TITLE

In people with COPD, there is limited evidence that exercise training reduces sedentary time and behavior change techniques are poorly reported: Systematic Review and Meta-Analysis

RUNNING HEAD

Limited evidence that interventions change sedentary behavior in people with COPD

TOC CATEGORY

Cardiovascular/Pulmonary

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Review

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ABSTRACT

Objective: In people with chronic obstructive pulmonary disease (COPD) to explore; (i) the effect of any intervention on the time spent in sedentary behavior and, (ii) which behavior change techniques (BCTs) have shown promise in achieving this lifestyle target.

Methods: Five electronic databases were searched on the 7th January 2021. Studies were included if they; (i) recruited people with stable COPD, (ii) applied an intervention ≥4 weeks and, (iii) measured sedentary time (ST) before and after the intervention period, using wearable technology or via self-reports of television viewing. The primary analyses were restricted to data reported in randomized controlled trials (RCT). All BCTs described during the intervention periods were mapped using an established taxonomy.

Results: Of the 1142 records identified, eight were RCTs, of which six had exercise training as the intervention. Random effects meta-analysis of data from four of these six trials that implemented whole-body exercise training showed no clear effect on ST (mean difference -5.0 minutes, 95% confidence interval -30.7 minutes to 21.0 minutes). Commonly mapped BCTs in the majority of studies included action planning and instruction on how to perform the behavior. Of all the BCTs mapped, 25% were reported with sufficient information to be graded 'beyond reasonable doubt'.

Conclusion: Despite robust evidence that exercise training improves functional outcomes and reduces dyspnea, this intervention does not seem to translate into behaviour change. The primary analysis demonstrated that, in adults with COPD, the effect of exercise training on ST was at best, uncertain. The BCTs embedded within the interventions were often poorly reported. Future RCTs are required that appropriately report BCT and ST to improve the precision of our estimate of the effect exercise training may have on ST, and BCTs used during intervention periods need to be reported with greater specificity.

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Impact: In people with COPD there is currently limited evidence to suggest that exercise training will reduce sedentary behavior. To move this area of research forward, BCTs embedded within these interventions need to be described with greater precision.

Lay summary: In people with COPD, interventions such as exercise training do not seem to produce reduction in sedentary behavior (i.e. time spent sitting or lying down) during daily life. The techniques used to change this behavior were poorly reported.

KEYWORDS: sedentary behavior, behavior change technique, sedentary time, chronic obstructive pulmonary disease, systematic review, meta-analysis.

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INTRODUCTION

Compared with the general population of similar age and sex proportion, people with chronic obstructive pulmonary disease (COPD) are at greater risk of both developing cardiovascular disease and dying from cardiovascular causes.[1] This finding holds true even after the analyses are adjusted for difference in typical cardiovascular risk factors such as serum total cholesterol, hypertension and obesity.[2] The reasons for this increased risk are likely to be the overlap in factors contributing the development of COPD and cardiovascular disease, namely extensive cigarette smoking, systematic inflammation and little participation in regular moderate-to-vigorous intensity physical activity (MVPA).[1,3,4] In addition to ceasing cigarette smoking, increasing participation in MVPA is a malleable lifestyle choice that can mitigate the increased risk of cardiovascular disease.[1,3,4] Nevertheless, the multitude of studies that have explored interventions that aim to optimise participation in MVPA in people with COPD clearly show that achieving this lifestyle target is, at best, challenging.[5] This finding is unsurprising as earlier work has shown that people with COPD adopt a very sedentary lifestyle presumably as a strategy to avoid the sensation of dyspnea.[6] Notably, this lifestyle modification has been observed even in those with mild disease and progressively worsens with increasing disease severity.[6]

In the general population, there is now increased awareness that prolonged time spent in sedentary behavior (i.e. prolonged sedentary time [ST]) is a risk factor for premature mortality,[7-9] largely as a result of exacerbating metabolic disease.[7,8,10] Sedentary behavior is defined as any behavior undertaken during waking hours, in sitting or reclining posture, that requires energy expenditure ≤1.5 metabolic equivalent tasks (METs) (e.g. television viewing, screen time).[11] Of note, the risk associated with increased ST appears largely uninfluenced by participation in MVPA.[10,12] Over the last few years, data have emerged that demonstrate the deleterious health impact of ST in people with COPD.[13] Specifically, in this population,

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increased ST contributes to the risk of hospitalisation[14,15] and mortality.[14] However, in contrast to increasing participation in MVPA, it is likely that reducing ST by increasing participation in light intensity physical activity (LIPA) is a change in behavior that is realistic for people with COPD, even amongst those with marked functional impairment.

This systematic review sought to find studies that applied to any intervention lasting at least four weeks to people with COPD and collected measures of ST before and after the intervention period. Data reported in these studies were used to:

1. Synthesise the evidence for the effect of these interventions on ST (no other outcomes were considered); and
2. Explore the use and promise of specific behavior change techniques (BCTs) embedded within these interventions to reduce ST.

The results of this systematic review will provide information to clinicians on approaches that may be used to target reductions in ST in people with COPD.

METHODS

Data presented in this systematic review represent part of a larger program of research which was prospectively registered in PROSPERO (CRD42019138106). This review has been reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[16] Studies were eligible for inclusion in this review if: (i) ≥ 70% of the participants have stable COPD; (ii) if the intervention period was a minimum of four weeks in duration; (iii) measures of ST were collected before and after the intervention period via wearable technology (e.g. accelerometers, inclinometers) or self-report. Consistent with large epidemiological studies,[17] ST needed to be assigned to the specific behavior of television viewing if self-reported, as this is the most common sedentary leisure time

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104 behavior.[18] Conference abstracts and studies published in a language other than English were
105 excluded.

