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Physical activity promotion interventions in chronic airways disease: a systematic review and meta-analysis

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Shareable abstract (@ERSpublications)
Utilising wearable activity monitors in conjunction with established behaviour change techniques leads to the greatest improvement in step-based physical activity in people with chronic airways disease. https://bit.ly/3Ujs8y7

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Abstract

Physical inactivity is common in people with chronic airways disease (pwCAD) and associated with worse clinical outcomes and impaired quality of life. We conducted a systematic review and meta-analysis to characterise and evaluate the effectiveness of interventions promoting step-based physical activity (PA) in pwCAD. We searched for studies that included a form of PA promotion and step-count outcome measure. A random-effects model was used to determine the overall effect size using post-intervention values. 38 studies (n=32 COPD; n=5 asthma; n=1 bronchiectasis; study population: n=3777) were included. Overall, implementing a form of PA promotion resulted in a significant increase in step-count: median (IQR) 705 (183–1210) when compared with usual standard care: −64 (−597–229), standardised mean difference (SMD) 0.24 (95% CI: 0.12–0.36), p<0.01. To explore the impact of specific interventions, studies were stratified into subgroups: PA promotion+wearable activity monitor-based interventions (n=17) (SMD 0.37, p<0.01); PA promotion+step-count as an outcome measure (n=9) (SMD 0.18, p=0.09); technology-based interventions (n=12) (SMD 0.16, p=0.01). Interventions promoting PA, particularly those that incorporate wearable activity monitors, result in a significant and clinically meaningful improvement in daily step-count in pwCAD.

Introduction

Chronic lung disease affects over 550 million people worldwide and is a leading cause of morbidity and mortality [1]. Collectively, common obstructive airway diseases such as asthma and COPD contribute significantly to the overall prevalence of non-communicable disease [2] and are projected to remain a major burden on society for the foreseeable future [3]. Despite this outlook, prevention and intervention strategies exist to slow physiological deterioration, optimise prognosis and improve quality of life [4].

Exertional dyspnoea and activity limitation are often the earliest clinical indications of underlying respiratory disease due to airflow impairment and/or gas exchange abnormalities (and cardiovascular dysfunction and/or peripheral muscle wasting in those with comorbid illness) [5]. It is therefore common for people with chronic airways disease (pwCAD) to avoid physical activity (PA) or strenuous exercise in an attempt to minimise or control their respiratory symptoms [4, 6]. However, this approach is considered ineffective on the basis that physical inactivity leads to deconditioning, which ultimately contributes to increased symptom burden and lower functional capacity [7, 8]. Furthermore, physical inactivity (assessed *via* daily steps) is now recognised as an independent risk factor for both mortality and hospitalisation in people with COPD [9–11].

To counteract this "cycle of physical inactivity", it is therefore recommended that pwCAD should be referred to pulmonary rehabilitation programmes that encompass exercise training, education and PA promotion, to encourage long-term adherence to health-enhancing behaviours [4]. Despite substantial evidence supporting the clinical value of pulmonary rehabilitation [12], access and resources remain limited [13, 14], and without effective maintenance strategies, the associated improvements in PA typically diminish within 1–2 years [15, 16].

Improvements in functional capacity following pulmonary rehabilitation also often fail to translate into increased daily PA [17, 18]. The reasons for this are complex and relate to physiological, psychological, social, cultural, environmental and economic factors which may affect behaviour in relation to PA [19]. Historically, PA promotion strategies have primarily centred on goal setting, action planning, support mechanisms, self-affirmation and motivational techniques [20]. However, novel behaviour change techniques to promote activity continue to emerge [21] and technological developments over the past decade (*i.e.*, wearable activity monitors, in-built smartphone pedometers and mobile applications) have also shown promise in this setting [22]. Despite this, there is currently limited guidance concerning the optimal or most effective form of PA promotion to elicit long-term behaviour change and/or lifestyle modification in pwCAD [23].

The primary aim of this study was therefore to conduct a systematic review and meta-analysis to characterise and evaluate the effectiveness of interventions promoting step-based PA in pwCAD. A secondary objective was to identify unmet need, provide direction for research and inform the design of future interventions.

Methods

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [24]. The review was registered prospectively with the PROSPERO database (registration number: CRD42019134918).

Study selection and eligibility criteria

PubMed, CINAHL, PsycINFO, Embase and EBSCO were used to search for published articles between January 2010 and July 2022. The search strategy comprised broad terms including: "asthma" OR "chronic obstructive pulmonary disease" OR "COPD" OR "emphysema" OR "chronic bronchitis" OR "bronchiectasis" OR "cystic fibrosis" OR "airways disease" OR "airway obstruction" OR "bronchoconstriction" OR "expiratory airflow limitation" AND "physical activity" OR "exercise" OR "step-count". The results were combined and duplicate articles removed. Any additional relevant articles identified by the authors or sourced from the reference list of identified studies were also included.

Inclusion and exclusion criteria

Studies were required to meet the following PICOS criteria: 1) participants: adults >18 years of age with a prior diagnosis of airways disease; 2) intervention: a form of PA promotion (*e.g.* educational resources, face-to-face or remote support, feedback on PA, behavioural techniques); 3) comparator or control group (*i.e.*, no PA promotion or usual standard care); 4) outcomes: PA objectively assessed *via* change in step-count (pre-to-post intervention); and 5) study design: randomised controlled trials and non-randomised controlled trials. Studies were excluded if they were published in a non-English language, reviews, expert opinion, editorials, qualitative or consensus position papers. Studies were also excluded if there was no control arm or incomplete pre-to-post intervention data (*i.e.*, mean±SD) was not provided or could not be calculated. Two independent reviewers (C. Reilly and J. Sails) screened the titles and abstracts of all studies against the inclusion and exclusion criteria. Any disparity between the two reviewers was resolved by a third independent reviewer (O. Price).

