR with balance training		NR	None	BBS, BESTest, ABC
Harrison, 2015 [57]	6	18	60	18	PR with balance training		None	Yes	BBS, BESTest
Jacome and Marques, 2014 [58]	12	36	60	2160	PR with balance training		NR	None	TUG
Lui, 2019 [59]	8 inpatient 16 outpatient	40 40	150 90	600 3600	PR		NR	None	TUG

Continued

TABLE 2 Continued

First author, year [ref.]	Total duration (weeks)	Total sessions (n)	Session duration (mins)	Total duration (n × duration)	Exercise intervention	Control	Adverse events	Fidelity check	Balance outcomes used
Marques, 2015 [60]	12	36	5	180	PR with balance training		NR	None	TUG
Marques, 2015 [61]	12	36	60	2160	Family-based PR with balance training		NR	None	TUG
Mesquita, 2016 total group [62]	8 inpatient 16 outpatient	40 40	150 90	6000 3600	PR		NR	None	TUG
Minet, 2015 [63]	3	9	45	405	Telemedicine exercise training (endurance, resistance, mobility and breathing exercises) and counselling on energy conservation techniques		None	None	TUG
Ozsoy, 2021 [64]	8	112	30	3360	ISMT with diaphragmatic breathing, abdominal wall activation, core stability, dynamic trunk activation and postural control exercises	Non-COPD older adults followed same treatment protocol	NR	None	BBS, posturography
Pichon, 2012 [65]	3	36	30	1080	PR with outdoor walking and functional training		NR	None	TUG, Tinetti, SLS, VAS balance confidence
Wshah, 2019 [66]	8	16	60	960	Instructor led dance class		None	None	BBS, BESTest, ABC
Berriet, 2022 [67]	4	20	30	600	PR		NR	None	Brief BESTest, FES-I, 12-month falls number

NMES: neuromuscular electrical stimulation; NR: not reported; BBS: Berg Balance Scale; TUG: Timed Up and Go test; PR: pulmonary rehabilitation; BESTest: Balance Evaluations Systems Test; WBVT: whole bodyweight vibration training; SLS: Single-Leg Stance test; ABC: Activities-specific Balance Confidence scale; EFST: Elderly Falls Screening Test; LOS: length of stay; ISMT: inspiratory muscle training; PT: physiotherapy; VAS: visual analogue scale; FES-I: Falls Efficacy Scale–International.