106 **Data sources and searches**

107 Studies were identified by searching five electronic databases: CINAHL, the Cochrane
108 Library, EMBASE (via OVID), PEDro (Physiotherapy Evidence Database), and PubMed
109 from their inception to 7th January 2021. Reference lists (hand searches) from relevant papers
110 were also screened. The search strategy used for PubMed which was adapted for use in other
111 databases (see online supplement: Figure S1).

112 **Study selection**

113 Using Covidence software,[19] two review authors (FC and SW) independently screened titles,
114 abstracts and full papers, as required, to identify eligible studies. The same two review
115 authors independently completed the risk of bias assessment. Disagreement was resolved by
116 discussion or when needed by a third review author (KH).

117 **Data extraction and quality assessment**

118 Data were extracted into Microsoft Excel database by one author (FC) and checked by
119 another author (SW). In the case of missing data, study authors were contacted via email on a
120 maximum of three occasions every two weeks.

121 Following completion of the BCTs v1 Taxonomy online training module (www.bct-
122 taxonomy.com), data regarding BCTs were extracted by one author (FC).[20] The process was
123 checked by another author (DG) who has extensive experience in this methodology.

124 For RCTs, the risk of bias was assessed using the Cochrane Collaboration's tool.[21] This tool
125 comprises seven evidence-based domains such as 'random sequence generation', and
126 'allocation concealment' (selection bias), 'blinding of participants and personnel'

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(performance bias), 'blinding of outcome assessment' (detection bias), 'incomplete outcome data' (attrition bias), 'selective outcome reporting' (reporting bias) and 'other bias'. Studies were scored in each domain as being at a 'high', 'unclear', or 'low' risk of bias.[21]

Data synthesis and analysis

For the purposes of meta-analysis primary studies were first grouped by design, into two categories.

1. Randomized controlled trials in which the intervention group received any form of intervention, and at least one group served as a true control or received usual care such as health education. Thereafter, studies were grouped to ensure consistency in the type of intervention applied.
2. Randomized controlled trials in which both groups received exercise training defined as any form of structured, repetitive physical activity with the goal of improving exercise capacity.[22] The experimental group received an additional intervention (e.g. motivational interviewing) which was designed to either promote participation in physical activity and/or a reduction in ST during daily life.

Change in ST for each group was calculated by subtracting the mean pre-intervention measure from the mean post-intervention measure. Where possible the standard deviation (SD) of the change in measure was used. When this information was not reported, the SD of the pre-intervention value was used. In studies where participants were allocated to two intervention groups and one control group, data were managed in accordance with the recommendation from Cochrane.[23] Specifically, the sample size available for the control group was divided for comparison across the two intervention groups. The I^2 statistic was used to evaluate statistical heterogeneity and sensitivity analyses were conducted when I^2 approached or exceeded substantial heterogeneity (i.e. 50%). A random-effects model was

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used to calculate summary estimates, and data were meta-analysed using the inverse-variance DerSimonian and Laird method.[24] Results derived from the primary analysis were qualified using the GRADE (Grading of Recommendations Assessment, Development and Evaluation).[25] For all studies ST was reported as min/day and therefore the summary effect statistic derived from the meta-analyses was the mean difference with their corresponding 95% confidence interval (RevMan, version 5.3, Copenhagen).[26]

As research regarding the effect of intervention on ST in people with COPD is in its infancy we conducted a secondary analyses including data from; (i) single group studies and, (ii) randomized cross-over trials in which paired data were presented (i.e. data collected during the control and intervention periods were compared in the same group of participants) (iii) randomized trials in which all participants received one of two active interventions (e.g. allocated to home-based exercise training versus center-based exercise training). For meta-analysis of data reported in these studies, the mean and SD of ST measured before and after the intervention period were used.

Evaluation of behavior change techniques

When BCTs were deemed to be present, they were coded as either '++' if the authors were confident 'beyond reasonable doubt' that the BCT was present, or '+' if 'in all probability' the BCT was present though information was insufficient in detail.[20]

Role of the funding source

We received no funding for this study.

RESULTS

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The search strategy yielded 1142 records of which 157 (14%) were duplicates. Of the remaining 990 records, 745 (75%) were excluded based on title and abstract, and 232 (23%) were excluded following the full text review (Figure 1). Eight RCTs were eligible for inclusion in the primary analysis, of which seven had usable data (Figure 1). Five studies were eligible for inclusion in the secondary analysis, and four had usable data.

Results of primary analysis

Characteristics of the eight RCTs are presented in Table 1. Studies were conducted in Australia,[27] Austria,[28] Brazil,[29,30] Greece,[31] Japan,[32] United Kingdom[33] and the United States of America.[34] The total number of participants across the eight studies was 379 (72% males); forced expiratory volume in one second [FEV_1] ranged between 39 ± 14% and 68 ± 20% predicted, with the sample size of the included studies ranging between 24 and 147 participants.

Risk of bias

The risk of bias is presented Figure 2. The quality of the RCTs ranged from poor to high.

Interventions

The interventions used in the studies are described in Table 1. The intervention most frequently applied (seven out of eight studies) was exercise training and the intervention period ranged between 2 and 12 months.

Measurement of outcome

All included studies quantified ST using accelerometers. The details of these specific wearable devices are presented in Table 1.

Meta-analysis

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Six RCTs were found, in which the intervention group received any form of intervention, and at least one group served as a true control. Of these, five explored the effect of exercise training on ST. Of the five studies that explored the effect of exercise training on ST, one did not have usable data. In this study, the intervention group received three months of Nordic Walking and the control group received usual care.[28] On completion of the intervention period in that study, the intervention demonstrated a reduction in ST that was over and above any reported control group.[28] A meta-analysis of data reported in the four studies that explored any type of exercise training showed no clear effect on ST (Figure 3a). The certainty of evidence (GRADE) for this meta-analysis was deemed low (online supplement Table S1). A sensitivity analysis was undertaken where one study was omitted,[34] on the basis the exercise training was upper limb resistance exercises without any whole body exercise.[34] The result of this meta-analysis was similar (Figure 3b).

