

# A systematic review of the characteristics of interventions that promote physical activity in adults with asthma

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## Abstract

Physical activity is promoted in the asthma population through pulmonary rehabilitation, but limited funding and facilities are available. This review aimed to examine the effectiveness of interventions that promote physical activity and identify the behaviour change techniques (BCTs) and other intervention components used. Five databases were searched, and 25 studies met the inclusion criteria. Interventions had a significant positive effect on physical activity, sedentary behaviour, quality of life and asthma symptoms. BCTs used across intervention and control groups were similar in studies that showed effects and those that did not. Future interventions should employ techniques that help to maintain behaviour change.

## Keywords

asthma, physical activity, exercise, intervention, systematic review

## Background

Physical activity is widely recommended in national and international guidelines for asthma management (British Thoracic Society, 2019; Global Initiative for Asthma, 2018). Engaging in regular physical activity ( $\geq 150$  minutes/week of moderate-vigorous physical activity) has shown to have extensive benefits for people living with asthma. Recent reviews have shown that increased physical activity is positively associated with improved lung function, asthma control, health status, and healthcare utilisation (Cordova-Rivera et al., 2018; Hansen et al., 2020). However, despite the guidelines, population-based studies have shown that people living with asthma engage in less physical activity

and are more sedentary than people without asthma (van 't Hul et al., 2016).

Pulmonary Rehabilitation (PR) is a comprehensive intervention designed to promote physical activity in patients with respiratory diseases and is defined as ‘patient-tailored therapies that

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include, but are not limited to, exercise training, education, and behaviour change, designed to improve the physical and psychological condition of people with chronic respiratory diseases and to promote the long-term adherence to health-enhancing behaviours' (Spruit et al., 2013:14). PR programmes are usually implemented by a dedicated multi-disciplinary team of healthcare professionals within hospitals or community settings (Spruit et al., 2013). The benefits of PR are well established, including significant positive effects on quality of life and exercise capacity in chronic obstructive pulmonary disease (Jácome and Marques, 2014; McCarthy et al., 2015). However, as asthma patients are increasingly being referred to the programme, systematic reviews have concluded that PR improves quality of life, exercise tolerance, symptoms, reduces the number of exacerbations and could improve pulmonary functions (Feng et al., 2021; Linhas et al., 2017).

Despite the strong evidence and the guidelines recommending the use of PR, patients are significantly under-referred, and of those patients who are referred, uptake and completion are low (National COPD Audit Programme, 2015). A retrospective analysis found that of 711 patients invited to attend PR, 31.8% did not attend, and a further 29.1% were non-adherent (Hayton et al., 2013). Major barriers to uptake and completion of PR include travel to attend sessions, disruption to routines, inconvenient timing (Jones et al., 2017), and not being suitable or accessible to those with co-morbidities (Keating et al., 2011). In addition, the coronavirus (COVID-19) and the response to the pandemic (e.g. lockdown and shielding) represent another barrier for patients.

Consequently, there is a need to develop interventions that overcome the major barriers reported by patients to promote physical activity within the asthma population. The benefits of PR are well established, but no systematic reviews to date have examined the effectiveness of other interventions that have been developed to promote physical activity or their components. For instance, there is a lack of evidence regarding the behaviour change techniques

(BCTs), the 'active ingredients' of behaviour change interventions, used within them. BCTs that have been found to be effective in the promotion of physical activity include techniques in the groupings 'Goals and Planning' and 'Feedback and Monitoring' categories, as well as 'Prompts and Cues', 'Graded Tasks' and 'Behavioural Practice/Rehearsal' (Howlett et al., 2019; Samdal et al., 2017). Therefore, the purpose of this review was to examine the effects of interventions that promote physical activity other than formal PR programmes on behavioural and health outcomes in adults diagnosed with asthma and to identify the BCTs and other intervention components, such as intensity, intervention provider, delivery focus, and mode of delivery used within them.

## Methods

The systematic review was conducted in accordance with the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2021) and the Preferred Reporting for Systematic Reviews and Meta-Analyses (PRISMA) checklist (Moher et al., 2009) (*Supplementary File 1*). The review protocol was registered on the PROSPERO international prospective register of systematic reviews (CRD42019124032).

### Eligibility criteria

We included published randomised, non-randomised, quasi-experimental, before-and-after interventional studies and feasibility studies. Included interventions had to be designed to promote physical activity and assess relevant behavioural and/or health outcomes, including physical activity, sedentary behaviour, quality of life, asthma control, asthma symptoms and medication usage. Participants had to be aged 18-years or over and have a diagnosis of asthma (any degree of severity). We excluded interventions using PR, defined as exercise training, education, and behaviour change, delivered by a multi-disciplinary team of physicians and healthcare professionals. Having a comparator group was not a requirement for inclusion.

## Data sources

Comprehensive searches were conducted in MEDLINE, EMBASE, PsycINFO, SPORTDiscus, and The Cochrane Central Register for Clinical Trials. The search strategy (*Supplementary File 2*) was used to search MEDLINE and modified for other databases. We imposed limits of adults and research papers published in the English language when carrying out the electronic searching, with date restrictions of 1990 and onwards. The search was conducted in August 2020.

## Data collection

**Study selection.** Studies identified using the searchers were transferred into Mendeley (Mendeley Desktop Version: 1.19.8), and duplicates were removed. Two review authors (LT, MM) independently screened the titles and abstracts of identified studies. The full-text copies of all studies judged to be potentially eligible were then retrieved and screened by the same two reviewers. In case of disagreement, the reviewers reached a consensus through discussion, and reasons for exclusion were recorded (*Supplementary File 3*).

**Data extraction.** Data was extracted by the first author (LT) using a standardised data extraction form designed to capture all relevant information, including general study characteristics, characteristics of study participants, details of the intervention and control group components, and study outcomes. Data extraction was independently validated by a second reviewer (MM). Extraction of the BCTs was undertaken by the same two reviewers (LT, MM) using the Behaviour Change Technique Taxonomy v1 (BCTTv1) (Michie et al., 2013) based on the published manuscript and supplementary materials. Both reviewers completed online BCTTv1 training before extraction [<http://www.bct-taxonomy.com>]. In case of disagreement, a consensus was reached through discussion, and a third reviewer (WH) was involved when the discussion did not lead to a consensus. BCTs were extracted following BCTTv1 guidance,

and they were coded as definitely (coded ++) or probably (coded +) present. BCTs were coded in relation to the target behaviours: physical activity and sedentary behaviour.

**Risk of bias.** The first author (LT) assessed risk of bias of the included studies using the criteria in the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2021) and assigned judgement of low, high, and unclear. Risk of bias was independently validated by a second reviewer (MM).

## Synthesis of results

Due to the range of very different studies included in this systematic review in relation to the research design, types of intervention and outcome data, the synthesis of the included studies was narrative. Results from the studies were tabulated and organised into groups based on outcomes assessed, so patterns across the data set could be identified. Interventions were deemed effective if they reported significant positive results in all the relevant outcomes they assessed.

## Data sharing statement

The current article includes the data extraction forms for all included studies. Pending acceptance for publication, all the files will be automatically uploaded to the *Figshare* repository.

## Results

The search yielded 3685 citations, resulting in a total of 2997 after the duplicates were removed. From this list, 92 were identified as potentially relevant, and full texts were retrieved for closer inspection. Two review authors (LT, MM) independently decided that 25 of these articles fulfilled the review's inclusion criteria. *Supplementary File 4* shows the detailed process of study inclusion.