Data extraction

C. Reilly and J. Sails independently performed study screening (titles and abstracts) and extracted data using a standardised data extraction template developed specifically for this review. Information concerning year of publication, title, study design, sample size, participant characteristics (specific type of airways disease, severity of condition and sub-type, sex and age), intervention (form of PA promotion employed, study duration and follow-up) and outcome measures (type of PA monitor, steps per day (pre-to-post intervention)) were extracted. If mean differences in step-count pre-to-post intervention were not reported, corresponding authors were approached to provide the data. Studies were excluded from the analysis if authors did not respond within 2 weeks or were unable to provide the requested data.

Quality assessment

C. Reilly and J. Sails evaluated eligible studies using the Downs and Blacks checklist which consists of a 27-item instrument including five domains: reporting, external validity, internal validity, confounding assessment and statistical power [25]. All studies were scored and assigned a quality grade: excellent (26–28); good (20–25); fair (15–19); and poor (<14). Any disparity between the two reviewers was resolved by a third independent reviewer (O. Price).

Data synthesis and analysis

A random-effects model was used to determine the overall effect size using post-intervention values (mean step-count) to calculate the standardised mean difference (SMD) between studies and 95% confidence intervals (CIs). p-values were calculated from the CIs. For studies that reported step-count data as medians, interquartile ranges and CIs, means and standard deviations were estimated using established referenced formulas [26, 27]. The post-intervention values were used to calculate the effect size rather than change scores as it was not possible to calculate the standard deviation of the mean change in step-count for each study. The comparison of final measurements is considered to produce the same estimate as a comparison of change from baseline when examining randomised controlled trials [27] but does mean that baseline step-count is not accounted for. Accordingly, subgroup analysis was undertaken to assess the impact of baseline step-count (<4000 or ⩾4000 steps) [28–30]. A random-effects model was used, based on the assumption that study effect sizes are different and that the collected studies represent a random sample from a larger population of studies. Heterogeneity was measured using I^2 statistics and Cochran's Q statistic. An I^2 value of 25% was considered to demonstrate low heterogeneity, 25–50% moderate and >50% high [27]. For the Cochran's Q test, p<0.05 was used to define statistically significant heterogeneity. The effect size (SMD) was calculated using Hedges' g formula:

$$Hedges'g = \frac{Mean_{intervention} - Mean_{control}}{SD^{*}_{pooled}}$$

The pooled weighted standard deviation (SD^{*}_{pooled}) was calculated using the following formula:

$$SD^{*}_{pooled}\sqrt{\frac{(n-1)SD_1^2 + (n_2-1)SD_2^2}{n_1 + n_2 - 2}}$$

Hedges' g was employed to account for small and variable sample sizes between intervention and control groups [27]. All statistical analyses were conducted using STATA version 15.1 (Stata Corporation, College Station, TX, USA).

Results

Study characteristics and quality assessment

In total, 13 568 studies were identified. Of these, 38 studies (n=37 randomised controlled trials [28–64]; n=1 non-randomised controlled trial [65]) were considered eligible for inclusion in the systematic review and meta-analysis (figure 1). The included studies resulted in a combined study population of n=3777 (intervention: n=1995 and control: n=1782) (male: 65%). Of these, 32 studies included people with COPD (n=3498), five studies included people with asthma (n=216) and one study included people with bronchiectasis (n=63). Study variables and characteristics including the type of PA monitor employed are summarised for reference in table 1. Downs & Black Quality Assessment Scores ranged from 16 to 25, and studies were rated as fair (n=4) and good (n=34) (table 2).

PA promotion versus *usual standard care (n=38)*

Five behaviour change techniques were employed across all 38 studies: 1) motivational interviewing, 2) real-time feedback on step-count, 3) diaries/logbooks, 4) face-to-face support and 5) remote support. The majority of interventions (95%) combined at least two techniques (table 3). Baseline daily step-count was not significantly different between intervention (5043±1653 steps) and control (5143±1542 steps) (p=0.359). However, PA promotion was associated with a larger effect size favouring intervention in those with a higher baseline step-count (⩾4000 steps): SMD=0.28 (95% CI: 0.11–0.45) in comparison to those with lower baseline steps (<4000 steps): SMD=0.15 (95% CI: 0.02–0.29). The duration of the interventions was <8 weeks (n=8 studies), nine to 12 weeks (n=9 studies) and over 12 weeks (mean±SD: 27±14 weeks) (n=5 studies). The greatest improvement in step-count was observed for studies lasting between 9 and 12 weeks: median (IQR): 890 (360–1558); SMD 0.40 (95% CI: 0.09–0.71), p=0.01 (figure 2).