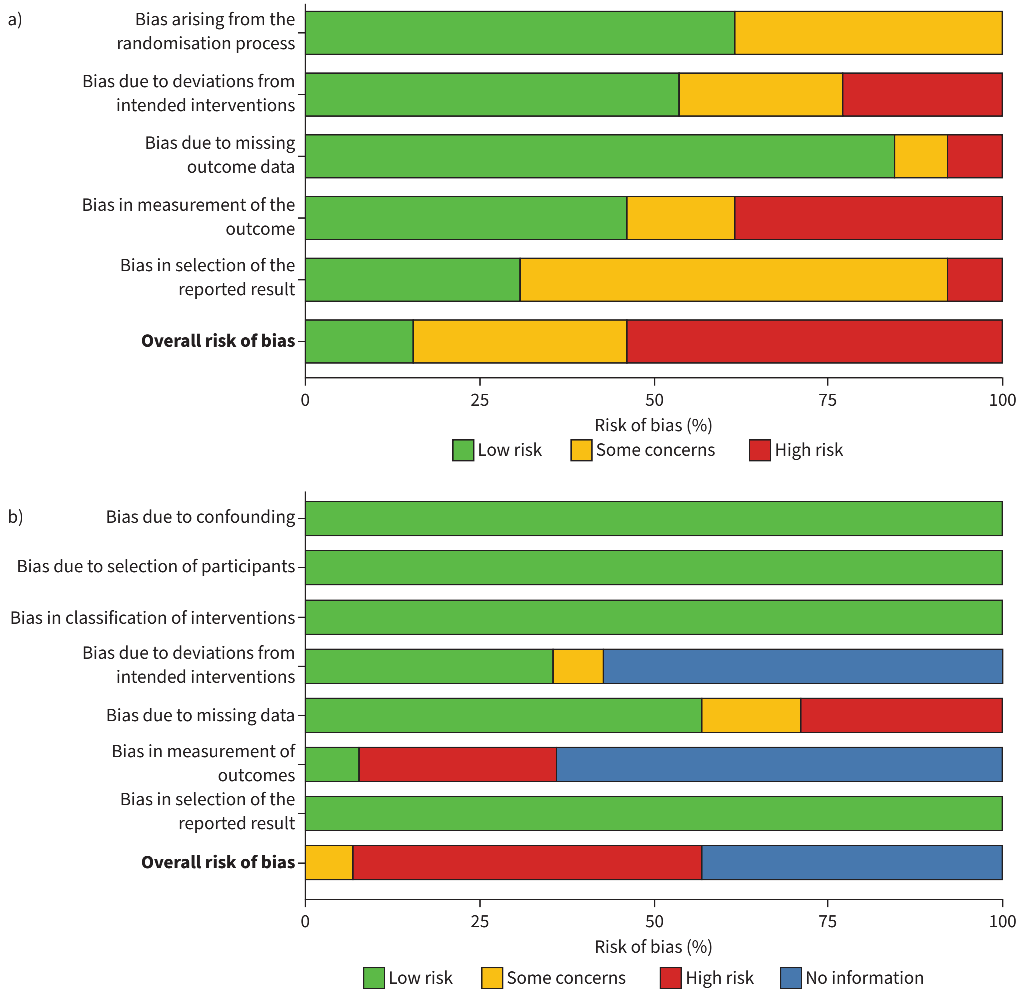


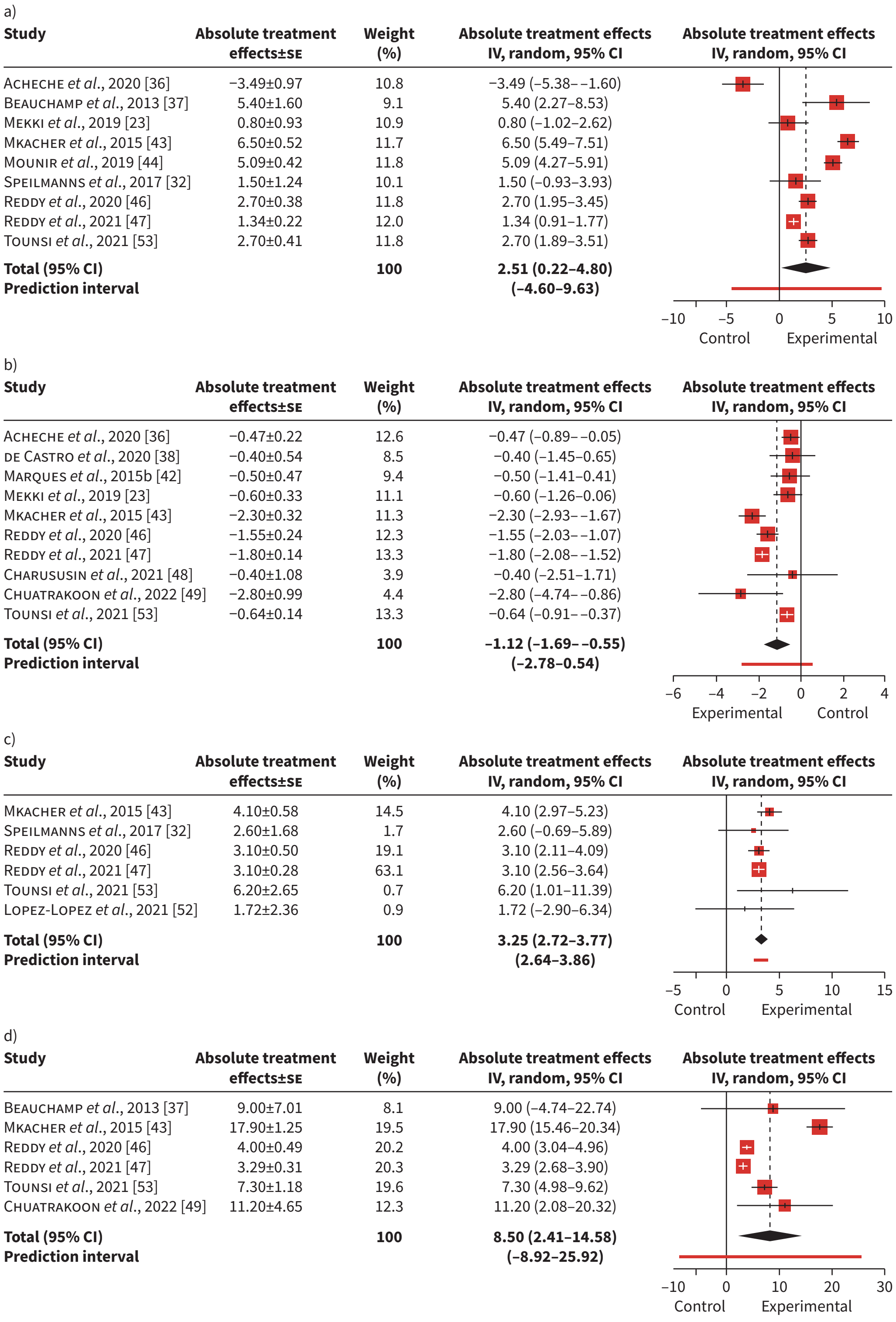
FIGURE 2 Risk of bias summary for a) randomised trials using the revised Risk of Bias 2 (ROB 2) tool and b) non-randomised studies using the Risk of Bias in Non-randomised Studies – of Interventions (ROBINS-I) tool.