Two RCTs were found in which both groups received exercise training but the experimental group received additional intervention to increase physical activity during daily life. Meta-analysis of data reported in these studies showed no clear effect on ST with very high heterogeneity ($I^2 = 87\%$) which precluded meaningful interpretation of the result (online supplement Figure S2).

The use and promise of specific behavior change techniques

Across eight RCTs eligible for inclusion in the primary analysis, 25 BCTs of the possible 93 BCTs described in the Taxonomy were represented (i.e. 25%).[35] The number of unique BCTs identified within each study ranged from 5 to 11. The most commonly mapped BCT were action planning (1.4 on Taxonomy n=8 studies) and instruction on how to perform the behavior (item 4.1 on Taxonomy n=8 studies) (Figures 4a and b). Where a BCT was mapped, one quarter were assigned a confidence level '++' (n=31; 25%) (Figure 4).

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Results of the secondary analysis

The results of these secondary analyses can be found in the online supplement Table S2, Figure S3 and Figure S4.[36-40]

DISCUSSION

This is the first systematic review with meta-analyses to evaluate the effect of any intervention of at least 4 weeks in duration on measures of ST in people with COPD. The main findings of this review are that, using data available from RCTs that collected measures of ST before and after an intervention period; (i) there was no convincing evidence of a reduction in ST in this population and, (ii) BCTs, when used, were poorly reported. As all studies included in the current meta-analyses used wearable devices to quantify ST, the lack of effect on ST does not reflect the known poor precision of self-reported measures of ST. [41] Poor reporting of BCTs compromises our capacity to understand what exactly has been trialled and, if appropriate, how to replicate these techniques in clinical practice or future research.

The intervention explored in most of studies was exercise training. It is well-established that in people with COPD, exercise training increases exercise tolerance, reduces symptoms of dyspnea and fatigue and improves health-related quality of life.[42] This is achieved, as least in part, by improving the oxidative capacity of the quadriceps femoris muscles.[43] Nevertheless, the effect of this intervention on ST was, at best, uncertain. The pooled point estimate was -3.4 minutes and the 95% confidence intervals from -27.9 minutes to 21.0 minutes (Figure 3a). This means that the true effect of exercise training on ST may be either a reduction of 27.9 minutes or an increase of 21.0 minutes. The results of our sensitivity analysis (Figure 3b) was similar to the main analysis (Figure 3a) suggesting that our a-priori decision to pool studies

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that investigated any form of exercise training did not appear to influence the overall estimate of the result. Further studies are needed to improve the precision around the estimate. Although the results of the secondary meta-analyses approached a significant reduction in ST (online supplement Figure S3), the 95% confidence interval around this difference was reasonably wide. This is because the results of individual studies on ST were inconsistent. Further, because the studies included in the secondary analysis did not recruit a control group who received no intervention, the result is as high risk of bias[21] and we have low confidence that this change can be attributed to the intervention.

When described, BCTs embedded within the interventions described in the RCTs stated the target behavior to be an increase in physical activity and/or increased participation structured exercise.[27-32,34] Measures of ST were included as a secondary outcome. Earlier work in the general population has suggested that a reduction in ST is more likely when the intervention message is highly specific to this behavior (i.e. reducing ST), and does not have the concurrent goal of increasing physical activity.[44] Therefore, one interpretation of our data is that the uncertain effect on ST was because the BCTs embedded within the interventions focussed on changing time spent in physical activity rather than specifically focussing on reductions in ST. Nevertheless, we believe that changes in physical activity were unlikely to have occurred in these studies. This is because ST and time in LIPA are almost perfectly inversely related in people with COPD[45] and therefore our findings of no effect on ST suggest that these studies also had no effect on the time spent in LIPA. Further, a recent Cochrane review which included many of the same studies of exercise training as this review and, reported on physical activity outcomes, also demonstrated very little evidence of an change.[5] As several previous reviews have shown that exercise training is unlikely to produce meaningful changes in physical activity[46-48] and the data in this study suggest the same is true for changes of ST, perhaps greater attention is needed on implementing BCTs that have

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shown promise in successfully modifying other health behaviors in this population. For example, earlier work has demonstrated that BCTs which show promise in changing other health behaviors that are of particular relevance to people with COPD, such as the cessation of cigarette smoking include; social support (unspecified) (item 3.1 on the Taxonomy), behavior substitution (item 8.2 on the Taxonomy) and feedback on outcome(s) of behavior (item 2.7 on the Taxonomy).[49]

An important finding of this work is that the specific reporting of BCTs embedded within interventions, such as exercise training, was often poor. As an example, within the context of exercise training the term 'supervision' was often used to describe a healthcare professional overseeing the exercise training class. However, within the physiotherapy vernacular the term 'supervision' often implies BCTs such as; goal setting (behavior) (item 1.1 on Taxonomy), instruction on how to perform the behavior (4.1 on the Taxonomy), action planning (1.4 on the Taxonomy), feedback and monitoring (2.4 on the Taxonomy), graded tasks (8.7 on the Taxonomy), social support (unspecified) (item 3.1 on the Taxonomy). Unfortunately, using the term 'supervision' leaves us with no information about specific BCTs that were applied and hinders any evaluation of which BCTs may show promise in this population. Further, when BCTs were reported 25% lacked details to allow us to be sure that it was applied 'beyond reasonable doubt'. This finding, in part, may reflect that reporting standards such as TIDieR[50] and CERT,[51] do not require BCTs to be described in accordance with an established Taxonomy.