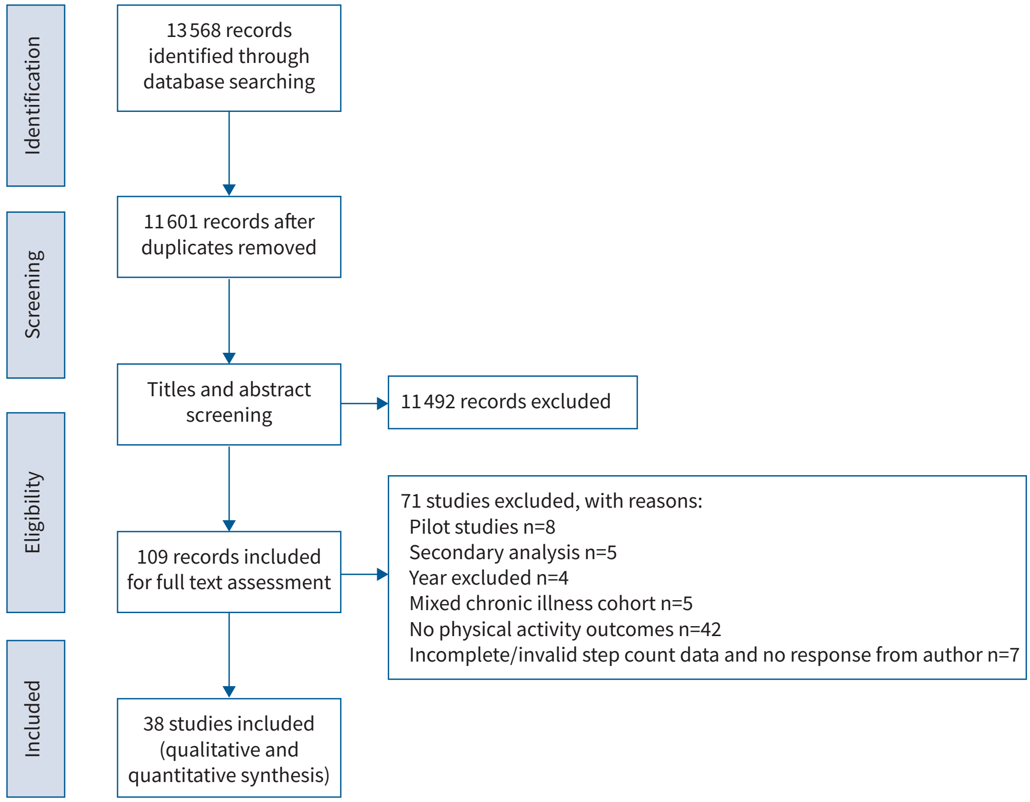

FIGURE 1 PRISMA flowchart representing search results.

Irrespective of the study duration, implementing any form of PA promotion resulted in a significant increase in step-count from baseline: median (IQR): 705 (183–1210) when compared with usual standard care: −64 (−597–229); SMD 0.24 (95% CI: 0.12–0.36), p<0.01 (small effect size) (figure 3). However, a high degree of heterogeneity was observed between studies (I^2=66%), and thus to explore the effectiveness of specific interventions, studies were stratified into three distinct subgroups according to the primary methods of PA promotion (detailed below).

PA promotion+wearable activity monitor-based interventions (n=17)
17 out of 38 studies (44.7%) (n=1304) included PA promotion with a wearable activity monitor-based intervention (*i.e.*, pedometer or accelerometer incorporated as a tool to monitor and provide feedback on step-count throughout the intervention). This combination resulted in the greatest increase in step-count: median (IQR): 1153 (791–3199) when compared with usual standard care: 138 (−114–737); SMD 0.37 (95% CI: 0.10–0.64), p<0.01 (small effect size) (figures 3 and 4).

PA promotion+step-count as an outcome measure (n=9)
Nine out of 38 studies (23.7%) (n=797) utilised PA promotion+step-count as an outcome measure (*i.e.*, pedometer or accelerometer only used to evaluate step-count pre-to-post intervention). This form of PA promotion also resulted in an increase in step-count (albeit to a lesser extent): median (IQR): 520 (332–902) compared to usual standard care: −106 (−497–490); SMD 0.18 (95% CI: −0.03–0.39), p=0.09 (small effect size) (figures 3 and 4).

Technology-based interventions (n=12)
12 out of 38 studies (31.6%) (n=1676) employed a technology-based intervention (*i.e.*, using smartphone applications and/or website resources to provide information to promote PA). Importantly, all technology-based interventions also objectively monitored step-count throughout the study. This approach also led to a significant increase in step-count: median (IQR): 355 (−300–780) compared to usual standard care: −639 (−793–23); SMD 0.16 (95% CI: 0.04–0.29), p=0.01 (small effect size) (figures 3 and 4).