exercise and inspiratory muscle training programme (mean effect±SD 2.7±1.8, p<0.001) [64]. However, no change was observed following an 8-week dance intervention (mean change±SD 0.75±2.4, p=0.79) [66].

Five non-RCTs reported the TUG test [59, 60, 62, 63, 65]. Four observed improvements following interventions ranging from three to 16 weeks, including telemedicine (median pre 9.35, IQR 7.16–12.62; post 8.34, IQR 6.27–11.12; p<0.01), inpatient PR with gymnastic activity (mean change±SD −1.9±1.4, 95% CI −1.1–2.6, p<0.0001) and PR alone (effect size (ES) 0.16, mean change −0.5, 95% CI −0.6– −0.3, p<0.0001) or PR with balance training (mean change±SD −1.7±1.4, 95% CI −2.3– −1.1, p=0.001) [60, 62, 63, 65]. One study reported no change following 8 weeks of PR (mean±SD pre 8.8±1.3, post 8.7±1.1, p=0.65) [59].

Four studies employed the Balance Evaluations Systems Test (BESTest) [37, 44, 54, 66]. Between-group differences were observed in two RCTs investigating PR with balance training in favour of the balance training groups (mean difference 9.6, 95% CI 3.9–15.3, p<0.01) (time × group f-value=147.82, p=0.002) [37, 44] and within-group improvements were seen in non-RCTs after a 6-month home-based falls prevention programme (mean difference±SD baseline 65.5±12.6, 6-month post 76.0±12.3, p=0.001) and 8 weeks of dance (ES 1.29, mean difference±SD 7.2±5.6, p<0.001) [54, 66].

The Tinetti balance assessment tool was used in two studies [43, 65]. Between-group differences in post scores were seen in favour of PR with balance training delivered for 6 months (mean±SD post scores for intervention 27.6±0.3 and control 24.7±0.3, p<0.01) [43], and no difference was reported for within-group Tinetti scores after 21 days of PR with gymnastic activity (median pre to post difference 0, IQR 0–1, p-values not provided) [65].



a)

Study	Absolute treatment effects±SE	Weight (%)	Absolute treatment effects IV, random, 95% CI
Acheche *et al.*, 2020 [36]	−3.49±0.97	10.8	−3.49 (−5.38–−1.60)
Beauchamp *et al.*, 2013 [37]	5.40±1.60	9.1	5.40 (2.27–8.53)
Mekki *et al.*, 2019 [23]	0.80±0.93	10.9	0.80 (−1.02–2.62)
Mkacher *et al.*, 2015 [43]	6.50±0.52	11.7	6.50 (5.49–7.51)
Mounir *et al.*, 2019 [44]	5.09±0.42	11.8	5.09 (4.27–5.91)
Speilmanns *et al.*, 2017 [32]	1.50±1.24	10.1	1.50 (−0.93–3.93)
Reddy *et al.*, 2020 [46]	2.70±0.38	11.8	2.70 (1.95–3.45)
Reddy *et al.*, 2021 [47]	1.34±0.22	12.0	1.34 (0.91–1.77)
Tounsi *et al.*, 2021 [53]	2.70±0.41	11.8	2.70 (1.89–3.51)
Total (95% CI)		**100**	**2.51 (0.22–4.80)**
Prediction interval			**(−4.60–9.63)**

b)