## Overview of included studies

The 25 included studies (Table 1) were published between 1992 and 2021. Most studies

Table 1. Study characteristics.

Author (year) and country of study	Study design	Inclusion criteria and setting	Sample size and recruitment methods	Participant characteristics (disease severity, age, gender, ethnicity and co-morbidities)
Bidwell et al., 2012 USA	Randomised study	FEV1/FVC ratio of <80% of predicted, use of bronchodilators at least once daily, and symptoms of wheezing and/or coughing for a minimum of 2-years that improves either spontaneously or with drug therapy. Setting NR.	N=19 Volunteers from flyers at various physicians' offices as well as campus news.	Mild/moderate asthma. <i>M</i> =41.5 Years. Age Range 20–65 Years. 100% Female.
Boyd et al., 2012 USA	Randomised study	Persistent asthma (as defined by the NAEPP guidelines) with at least 12% FEV1 reversibility. Community.	N=19 Recruited at the UAB Lung Health Centre, Birmingham, AL.	Mild/moderate asthma. <i>M</i> =53 Years. Age Range 33–78 Years. 6% Male. 94% Female. 38% Non-White.
Coelho et al., 2018 Brazil	Randomised study	Diagnosis for at least 6-months, under regular drug therapy and clinically stable during the run-in period. Self-directed (home-based).	N=37 Recruited from outpatient asthma clinic.	Moderate/severe asthma. <i>M</i> =46 Years. 14% Male. 86% Female.
Dogra et al., 2010 Canada	Quasi-experimental	Current prescription for asthma medication and were physically inactive as per the Canadian PA Guidelines. Self-directed (home-based).	N=30 Recruited from the Greater Toronto Area in Ontario, Canada.	Partially controlled asthma. <i>M</i> =32.6 Years. 25% Male. 75% Female.
Dogra et al., 2011 Canada	Non-randomised study	Current prescription for asthma medication and were physically inactive as defined by the Canadian PA Guidelines. Setting NR.	N=36 Recruited from the Greater Toronto Area in Ontario, Canada.	Partially controlled asthma. <i>M</i> =34.1 Years. 27% Male. 73% Female.
Evaristo et al., 2020 Brazil	Randomised study	Body mass index <35kg/m <sup>2</sup> , sedentary (<60 minutes of physical activity/week during leisure time), under medical treatment for at least 6-months, and clinically stable (i.e., no crises or changes in medication for > 30 days). Setting NR.	N=54 Recruited during a regular medical visit.	Moderate/severe asthma. <i>M</i> =50.2 Years. Age Range 30–65 Years. 27% Male. 73% Female.
França-Pinto et al., 2015 Brazil	Randomised study	Inclusion criteria NR. Setting NR.	N=58 Recruited from a University Hospital.	Moderate/severe asthma. <i>M</i> =42 Years. Age Range 20–59 Years. 21% Male. 79% Female.
Freitas et al., 2017 Brazil	Randomised study	Outpatients with a BMI greater than or equal to 35 and less than 40 kg/m <sup>2</sup> , who were under optimum medical treatment, clinically stable, and physically inactive. Secondary care.	N=55 Recruited from an outpatient asthma clinic.	Moderate/severe asthma. <i>M</i> =47.2 Years. Age Range 30–60 Years. 2% Male. 98% Female.
Freitas et al., 2018 Brazil	Randomised study	Outpatients with grade II obesity, receiving optimal medical treatment for at least 6-months, were clinically stable and performed <60 minutes of structured or planned PA per week. Secondary care.	N=55 Recruited from an outpatient asthma clinic.	Moderate/severe asthma. <i>M</i> =47.2 Years. Age Range 30–60 Years. 2% Male. 98% Female.
Goncalves et al., 2008 Brazil	Randomised Study	Under outpatient medical treatment for at least 6-months and demonstrate clinical stability (without hospitalisation episodes or need for emergency care for, at least 30-days). Secondary care.	N=20 Selected after a medical consultation.	Moderate/severe asthma. <i>M</i> =34.6 Years. Age Range 20–50 Years. 30% Male. 70% Female.
Hildenbrand et al., 2010 USA	Before-and-after study	Asthma which was being medically managed daily or on an 'as needed' basis. Community.	N=20 Public forums.	Mixed asthma severities. <i>M</i> (SD)=22 (5.27) Years. 44% Male. 56% Female. 75% Caucasian.

(Continued)

**Table 1. (Continued)**

Author (year) and country of study	Study design	Inclusion criteria and setting	Sample size and recruitment methods	Participant characteristics (disease severity, age, gender, ethnicity and co-morbidities)
Jain and Talukdar, 1993 India	Before-and-after study	Inclusion criteria NR. Secondary care.	N=42 Recruited from outpatient clinic.	Moderate/severe asthma. M (SD) =48.2 (4.17) Years. 74% Male. 26% Female.
Ma et al., 2015 USA	Randomised study	BMI greater than or equal to 30kg/m2, and confirmation of uncontrolled persistent asthma through a multistage screening process. Setting NR.	N=330 Recruited from eight medical centres.	Uncontrolled Asthma. M (SD) =47.6 (12.4) Years. Age Range 18–70 Years. 29% Male. 71% Female. 50% Non-Hispanic White. 20% Non-Hispanic Black. 8% Asian/Pacific Islander. 20% Hispanic/Latino.
Mancuso et al., 2012a USA	Randomised study	Mild/moderate asthma and speak English. Self-directed (home-based).	N=258 Recruited from primary care practice.	Mild/Moderate Asthma. M (SD) =43 (12) Years. 25% Male. 75% Female. 54% White. 22% African American. 24% Other.
Mancuso et al., 2012b USA	Randomised study	Mild/moderate asthma, speak English, access to a telephone, no limitations in mobility, and no other respiratory or major comorbidity. Self-directed (home-based).	N=258 Recruited from primary care practice.	Mild/moderate asthma. M (SD) =43 (12) Years. 25% Male. 75% Female. 54% White. 22% African American. 8% Asian. 16% More than one.
Mendes et al., 2010 Brazil	Randomised study	Under medical treatment for > 6 months and considered clinically stable.	N=101 Recruited from a University Hospital.	Moderate/severe asthma. M = 39.25 Years. Age Range 20–50 Years. 83% Male. 17% Female.
Mendes et al., 2011 Brazil	Randomised study	Under medical treatment for > 6 months and considered clinically stable. Secondary care.	N=68 Recruited from a University Hospital.	Moderate/severe asthma. M = 36.95 Years. Age Range 20–50 Years. 19% Male. 81% Female.
Nyenhuis et al., 2020 USA	Feasibility study	Self-identified as African American and female, registered as a patient at the medical centre, were low-active as defined by self-report of < 150 minutes of MVPA per week and had sub-optimally controlled asthma. Community and self-directed (home-based).	N=10 Recruited from a large urban medical centre.	Uncontrolled Asthma. M (SD) =48.29 (11.22). Age Range 18–70 Years. 100% Female. 100% African American.
O'Neill and Dogra, 2021 Canada	Before and after study	Non-smoking, moderately active with a current prescription for a short-acting bronchodilator. Setting NR.	N=20 Recruitment NR.	Mixed asthma severities. Mean (SD) =22.5 (3.2) Years. 45% Male. 55% Female.
Robinson et al., 1992 New Zealand	Non-randomised study	Adults diagnosed asthma. Community.	N=25 Asthmatics attending asthma clinic. Control group was recruited from new clients at the gymnasium. N=62	Moderate/severe asthma. Age Range 20–45 Years. 44% Male. 56% Female.
Sabina et al., 2005 USA	Randomised study	Diagnosis for at least 6-months, taking at least one of the following: inhaled B-agonists, methylxanthines, anticholinergics, inhaled corticosteroid, leukotriene inhibitors or receptor antagonists, or mast cell-stabilising agents for at least 6-months and stable medication dosing for the past month. Research centre.	N=62 Newspaper advertisements, posting in pulmonary clinics and the community at large, and direct mailing to patients of pulmonary clinics and primary care centres.	Mild/moderate asthma. M = 51.1 Years. Age Range 18–76 Years. 26% Male. 74% Females. 84% White. 10% African American. 6% Hispanic.
Scott et al., 2013 Australia	Randomised Study	Inclusion criteria NR. Community and secondary care.	N=46 Recruitment from the John Hunter Hospital, Australia.	M =40.26 Years. Age Range 18–65 Years. 47% Male. 53% Female.

