Original Article

A Systematic Review of Associations of Physical Activity and Sedentary Time with Asthma Outcomes

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What is already known about this topic? Compared with controls, subjectively measured physical activity seems to be reduced in adults with asthma. Higher levels of physical activity might have a beneficial impact on asthma.

What does this article add to our knowledge? Physical activity is reduced in adults with asthma, especially in females and older people with asthma. Sedentary time did not differ between people with and without asthma. Higher levels of activity are associated with better asthma outcomes.

How does this study impact current management guidelines? These results suggest that addressing inactivity and sedentary time may be a potential nonpharmacological approach in the management of asthma. Disease severity, sex, and age should guide these approaches.

BACKGROUND: Physical inactivity and high sedentary time are associated with adverse health outcomes in several diseases. However, their impact in asthma is less clear.
OBJECTIVE: We aimed to synthesize the literature characterizing physical activity and sedentary time in adults with asthma, to estimate activity levels using meta-analysis, and to evaluate associations between physical activity and sedentary time and the clinical and physiological characteristics of asthma.
METHODS: Articles written in English and addressing the measurement of physical activity or sedentary time in adults ≥18 years old with asthma were identified using 4 electronic databases. Meta-analysis was used to estimate steps/day in applicable studies.
RESULTS: There were 42 studies that met the inclusion criteria. Physical activity in asthma was lower compared with controls. The pooled mean (95% confidence interval) steps/day for people with asthma was 8390 (7361, 9419). Physical activity tended to be lower in females compared with males, and in older people with asthma compared with their younger counterparts. Higher levels of physical activity were associated with better measures of lung function, disease control, health status, and health care use. Measures of sedentary time were scarce, and indicated a similar engagement in this behavior between participants with asthma and controls. High sedentary time was associated with higher health care use, and poorer lung function, asthma control, and exercise capacity.
CONCLUSIONS: People with asthma engage in lower levels of physical activity compared with controls. Higher levels of physical activity may positively impact on asthma clinical outcomes. Sedentary time should be more widely assessed. © 2018 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2018;6:1968-81)

Key words: *Asthma; Physical activity; Sedentary time; Accelerometry; Questionnaire; Associations; Clinical outcomes; Meta-analysis*

Asthma is an obstructive airway disease that causes symptoms of dyspnea, wheezing, and chest tightness. These symptoms, and the fear of provoking exercise-induced bronchoconstriction (EIB), may have a negative impact on the engagement in physical activity in people with asthma.[1-3]

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Abbreviations used
BMI- Body mass index
CI- Confidence interval
COPD- Chronic obstructive pulmonary disease
EE- Energy expenditure
EIB- Exercise-induced bronchoconstriction
MVPA- Moderate and vigorous physical activity
OR- Odds ratio
RCT- Randomized control trial
SE- Standard error

Physical activity and sedentary time have been widely studied in the general population[4] and in chronic obstructive pulmonary disease (COPD). People with COPD are considerably less active and more sedentary than people without respiratory conditions.[5,6] Furthermore, inactivity in COPD is associated with more exacerbations resulting in hospitalization,[7] a reduced time to readmission,[8] and increased all-cause mortality.[8-10] As a result, there are well-established exercise programs for people with COPD that seek to address physical inactivity.[11,12] In asthma, however, the role of physical activity and sedentary time is less clear,[13] and thus guidelines and interventions to target these behaviors in this population are limited.

In a prior systematic review in adults and children, Eijkemans et al[14] suggested that people engaging in higher levels of physical activity might have a lower risk of asthma incidence. In adults with asthma, they also found a trend toward lower levels of physical activity compared with controls.[14] However, none of the included studies used objective measures (accelerometry) to quantify physical activity in adults, and sedentary time was not addressed. Another review found that children and adolescents with and without asthma engage in a similar amount of objectively measured physical activity.[15] Despite this evidence, there are no reviews of the literature that have evaluated the prevalence of sedentary time in adults with asthma, nor reviewed the use of accelerometry to quantify physical activity and sedentary time in this population. In addition, the degree to which the level of physical activity and sedentary time impact on the airway symptoms or clinical outcomes in adults with asthma has not been reviewed.

Our aim therefore is to update and synthesize the evidence in relation to the prevalence of physical activity and sedentary time in adults with asthma. We conducted a meta-analysis of studies reporting steps/day in people with asthma, and sought to evaluate the associations of these behaviors with the clinical and physiological characteristics of the disease.

METHODS

Literature search

Articles written in English and addressing the measurement of physical activity or sedentary time in adults ($\geq$18 years) with asthma were identified by a comprehensive search using the Medline, Embase, PEDro, and Cochrane databases. The search was conducted in April 2017, and updated in October 2017, and included all articles published until the search date.

Eligible studies were those that examined the prevalence and patterns of these behaviors in asthma populations, or studies analyzing the association of these behaviors with clinical or biological markers of the disease. We did not include a filter for study design. Details of the search strategy are provided in Table I.