Study	Absolute treatment effects±SE	Weight (%)	Absolute treatment effects IV, random, 95% CI
Acheche *et al.*, 2020 [36]	−0.47±0.22	12.6	−0.47 (−0.89–−0.05)
de Castro *et al.*, 2020 [38]	−0.40±0.54	8.5	−0.40 (−1.45–0.65)
Marques *et al.*, 2015b [42]	−0.50±0.47	9.4	−0.50 (−1.41–0.41)
Mekki *et al.*, 2019 [23]	−0.60±0.33	11.1	−0.60 (−1.26–0.06)
Mkacher *et al.*, 2015 [43]	−2.30±0.32	11.3	−2.30 (−2.93–−1.67)
Reddy *et al.*, 2020 [46]	−1.55±0.24	12.3	−1.55 (−2.03–−1.07)
Reddy *et al.*, 2021 [47]	−1.80±0.14	13.3	−1.80 (−2.08–−1.52)
Charususin *et al.*, 2021 [48]	−0.40±1.08	3.9	−0.40 (−2.51–1.71)
Chuatrakoon *et al.*, 2022 [49]	−2.80±0.99	4.4	−2.80 (−4.74–−0.86)
Tounsi *et al.*, 2021 [53]	−0.64±0.14	13.3	−0.64 (−0.91–−0.37)
Total (95% CI)		**100**	**−1.12 (−1.69–−0.55)**
Prediction interval			**(−2.78–0.54)**

c)

Study	Absolute treatment effects±SE	Weight (%)	Absolute treatment effects IV, random, 95% CI
Mkacher *et al.*, 2015 [43]	4.10±0.58	14.5	4.10 (2.97–5.23)
Speilmanns *et al.*, 2017 [32]	2.60±1.68	1.7	2.60 (−0.69–5.89)
Reddy *et al.*, 2020 [46]	3.10±0.50	19.1	3.10 (2.11–4.09)
Reddy *et al.*, 2021 [47]	3.10±0.28	63.1	3.10 (2.56–3.64)
Tounsi *et al.*, 2021 [53]	6.20±2.65	0.7	6.20 (1.01–11.39)
Lopez-Lopez *et al.*, 2021 [52]	1.72±2.36	0.9	1.72 (−2.90–6.34)
Total (95% CI)		**100**	**3.25 (2.72–3.77)**
Prediction interval			**(2.64–3.86)**

d)

Study	Absolute treatment effects±SE	Weight (%)	Absolute treatment effects IV, random, 95% CI
Beauchamp *et al.*, 2013 [37]	9.00±7.01	8.1	9.00 (−4.74–22.74)
Mkacher *et al.*, 2015 [43]	17.90±1.25	19.5	17.90 (15.46–20.34)
Reddy *et al.*, 2020 [46]	4.00±0.49	20.2	4.00 (3.04–4.96)
Reddy *et al.*, 2021 [47]	3.29±0.31	20.3	3.29 (2.68–3.90)
Tounsi *et al.*, 2021 [53]	7.30±1.18	19.6	7.30 (4.98–9.62)
Chuatrakoon *et al.*, 2022 [49]	11.20±4.65	12.3	11.20 (2.08–20.32)
Total (95% CI)		**100**	**8.50 (2.41–14.58)**
Prediction interval			**(−8.92–25.92)**

FIGURE 3 Pooled mean treatment effects (intervention minus control) of exercise-based interventions on balance outcomes for people with COPD. a) Berg Balance Scale total score; b) Timed Up and Go duration (s); c) Single-Leg Stance duration (s); d) Activities-specific Balance Confidence scale (%).