TABLE 1 Summary of key study variables and characteristics

Intervention/studies	Population	FEV_1 % pred	Sample size (n)		Study duration weeks	Physical activity monitor
			Intervention	Control		
Physical activity promotion+wearable activity monitor-based intervention						
Altenburg *et al.* [28]	COPD	60	65	55	12	Yamax Digiwalker SW-200
Armstrong *et al.* [31]	COPD	50	24	24	8	Actigraph Wgt3x
Bender *et al.* [32]	COPD	54	50	50	12	Omron
Bertici *et al.* [65]	COPD	41	21	21	3	Canyon
Cheng *et al.* [33]	COPD	56	34	34	6	activPAL
Coelho *et al.* [34]	Asthma	81	15	15	12	Actigraph Wgt3x
Cruz *et al.* [29]	COPD	66	16	16	12	Yamax Digiwalker SW-200
Freitas *et al.* [35]	Asthma	70	28	28	13	Yamax Power Walker EX-510
Freitas *et al.* [36]	Asthma	66	26	26	8	Actigraph GT9X
Geidl *et al.* [37]	COPD	54	160	160	6	Actigraph Wgt3x
Hiles *et al.* [38]	Asthma	75	9	9	12	Actigraph Wgt3x
Hornikx *et al.* [39]	COPD	43	15	15	6	Fitbit Ultra
Mendoza *et al.* [40]	COPD	66	47	47	12	Tanita PD724
Nolan *et al.* [41]	COPD	51	57	57	8	Yamax Digiwalker CW700
Nyenhuis *et al.* [42]	Asthma	62	28	28	24	Actigraph GT3XP
Varas *et al.* [30]	COPD	49	16	16	8	Omron HJ 320-e
Widyastuti *et al.* [43]	COPD	66	18	18	6	Omron HJ 321
Physical activity promotion+step-count as an outcome measure						
Effing *et al.* [44]	COPD	50	68	68	26	Yamax Digiwalker SW-200
Evaristo *et al.* [45]	Asthma	71	25	25	13	PowerWalker SW610
Holland *et al.* [46]	COPD	50	33	33	8	Sensewear Armband
José *et al.* [47]	Bronchiectasis	53	28	28	9	Actigraph Wgt3x
Ko *et al.* [48]	COPD	48	57	57	8	Actigraph Wgt3x
Lahham *et al.* [49]	COPD	90	29	29	8	Omron Walking Style Pro
Rausch *et al.* [50]	COPD	81	18	18	17	Sensewear Pro armband
Selzler *et al.* [51]	COPD	56	85	85	8	Fitbit Flex
Wootton *et al.* [52]	COPD	43	39	39	10	Sensewear Armband
Technology-based intervention						
Arbillaga-Etxarri *et al.* [53]	COPD	56	148	148	52	Dynaport movemonitor
Benzo *et al.* [54]	COPD	43	74	74	8	Actigraph Wgt3x
Demeyer *et al.* [55]	COPD	56	132	132	12	Dynaport movemonitor/ Actigraph
Moy *et al.* [56]	COPD		68	68	18	Omron HJ 720 ITC
Moy *et al.* [57]	COPD		84	84	52	Omron HJ 720 ITC
Park *et al.* [58]	COPD	65	20	20	26	Actigraph wGT-3X-BT
Robinson *et al.* [59]	COPD	61	78	78	26	Fitbit zip
Simmich *et al.* [60]	COPD		6	6	3	Fitbit Alta HR or Fitbit Charge HR 2
Spielmanns *et al.* [61]	COPD	44	34	34	26	POLAR A370 watch
Tabak *et al.* [62]	COPD	52	16	16	4	Yamax Digiwalker 200
Vorrink *et al.* [63]	COPD	56	67	67	12	SenseWear PRO / MF-SW Mini armband
Wan *et al.* [64]	COPD	63	52	52	12	Omron HJ 720 ITC

FEV_1: forced expiratory volume in 1 s.

Discussion

Physical inactivity is common in pwCAD and associated with worse clinical outcomes and impaired quality of life [4, 6]. The development of effective strategies to promote PA to elicit long-term behaviour change and lifestyle modification therefore remains a priority. In this comprehensive systematic review and meta-analysis, we confirm that interventions promoting PA, particularly those that incorporate wearable activity monitors, led to a significant increase in step-based activity when compared to usual standard care. Importantly, the total increase in daily step-count met the current threshold or smallest effect associated with a clinically relevant or perceived beneficial outcome from data in people with COPD (600–1110 steps·day^{-1}) [11].

TABLE 2 Downs and Black assessment checklist scores

Intervention/studies	Reporting (out of 11)	External validity (out of 3)	Internal validity (out of 7)	Confounding bias (out of 6)	Power (out of 1)	Total score (out of 28)
Physical activity promotion+wearable activity monitor-based intervention						
Altenburg *et al.* [28]	10	2	5	2	1	20
Armstrong *et al.* [31]	11	2	5	2	1	21
Bender *et al.* [32]	8	2	5	2	0	17
Bertici *et al.* [65]	9	2	5	0	0	16
Cheng *et al.* [33]	10	2	7	4	1	24
Coelho *et al.* [34]	10	2	5	3	1	21
Cruz *et al.* [29]	11	2	6	3	1	23
Freitas *et al.* [35]	10	2	6	4	1	23
Freitas *et al.* [36]	10	2	7	3	1	23
Geidl *et al.* [37]	10	2	6	3	0	21
Hiles *et al.* [38]	11	2	5	4	0	22
Hornikx *et al.* [39]	11	2	5	3	1	22
Mendoza *et al.* [40]	10	2	7	4	1	24
Nolan *et al.* [41]	10	2	6	4	0	22
Nyenhuis *et al.* [42]	11	2	5	2	0	20
Varas *et al.* [30]	10	2	7	4	0	23
Widyastuti *et al.* [43]	10	2	5	2	1	20
Physical activity promotion+step-count as an outcome measure						
Effing *et al.* [44]	11	2	5	3	1	22
Evaristo *et al.* [45]	11	2	6	4	1	24
Holland *et al.* [46]	11	2	7	4	1	25
José *et al.* [47]	11	2	5	3	1	22
Ko *et al.* [48]	10	2	6	4	1	23
Lahham *et al.* [49]	10	2	6	3	1	22
Rausch *et al.* [50]	11	2	6	3	0	22
Selzler *et al.* [51]	10	2	7	3	1	23
Wootton *et al.* [52]	10	2	7	4	1	24
Technology-based intervention						
Arbillaga-Etxarri *et al.* [53]	11	2	6	3	1	23
Benzo *et al.* [54]	11	2	6	2	1	22
Demeyer *et al.* [55]	11	2	5	3	1	22
Moy *et al.* [56]	11	2	5	3	1	22
Moy *et al.* [57]	11	2	5	3	1	22
Park *et al.* [58]	11	2	5	3	1	22
Robinson *et al.* [59]	11	2	7	4	1	25
Simmich *et al.* [60]	10	2	5	2	0	19
Spielmanns *et al.* [61]	11	2	5	3	1	22
Tabak *et al.* [62]	10	2	5	2	0	19
Vorrink *et al.* [63]	11	2	6	2	1	22
Wan *et al.* [64]	10	2	6	2	1	21