TABLE I. Terms search

Search strategy: (#1) AND (#2 OR #3)	
#1	Asthma* or wheez* or "bronchoconstriction"
#2	"physical activity" or ("physical exercise" or "exercise") or "walking" or "motor activity"
#3	("sedentary behaviour" OR "sedentary behavior" OR "sedentary time") OR ("sedentary lifestyle") OR ("internet time") OR ("computer time") OR ("television watching" OR "television viewing" OR "television time") OR ("TV watching" OR "TV viewing" OR "TV time") OR ("screen time") OR "sitting time" OR "reading time"

Analysis

Statistical analysis was performed using STATA 13 (Stata Corp., College Station, Tex). The continuous outcome (mean steps/day) from relevant studies[16-22] was pooled using the random-effect model. Authors of 3 studies were contacted, and provided further details of their results.[16,20,21]

RESULTS

The initial search yielded 2803 references. A flow diagram[23] of the literature search is provided in Figure 1.

We identified 42 eligible studies investigating physical activity and/or sedentary time in adults with asthma. Population characteristics are presented in Table II. From these studies, 18 compared the level of these behaviors in asthma with a control group.[16-19,21,27,28,30-32,37,39,41,42,44-47] Table III summarizes the physical activity measurements utilized in these 18 studies. Three studies[20,22,50] without a control group were also included in Table III to provide further details of the activity monitors used. Associations with disease characteristics were assessed in 24 studies[16-18,21,22,24,28,29,31,33,35,39,40,42,43,47,49-51,53-57] (Table IV). In addition, 2 studies reported physical activity as a confounder of body mass index (BMI),[26,34] and 2 studies reported physical activity before a randomized controlled trial (RCT) exercise intervention.[20,38] In 5 studies, the association between current asthma and different levels of physical activity was assessed.[25,26,48,52,58] In general, the studies were quite heterogeneous in terms of the population and assessments of activity/sedentary time. Studies included 193,821 participants with asthma and 1,417,540 controls. Most participants were women, and in 31% of the studies, the mean age was below 45 years. Twenty-three studies used a self-reported asthma diagnosis.[25-33,36,37,39,43,44,46-48,52,53,55-58] Disease severity or level of control was reported in 15 studies, and populations included people with mild, moderate, and severe asthma.[16-18,20-22,26,34,38,40-42,47,49,56]

Prevalence of physical activity

Among studies using a control group, eleven[16-18,21,28,30,32,39,41,44,46] (asthma sample = 32,606) reported less physical activity in asthma, and six reported no difference[19,31,37,42,46,47] (asthma sample = 7,824). One study[27] (asthma sample size = 1,070) reported increased physical activity in younger adults with asthma (<40 years old), but decreased physical activity in older participants (>50 years old).

Activity monitors were used in 8 studies.[16-22,50] Five of them included a control group[16-19,21] (Tables III and V). A meta-analysis (Figure 2) found that the weighted mean (95%