A RCT reported a between-group difference in favour of the intervention group for functional reach distance (mean change) pre to post 12 weeks of Sun-style Tai Chi (between-group mean difference 5.4 cm, 95% CI 3–8 cm, p-values not reported) [41].

Three studies reported falls-related outcomes. Two RCTs reported a between-group difference in favour of the intervention group for the Elderly Falls Screening Test (lower scores indicate lower risk of falls) after 8 weeks of PR with balance training (mean±SD intervention group pre 3.80±0.42, post 0.80±0.42; control group pre 4.00±0.47, post 1.90±0.56; $p<0.05$ [46]; and mean±SD intervention group pre 2.14±0.34, post 0.80±0.45; control group pre 2.29±0.45, post 0.97±0.25; $p<0.05$ (difference between group mean post intervention scores $p<0.0001$, 95% CI −0.810– −0.550)) [47]. Improvements in Falls Efficacy Scale–International (FES-I) scores (lower scores) were reported within groups following standard PR (pre to post mean difference −3.36, 95% CI −5.1– −1.6, p=0.0003) [67].

Three non-randomised studies assessed balance confidence [54, 65, 66]. One reported improvement after an 8-week dance intervention (within-group differences mean±SD 6.4±9.4, p=0.007) [66]. However, two reported no improvement following 6 months of a home-based falls prevention programme (mean difference±SD pre 65.6±24.1, post 72.6±16.0, p=0.144) [54] or 21 days of PR with gymnastic activities (mean difference 0.5±2.8, 95% CI 0.1–0.8, no p-value reported) [65].

Nine studies applied posturography [23, 36, 38–41, 50, 51, 64]. A variety of individual measurement units were reported across several different conditions, meaning it was difficult to establish the impact of exercise-based interventions on postural control in people with COPD (supplement 3).

Factors associated with an improvement in balance

Exploratory meta-regression of balance outcomes revealed that the estimate of the residual heterogeneity variance (the variance that is not explained by the predictor) for the ABC scale was moderated by study sex composition (male *versus* mixed). When participant composition was entirely male, a superior mean treatment effect was observed for the ABC scale and SLS test in comparison to mixed-sex compositions (mean effect ABC 12.80, 95% CI 5.79–19.81; SLS 1.12, 95% CI 0.26–1.98). There was no moderation effect for any other balance outcomes. No moderation was found when including those with a targeted history of falls (history of falls *versus* everyone) for any outcome. A moderation effect was found for study intervention characteristics (balance training *versus* other) for both the BBS and TUG test. Studies including balance training in addition to PR had a superior treatment effect for the BBS (4.30, 95% CI 0.50–8.10) and TUG test (−1.16, 95% CI −1.62–0.72). There was no moderation effect for the SLS test or ABC scale.

Inter-individual response variation

Inter-individual variability ($\text{SD}_{\text{change}}$) was derived for the BBS in four studies [23, 32, 37, 53], for the TUG test in three studies [23, 38, 53] and for the SLS test in two studies [32, 53].

Inter-individual response variability in changes in BBS scores were calculated as $\text{SD}_{\text{change}}$ 3.9, 95% CI −2.7–6.1 [37]; −3.0, 95% CI −0.5– −4.3 [23]; and 1.3, 95% CI 0.4–1.8 [53]. In the study by Spielmanns *et al*. [32], the IQR remained consistent at four timepoints in both groups, making the estimated variance for individual responses virtually zero.

Inter-individual response variability in changes in TUG duration were calculated as $\text{SD}_{\text{change}}$ −0.66, 95% CI −1.2–0.8 [23]; 0.4, 95% CI −0.9–0.2 [38]; and 0.4, 95% CI −0.4–0.7 [53].

Inter-individual response variability in SLS duration were calculated as $\text{SD}_{\text{change}}$ −6.5, 95% CI −10.1–4.0 [53] and 2.23, 95% CI −4.5–3.5 [32].

These results indicated substantial uncertainty in the SD for individual responses across all three balance outcomes, as one might expect with studies that are not powered to detect differences in change variance, so the effect is unclear.