The impact of interventions promoting PA, in the context of chronic airways disease, has been extensively evaluated over the past 5 years [66, 67]. However, improvements in PA have not been systematically demonstrated following any particular intervention [23]. In keeping with prior reports, this systematic review emphasises the diverse range of interventions employed in contemporary research. Indeed, a variety of behaviour change strategies, including motivational interviewing, real-time feedback on step-count, diaries and logbooks, and face-to-face and remote support, were included in the 38 studies, with all but one combining at least two techniques.

In the current systematic review, we applied a stringent inclusion and exclusion criteria (*i.e.*, objective assessment of step-count pre-to-post intervention) in order to identify relevant studies. A lack of consistency and standardisation relating to the type of wearable activity monitors employed made it difficult to quantify the effect or relative benefit of specific PA interventions [18]. Accordingly, due to the considerable heterogeneity observed between studies, we stratified interventions by study duration

TABLE 3 Breakdown of physical activity promotion strategies

First author [ref.]	Motivational interviewing	Real-time feedback on step-count	Diaries and logbooks	Face-to-face support	Remote support	Total behaviour change strategies
Altenburg *et al.* [28]	✓	✓	✓	✓	×	4
Armstrong *et al.* [31]	✓	✓	✓	✓	×	4
Bender *et al.* [32]	✓	✓	×	✓	✓	4
Bertici *et al.* [65]	×	✓	✓	✓	✓	4
Cheng *et al.* [33]	✓	✓	✓	✓	✓	5
Coelho *et al.* [34]	×	✓	✓	✓	✓	4
Cruz *et al.* [29]	×	✓	✓	✓	✓	4
Freitas *et al.* [35]	×	✓	✓	✓	×	3
Freitas *et al.* [36]	✓	✓	✓	✓	×	4
Geidl *et al.* [37]	×	✓	✓	✓	×	3
Hiles *et al.* [38]	×	✓	✓	✓	×	3
Hornikx *et al.* [39]	×	✓	×	×	✓	2
Mendoza *et al.* [40]	×	✓	✓	✓	×	3
Nolan *et al.* [41]	×	✓	✓	✓	×	3
Nyenhuis *et al.* [42]	×	✓	✓	✓	✓	4
Varas *et al.* [30]	×	✓	✓	✓	✓	4
Widyastuti *et al.* [43]	×	✓	✓	✓	×	3
Effing *et al.* [44]	×	×	✓	✓	×	2
Evaristo *et al.* [45]	×	×	×	✓	×	1
Holland *et al.* [46]	✓	×	✓	✓	✓	4
José *et al.* [47]	×	×	✓	✓	✓	3
Ko *et al.* [48]	×	×	×	✓	✓	2
Lahham *et al.* [49]	✓	×	×	×	✓	2
Rausch *et al.* [50]	✓	×	×	✓	✓	3
Selzler *et al.* [51]	×	×	✓	✓	×	2
Wootton *et al.* [52]	×	×	×	✓	×	1
Arbillaga-Etxarri *et al.* [53]	✓	✓	✓	✓	✓	5
Benzo *et al.* [54]	✓	✓	✓	×	✓	4
Demeyer *et al.* [55]	✓	✓	✓	✓	✓	5
Moy *et al.* [56]	×	✓	×	×	✓	2
Moy *et al.* [57]	×	✓	×	×	✓	2
Park *et al.* [58]	×	✓	✓	✓	✓	4
Robinson *et al.* [59]	×	✓	✓	✓	✓	4
Simmich *et al.* [60]	×	✓	✓	×	✓	3
Spielmanns *et al.* [61]	×	✓	✓	×	✓	3
Tabak *et al.* [62]	×	✓	✓	×	✓	3
Vorrink *et al.* [63]	×	✓	✓	✓	✓	4
Wan *et al.* [64]	✓	✓	×	×	✓	3
Total	12	29	28	29	25	

(short-term: <8 weeks; medium-term: 9–12 weeks; long-term: >12 weeks) and the primary method of PA promotion (PA promotion+wearable activity monitor-based interventions; PA promotion+step-count as an outcome measure; technology-based interventions).

Longer-term pulmonary rehabilitation programmes (>12 weeks) have previously been reported to be more effective at increasing PA when compared to short-term interventions (<12 weeks) [17, 18]. In contrast to these findings, we found that (irrespective of the specific intervention) studies lasting between 9 and 12 weeks led to a greater improvement in daily step-count in comparison to shorter (<8 weeks) or longer-term (>12 weeks) interventions. This may relate to the challenges associated with maintaining participant interest over long-term periods and the burden associated with tracking and reporting progress (*i.e.*, completing step-count diaries and logbooks) which may lead to patient dropout and/or lower rates of engagement [68]. Equally, it may be that short-term setbacks are recoverable at different time points, which moving forward, justifies considering how different techniques are combined over time to elicit effective and prolonged behavioural change.