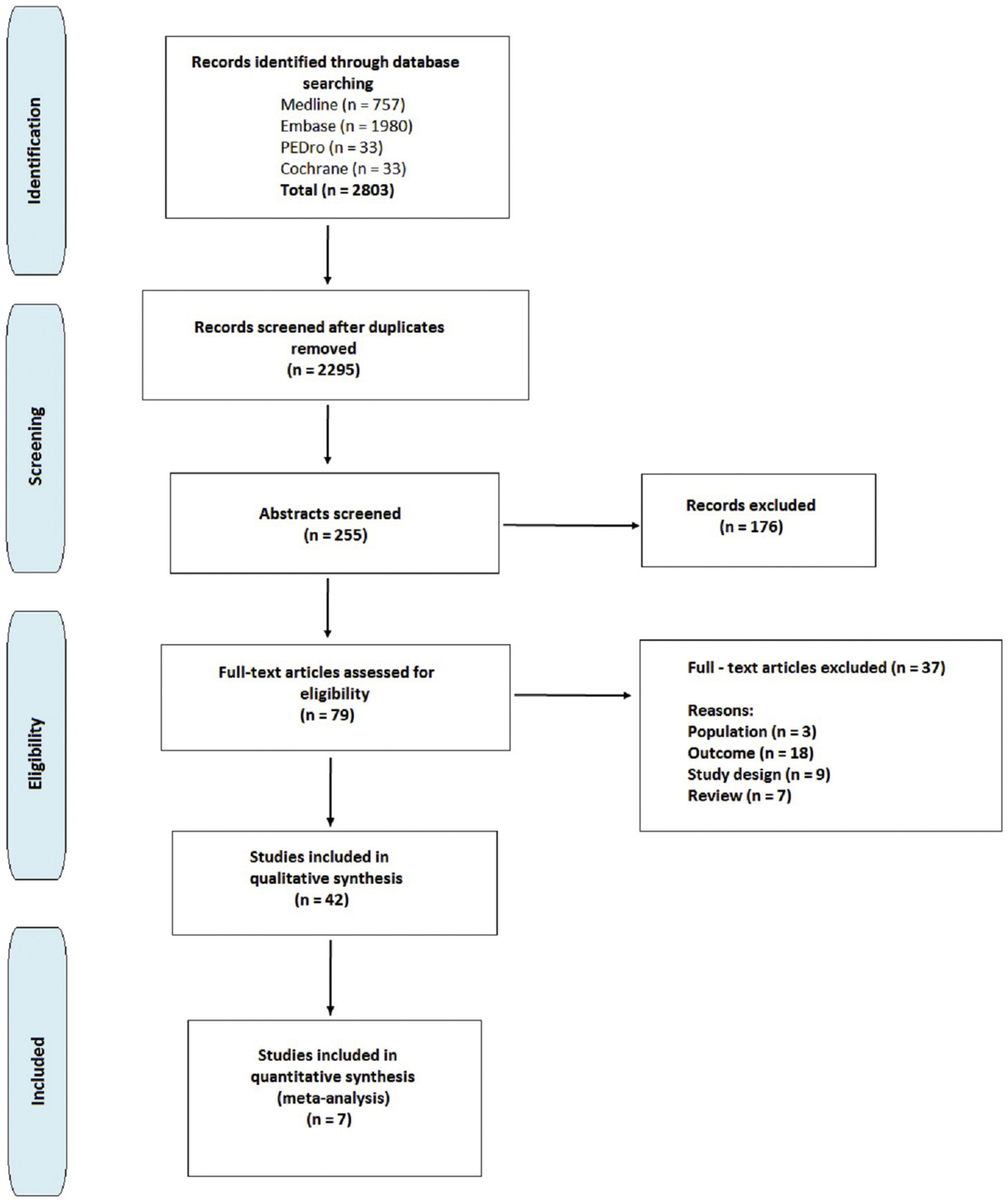

FIGURE 1. PRISMA Flow Diagram Literature search. Updated October 31, 2017.

confidence interval [CI]) number of steps/day for people with asthma was 8390 (7361, 9419). In the 4 studies that compared the volume and/or intensity of activity, people with asthma tended to accumulate less physical activity than controls (Table V).

Some studies reported an effect of age and sex on activity in asthma. Three studies reported that the decrease in activity in people with asthma was mostly seen in older participants (≥50 years old).[27,32,46] For instance, despite their overall results showing that people with asthma were more inactive than controls, Ford et al[32] did not find statistically significant differences in the association between activity and asthma status in people under the age of 60. Some studies reported that males with asthma presented higher levels of activity than females with