This review reveals a dearth of RCTs that specifically target reducing sedentary behavior in people with COPD and that in this population the effect of exercise training on ST is, at best, uncertain. An equally important conclusion of this review is that BCTs embedded within the interventions were poorly reported. The under-reporting of active ingredients in BCTs compromises our capacity to understand what has been trialled and what shows promise.

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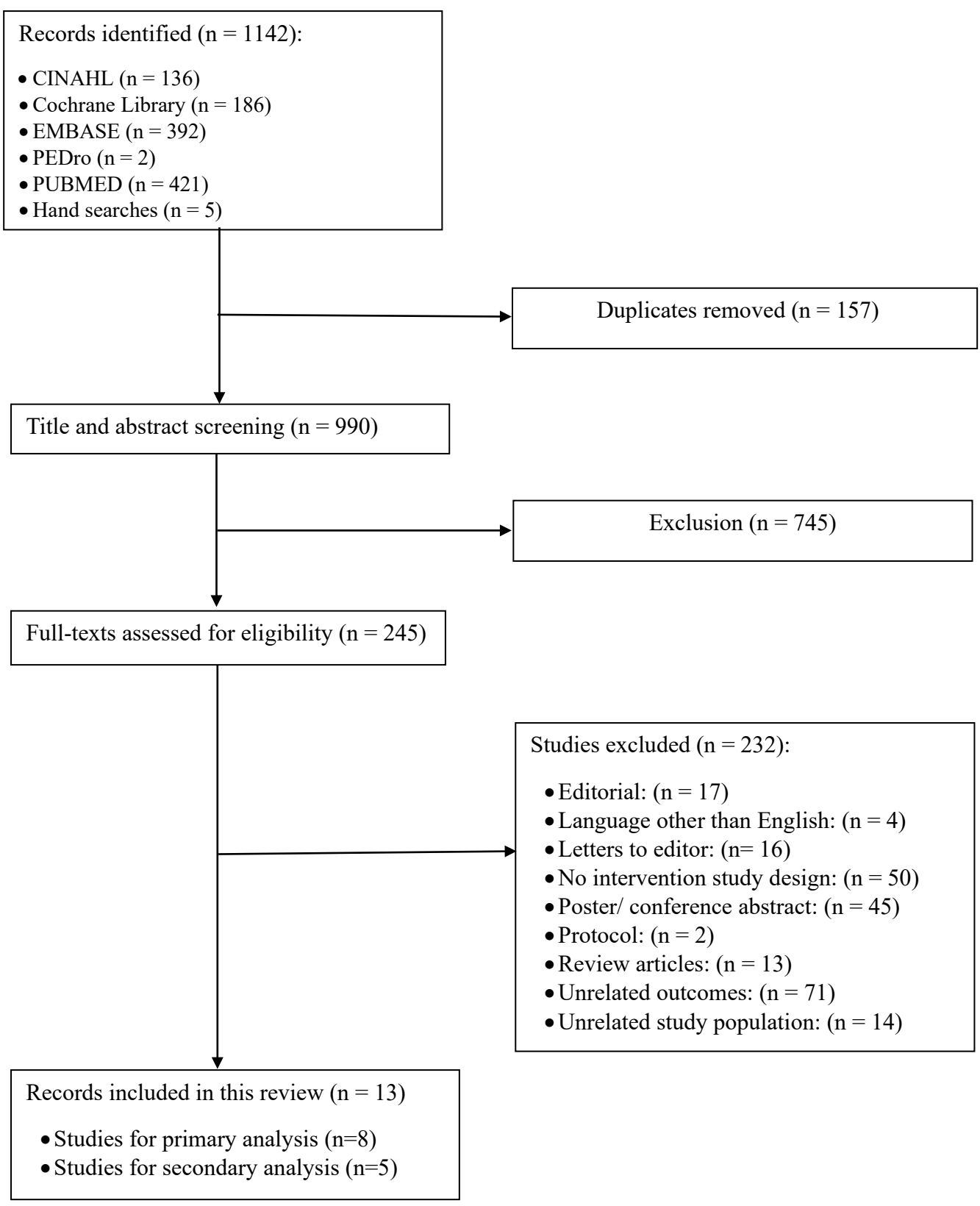

Figure 1. Flow of studies through the review.

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466**Table 1**. Characteristics of included primary analysis studies

Authors	Total sample size	Age (yr)	Males N (Y%)	FEV_1	Intervention	Duration of intervention period	Device used to measure ST
				Category 1			
Breyer (28)	60	Ix 62 (9) C 59 (8)	27 (45%)	Ix 48 (19)% C 47 (16)%	Ix Nordic Walking	12 weeks	DynaPort activity monitor
Larson (34)	49	Ix (a) 71 (8) Ix (b) 72 (9) C 71 (8)	41 (84%)	Ix (a) 61 (20)% Ix (b) 54 (17)% C 56 (17)%	Ix (a) Self-efficacy upper limb resistance training Ix (b) Upper limb resistance training	16 weeks	Actigraph 7164
Lord (33)	24	Ix 69 (11) C 68 (9)	12 (50%)	Ix 44 (14)% C 64 (26)%	Ix Supervised singing classes	8 weeks	SenseWear Pro3
Probst (30)	40	Ix 65 (10) C 67 (7)	21 (53%)	Ix 40 (9)% C 39 (14)%	Ix High intensity whole body endurance and strength training	12 weeks	DynaPort, SenseWear Pro3 Armband
Vasilopoulou (31)	147	Ix (a) 67 (10) Ix (b) 67 (7) C 64 (8)	119 (81%)	Ix (a) 50 (22)% Ix (b) 52 (17)% C 52 (21)%	Ix (a) Home-based maintanence PRP I (b) Outpatient-based maintanence PRP	12 months	Actigraph GT3X+

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Wootton (27)	101	Ix 69 (8) C 68 (9)	62 (61%)	Ix 42 (15)% C 43 (15)%	Ix Ground-based walking training	8 to 10 weeks	SenseWear Pro3 Armband
				Category 2			
Cruz (29)	32	Ix 69 (8) C 64 (8)	27 (84%)	Ix 66 (21)% C 68 (20)%	Ix Outpatient PRP, PA focussed behavioral intervention.	12 weeks	Actigraph GT3X+
Kawagoshi (32)	27	Ix 74 (8) C 75 (9)	24 (89%)	Ix 61 (21)% C 58 (23)%	Ix Outpatient PRP, pedometers and feedback	12 months	A-MES

46 Data are mean (SD) unless otherwise stated, Ix: intervention; C: control; FEV_1%: forced expiratory volume in 1 second expressed as a percent predicted; PRP: Pulmonary Rehabilitation Program, ST: sedentary time, PA: physical activity.