(Continued)

Table 1. (Continued)

Author (year) and country of study	Study design	Inclusion criteria and setting	Sample size and recruitment methods	Participant characteristics (disease severity, age, gender, ethnicity and co-morbidities)
Toennesen et al., 2018 Denmark	Randomised study	Body mass index of more than 20 and less than 30kg/m, and ACQ score of 1.0 or more, and at least one positive diagnostic test demonstrating variable airflow obstruction. Should either have been on a stable prophylactic treatment regime with inhaled corticosteroids (ICSs), ICS + long-acting beta 1-agonist, and/or leukotriene antagonist or have had no prophylactic treatment at least 3-months before enrollment. Secondary care.	N=149 Recruitment methods NR.	Age Range 18–65 Years. 31% Male. 69% Female.
Vempati et al., 2009 India	Randomised study	Diagnosis for at least 6-months, taking at least one of the following antihistines, anticholinergics and/or inhaled corticosteroids, and stable medication dosing for the past month. Secondary care and self-directed (home-based). Inclusion criteria NR. University health centre.	N=60 Referred to the Integral Health Clinic of the All India Institute of Medical Sciences or came to IHC in response to an advertisement. N=17 Recruited from an allergy and asthma clinic.	Mild/moderate asthma. M=33.45 Years. Age Range 18–65 Years. 58% Male. 42% Female.
Vedanathan et al., 1998 USA	Randomised study			Mild/moderate asthma. M=26.62 Years. Age Range 19–53 Years. 47% Male. 53% Female.

FEV1/FVC: forced expiratory volume in 1-second/forced vital capacity; NR: not reported; PA: physical activity; MVPA: moderate-vigorous physical activity; ACQ: asthma control questionnaire.

were conducted in either the USA ( $n=9$ ) or Brazil ( $n=8$ ), with others in Canada ( $n=3$ ), India ( $n=2$ ), New Zealand ( $n=1$ ), Australia ( $n=1$ ) and Denmark ( $n=1$ ). The study designs included randomised controlled trials ( $n=18$ ), non-randomised controlled trials ( $n=2$ ), before-and-after studies ( $n=3$ ), a quasi-experimental study ( $n=1$ ) and a feasibility study ( $n=1$ ). Within these studies, 21 unique interventions were reported.

The number of participants in each study ranged from 10 to 330. Asthma severity varied across studies, with only two studies failing to report the asthma severity of their participants (Scott et al., 2013; Toennesen et al., 2018). Seven studies included participants with mild/moderate asthma (Bidwell et al., 2012; Boyd et al., 2012; Mancuso et al., 2012a, 2012b; Sabina et al., 2005; Vedanathan et al., 1998; Vempati et al., 2009), 10 studies included participants with moderate/severe asthma (Coelho et al., 2018; Evaristo et al., 2020; França-Pinto et al., 2015; Freitas et al., 2017, 2018; Goncalves et al., 2008; Jain and Talukdar, 1993; Mendes et al., 2010, 2011; Robinson et al., 1992), and two studies included participants with mixed asthma severity (Hildenbrand et al., 2010; O'Neill and Dogra, 2021). Participants in two studies had partially controlled asthma (Dogra et al., 2010, 2011), and two had uncontrolled asthma (Ma et al., 2015; Nyenhuis et al., 2020).

### Risk of bias within studies

All 25 studies were judged to be at high risk of bias in at least one domain (see *Supplementary file 5* and *6*). The most common sources of bias were blinding of participants (21 studies judged as high risk) and blinding of outcome assessors (12 studies judged as high risk).

### Effects of interventions

We found that ten out of 25 studies, eight unique interventions, reported significant improvements in all the relevant behavioural and/or health outcomes they assessed (Bidwell et al., 2012; Dogra et al., 2011; Freitas et al., 2017;

Goncalves et al., 2008; Mancuso et al., 2012a; Mendes et al., 2010, 2011; O'Neill and Dogra, 2021; Toennesen et al., 2018; Vempati et al., 2009).

**Behavioural outcomes.** Intervention effects on behavioural outcomes are presented in Table 2.

### **Physical activity**

Ten of the 25 included studies assessed physical activity as an outcome (Coelho et al., 2018; Evaristo et al., 2020; Freitas et al., 2017, 2018; Ma et al., 2015; Mancuso et al., 2012a, 2012b; Nyenhuis et al., 2020; Robinson et al., 1992; Scott et al., 2013), five of which measured the outcome objectively. Four studies found evidence of significant positive between-group effects (Coelho et al., 2018; Freitas et al., 2017, 2018; Ma et al., 2015), and four found significant positive within-group effects (Mancuso et al., 2012a, 2012b; Robinson et al., 1992; Scott et al., 2013). However, in the only study to follow-up participants after the intervention, differences between groups were no longer significant 3-months post-intervention ( $p=0.31$ ) (Coelho et al., 2018). Although not significant, the remaining two studies did report improvements. Evaristo et al. (2020) found that participants in the intervention and control group increased their daily step count by approximately 2000 steps after the intervention, reaching 10000 steps. Similarly, Nyenhuis et al. (2020) found evidence of a small effect on moderate-to-vigorous physical activity.

### **Sedentary behaviour**

Sedentary behaviour was only assessed in three out of the 25 included studies (Freitas et al., 2017; Nyenhuis et al., 2020; Scott et al., 2013). Of these, two studies found evidence of a significant within-group decrease in time spent sedentary (Nyenhuus et al., 2020; Scott et al., 2013). Freitas et al. (2017) reported no significant between-group differences in time spent sedentary ( $p < 0.05$ ), but the intervention did not specifically target sedentary behaviour.

**Health Outcomes.** Intervention effects on health outcomes are presented in Table 3.

### **Quality of life and asthma control**

Sixteen of the 25 included studies assessed quality of life as an outcome (Bidwell et al., 2012; Coelho et al., 2018; Dogra et al., 2010, 2011; Evaristo et al., 2020; França-Pinto et al., 2015; Freitas et al., 2017; Goncalves et al., 2008; Hildenbrand et al., 2010; Ma et al., 2015; Mancuso et al., 2012b; Mendes et al., 2010; Sabina et al., 2005; Scott et al., 2013; Toennesen et al., 2018; Vempati et al., 2009). Of these, five studies found evidence of a significant positive within-group effect (Dogra et al., 2011; Evaristo et al., 2020; Scott et al., 2013; Toennesen et al., 2018; Vempati et al., 2009) and five found significant positive between-group effects (Bidwell et al., 2012; França-Pinto et al., 2015; Freitas et al., 2017; Goncalves et al., 2008; Mendes et al., 2010).