TABLE II. Demographic characteristics of studies included

		Asthma participants					Controls		
Cross-sectional studies	**Country**	**n**	**Female (%)**	**Age**	**Current smoking (%)**	**Disease severity (%)**	**n**	**Female (%)**	**Age**
Bacon et al 2015[24]	Canada	643	60	53.4 ± 15.4	8.7	n/r	n/a	n/a	n/a
Bahmer et al 2017[16]	Germany	146	51 severe 53 mild to mod.	55.5 48.1	22 24	43.1 56.8	29	38	42.1
*Beckett et al 2001[25]	USA	4,547	52	18 to 30	41.1	n/r	4131	55.2	18 to 30
Barros et al 2017[26]	Portugal	2,578	62	20 to >85	21.4	Current: 44 Persist: 38 Severe:18	30,066	52.4	20 to >85
Bruno et al 2016[17]	Italy	24	66	38.5 ± 14.2	n/r	Mild to mod.	18	55	43.1 ± 14.3
Chen et al 2001[27]	Canada	1,070	61.7	12 to >70	26.7	n/r	15,743	55	12 to >70
Cordova-Rivera et al 2017[18]	Australia	61	52.5	59 (43 to 68)	6.6	Severe	61	52.5	54 (34 to 63)
Doggett and Dogra 2015[28]	Canada	1,830	69.2	20 to >55	33.1	n/r	18,978	54.4	20 to >55
Dogra and Baker 2006[29]	Canada	11,243	62	40 to 44	n/r	n/r	n/a	n/a	n/a
Dogra et al 2008[30]	Canada	1,772† 3,123‡	63† 68‡	45 to 79	n/r	n/r	19,864	57	65 to 79
Dogra et al 2009[31]	Canada	6,835	62	20 to 64	28.5	n/r	78,051	51	20 to 64
Ford et al 2003[32]	USA	12,489	64	18 to >70	n/r	n/r	147,742	48.9	18 to >70
Ford et al 2004[33]	USA	12,111	63.7	44.2 (0.3)	26	n/r	n/a	n/a	n/a
Grammatopoulou et al 2010[34]	Greece	100	79	n/r	20	Mild: 58 Mod:32 Severe: 10	n/a	n/a	n/a
Iikura et al 2013[35]	Japan	437	53.3	64 (51 to 74)	7.1	n/r	n/a	n/a	n/a
Kilpelainen et al 2006[36]	Finland	10,023	61	18 to 25	3.4§	n/r	n/a	n/a	n/a
Liang et al 2015[37]	Australia	723	51§	18 to 29	2.7	n/r	1,891	51§	18 to 29
Ma et al 2016[38]	USA	330	10.6	47.6 ± 12.4	5.8	UA	n/a	n/a	n/a
Malkia and Impivaara 1998[39]	Finland	178	59	30 to 89	n/r	n/r	7,015	30 to 89	n/r
Mancuso et al 2007[40]	USA	258	75	42 ± 12	11	Mild to mod	n/a	n/a	n/a
Moore et al 2015[19]	Canada	16	38	27.8 ± 6.1	n/r	n/r	16	50	26.6 ± 5.2
Ramos et al 2015[41]	Brazil	20	70	44 ± 6.0	n/r	Mod to severe	15	93	39 ± 6.0
Ritz et al 2010[42]	USA	20	70	28 ± 6.8	n/r	Mod	20	70	31.6 ± 5.9
Scott et al 2013[20]	Australia	14	78.6	43.3 (37 to 7.8)	30.8	Mild inter: 8 Mild persist:23 Mod: 54 Severe: 15	n/a	n/a	n/a
Strine et al 2007[43]	USA	11,962	65.5	18 to >75	23.6	n/r	n/a	n/a	n/a
Teramoto and Moonie 2011[44]	USA	880	57.2	18 to >70	n/r	n/r	2,960	n/r	18 to >70
Tsai et al 2011[45]	Taiwan	27	44	60.8 ± 10.2	11	n/r	27	37	56.8 ± 1.1
Vancampfort et al 2017[46]	LMICs	11,857	50.8§	18 to >65	n/r	n/r	216,167	50.8§	n/a
Van't Hul et al 2016[21]	The Netherlands	226	62	47.3 ± 15.3	n/r	CA:17 PC:18 UA: 65	201	75.6	42.3 ± 16.3
Verlaet et al 2013[47]	Portugal	CA:125 UA:78	53 85	43 ± 28 54 ± 21.5	33	61.6 38.4	606	50.5	53 ± 24
Vermeulen et al 2016[22]	Belgium	20	65	39.0 ± 11.9	n/r	CA: 10 PC: 10 UA: 80	n/a	n/a	n/a
Vogt et al 2008[48]	USA	311	72.3	18 to > 75	n/r	n/r	4,420	n/a	n/a
Westermann et al 2008[49]	USA	258	75.9	42 ± 12	n/r	Mild to mod	n/a	n/a	n/a
Yamasaki et al 2017[50]	Japan	18	55.6	63 ± 11	0	n/r	n/a	n/a	n/a
Yawn et al 2015[51]	USA	533	76	40.6	15.4	n/r	n/a	n/a	n/a
Zahran and Bailey 2013[52]	USA	74,779	76	18 to >65	19.5	n/r	869,519	51.3	18 to 65+

Longitudinal studies	**Country**	**Follow-up**	**n**	**Female (%)**	**Age**	**Current smoking (%)**	**Disease severity (%)**	**n**	**Female (%)**	**Age**
Bedard et al 2017[58]	France	Up to 11 y	15,353	100	59.2 ± 6.3	8.5	n/r	n/a	n/a	n/a
Brumpton et al 2017[53]	Norway	Mean 11.6 y	1,329	51.6	44.1 ± 12.9	25.1	n/r	n/a	n/a	n/a

(continued)

TABLE II. *(Continued)*

Longitudinal studies	Country	Follow-up	n	Female (%)	Age	Current smoking (%)	Disease severity (%)	n	Female (%)	Age
Fisher et al 2016[54]	Denmark	Mean 16 y	1,347	61.8	57.1 ± 4.5	34.9	n/r	n/a	n/a	n/a
Garcia-Aymerich et al 2007[55]	Denmark	Mean 11 y	153	n/r	52.4 ± 11.6	n/r	n/r	n/a	n/a	n/a
Garcia-Aymerich et al 2009[56]	USA	Mean 2 y	2,818	100	62.7 ± 6.9	5.8	Mild inter: 20.3 Mild persist:35.6 Mod: 34.6 Severe: 9.5	n/a	n/a	n/a
Russell et al 2017[57]	Norway	Mean 10 y	209‖ 947¶	n/r n/r¶	n/r n/r¶	n/r n/r¶	n/r n/r¶	n/a	n/a	n/a