Category 1: Intervention versus true control; Category 2: Intervention (same for Ix and C) plus an additional intervention versus intervention (same for Ix and C).

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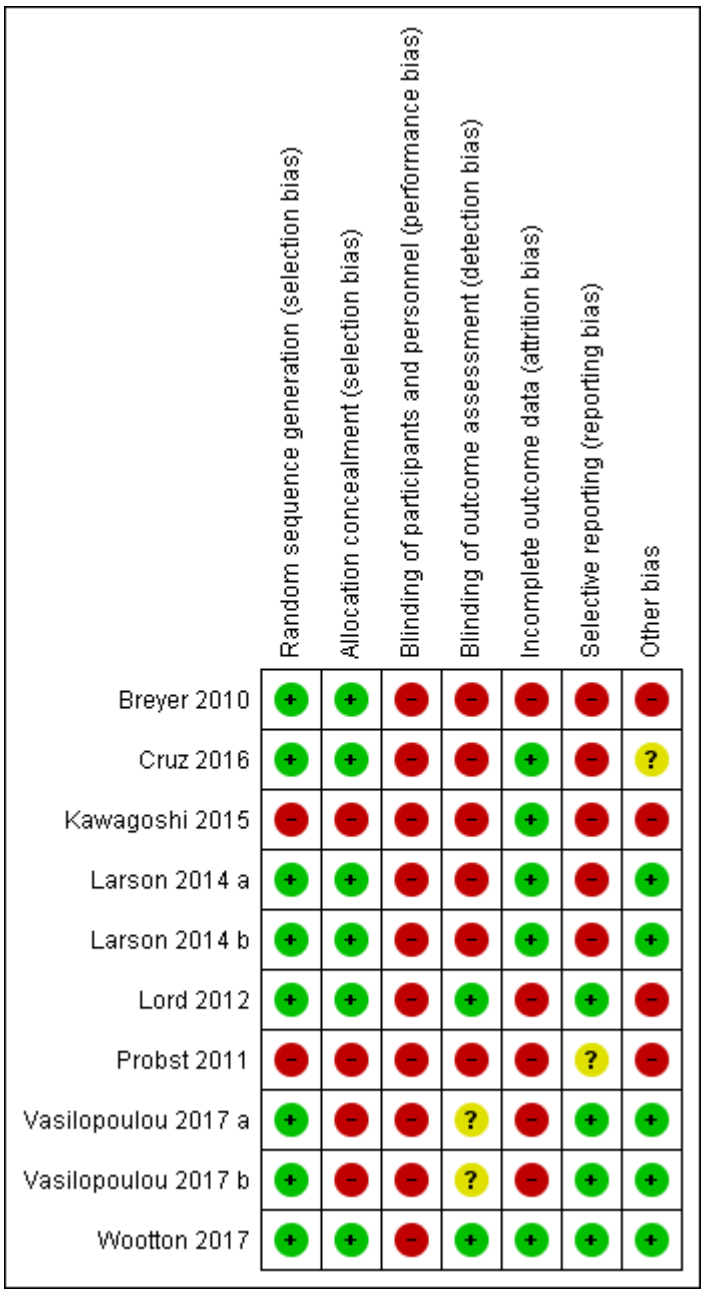

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Figure 2. Risk of bias summary of RCTs and RTs: review authors' judgements about each risk of bias item for each included study. Low risk of bias, unclear risk of bias high risk of bias. Quality assessment: high 6-7 criteria met, moderate 4-5 criteria met, fair 2-3, poor 1 or less criteria met.

doi: 10.1093/ptj/pzab097

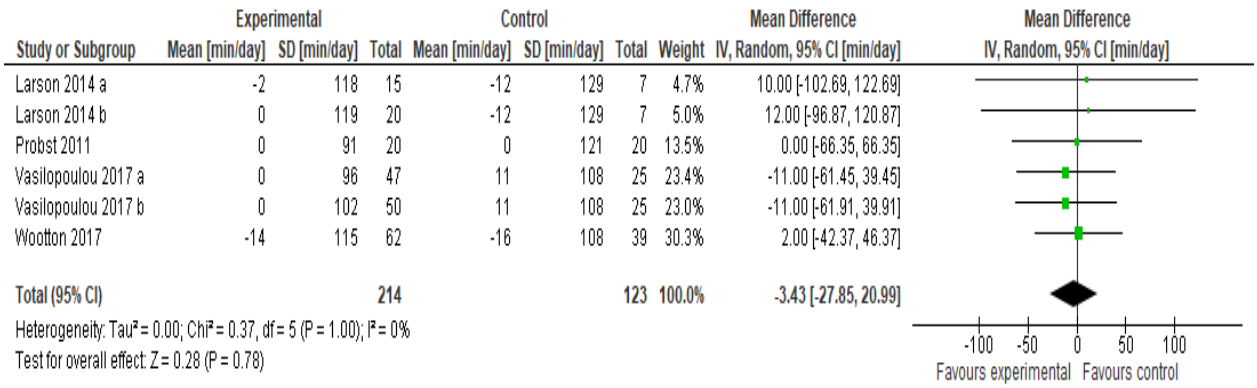

Figure 3a. Forest plot of RCTs included in category 1: exercise training intervention versus true control studies. Sedentary time [min/day].