Only twelve studies assessed asthma control as an outcome (Boyd et al., 2012; Coelho et al., 2018; Dogra et al., 2010, 2011; Evaristo et al., 2020; França-Pinto et al., 2015; Freitas et al., 2017; Ma et al., 2015; Mancuso et al., 2012b; O'Neill and Dogra, 2021; Scott et al., 2013; Toennesen et al., 2018). Four reported significant positive within-group effects (Evaristo et al., 2020; Mancuso et al., 2012b; O'Neill and Dogra, 2021; Toennesen et al., 2018), and two reported a significant between-group effect (Dogra et al., 2011; Freitas et al., 2017). Although not significant, several of the remaining studies reported a trend of improved asthma control in the intervention group compared to the control (Boyd et al., 2012; França-Pinto et al., 2015; Ma et al., 2015; Scott et al., 2013). Although Dogra et al. (2010) did not report significant positive effects in asthma control, participants perceived asthma control significantly improved post-intervention ( $p=0.014$ ).

### **Asthma symptoms and medication usage**

Asthma symptoms were assessed as an outcome in eleven studies (Evaristo et al., 2020;

**Table 2.** Intervention characteristics and behavioural outcomes.

Author (year) and country of study	Description of intervention and comparator group(s)	Intervention length and intensity	Intervention provider(s) and mode and focus of delivery	Behavioural outcome(s)	Intervention effect
Coelho et al., 2018 Brazil	IG: Unsupervised pedometer-based programme. PA subscription, consisting of targets calculated weekly. CG: Individual standard education session. Received exacerbation diary and encouraged to start walking.	≤3 months 5 × p/w, 30 minutes	Physiotherapist(s). Face-to-face and telephone. Individual.	PA: Pedometer.	PA: Statistically sig difference in daily steps between-groups ( $p=0.005$ ). No longer sig after 24–28 weeks ( $p=0.310$ ).
Evaristo et al., 2020 Brazil	IG: Education and aerobic exercise training programme, performed on an indoor treadmill. CG: Education and breathing exercise programme.	≤3 months. 2 × p/w, 40 minutes	Care providers, teams, or centres performing the intervention. Face-to-face. Group.	PA: Accelerometer.	PA: Changes between-groups were not sig ( $p>0.05$ ).
Freitas et al., 2017 Brazil	WL+E: Weight-loss programme incorporating aerobic and resistance muscle training. WL+S: Weight-loss programme incorporating breathing and stretching exercises.	≤3 months. 2 × p/w.	Nutritionist(s), psychologist(s) and physiotherapist(s). Face-to-face. Combination.	PA: Accelerometer.	PA: IG demonstrated a sig increase in daily life PA levels compared to the CG ( $p<0.001$ ).
Freitas et al., 2018 Brazil	WL+E: Weight-loss programme incorporating aerobic and resistance muscle training. WL+S: Weight-loss programme incorporating breathing and stretching exercises.	≤3 months. 2 × p/w.	Nutritionist(s), psychologist(s) and physiotherapist(s). Face-to-face. Combination.	PA: Accelerometer. SB: Accelerometer.	PA: IG demonstrated a sig increase in daily step count ( $p<0.001$ ) and MVPA ( $p<0.001$ ) compared to the CG. SB: Neither group demonstrated sig changes ( $p=0.784$ ).
Nyenhuis et al., 2020 USA	Received tailored walking prescription and pedometer (optional walking sessions), asthma education session, written materials on exercise with asthma, group discussions to address goals and barriers, and motivational telephone calls and text messaging.	≤3 months. Increase 150 steps p/d.	Intervention provider(s) NR. Face-to-face, written materials, telephone and SMS messages. Combination.	PA: Accelerometer and Fitbit. SB: Accelerometer and Fitbit.	PA: Small, but not sig negative effect on step count and positive effect on MVPA ( $p>0.05$ ). SB: Statistically sig difference between the total and adjusted time in week 1 ( $p=0.006$ ), 2 ( $p=0.01$ ), 3 ( $p=0.009$ ), 4 ( $p=0.049$ ), 5 ( $p=0.04$ ), and 6 ( $p=0.04$ ).
Ma et al., 2015 USA	IG: Lifestyle intervention, dually targeting modest weight-loss and increased PA. CG: Usual care enhanced with a pedometer, a weight scale, information about existing weight management services at participating clinics, and an asthma education DVD.	≤12 months. 150mins p/w of MPA.	Intervention provider(s) NR. Face-to-face and telephone. Combination.	PA: Stanford 7-Day PA Interview.	PA: Sig between-group difference in change of leisure-time physical activity and total daily energy expenditure ( $p<0.05$ ).
Mancuso et al., 2012a USA	IG: Contract to increase PA and received a pedometer and an asthma workbook. Received bimonthly follow-up telephone calls and small gifts and instructions in fostering positive affect and self-affirmation. IG: Identical protocol but did not receive small gifts and instructions.	≤12 months. Intervention intensity NR.	Intervention provider(s) NR. Face-to-face, post and telephone. Individual.	PA: Puffenberger PA and Exercise Index.	PA: Energy expenditure significantly increased in the CG ( $p=0.02$ ) and IG ( $p=0.002$ ).

(Continued)



**Table 2.** (Continued)

Author (year) and country of study	Description of intervention and comparator group(s)	Intervention length and intensity	Intervention provider(s) and mode and focus of delivery	Behavioural outcome(s) Measurement tool	Intervention effect
Mancuso et al., 2012b USA	IG: Contract to increase PA and received a pedometer and an asthma workbook. Received bimonthly follow-up telephone calls and small gifts and instructions in fostering positive affect and self-affirmation. IG: Identical protocol but did not receive small gifts and instructions.	≤12 months. Intervention intensity NR.	Intervention provider(s) NR. Face-to-face, post and telephone. Individual.	PA: Paffenbarger PA and Exercise Index.	PA: Energy expenditure increased by a clinically important change in both groups ( $p < 0.05$ ).
Robinson et al., 1992 New Zealand	IG: Training programme, consisting of a warm-up and between one and four circuits of seven exercises. CG: Identical protocol except that they did not receive salbutamol or have PEFE measurements.	≤3 months. Increase the number of circuits.	Intervention provider(s) NR. Face-to-face. Group.	PA: Life in New Zealand Survey.	PA: Two variables were found to be significantly higher following training in both groups ( $p < 0.05$ ).
Scott et al., 2013 Australia	EG: Aerobic and resistance training. Received a 12-week gym membership and personal training session and educational materials regarding national PA recommendations. DG: Dietary restrictions. E/DG: Aerobic and resistance training and dietary restrictions.	≤3 months. Personal training session for 1h p/w. Attend gym 3x p/w. Increase steps by 10%.	Nutritionist(s), psychologist(s) and physiotherapist(s). Face-to-face and telephone. Combination.	PA: International PA Questionnaire. SB: International PA Questionnaire.	PA: EG demonstrated a sig increase in PA ( $p = 0.022$ ). SB: EG demonstrated a sig reduction in physical inactivity ( $p = 0.031$ ).

IG: intervention group; PA: physical activity; CG: control group; p/w: per week; sig: significant; SB: sedentary behaviour; WL+E: weight-loss and exercise; WL+S: weight-loss and sham; MVPA: moderate-vigorous physical activity; MPA: moderate physical activity; p/d: per day; PEFE: peak expiratory flow; EG: exercise group; DG: diet group; E/DG: exercise and diet group; NR: not reported.