CA, Controlled asthma; *Inter*, intermittent; *IQR*, interquartile range; *LMIC*, low- and medium-income country; *Mod*, moderate asthma; *n/a*, not assessed; *n/r*, not reported; *PC*, partially controlled; *Persist*, persistent; *UA*, uncontrolled asthma.
Age reported as mean ± SD or (SE), or median (IQR), or range.
*Cross-sectional data from a longitudinal cohort.
†Values for older adults.
‡Values for middle-aged adults.
§% reported for the whole sample.
‖Only participants with asthma at baseline.
¶Results reported correspond to cross-sectional data.

asthma or their healthy counterparts.[39,47,49,51] Furthermore, 2 studies demonstrated that the decrease in activity that develops in older people with asthma occurs earlier, or exclusively, in females than males.[27,30] Dogra et al,[30] for instance, found that the levels of physical activity between middle-aged and older males with asthma were similar, whereas older females with asthma were considerably less active than their younger counterparts.

Reduced physical activity in people with asthma

From the 11 studies reporting lower levels of physical activity in people with asthma compared with controls,[16-18,21,28,30,32,39,41,44,46] 4 studies used activity monitors.[16-18,21] Van't Hul et al[21] found that people with asthma spent significantly less time walking, engaging in vigorous physical activity, and accumulated less steps/day than controls. Cordova-Rivera et al[18] reported that in participants with severe asthma, steps/day and moderate and vigorous physical activity (MVPA) were reduced by 31.4% and 47.5%, respectively, compared with controls ($P < .001$ both results).

From the studies using questionnaires, Teramoto and Moonie[44] reported that control participants spent an additional 60 minutes/week engaged in moderate physical activity and 67 minutes/week in vigorous activity compared with the asthma group ($P < .001$). Ford et al[32] reported that people with current asthma were more inactive (asthma = 30.9%, never asthma = 27.8%; $P < .001$) and engaged in less vigorous physical activity (asthma = 12.7%, never asthma = 14.8%; $P < .001$) than people without a history of asthma. Vancampfort et al[46] reported that asthma was significantly associated with low physical activity (engaging in <150 minutes/week of MVPA), especially in people >50 years old (odds ratio [OR] [95% CI] 1.67 [1.33-2.10]; $P < .0001$).

The level of activity decreased with loss of asthma control,[21] and increasing asthma severity.[16,17] Bahmer et al[16] reported that both steps/day and the time spent in MVPA in participants with severe asthma were reduced by 21% and 17%, respectively, compared with participants with less severe disease ($P < .05$).

Maintained physical activity in people with asthma

In 6 studies, there were no consistent differences in the level of the activity between the asthma and control groups.[19,31,37,42,45,47] One study used an activity monitor.[19] Verlaet et al[47] found that the proportion of participants performing MVPA was similar among people with controlled and uncontrolled asthma compared with controls; 32%, 38.5%, and 33.7% ($P > .05$) for each group, respectively. Liang et al[37] reported that the prevalence ratio (95% CI) for young adults with asthma (<30 years old) engaging in physical activity at the recommended level was 1.09 (0.92, 1.28) compared with those without asthma.

Increased physical activity in people with asthma

Chen et al[27] found that younger adults with asthma achieved higher levels of activity compared with their age-matched healthy counterparts, whereas this pattern of activity reversed in the older age group, especially in females. The mean (standard error [SE]) energy expenditure (EE) for men in the 25-39 years age group with asthma versus their control group was 2.16 (0.22) compared with 1.72 (0.15) kcal/kg/day; and 1.60 (0.14) versus 1.28 (0.06) kcal/kg/day in the female asthma group compared with female controls ($P = .02$ for both). At the age of 40, this trend started to reverse, becoming statistically significant in women >55 years, and for both sexes in the ≥70 years group. In the ≥70 years age group, males with asthma reported a mean (SE) EE of 0.72 (0.34) versus age-matched controls 1.45 (0.15) kcal/kg/day, whereas females reported a mean of 0.79 (0.17) versus 1.17 (0.07) kcal/kg/day ($P \leq .02$ both results).

Prevalence of sedentary time

Sedentary time was reported by 4 studies.[18,21,28,47] Two used an activity monitor.[18,21] Van't Hul et al[21] reported that participants with asthma spent more time lying down compared with controls (hours/day mean difference [95% CI] 0.59 [0.15, 1.03]; $P < .01$), but less time sitting than controls ($P > .05$). Similarly, another study did not find a significant difference in sedentary time between people with severe asthma and controls (minutes/day mean ± SD 674.4 ± 71 vs 676.2 ± 65, respectively; $P > .05$).[18] Doggett and Dogra[28] reported that the time spent watching TV for more than 10 hours/week was 50.4% in the asthma population compared with 42.9% in the nonasthma group ($P < .05$).