Our findings support the concept that wearable activity monitors contribute to an increase in step-based activity. Indeed, a recent meta-analysis of randomised controlled trials in COPD concluded that

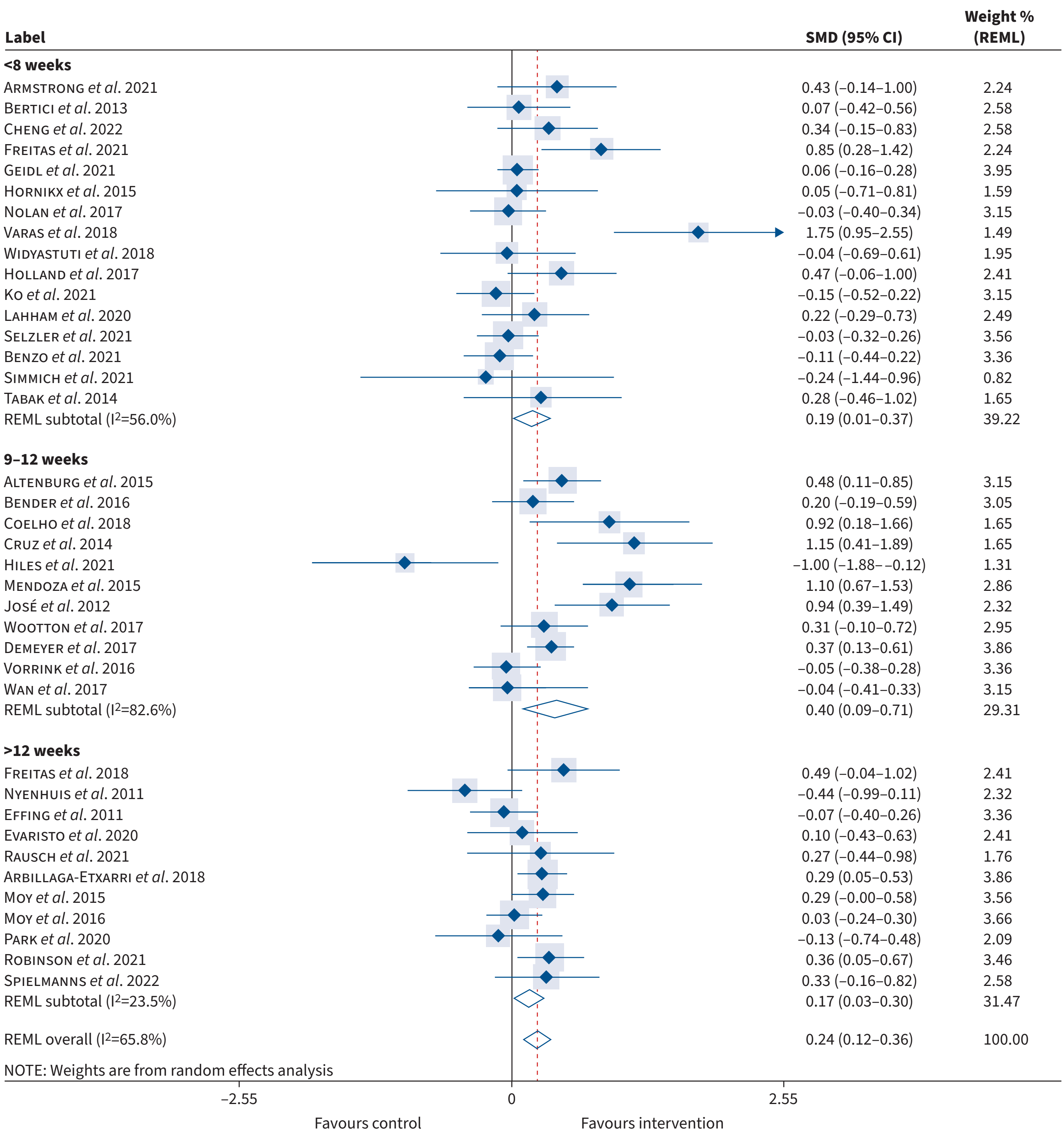

FIGURE 2 Standard mean difference (SMD) in daily step-count according to intervention duration (pre-to-post intervention). REML: restricted maximum likelihood.

incorporating pedometers either as a standalone intervention or in conjunction with pulmonary rehabilitation led to a significant improvement in daily steps, particularly in those with higher baseline step-count (⩾4000 steps) [22]. Sub-dividing studies according to intervention (n=17) *versus* outcome (n=9) represents an important extension and unique aspect of the current analysis. Indeed, for the first time, our analysis indicates that the greatest improvement in daily steps occurs when wearable activity monitors are