**Table 3.** Intervention characteristics and health outcomes.

Author (year) and country of study	Description of intervention and comparator group(s)	Intervention length and intensity	Intervention provider(s) and mode of delivery	Health outcome(s)	Measurement tool	Intervention effect
Bidwell et al., 2012 USA	IG: Supervised yoga training session. Required to perform written lesson plans at home. CG: No yoga or related breathing practised.	≤3 months. 2× p/w, 60 minutes. Home practice 1x p/w, 30mins.	Certified yoga instructor(s). Face-to-face. Group.	QoL: SGRQ.	QoL: SGRQ.	QoL: IG significantly improved compared to the CG, who showed no improvements ( $p < 0.05$ ).
Boyd et al., 2012 USA	IG: Walking programme exercising at 60%–75% of MRmax and brief education. Received 3-month free gym membership. CG: Brief education.	≤3 months. 3× p/w, 30 minutes.	Intervention provider(s) NR. Face-to-face. Focus NR.	AC: ACQ.	AC: ACQ.	AC: Changes between-groups were not sig ( $p > 0.05$ ), but changes did exhibit a trend towards improvements.
Coelho et al., 2018 Brazil	IG: Unsupervised pedometer-based programme. PA subscription, consisting of targets calculated weekly. CG: Individual standard education session. Received exacerbation diary and encouraged to start walking.	≤3 months 5× p/w, 30mins.	Physiotherapist(s). Face-to-face and telephone. Individual.	AC: ACQ. QoL: AQLQ. Medication Usage: NR.	AC: ACQ. QoL: AQLQ. Medication Usage: NR.	AC: Changes between-groups were not sig ( $p = 0.58$ ). QoL: Changes between-groups were not sig ( $p = 0.65$ ). Medication Usage: Changes between-groups were not sig ( $p = 0.50$ ).
Dogra et al., 2010 Canada	IG: Self-directed individualised exercise programme. Sent pictures and descriptions of strength and stretching exercises, modified every 3-weeks. CG: Maintain current lifestyle.	≤3 months. Intensity progressively increased.	Exercise specialist(s). Post. individual.	AC: ACQ. QoL: Mini-AQLQ	AC: ACQ. QoL: Mini-AQLQ	AC: Changes between-groups were not sig ( $p = 0.956$ ), but changes in perceived asthma control were sig between-groups ( $p = 0.014$ ). QoL: Changes between-groups were not sig ( $p = 0.466$ ).
Dogra et al., 2011 Canada	IG: Exercise training followed by a period of prescribed self-administered exercise. CG: Maintain current lifestyle.	≤6 months. Intensity progressively increased.	Exercise specialist(s). Face-to-face. individual.	AC: ACQ. QoL: Mini-AQLQ	AC: ACQ. QoL: Mini-AQLQ	AC: ACQ without spirometry significantly improved in the IG compared to the CG ( $p < 0.05$ ). QoL: Clinically sig improvements in IG ( $p < 0.05$ ), maintained over the follow-up period ( $p < 0.05$ ).
Evaristo et al., 2020 Brazil	IG: Education and aerobic exercise training programme, performed on an indoor treadmill. CG: Education and breathing exercise programme.	≤3 months. 2× p/w, 40 minutes.	Care providers, teams, or centre performing the intervention. Face-to-face. Group.	AC: ACQ. QoL: AQLQ. Medication Usage: Daily Diary. Symptoms: Daily Diary.	AC: ACQ. QoL: AQLQ. Medication Usage: Daily Diary. Symptoms: Daily Diary.	AC: IG demonstrated a sig decrease in scores ( $p < 0.001$ ), maintained over the follow-up period ( $p < 0.001$ ). QoL: IG demonstrated clinically sig improvements ( $p < 0.05$ ), maintained over the follow-up period ( $p < 0.05$ ). Medication Usage: 34% of participants from the IG and 8% from the CG showed a reduction in using rescue medication of more than 5-days ( $p < 0.04$ ). Symptoms: Number of asthma symptoms-free days increased during the intervention period ( $p = 0.004$ ).

(Continued)

**Table 3.** (Continued)

Author (year) and country of study	Description of intervention and comparator group(s)	Intervention length and intensity	Intervention provider(s) and mode of delivery	Health outcome(s)	Intervention effect
				Measurement tool	
França-Pinto et al., 2015 Brazil	IG: Education, breathing exercise and aerobic training programme, completed on an indoor treadmill. CG: Education and breathing exercise programme.	≤3 months. 2× p/w, 35mins.	Physiotherapist(s). Face-to-face. Focus NR.	AC: ACQ. QoL: AQLQ. Symptoms: Daily Diary.	AC: Changes between-groups were not sig ( $p=0.457$ ). QoL: Between-group differences were observed in the activity limitation domain ( $p=0.009$ ) and total score ( $p=0.034$ ), in favour of the IG. Symptoms: Number of symptom-free days significantly increased in the IG ( $p=0.043$ ). Frequency of exacerbations during the intervention was lower in the IG compared to the CG ( $p=0.021$ ). AC: Scores significantly improved in the IG compared to the CG ( $p=0.003$ ). QoL: Between-group differences were observed in the activity limitation domain and total score ( $p<0.05$ ) in favour for the IG. Sig within-group improvements in the other three domains in the IG ( $p<0.01$ ). Symptoms: IG had a sig increase in the number of asthma-free days, compared to the CG ( $p<0.05$ ).
Freitas et al., 2017 Brazil	WL+E: Weight-loss programme incorporating aerobic and resistance muscle training. WL+S: Weight-loss programme incorporating breathing and stretching exercises.	≤3 months. 2× p/w.	Nutritionist(s), psychologist(s) and physiotherapist(s). Face-to-face. Combination.	AC: ACQ. QoL: AQLQ.	AC: Scores significantly improved in the IG compared to the CG ( $p=0.003$ ). QoL: Between-group differences were observed in the activity limitation domain and total score ( $p<0.05$ ) in favour for the IG. Sig within-group improvements in the other three domains in the IG ( $p<0.01$ ). Symptoms: IG had a sig increase in the number of asthma-free days, compared to the CG ( $p<0.05$ ).
Freitas et al., 2018 Brazil	WL+E: Weight-loss programme incorporating aerobic and resistance muscle training. WL+S: Weight-loss programme incorporating breathing and stretching exercises.	≤3 months. 2× p/w.	Nutritionist(s), psychologist(s) and physiotherapist(s). Face-to-face. Combination.	Symptoms: Daily Diary.	Symptoms: IG had a sig increase in the number of asthma-free days, compared to the CG ( $p<0.05$ ).
Goncalves et al., 2008 Brazil	IG: Education and respiratory exercise programme. Submitted to aerobic training on a treadmill. CG: Education and respiratory exercise programme.	≤3 months. 2× p/w, 30mins.	Intervention provider(s) NR. Face-to-face. Group.	QoL: EPM Questionnaire. Symptoms: Daily Diary.	QoL: IG significantly improved in the following domains: physical limitations, frequency of symptoms, psychosocial limitations, and the total score ( $p<0.001$ ). Symptoms: Sig increase in the number of symptom-free days in the IG after 30 days, maintained over 60- and 90-days ( $p<0.05$ ). QoL: Changes within-group were not sig ( $p=0.645$ ). Medication Usage: Changes within-group were not sig ( $p=0.203$ ).
Hildenbrand et al., 2010 USA	Aquatic exercise programme.	≤3 months. 3× p/w, 30-45mins.	Swimming Instructor(s). Face-to-face. Group.	QoL: AIS and a 7-question survey. Medication Usage: NR.	QoL: Changes within-group were not sig ( $p=0.645$ ). Medication Usage: Changes within-group were not sig ( $p=0.203$ ).
Jain and Talukdar, 1993 India	Admitted to hospital for a period of 40-days. Given vegetarian diet and daily yoga training.	≤3 months. 1h 30mins morning and 1h evening.	Intervention provider(s) NR. Face-to-face and mail. Focus NR.	Symptoms: MRC Dyspnoea Scale.	Symptoms: 18 patients initially with moderate-severe asthma remained asymptomatic for 1-year.