TABLE III. Physical activity measurements in studies with a control group

Studies using questionnaires

Study	Asthma definition	PA or ST measurement	PA or ST domain	Recall period	Outcome
Chen et al 2001[27]	Self-reported asthma diagnosed by a health professional	PA questionnaire from National Population Health Survey Canada	LTPA	12 mo	Mean daily energy expenditure (EE) (kcal/kg/day)
Doggett and Dogra 2015[28]	Self-reported physician-diagnosed asthma and use of asthma medication	Questionnaire	LTPA Television-viewing time (TVT)	PA: 1 wk TVT: typical week in last 3 mo	PA: frequency and intensity of (measured as an increase of heart rate and breathing) TVT: >10 h/wk as high TVT; ≤10 h/wk as low TVT
Dogra et al 2008[30]	Self-reported physician-diagnosed asthma	Questionnaire from CCHS cycle 2.1	LTPA	n/r	Active (≥1.5 kcal/kg/day), inactive (<1.5 kcal/kg/day) (estimated from EE)
Dogra et al 2009[31]	Self-reported physician-diagnosed asthma	From CCHS cycle 3.1	LTPA	n/r	Active (>3.0 kcal/kg/day), “moderately active” (1.5-3.0 kcal/kg/day), “inactive” (<1.5 kcal/kg/day)
Ford et al 2003[32]	Self-reported physician-diagnosed asthma	Questionnaire from 2000 BRFSS	LTPA	1 mo	Frequency and duration EE/week, and PA Index
Liang et al 2015[37]	Self-reported asthma	Questionnaire from Australian National Health Survey 2007-08	PA	1 wk	Intensity and frequency ≥800 MET: meeting PA guidelines
Malkia and Impivaara 1998[39]	Self-reported physician-diagnosed asthma and spirometry	Questionnaire	LTPA, PA at work and during commuting	n/r	Intensity and frequency METs at work and spare time. PA during commuting
Ramos et al 2015[41]	Asthma diagnosed by a physician	IPAQ—short form	LTPA	Average day in the last week	PA from EE + duration (METs min/wk)
Ritz et al 2010[42]	Asthma diagnosed by a physician	Electronic diary	PA in the past 30 min	3 times/d for 21 d	Frequency and intensity
Teramoto and Moonie 2011[44]	Self-reported current or lifetime asthma diagnosed by a health professional	Questionnaire from 2009 Nevada BRFSS	LTPA	1 mo	Engagement on PA, meet PA guidelines min/wk of MVPA
Tsai et al 2011[45]	Asthma diagnosed by a physician	Stanford 7-Day Physical Activity Recall	LTPA	1 wk	Frequency and intensity METs
Vancampfort et al 2017[46]	Self-reported lifetime diagnosis of asthma	Extract from IPAQ	LTPA	1 wk	Volume of MVPA (<150 min/wk = low PA)
Verlaet et al 2013[47]	Self-reported asthma	IPAQ—short form	LTPA Daily sitting time	Average day in the last week	LTPA: MET min/wk Volume of daily sitting time in min

Studies using activity monitors

Study	Asthma definition	PA or ST measurement	PA or ST domain	Wear-time protocol	Outcome
Bahmer et al 2017[16]	Physician-diagnosed asthma, and in specialist care for >3 mo	SenseWear Pro Armband	Total PA	Worn for 1 wk Inclusion: ≥5 d of 22.5 h	Steps/d Average minutes of at least moderate activity/day (EE>3 METs)
Bruno et al 2016[17]	Recruited according the ATS criteria	SenseWear Armband	Total PA	Worn over triceps area for 4 d, 24 h/d (excluded water-based activities) Inclusion: n/r	PA level (min/d); active EE (kcal/d); steps/d; total EE (kcal/d)

(continued)

TABLE III. *(Continued)*

Studies using activity monitors

Study	Asthma definition	PA or ST measurement	PA or ST domain	Wear-time protocol	Outcome
Cordova-Rivera et al 2017[18]	Asthma diagnosed by a respiratory physician according to GINA guidelines	ActiGraph wGT3X-BT	Sedentary time Total PA	Worn on dominant hip for 14 consecutive days, 24 h/d (sleeping and nonwear time excluded)	Min/d of: sedentary time, light PA and moderate and vigorous and very vigorous PA Steps/d
Moore et al 2015[19]	History of asthma and any of the following: positive spirometry, positive methacholine challenge, ≥10% decrease in FEV_1 after an exercise challenge	SenseWear Pro3 Armband	Total PA	Worn over triceps area of dominant arm for 3 d, 24 h/d Inclusion: preferably 2 wk/d, 1 weekend day	Steps/d Energy expenditure
*Scott et al 2013[20]	Physician-diagnosed asthma, and history of airway hyperresponsiveness	Pedometer	Steps	Worn for 7 d, recording steps a diary, (prior randomization)	Steps/d
Van't Hul et al 2016[21]	Asthma diagnosed by a respiratory physician and use of asthma medication	DynaPort MoveMonitor	Total PA Sitting and lying time	Worn on lower lumbar spine for 7 consecutive days, 24 h/d (excluded water-based activities) Inclusion: ≥2 (PA) and ≥5 (lying) days of ≥22.5 h	H/d in walking, sitting, and lying. Steps/d D PA level (total EE/d): >1.70 active, 1.40-1.69 predominantly sedentary, <1.40 very inactive
*Vermeulen et al 2016[22]	Previous asthma diagnosis, asthma exacerbation	SenseWear Armband	Total PA	Worn for 7 d Inclusion: n/r	Steps/d, % of time at an intensity: < 3 METs, 3-6 METs, 6-9 METs and ≥ 9 METs
*Yamasaki et al 2017[50]	Asthma diagnosed by a respiratory physician	Actiwatch 2	Total PA	Worn for 7 d Inclusion: n/r	Activity counts