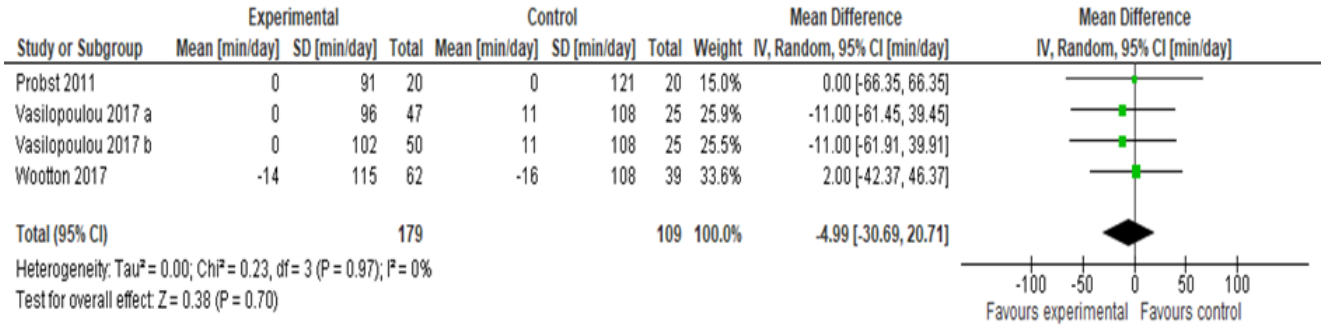

Figure 3b. Forest plot of RCTs included in category 1: whole body exercise training intervention versus true control studies post sensitivity analysis. Sedentary time [min/day].

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Group	BCT identified (number represents the coding of the BCT)	Breyer (2010)	Larson (2014a)	Larson (2014b)	Lord (2012)	Probst (2011)	Vasilopoulou (2017a)	Vasilopoulou (2017b)	Wootton (2017)
		Promising	Non-promising						
Group 1. Goals and planning	1.1 Goal setting (behavior)					+			2 ++
Group 1. Goals and planning	1.2 Problem solving		++						
Group 1. Goals and planning	1.3 Goal setting (outcome)			3 +					
Group 1. Goals and planning	1.4 Action planning	+	4 +		7 +	2 ++/+	2 +	3 ++= 1	4 ++
Group 1. Goals and planning	1.5 Review of behavior goal(s)								2 ++/ +
Group 1. Goals and planning	1.8 Behavioral contract								
Group 2. Feedback and monitoring	2.1 Monitoring of behavior by others without feedback						+		
Group 2. Feedback and monitoring	2.2 Feedback on behavior		3 +				++		
Group 2. Feedback and monitoring	2.3 Self-monitoring of behavior						3 +		
Group 2. Feedback and monitoring	2.4 Self- monitoring of outcome(s) of behavior				+				2 ++
Group 2. Feedback and monitoring	2.5 Monitoring of outcome(s) of behavior without feedback	+			+				
Group 2. Feedback and monitoring	2.6 Biofeedback	+					+		2 ++/+
Group 3. Social support	3.1 Social support (unspecified)		3 ++= 1		+				2 +
Group 3. Social support	3.2 Social support (practical)				2+		2 +		
Group 4. Shaping knowledge	4.1 Instruction on how to perform the behavior	+			9+		2 ++/+		2 ++
Group 4. Shaping knowledge	4.2 Information about Antecedents		++						
Group 5. Natural consequences	5.1 Information about health consequences	+	++						
Group 5. Natural consequences	5.2 Salience of consequences		++						
Group 6. Comparison of behavior	6.1 Demonstration of the behavior		++		+		3 ++= 2		
Group 6. Comparison of behavior	6.2 Social comparison		++						
Group 8. Repetition and substitution	8.1 Behavioral practice/rehearsal			+			+		
Group 8. Repetition and substitution	8.7 Graded tasks		+		+	+	2 +		+
Group 10. Reward and threat	10.4 Social reward								
Group 12. Antecedents	12.1 Restructuring the physical environment			+					
Group 12. Antecedents	12.6 Body changes		+		5 +	+		++	
	Total	5	18	5	28	5	17	4	17

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doi: 10.1093/ptj/pzab097

Figure 4a. Behavior change techniques (BCT) coded for primary analysis category 1 of included studies, where Larson (2014a) represents the group that received self-efficacy and upper body resistance training, and Larson (2014b) represents the group that received upper body resistance training. Vasilopoulou (2017a) represents the group that received home-based maintanence telerehabilitation, and Vasilopoulou (2017b) represents the group that received hospital-based, outpatient, maintanence rehabilitation.

( ) = BCT coded once within the study; ( ) = BCT coded more than once within the study (the number in the box indicates the number of occasions that the BCT was coded); '++' = confident the BCT was present 'beyond reasonable doubt'; '+' = confident the BCT was present in 'all probability', but supporting information was lacking. For example, 3 ++= 1 indicates that the BCT was coded in the study three times and considered to be present once 'beyond reasonable doubt'.

Studies have been ordered according to level of promise with 'promising': denoting that sedentary time (ST) is significantly reduced between intervention and control groups, and/ or within intervention groups, and non-promising denotes there is no significant reduction in ST.