Publication bias

Publication bias was assessed for the TUG test (⩾10 included studies) [28]. Evaluating the studentised residuals showed that all studies fell within a range not exceeding ±2.8, suggesting no outliers for this model. Based on Cook's distances, no individual study seemed unduly influential and neither rank correlation nor regression tests showed signs of funnel plot asymmetry (p=0.60 and p=0.80, respectively) (supplement 4).

Behaviour change techniques

Of the BCTs, 11 interventions were rated as very promising [23, 37, 39–41, 43, 44, 49–52], 20 as quite promising [32, 36, 38, 42, 45–47, 53–55, 57, 58, 60–67] and three as non-promising [48, 56, 59] when identifying between-group and within-group findings for balance outcomes [35, 70]. Percentage agreement for assessment of intervention promise was excellent (94%).

Percentage agreement for BCT coding was 46%. This low level of agreement was resolved during in-depth discussions between coders. Decisions were made regarding codes and were applied to future coding (*e.g.* if a paper referred to "psychosocial support" this was coded as social support unspecified). A total of 16 different BCTs were identified across the 34 included studies. The median number of BCTs used across all 34 interventions was four (IQR 3–5.75). Very promising interventions included one to seven BCTs (median 4.0, IQR 2.5–5.5); quite promising interventions between one and 10 BCTs (median 4.50, IQR 3–6.25); and non-promising interventions reported five, four and three BCTs respectively (median 4.0, IQR 3.5–4.5) [48, 56, 59].

11 promising BCTs (ratios ⩾2) were identified within patient interventions (table 3). These were presented to the Breathe Easy support group members who ranked them in order of importance, with the caveat that they are best applied in combination. Credible source, instructions on how to perform the behaviour, demonstration of the behaviour and information about health consequences were ranked joint first, followed by problem-solving [6]. Monitoring behaviour by others without feedback was considered least important.

Only one study provided data on interventionist training [57]. Four BCTs were identified: feedback on behaviour, instruction on how to perform a behaviour, information about health consequences, demonstration of the behaviour and credible source (inter-rater agreement 57%).

Fidelity and implementation

One of the 34 studies reported a fidelity strategy (matched dose intensity) [49] and inter-rater reliability was 100%. Only one study reported any implementation strategies [57] (inter-rater reliability 100%). Six strategies were identified and agreed by both reviewers: change physical structure and equipment, change records, conduct educational meetings, conduct educational outreach visits, develop and implement tools for quality monitoring, and facilitate relay of clinical data to providers.

Discussion

This is the first systematic review and meta-analysis to examine the pooled treatment effect of exercise-based interventions on balance and falls in people with COPD. It is also the first study to report on promising BCTs associated with effectiveness. However, findings indicate that evidence is weak for exercise-based interventions eliciting clinically meaningful improvements in balance in people with COPD.

TABLE 3 Behaviour change technique (BCT) promise ratios

BCTs	Promising[#]	Non-promising[¶]	Ratio[+] (or total of BCTs in promising interventions) ⩾2
1.2 Problem-solving	4		4[+]
1.4 Action planning	1		1
2.1 Monitoring of behaviour by others without feedback	2		2
2.2 Feedback on behaviour	1		1
2.3 Self-monitoring of behaviour	5		5[+]
3.1 Social support±unspecified	9	1	9[+]
3.2 Social support±practical	1		1
4.1 Instruction on how to perform a behaviour	22	3	7[+]
4.2 Information about antecedents	1		1
5.1 Information about health consequences	9	1	9[+]
6.1 Demonstration of the behaviour	3		3[+]
8.7 Graded tasks	24	2	12[+]
9.1 Credible source	20	3	7[+]
10.4 Social reward	1		1
11.2 Reduce negative emotions	7		7[+]
12.6 Body changes	16	2	8[+]

[#]: n=31 studies including that BCT; [¶]: n=3 studies including that BCT; [+]: promise ratio ⩾2=promising.

There is considerable uncertainty in the distribution of true effects (ranging from clinically important to no change) and the probability that the mean treatment effect in a future study would exceed the MCID is <50%. Very few studies (n=3) reported falls as an ultimate or functional outcome measure; consequently, the impact of exercise-based interventions on falls in people with COPD remains unknown.