BRFSS, Behavioral risk factor surveillance system; *CCHS*, Canada community health survey; *EE*, energy expenditure; *GINA*, Global Initiative for Asthma; *IPAQ*, International physical activity questionnaire; *kcl*, kilocalorie; *LTPA*, leisure time physical activity; *MET*, metabolic equivalent task; *MVPA*, moderate to vigorous PA; *n/r*, not reported; *PA*, physical activity; ST, sedentary time.
*These studies did not have a control group, but were included in this table to provide further details of the activity monitors used.

Associations between physical activity or sedentary time and asthma health outcomes

Twenty-seven studies reported associations between the level of activity and asthma health outcomes. Five were longitudinal.[53-57] Associations with sedentary time were addressed in 3 studies.[18,28,47] Table IV reports the main findings of these studies. Further descriptions of these associations are summarized in this article's Online Repository at www.jaci-inpractice.org.

The relationship between physical activity and lung function was assessed in 10 studies.[16-18,21,39,40,42,50,53,55] Weak but significant associations were reported in 8 studies,[16-18,39,42,50,53,55] from which 2 were of longitudinal design.[53,55] Measures of asthma control or asthma-related health status were reported in 13 studies, 12 of them of cross-sectional design.[18,21,22,24,29,33,35,40,42,47,49,51,57] Most of the studies found a positive association between higher physical activity and better clinical outcomes, although in some studies, these associations were attenuated to the null when BMI was included as a confounder.[24,49,51,57] For instance, in their longitudinal analysis, Russell et al[57] reported that the protective effect found for light physical activity on current asthma (defined as reporting asthma symptoms, taking asthma medication, or having an asthma exacerbation in the last 12 months) was no longer significant after adjusting for BMI. Vigorous physical activity was associated with more asthma symptoms in 3 studies.[42,47,57]

Measures of health care utilization were evaluated in 6 studies.[28,31,43,51,54,56] Less physical activity was associated with increased exacerbation and/or higher health care utilization in 4 of them.[28,31,43,56] However, contradicting results were reported in the 2 longitudinal cohorts.[54,56] Positive associations between measures of exercise capacity and physical activity were reported in 2 cross-sectional studies.[18,40] Higher physical activity (steps/day) was associated with lower systemic inflammation (high-sensitivity C-reactive protein) in one study.[18] No significant associations were found between physical activity and measures of eosinophilic airway inflammation.[18]

Higher levels of sedentary time were associated with worse asthma clinical outcomes in 2 cross-sectional studies.[18,28] In one of them, these associations were no longer significant after adjustment for physical activity.[18] Doggett and Dogra[28] reported an increased OR (95% CI) for general practitioner (GP) consultations, 2.59 (2.34, 2.87), and hospitalizations in the past year, 1.95 (1.82, 2.08), and past 5 years, 1.13 (1.07, 1.18) ($P < .001$ for all results) for adults with asthma who reported >10 hours of television time/week compared with those who reported ≤10 hours.

TABLE IV. Association between physical activity and sedentary time with asthma outcomes