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doi: 10.1093/ptj/pzab097

Group	BCT identified (number represents the coded BCT)	Cruz (2016)	Kawagoshi (2015)
		Promising	Non-promising
Group 1. Goals and planning	1.1 Goal setting (behavior)	3 ++=2	2 +
Group 1. Goals and planning	1.2 Problem solving		
Group 1. Goals and planning	1.3 Goal setting (outcome)		
Group 1. Goals and planning	1.4 Action planning		+
Group 1. Goals and planning	1.5 Review of behavior goal(s)	2 +	+
Group 1. Goals and planning	1.8 Behavioral contract	2 ++/+	
Group 2. Feedback and monitoring	2.1 Monitoring of behavior by others without feedback		
Group 2. Feedback and monitoring	2.2 Feedback on behavior	2 +	3 +
Group 2. Feedback and monitoring	2.3 Self-monitoring of behavior	2 ++	
Group 2. Feedback and monitoring	2.4 Self- monitoring of outcome(s) of behavior	+	
Group 2. Feedback and monitoring	2.5 Monitoring of outcome(s) of behavior without feedback		
Group 2. Feedback and monitoring	2.6 Biofeedback		
Group 3. Social support	3.1 Social support (unspecified)		
Group 3. Social support	3.2 Social support (practical)		
Group 4. Shaping knowledge	4.1 Instruction on how to perform the behavior		+
Group 4. Shaping knowledge	4.2 Information about Antecedents		
Group 5. Natural consequences	5.1 Information about health consequences		
Group 5. Natural consequences	5.2 Salience of consequences		
Group 6. Comparison of behavior	6.1 Demonstration of the behavior		
Group 6. Comparison of behavior	6.2 Social comparison		
Group 8. Repetition and substitution	8.1 Behavioral practice/rehearsal		
Group 8. Repetition and substitution	8.7 Graded tasks		
Group 10. Reward and threat	10.4 Social reward	+	
Group 12. Antecedents	12.1 Restructuring the physical environment		
Group 12. Antecedents	12.6 Body changes	+	+
	Total	14	9

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Figure 4b. Behavior change techniques (BCTs) coded for primary analysis category 2 of included studies.

( ) = BCT coded once within the study; ( ) = BCT coded more than once within the study (the number in the box indicates the number of occasions that the BCT was coded); '++' = confident the BCT was present 'beyond reasonable doubt'; '+' = confident the BCT was present in 'all probability', but supporting information was lacking. For example, 3 ++= 2 indicates that the BCT was coded in the study three times and considered to be present twice 'beyond reasonable doubt'.

Studies have been ordered according to level of promise with 'promising': denoting that sedentary time (ST) is significantly reduced between intervention and control groups, and/ or within intervention groups, and non-promising denotes there is no significant reduction in ST.

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doi: 10.1093/ptj/pzab097

ONLINE SUPPLEMENT

TITLE

In people with COPD, there is limited evidence that exercise training reduces sedentary time and behavior change techniques are poorly reported: Systematic Review and Meta-Analysis

RUNNING HEAD

Limited evidence that interventions change sedentary behavior in people with COPD

TOC CATEGORY

Cardiovascular/Pulmonary

ARTICLE TYPE

Review

AUTHORS

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CORRESPONDING AUTHOR

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METHODS

#1 Pulmonary disease, chronic obstructive [MeSH Terms]

#2 COPD [Title/Abstract]

#3 Emphysema [Title/Abstract]

#4 Chronic Bronchitis [Title/Abstract]

#5 Chronic Lung Disease [Title/Abstract]

#6 #1 OR #2 OR #3 OR #4 OR #5

#7 Sedentary behavior [MeSH Terms]

#8 Sedentary behavio* [Title/Abstract]

#9 Sedentary lifestyle* [Title/Abstract]

#10 Sedentary time [Title/Abstract]

#11 Sedentariness [Title/Abstract]

#12 Physical inactivity [Title/Abstract]

#13 Physically inactive [Title/Abstract]

#14 Sitting [Title/Abstract]

#15 #7 OR #8 OR…#14

#16 #6 AND #1

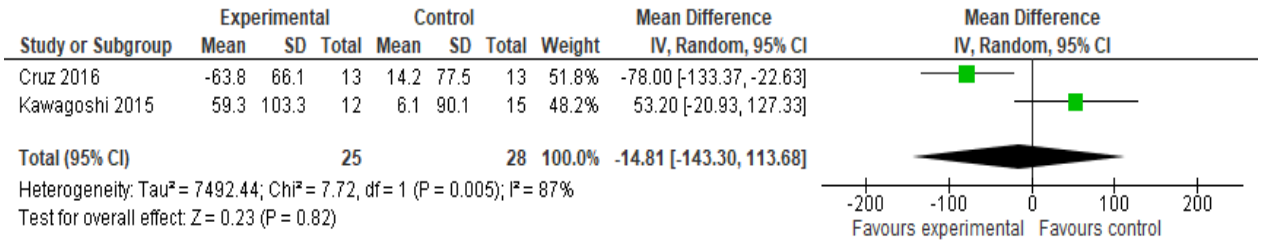
Figure S1: PubMed search strategy

RESULTS OF PRIMARY ANALYSIS

Table S1. Grading of Recommendations, Assessment, Development and Evaluation: Summary of Findings of primary analysis category 1.

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**any intervention**	**true control group**	**Relative (95% CI)**	**Absolute (95% CI)**		
Sedentary time (assessed with: min/day)												
4	randomised trials	serious [a]	not serious	not serious	serious [b]	none	228	137	not estimable	MD -3.34 (-27.85 to 20.99)	⨁⨁◯◯ LOW	NOT IMPORTANT

a. Blinding of participants and therapists uncontrolled in all studies; detection bias (3 studies), selection bias (2 studies), attrition bias (2 studies) and reporting bias (2 studies).
b. Wide CI of pooled effect.



Supplementary Figure S2. Forest plot of RCTs included in category 2: exercise training plus intervention vs exercise training. Sedentary time [min/day]. This analysis had high heterogeneity (I^2 = 87%) and demonstrated an uncertain effect on ST.