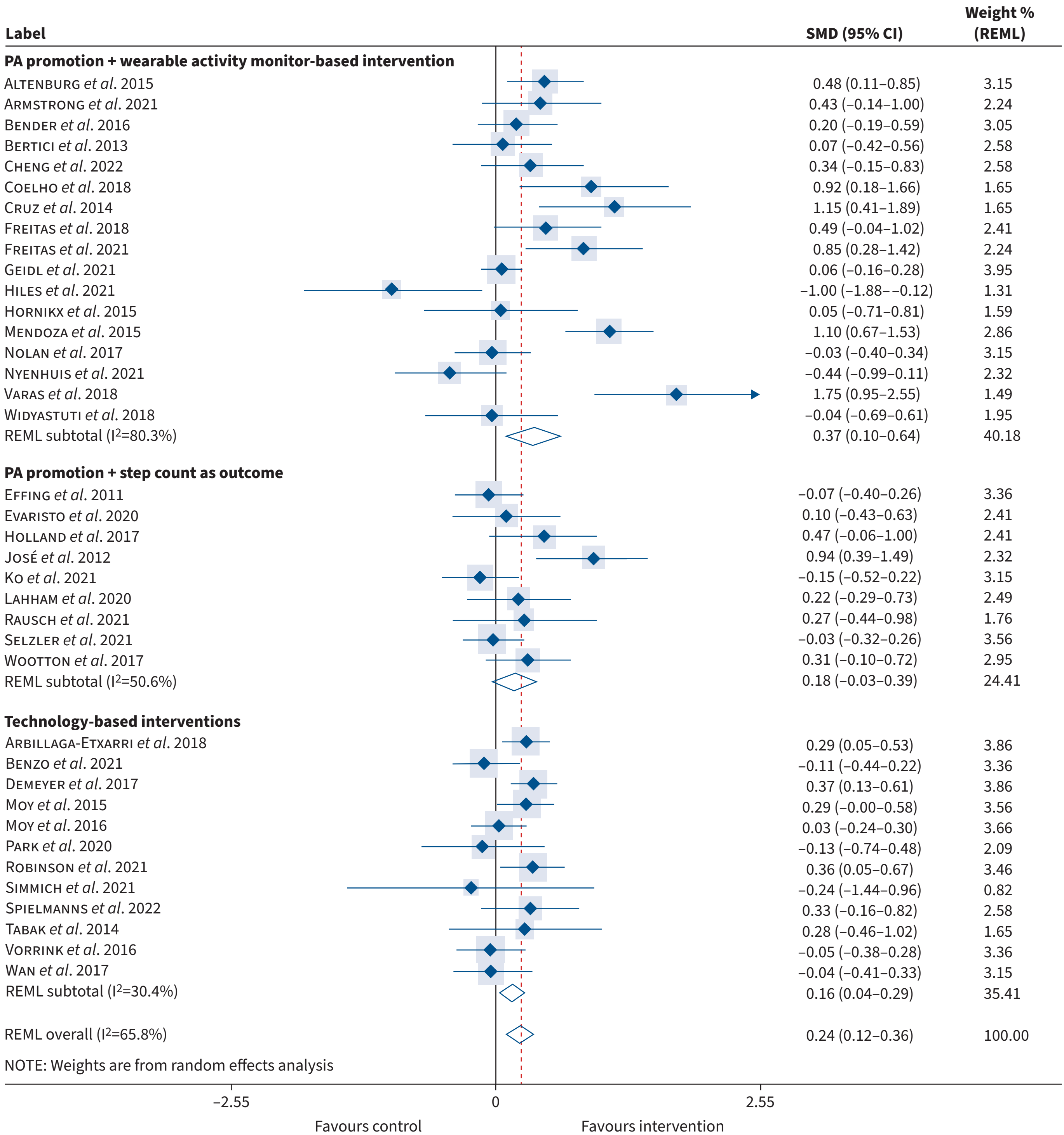

FIGURE 3 Standard mean difference (SMD) in daily step-count according to primary method of physical activity promotion (pre-to-post intervention). PA: physical activity; REML: restricted maximum likelihood.

incorporated during the intervention (*i.e.*, continuous monitoring with real-time feedback), as opposed to simply quantifying change pre-to-post intervention. These findings are consistent with a recent systematic review and meta-analysis that reported a strong association between the use of wearable activity trackers when combined with healthcare professional consultations and increased PA in people with cardiometabolic conditions [69]. From a behavioural perspective, it is plausible that utilising wearable