(Continued)

**Table 3.** (Continued)

Author (year) and country of study	Description of intervention and comparator group(s)	Intervention length and intensity	Intervention provider(s) and mode and focus of delivery	Health outcome(s) Measurement tool	Intervention effect
Ma et al., 2015 USA	IG: Lifestyle intervention, dually targeting modest weight-loss and increased PA. CG: Usual care enhanced with a pedometer, a weight scale, information about existing weight management services at participating clinics, and an asthma education DVD.	≤12 months. 150mins p/w of MPA.	Intervention provider(s) NR. Face-to-face and telephone. Combination.	AC: ACQ and ACT. QoL: Mini-AQLQ. Medication Usage: Electronic Health Record.	AC: Changes between-groups were not sig at 6-months ( $p=0.15$ ) or 12-months ( $p=0.92$ ). QoL: Changes between-groups were not sig at 6-months ( $p=0.28$ ) or 12-months ( $p=0.42$ ). Medication Usage: Groups did not differ in any measures.
Mancuso et al., 2012b USA	IG: Contract to increase PA and provided with a pedometer and an asthma workbook. Received bimonthly follow-up telephone calls and small gifts and instructions in fostering positive affect and self-affirmation. IG: Identical protocol but did not receive small gifts and instructions.	≤12 months. Intervention intensity NR.	Intervention provider(s) NR. Face-to-face, post and telephone. Individual.	AC: ACQ. QoL: AQLQ.	AC: IG significantly improved from 1.43 to 0.83 ( $p<0.0001$ ). QoL: Changes between-groups were not sig ( $p>0.05$ ).
Mendes et al., 2010 Brazil	IG: Aerobic training programme. Received an educational programme and taught yoga breathing exercises. CG: Received an educational programme and taught yoga breathing exercises.	≤3 months. 2 × p/w, 30 mins.	Intervention provider(s) NR. Face-to-face. Group.	QoL: Simplified AQLQ. Symptoms: Daily Diary.	QoL: Sig improvements in the physical limitations, frequency of symptoms, psychosocial domains and total score occurred only in the IG ( $p<0.001$ ). Symptoms: IG showed a sig increase in the number of symptom-free days after 30-days ( $p<0.001$ ), maintained after 60- and 90-days ( $p<0.001$ ). Symptoms: IG showed a sig increase in the number of symptom-free days after 30-days ( $p<0.001$ ), maintained after 60- and 90-days ( $p<0.001$ ).
Mendes et al., 2011 Brazil	IG: Aerobic training programme. Received an educational programme and taught yoga breathing exercises. CG: Received an educational programme and taught yoga breathing exercises.	≤3 months. 2 × p/w, 30 mins.	Intervention provider(s) NR. Face-to-face. Group.	Symptoms: Daily Diary.	Symptoms: IG showed a sig increase in the number of symptom-free days after 30-days ( $p<0.001$ ), maintained after 60- and 90-days ( $p<0.001$ ).
O'Neill and Dogra, 2021 Canada	High-intensity interval training. yoga breathing exercises.	≤3 months. 3 × p/w, 20 mins.	Intervention provider(s) NR. Face-to-face. Focus NR.	AC: ACQ. Symptoms: RPD Scale.	AC: Sig improvements were observed when comparing pre- and post-intervention sessions ( $p=0.02$ ). Symptoms: Sig improvements were observed when comparing pre- and post-intervention sessions ( $p=0.01$ ). Medication Usage: No sig changes ( $p>0.05$ ). Symptoms: No sig changes ( $p>0.05$ ).
Robinson et al., 1992 New Zealand	IG: Training programme, consisting of a warm-up and between one and four circuits of seven exercises. CG: Identical protocol except that they did not receive salbutamol or have PEFE measurements.	≤3 months. Increase the number of circuits.	Intervention provider(s) NR. Face-to-face. Group.	Medication Usage: Daily Diary. Symptoms: Daily Diary.	Symptoms: Daily Diary.

(Continued)

**Table 3. (Continued)**

Author (year) and country of study	Description of intervention and comparator group(s)	Intervention length and intensity	Intervention provider(s) and mode of delivery	Health outcome(s)	Intervention effect
				Measurement tool	
Sabina et al., 2005 USA	IG: Yoga training programme. Provided with printed materials and audiocassettes and encouraged to practice at home. CG: Shame intervention of basic muscle stretching exercises. Provided with printed materials and audiocassettes and encouraged to practice at home.	≤3 Months. 2 × p/w, 90mins. Home practice for 20 mins p/d.	Exercise specialist(s). Face-to-face and printed materials and audiocassettes. Combination.	QoL: Mini-AQLQ. Medication Usage: Brief Questionnaire. Symptoms: Daily Diary.	QoL: Changes between-groups were not sig ( $p > 0.05$ ). Medication Usage: Changes between-groups were not sig ( $p > 0.05$ ). Symptoms: Sig improvement in morning symptoms in the IG and CG at 4 weeks ( $p = 0.03$ ) and 16 weeks ( $p = 0.001$ ).
Scott et al., 2013 Australia	EG: Aerobic and resistance training. Received a 12-week gym membership and personal training session and educational materials regarding national PA recommendations. DG: Dietary restrictions. EDG: Aerobic and resistance training and dietary restrictions.	≤3 months. Personal training session for 1h p/w. Attend gym 3 × p/w. Increase steps by 10%.	Nutritionist(s), psychologist(s) and physiotherapist(s). Face-to-face and telephone. Combination.	AC: ACQ. QoL: AQLQ.	AC: No sig improvement in the EG ( $p > 0.05$ ) but sig improvement in the EDG ( $p < 0.05$ ) were observed. QoL: Sig within-group improvements in the EG ( $p < 0.05$ ) and EDG ( $p < 0.01$ ) were observed.
Toennesen et al., 2018 Denmark	EG: High-intensity interval training. DG: High protein and low glycaemic diet. E&DG: High-intensity interval training and diet. CG: No intervention.	≤3 Months. 3 × p/w.	Trained spinning instructor(s) and dietician(s). Face-to-face. Combination.	AC: ACQ. QoL: Mini-AQLQ.	AC: Sig within-group improvements in all treatment groups, but when compared to the CG only EDG had statistically sig improvements ( $p < 0.05$ ). QoL: Sig within-group improvements in all treatment groups, but when compared to the CG only EDG had statistically sig improvements ( $p < 0.01$ ).
Vempati et al., 2009 India	IG: Yoga-based lifestyle modification and stress management programme. Provided with printed materials, audiocassettes and telephonic support. CG: Waiting list.	≤3 Months. 4 hours p/d.	Qualified yoga instructor(s) and physician(s). Face-to-Face, telephone and printed materials and audio cassettes. Combination.	QoL: AQLQ. Medication Usage: Daily Diary.	QoL: Significantly improved in both groups but achieved earlier in the IG ( $p = 0.013$ ). Medication Usage: Significantly decreased in both groups but the decrease was achieved earlier in the IG ( $p < 0.05$ ).
Vedanthan et al., 1998 USA	IG: Yoga training. Received audio cassettes and written information to continue practising at home. CG: No intervention.	≤6 Months. 3 × p/w, 45 mins.	Trained yoga teacher(s). Face-to-face. Group.	Medication Usage: NR. Symptoms: Weekly symptom questionnaire.	Medication Usage: Changes between-groups were not sig ( $p > 0.05$ ), but changes did exhibit a trend towards improvements. Symptoms: Average weight score for the IG was much higher than for the CG, but between-group differences were not sig ( $p > 0.05$ ).