RESULTS OF THE SECONDARY ANALYSIS

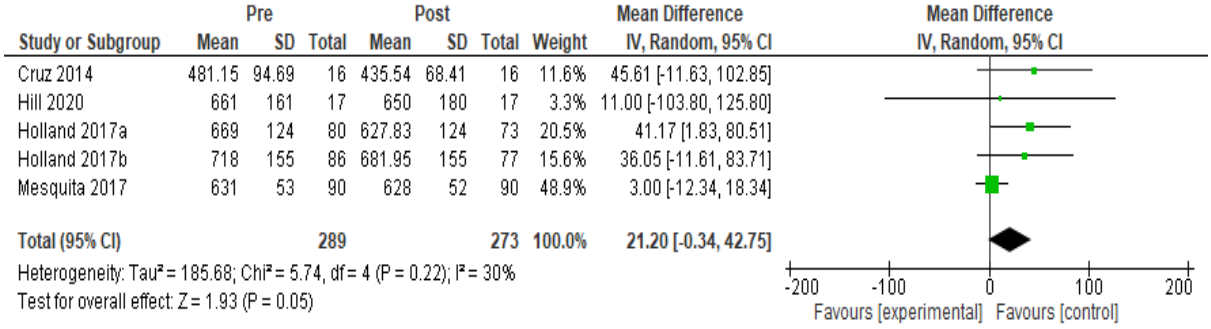
Table S2. Characteristics of included secondary analysis studies

Authors	Total sample size	Age (yr)	Males N (Y%)	FEV_1	Intervention	Duration of intervention period	Device used to measure ST
Cruz (36)	16	66 (11)	11 (69%)	70 (23)%	Outpatient PRP	12 weeks	Actigraph GTX3+
Hill (37)	17	73 (9)	10 (59%)	33 (25)%	Ix 4WW	4 weeks	ActivPAL SAM
Holland (38)	Ix (a) 80 Ix (b) 86	Ix (a) 69 (13) Ix (b) 69 (10)	99 (59%)	Ix (a) 52 (19)% Ix (b) 49 (19)%	Ix (a) Home-based PRP Ix (b) Outpatient PRP	8 weeks	SenseWear Armband
Kamei (39)	Ix (a) 22 Ix (b) 22	Ix (a) 72 (7) Ix (b) 71 (7)	20 (91%) 20 (91%)	Ix (a) 60 (15)% Ix (b) 58 (15)%	Ix (a) Aclidinium Ix (b) Tiotropium	8 weeks	ActiGraph GTX3+
Mesquita (40)	90	67 (8)	54 (60%)	47 (32-62)%	Outpatient PRP	13 weeks (40 sessions)	CIRO activity monitor (CAM) or MOX activity monitor

Data are mean (SD) unless otherwise stated, Ix: intervention; FEV_1%: forced expiratory volume in 1 second expressed as a percent predicted; PRP: Pulmonary Rehabilitation Program, ST: sedentary time, PA: physical activity.

Secondary meta-analysis

Studies grouped into the secondary analysis were single arm studies[36,40] one randomized cross-over trial[37] and one randomized trial with two intervention arms[38] explored the effect of exercise training. Meta-analysis of data reported in studies shows no effect on ST (Figure S3). The statistical heterogeneity in the analysis was mild to moderate heterogeneity (I^2 = 30%).



Supplementary Figure S3. Forest plot of studies included in the secondary analysis: Single-arm intervention studies. Sedentary time [min/day].

Group	BCT identified (number represents the coded BCT)	Cruz (2014)	Hill (2020)	Holland (2017a)	Holland (2017b)	Kamei (2019)	Mesquita (2017)
		Non-promising					
Group 1. Goals and planning	1.1 Goal setting (behavior)			7 ++= 1			
Group 1. Goals and planning	1.2 Problem solving			+			
Group 1. Goals and planning	1.3 Goal setting (outcome)			+			
Group 1. Goals and planning	1.4 Action planning	2 ++/+	+	4 ++= 1	3 +		+
Group 1. Goals and planning	1.5 Review of behavior goal(s)	+		+			
Group 2. Feedback and monitoring	2.2 Feedback on behavior	2 ++/+	+				
Group 2. Feedback and monitoring	2.3 Self-monitoring of behavior			4 ++= 1			
Group 2. Feedback and monitoring	2.4 Self-monitoring of outcome(s) of behavior			+			
Group 3. Social support	3.1 Social support (unspecified)			8 ++= 2			
Group 3. Social support	3.2 Social support (practical)			3 ++= 1			
Group 4. Shaping knowledge	4.1 Instruction on how to perform the behavior	+	2+	++	+		2 +
Group 4. Shaping knowledge	4.2 Information about antecedents			+			
Group 12. Antecedents	12.1 Restructuring the physical environment			++			
Group 12. Antecedents	12.6 Body changes	3 +		2 ++/+	+		3 +
	Total	9	4	35	5	0	6

1

Supplementary Figure S4. Behavior change techniques (BCT) coded across studies grouped for secondary analysis, where Holland (2017a) represents the group that received home-based pulmonary rehabilitation, and Holland (2017b) represents the group that received outpatient pulmonary rehabilitation.

( ) = BCT coded once within the study; ( ) = BCT coded more than once within the study (the number in the box indicates the number of occasions that the BCT was coded); '++' = confident the BCT was present 'beyond reasonable doubt'; '+' = confident the BCT was present in 'all probability', but supporting information was lacking. For example, 3 ++= 1 indicates that the BCT was coded in the study three times and considered to be present once 'beyond reasonable doubt'.

Studies have been ordered according to level of promise with 'promising': denoting that sedentary time (ST) is significantly reduced within intervention groups, and non-promising denotes there is no significant reduction in ST.

2

a.3

4