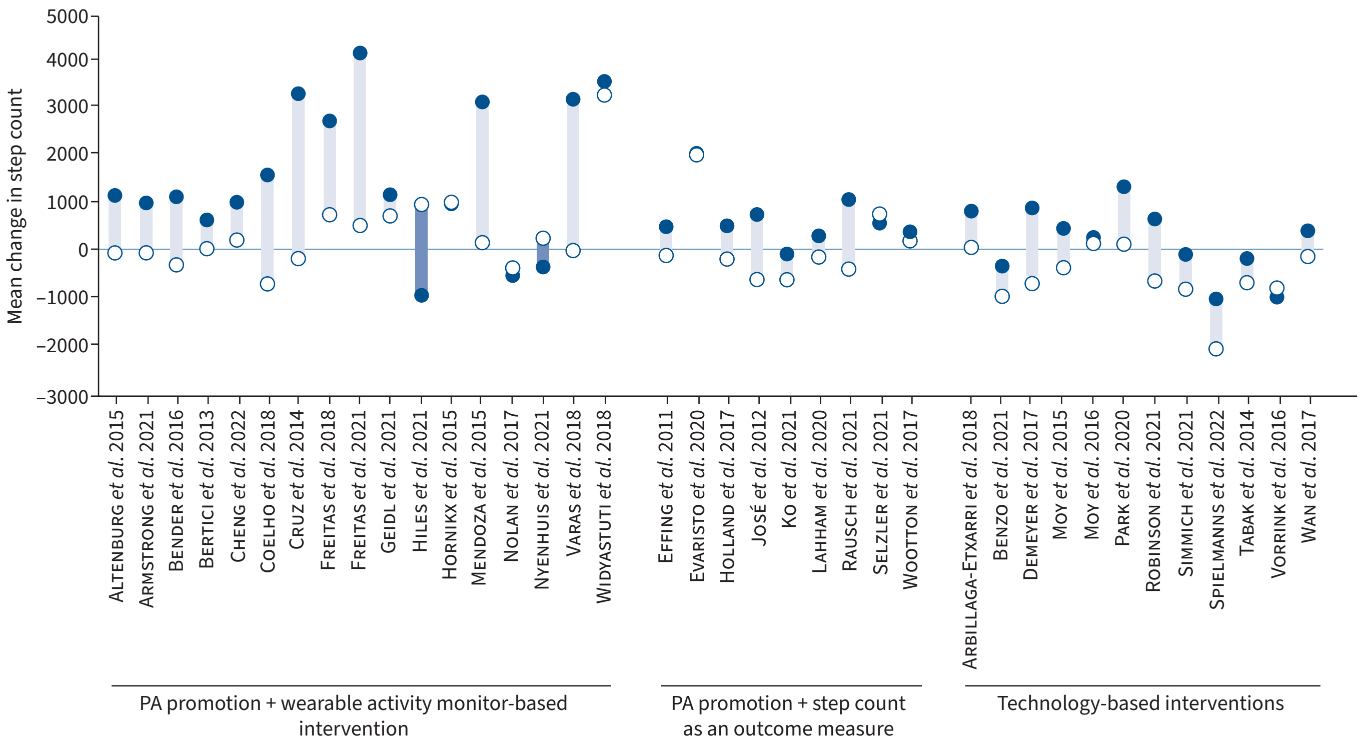

FIGURE 4 Daily step-count stratified according to subgroups pre-to-post intervention (closed and open circles denote intervention and controls, respectively). PA: physical activity.

devices to promote PA acts to support real-time self-regulatory mechanisms (*e.g.* goal setting and self-monitoring), *i.e.*, established behaviour change techniques recognised to promote long-term health-enhancing behaviours [20, 70].

Our analysis also indicates that studies incorporating a technology-based intervention (n=12) had a comparable effect to those that used activity monitors as an outcome measure only (*i.e.*, pre-to-post intervention). This was despite the fact that all technology-based studies objectively monitored and provided feedback on daily step-count throughout the intervention. While speculative, the disparity between traditional wearable (*i.e.*, pedometer and accelerometer) and smartphone-based interventions may be due to the fact that some patients (*i.e.*, particularly elderly individuals or those with severe disease) struggle to operate modern smartphone devices and/or access online resources. It is also plausible that some individuals may require a more personalised approach (*i.e.*, face-to-face contact) to optimise and maintain PA. Irrespective of these potential limitations, advances in modern user-friendly remote technologies and continued global growth in smartphone users (with the functionality to quantify step-count accurately [71]) offer promise as a low cost and scalable solution to address physical inactivity in this setting moving forward.

A secondary aim of this systematic review was to identify unmet need and provide direction for future research. It was notable that the majority of studies focused on people with COPD, despite the significant global burden of other respiratory diseases such as asthma, bronchiectasis and cystic fibrosis, where exercise intolerance and activity limitation are central features [1, 2]. Despite the identification of sex-based differences across the spectrum of chronic airways disease (*i.e.*, higher prevalence of asthma and bronchiectasis and rising incidence of COPD in females) [72], almost two-thirds of the study population were male. In the current era of personalised and precision medicine, a key focus for future research is therefore to quantify activity status using valid research grade objective assessment tools [73] and evaluate PA promotion strategies in more diverse and inclusive populations, with consideration for disease sub-type, severity, comorbid illness, age, sex and ethnicity. Ultimately, this approach will help to identify novel clinical end-points, establish the minimal important difference according to specific populations, and permit the implementation of targeted and effective PA promotion interventions.

Clinical implications and practical application

While many healthcare professionals acknowledge the importance of PA, factors such as time constraints during consultation, lack of knowledge and confidence may limit the advice provided [74]. Indeed, brief, non-individualised and generic recommendations featuring in many contemporary consultations may lack essential components to initiate change [75]. The best available evidence to date (albeit primarily in COPD) indicates that the greatest improvement in daily step-count occurs by combining established behaviour change techniques with wearable activity monitors *during* the intervention. In terms of practical application, healthcare professionals could therefore encourage the use of low-cost wearable activity monitors and/or in-built smartphone pedometers to record and track daily steps during medical consultation. The potential advantages of electronic information supplemented by encouragement from a clinician may reduce healthcare utilisation while ensuring PA promotion interventions adhere to best practice and current guidelines. This recommendation is particularly pertinent in view of the ongoing SARS-CoV-2 pandemic. Indeed, it is now recognised that low levels of PA are strongly associated with a higher risk of severe COVID-19 [76] and that a significant proportion of individuals experience long-term sequelae [77, 78] including impaired functional capacity and activity limitation [79].

Methodological considerations and future research

Several methodological limitations are worthy of consideration. First, an arbitrary classification was applied to sub-divide studies, and thus findings should be interpreted with a degree of caution. Second, our analysis emphasised differences in post-intervention step-count between control and intervention groups, yet the many features affecting PA may not be captured in a single measurement. For that reason, future PA promotion-based studies should therefore aim to adopt a more holistic approach to assessment, with consideration for other relevant aspects or refined markers of PA, such as sports participation/structured exercise, time spent in sedentary living, moderate-to-vigorous activity and/or activity-related energy expenditure [80]. Third, some studies failed to report whether PA promotion interventions were evaluated in isolation or embedded within a pulmonary rehabilitation programme, which limited our ability to provide a direct comparison. Fourth, PA is highly dependent on environmental conditions and seasonality, and we were unable to account for these factors in our analysis. Finally, few studies included long-term surveillance, which limits our ability to draw robust conclusions concerning sustained benefit.

Conclusion

In summary, our findings indicate that interventions promoting PA, particularly those that incorporate wearable activity monitors, result in a significant and clinically meaningful improvement in daily step-count in pwCAD. Further multicentre randomised controlled trials with longitudinal follow-up, in diverse and inclusive populations, according to airways disease sub-type and sex, remain an important avenue for future research.

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