IG: intervention group; CG: control group; p/w: per week; QoL: quality of life; SGRQ: St. Georges quality of life questionnaire; HRmax: maximum heart rate; NR: not reported; AC: asthma control; ACQ: asthma control questionnaire; AQLQ: asthma quality of life questionnaire; AIS: asthma impact survey; PA: physical activity; WL+E: weight-loss and exercise; WL+S: weight-loss and sham; MRC: medical research council; ACT: asthma control test; p/d: per day; EG: exercise group; DG: diet group; EDG: exercise and diet group.

França-Pinto et al., 2015; Freitas et al., 2018; Goncalves et al., 2008; Jain and Talukdar, 1993; Mendes et al., 2010, 2011; O'Neill and Dogra, 2021; Robinson et al., 1992; Sabina et al., 2005; Vedanthan et al., 1998), with four reporting significant positive within-group effects (Evaristo et al., 2020; França-Pinto et al., 2015; O'Neill and Dogra, 2021; Sabina et al., 2005) and four reporting a significant positive between-group effect (Freitas et al., 2018; Goncalves et al., 2008; Mendes et al., 2010, 2011). Although not significant, two of the remaining studies reported improved asthma symptoms in the intervention group over time (Jain and Talukdar, 1993; Vedanthan et al., 1998).

Eight out of the 25 included studies assessed medication usage as an outcome (Coelho et al., 2018; Evaristo et al., 2020; Hildenbrand et al., 2010; Ma et al., 2015; Robinson et al., 1992; Sabina et al., 2005; Vedanthan et al., 1998; Vempati et al., 2009). Only two of the eight studies found within-group evidence of a significant reduction in the use of rescue inhalers in the intervention group (Evaristo et al., 2020; Vempati et al., 2009).

### *Intervention components*

Interventions were heterogeneous in terms of intervention duration, physical activity type, intensity and duration, mode of delivery, delivery focus and intervention provider. These are presented in Tables 2 and 3.

*Intervention duration/intensity and physical activity.* The majority of the 21 unique included interventions lasted no more than 3-months ( $n=17$ ), with others lasting no more than 6-months ( $n=2$ ) and no more than 12-months ( $n=2$ ). The activity performed within the intervention varied across studies but included aerobic exercises and/or strength/resistance training ( $n=8$ ), yoga training ( $n=5$ ), walking only ( $n=5$ ), high-intensity interval training ( $n=2$ ), indoor circuit training ( $n=1$ ), and aquatic training ( $n=1$ ). Participants were most commonly asked to perform the activity two or three times

per week, for between 30 and 60 minutes ( $n=9$ ). However, two studies did not report information on the intensity of the intervention (Mancuso et al., 2012a, 2012b).

*Intervention provider, mode of delivery and delivery focus.* In most interventions, the provider was not reported ( $n=8$ ), with others using exercise specialists, including yoga and swimming instructors ( $n=6$ ), physiotherapists ( $n=2$ ), or a combination of providers ( $n=5$ ). Intervention providers delivered most of the interventions face-to-face ( $n=13$ ) or using a combination of methods, including face-to-face and telephone, post, printed materials and/or tapes ( $n=7$ ). Nyenhuis et al. (2020) was the only intervention that used data collected from the participant's activity tracker to send tailored SMS messages. Only one of the included interventions had no face-to-face contact and was delivered via post only (Dogra et al., 2010). The majority of interventions were delivered in groups only ( $n=6$ ) or used a combination of group and individual sessions ( $n=7$ ). Four interventions used individual sessions only (Coelho et al., 2018; Dogra et al., 2010, 2011; Mancuso et al., 2012a, 2012b), and four studies did not report the focus of delivery (Boyd et al., 2012; França-Pinto et al., 2015; Jain and Talukdar, 1993; O'Neill and Dogra, 2021).

*Relationship between intervention components and outcomes based on a narrative synthesis.* Six of the eight unique interventions found to be effective only reported short-term effects (<3 months) (Bidwell et al., 2012; Freitas et al., 2017; Goncalves et al., 2008; Mendes et al., 2010, 2011; O'Neill and Dogra, 2021; Toennesen et al., 2018; Vempati et al., 2009). Participants within these interventions were most commonly asked to perform aerobic exercise and/or strength/resistance training ( $n=3$ ) two or three times per week for 30-60 minutes ( $n=4$ ). Most interventions were delivered by a combination of providers ( $n=3$ ) or did not report the provider ( $n=2$ ). They were mostly delivered face-to-face ( $n=5$ ) and within groups ( $n=2$ ) or

used a combination of group and individual sessions ( $n=3$ ).

**Behaviour change techniques.** A total of 25 of the 93 BCTs from the BCTTv1 were identified (*Supplementary File 7*). BCTs related to increasing physical activity and, in some studies, reducing sedentary behaviour. The number of BCTs identified in individual interventions ranged from 6 to 15, with an average of 9 BCTs per intervention. The most prevalent BCTs (coded in at least 25% interventions) were: ‘Action Planning’ ( $n=25$ ); ‘Goal Setting (Behaviour)’ ( $n=25$ ); ‘Instruction on How to Perform Behaviour’ ( $n=22$ ); ‘Demonstration of Behaviour’ ( $n=20$ ); ‘Behavioural Practice/Rehearsal’ ( $n=20$ ); ‘Self-Monitoring of Behaviour’ ( $n=14$ ); ‘Self-Monitoring Outcome(s) of Behaviour(s)’ ( $n=11$ ); ‘Social Support (Unspecified)’ ( $n=10$ ); ‘Adding Objects to the Environment’ ( $n=10$ ); ‘Graded Tasks’ ( $n=9$ ); ‘Pharmacological Support’ ( $n=9$ ); ‘Monitoring of Outcome(s) of Behaviour Without Feedback’ ( $n=8$ ); ‘Body Changes’ ( $n=8$ ); ‘Feedback on Behaviour’ ( $n=7$ ); and ‘Information About Health Consequences’ ( $n=7$ ). In terms of ‘Pharmacological Support’, this concerned intervention providers encouraging participants to adhere to their asthma medication. Twenty of the 25 identified BCTs were included in the seven unique, effective interventions. The most commonly used BCTs in effective interventions were: ‘Action Planning’ (100%); ‘Goal Setting (Behaviour)’ (100%); ‘Instruction on how to Perform Behaviour’ (89%); ‘Demonstration of Behaviour’ (89%); ‘Behavioural Practice/Rehearsal’ (89%). BCTs identified in effective interventions were also included in the interventions which did not show evidence of effectiveness.