Some variability in treatment response (effects on balance) can be explained by intervention type and by the inclusion of some studies that incorporated components of core balance training in addition to conventional PR, which had a superior treatment effect on balance outcomes compared to those without balance training. This supports previous findings that PR with balance training has the greatest effect sizes [5]. An unexpected finding was that targeting people with a history of falls (*versus* targeting anyone regardless of falls history) did not produce a moderation effect on balance outcomes. However, criteria used to identify those at greater falls risk were inconsistent across studies, ranging from a falls history of 1–5 years to the inclusion of a those reporting a "near miss" or self-reporting a decline in balance. Balance confidence appeared to be more likely to improve in groups consisting of all males; this finding is not easy to explain but could be due to sociocultural influences (*e.g.* societal expectations and gender-specific roles) that can affect how individuals perceive balance, engage in physical activity and report outcomes [71–74].

It was not possible to perform a meta-analysis of individual responses, meaning "true" inter-individual differences in response to balance outcomes remain unknown. The use of this novel technique within the field of respiratory sciences would allow interventions to be tailored according to response and targeted to those most likely to benefit. Improved reporting of $\mathrm{SD}_{\mathrm{change}}$ in future studies would facilitate this.

A total of 31 interventions (91%) were classified as promising according to p-values observed for within-group or between-group changes in balance outcomes. BCTs associated with self-regulation, reducing negative emotions and body changes were most frequently identified within promising studies. Half (50%) of the exercise-based interventions were delivered by physiotherapists as the only healthcare professional or as part of a multidisciplinary team, who often apply strategies to promote self-regulatory behaviour (*e.g.* self-monitoring of behaviour) [75, 76]. In addition to the physical influences on balance, emotions may also play an important role given the inclusion of techniques that reduce negative emotions such as anxiety within those interventions considered to be promising. To date, there has been little attention given to the psychological determinants of balance, although increased anxiety is associated with falls in the general population [77, 78].

Only one study reported on fidelity strategies [49] and one paper reported on implementation strategies [57]. Consequently, we do not know how well or how consistently balance training was delivered and engaged with, especially when considering that balance impairment is not a primary symptom of COPD and balance training is not a key component of PR. This is particularly important because a recent RCT investigating balance training delivered alongside PR found no impact on falls risk at 12-month follow-up, with the authors citing problems with implementation, not least due to the COVID-19 pandemic, but also due to issues with staffing and difficulties executing the intervention within different cultural settings [79, 80]. It is also unclear whether fidelity and implementation strategies were not applied or not reported.

A major strength of this review was the meticulous effort to calculate variables, enabling meta-analyses to be performed on a relatively large number of studies. Nevertheless, the limited sample sizes within studies means that the design was likely underpowered and insufficient to precisely define individual response variance. The analysis was planned to examine mediation variables (*e.g.* exercise capacity, strength, physical activity) to explain any improvement in balance. However, this was not possible with only a small number of studies and no access to individual-level data [81]. Including a variety of study types (non-RCTs) allowed a broader range of balance- and fall-related outcomes (*e.g.* FES-I and Brief BESTest) and intervention types (*e.g.* dance and inspiratory muscle training) to be considered.

The findings of this review indicate that future studies would benefit from 1) measuring falls as a key longer term outcome, 2) standardising reporting of outcome data (means and SDs of change scores) to enable quantification of individual responses and 3) applying psychological theories of behaviour change and selecting and reporting intervention content with reference to a published taxonomy. This systematic approach would facilitate replication and identification of intervention content to enable analyses to detect associated improvements in target outcomes [82]. Systematic intervention development and delivery approaches also serve to facilitate fidelity and implementation assessment that can inform re-development, refinement and tailoring of interventions, which is important in this case given the complexity of COPD symptoms [83, 84]. Furthermore, equity issues were not reported in any of the included studies, meaning the diverse population of people with COPD may not have been represented. This is in line with reports that people with COPD are often underserved by research recruitment [85, 86].

Overall, the evidence for exercise-based interventions improving balance to levels considered to be clinically meaningful in people with COPD is weak and the concomitant benefit on falls remains unknown. Targeted balance training delivered alongside PR elicited the greatest benefits compared with other intervention types with the caveat that treatment effects are heterogeneous. Future interventions would benefit from theory-informed systematic development and evaluation to assist with the identification of key active intervention ingredients associated with improvements in key outcomes.

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