## Discussion

We found that interventions that promote physical activity had significant benefits in terms of increasing physical activity (eight out of ten studies), decreasing time spent sedentary (two out of three studies), improving quality of life

(ten out of 16 studies) and decreasing asthma symptoms (eight out of 11 studies). However, we found no evidence of a positive effect on asthma control (six out of 12 studies) and medication usage (two out of eight studies). Ten out of the 25 included studies, comprising 786 out of 1849 participants, reported significant positive effects in all the relevant outcomes they assessed and were deemed effective. Participants within these interventions were most commonly asked to perform aerobic exercise and/or strength/resistance training two or three times per week for 30–60 minutes. Most interventions were delivered by a combination of providers or did not report the provider. They were delivered face-to-face and within groups or used a combination of group and individual sessions. However, we cannot say for definite that these intervention components increased effectiveness as components were similar across all interventions regardless of their effectiveness. The most commonly used BCTs in effective interventions were: ‘Action Planning’ (100%); ‘Goal Setting’ (100%); ‘Instruction on how to Perform the Behaviour’ (89%); ‘Demonstration of Behaviour’ (89%); and ‘Behavioural Practice/Rehearsal’ (89%). Due to the similarities of the BCTs used across all intervention and control groups, it was not possible to identify specific BCTs that showed promise of effectiveness.

Notably absent from the BCTs extracted from the included interventions were techniques that help self-regulate behaviour and sustain motivation, which are important for adopting and maintaining behaviour change. For example, ‘Problem Solving’, ‘Reviewing Behavioural Goals’, ‘Prompts/Cues’, ‘Habit Formation’ and ‘Self Reward’ have all been associated with behaviour maintenance (Howlett et al., 2019; Samdal et al., 2017), but were not identified in the included interventions. Although there was an increase in physical activity during the intervention period, the only intervention to follow-up participants beyond the intervention showed that the increase was not maintained (Coelho et al., 2018). For changes to be maintained, future

interventions should consider including the above techniques.

In terms of active ingredients of the intervention, 'Goal Setting' and 'Action Planning' were the most commonly used BCTs. Meta-analyses have shown that setting a specific and detailed plan on when, where and how to perform a behaviour and providing instructions increases self-efficacy (one's belief in their ability to engage in the behaviour successfully) and physical activity (Williams and French, 2011). Qualitative studies have found that major barriers to physical activity for adults with asthma are low self-efficacy and negative beliefs about their capabilities to be active (Mancuso et al., 2006; Nyenhuis et al., 2019). This would suggest that these BCTs are important for behaviour change in this population group, and although we cannot conclude that these are 'promising' or more likely to increase effectiveness as they were identified in both effective and ineffective interventions, the evidence supporting the use of these BCTs is well established.

Although identified in a small number of interventions, some evidence-based BCTs could be used more often to increase the likelihood of interventions being effective. For example, incorporating 'Practical Social Support' has been associated with better intervention effects. Planning how to elicit social support from individuals makes participants feel more in control and ensures that they are supported to make behavioural changes (Olander et al., 2013), but this BCT was only identified in one of the included studies. Social support has been reported as a facilitator to physical activity in this patient group (Mancuso et al., 2006; Nyenhuis et al., 2019). Including this BCT in future interventions could increase their effectiveness by ensuring that participants are supported and could help them cope with possible setbacks following asthma flare-ups. Another BCT associated with increased physical activity is 'Self-Monitoring of Outcomes of Behaviour' (Olander et al., 2013). One of the major barriers to physical activity reported by adults with asthma, even for those with mild

asthma, is fear and anxiety of triggering symptoms (Clarke and Mansur, 2015). If participants could see the benefits of physical activity to their asthma outcomes for themselves, it could reduce negative feelings and encourage them to continue to make positive improvements to increase their activity levels. Other BCTs that reduce negative emotions and conserve mental resources and BCTs in the 'Self Belief' group, such as 'Verbal Persuasion About Capability' and 'Focus on Past Success', could be included.

As there are limited facilities and funding available to deliver PR to patients, alternative interventions to PR could increase the number of patients who can access help and support to improve their physical activity levels. However, although the included interventions were not PR, most of them would not have overcome the major barriers previously reported by patients (Jones et al., 2017; Keating et al., 2011) as they still required participants to travel and would not have been suitable for those living with comorbidities. These barriers need to be considered in the development of future physical activity interventions, and alternative delivery methods should be considered to provide patients with tailored interventions at a convenient time and place for them. To help overcome these barriers, home-based programmes have been proposed as an alternative to traditional PR. Randomised controlled trials have shown that it produced short-term clinical outcomes equivalent to traditional PR (Holland et al., 2017), including improving exercise capacity and quality of life (Pradella et al., 2015). Home-based PR could be optimised by incorporating the BCTs most commonly used in effective interventions highlighted in this review to increase the number of people who can access help and support and improve long-term effects. Our findings highlight the potential use of digital interventions that have unique advantages over traditional in-person interventions, being more accessible and convenient for participants (Griffiths et al., 2006). Except for Nyenhuis et al. (2020), none of the included interventions were digital or had a digital component. Future research should investigate the development of



digital-physical activity interventions tailored to adults with asthma, and good-quality randomised trials should be carried out to understand their effectiveness in this population group.

### **Strengths and limitations**

This review followed a structured search protocol that used five electronic databases. The inclusion criteria were broad, and we included a wide range of study designs and interventions with all asthma severities. We used a detailed categorisation of BCTs with reference to standard classifications. However, some limitations need to be considered. There was a great deal of heterogeneity in the included studies in relation to the research design, type of intervention and outcome data. Therefore, we could not conduct a meta-analysis, and only a narrative review could be produced.

Furthermore, the level of detail needed for extracting BCTs was often not present in published intervention descriptions; included interventions might have used more BCTs than those extracted in this review. We addressed this problem by having two reviewers independently extract BCTs, and we included both probably (coded +) and definite (coded ++) BCTs. In addition to this, it was not always clear whether an intervention would qualify as PR or not due to the lack of detail provided in the intervention descriptions. Again, we tried to address this problem by a second reviewer validating the inclusion and exclusion of papers with the option to discuss with a third reviewer if there was a discrepancy. Nevertheless, this review provides an update on the literature on physical activity interventions and their effects on asthma outcomes and provides an insight into the literature gaps that need to be addressed in future studies.

### **Conclusion**

We included 25 studies that reported 21 unique physical activity interventions within this review. Interventions significantly increased physical

activity levels and decreased sedentary behaviour in adults diagnosed with asthma. They also positively affected quality of life and asthma symptoms, but not asthma control and medication usage. Ten out of the 25 included studies reported significant positive effects in all the relevant outcomes they assessed and were deemed effective. Participants within these interventions were most commonly asked to perform aerobic exercise and/or strength/resistance training two or three times per week for 30–60 minutes. Most interventions were delivered by a combination of providers or did not report the provider. They were delivered face-to-face and within groups or used a combination of group and individual sessions. The most commonly used BCTs in effective interventions were: ‘Action Planning’; ‘Goal Setting (Behaviour)’; ‘Instruction on how to Perform the Behaviour’; ‘Demonstration of the Behaviour’; and ‘Behavioural Practice/Rehearsal’. Due to the similarities in components and BCTs used across all intervention and control groups, it was not possible to identify specific intervention components that showed promise of effectiveness. We recommend that future interventions include evidence-based techniques that prompt self-regulation of behaviour and sustain motivation and behaviour change.

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## Supplemental material

Supplemental material for this article is available online.

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