Citation	Outcome measures	Conclusions
Bacon et al 2015[24]	PA, ACQ, and AQLQ	Participants engaging in high levels of PA (20.1 ± 8.9 METs h/wk) were nearly 2.5 times more likely to have good control (ACQ $\leq$ 0.8) compared with inactive patients (AOR [95% CI] 2.47 [1.06-5.73]). Results for AQLQ were not significant
*Bahmer et al 2017[16]	Steps, spirometry, body plethysmography, impulse oscillometry	Decreased PA in asthma is associated with airway resistance and small airway dysfunction, but not with airway limitation
Brumpton et al 2016[53]	PA, lung function decline	Less decline in FEV_1/FVC in active participants with asthma than inactive participants with asthma (FEV_1/FVC [%]: −0.14 [−0.27, −0.01] [$P = .03$])
*Bruno et al 2016[17]	PA, FEV_1/FVC, fat free mass (FFT) and intracellular water (ICW)	PA positively correlated with FEV_1/FVC (Rho = 0.34 [$P < .05$])
*Cordova-Rivera et al 2017[18]	ST, MVPA, Steps, 6MWD, spirometry, ACQ, AQLQ, hs-CRP, FeNO, sputum eosinophilia	Higher levels of PA and lower levels of ST were positively associated with most of the clinical/biological outcomes, especially for steps and exercise capacity (coeff [95% CI] 0.02 [0.00 to 0.04]; $P < .01$) and systemic inflammation, and MVPA and ACQ (coeff [95% CI] −1.94 [−3.69 to −0.18]; $P = .032$)
Doggett and Dogra 2015[28]	ST (TV time), PA, health care use	High levels of TV time associated with: more consultations (AOR [95% CI] 2.59 [2.34-2.87]), hospital stays in the last year (AOR 1.95 [1.82, 2.08]), and in the past 5 years (AOR = 1.13 [1.07, 1.18]) Insufficient PA associated with higher health care use: hospital stays in the past year (AOR 1.16 [1.08, 1.23]) or past 5 years (AOR 1.22 [1.16, 1.28])
Dogra and Baker 2006[29]	PA (EE), self-reported measures of health	Higher PA associated with better self-reported health outcomes
Dogra et al 2009[31]	PA (EE), health care use	Lower PA levels associated with higher health care use in people with asthma: overnight hospital stays (AOR [95% CI] 1.78 [1.31, 2.41]); $\geq$3 GP consultations (AOR 1.26 [1.03, 1.55])
Fisher et al 2016[54]	PA, asthma readmission	No association between PA and asthma hospital readmissions in people with asthma
Ford et al 2004[33]	PA, QoL	Physical inactivity (compared with VPA) significant independent predictor of impaired QoL: poor or fair health OR (95% CI) 2.36 (1.72, 3.22); >14 d with activity limitation: 2.76 (1.89, 4.02); >14 d physically or mentally limited: 1.90 (1.59, 2.32)
Garcia-Aymerich et al 2009[56]	PA (METs h/wk), asthma exacerbation	Higher levels of PA associated with a lower risk of asthma exacerbation
Garcia-Aymerich et al 2007[55]	Levels of PA, lung function decline	MVPA in participants with asthma improved lung function decline by gaining 10 and 7 mL/y of FEV_1 and FVC, respectively, compared with the low PA group (significance not reported)
Iikura et al 2013[35]	PA and asthma control test (ACT)	In MVRA, periodical PA (>3 METs h/wk) was significantly associated with better asthma outcome (coefficient = 0.152, $P = .002$)
Mancuso et al 2007[40]	PA (EE), 2MWT, CRT, asthma control (ACQ), severity, and lung function (spirometry)	PA positively correlated with physical performance in both test (2MWT Rho = 0.38; CRT Rho= −0.39) In MVRA, better asthma control associated with more EE from walking, but not with total EE. FEV_1 associated with PA only in SLRA
Malkia and Impivaara 1998[39]	PA intensity (METs), lung function (spirometry)	Weak but significant positive correlations of PA intensity and lung function in men only (Rho FEV_1 = 0.26; PEF = 0.35)
Ritz et al 2010[42]	PA intensity, lung function (spirometry), SOB, social activity, inhaler use	Higher PA levels associated with higher PEF, higher FEV_1 in the morning and evening only, and more SOB

(continued)

TABLE IV. *(Continued)*

Citation	Outcome measures	Conclusions
Russell et al 2016[57]	PA with follow-up current asthma (CA) and asthma symptoms (AS)	LPA ≥3 times/wk at baseline associated with less follow-up CA (OR [95% CI] 0.44 [0.22, 0.89]). Result attenuated by BMI. Result for VPA > 0.05 Asthma participants with normal BMI show a significant reduction of AS associated with PA, whereas the overweight and obese category did not
Strine et al 2007[43]	Inactivity and measures of asthma severity	People with asthma who were inactive had significantly poorer control compared with those who were not: >3 ER/y (AOR [95% CI]:2.4 [1.6, 3.6]); GP visit/year (AOR: 1.5 [1.1, 2.0]); absenteeism >2 wk/y: (AOR: 1.7 [1.3, 2.0]); daily symptoms (AOR: 2.5 [1.9, 3.4]); inhaler 30+ times/mo (AOR: 1.9 [1.5, 2.5])
*Van't Hul et al 2016[21]	PA, ACQ, AQLQ, and lung function (spirometry)	Low PA was correlated with poorer asthma control. No correlation between spirometry and PA (value not reported). Nil reference regarding AQOL
*Vermeulen et al 2016[22]	Steps/d, activity limitation (ACQ question 3)	No correlation found between PA and activity limitation
Verlaet et al 2013[47]	PA or daily sitting time (ST), and asthma control (CARAT Questionnaire)	MPA and ST predictor of controlled asthma in men: AOR (95% CI) 1.84 (1.02, 3.30); OR: 1.87 (1.06, 3.28), respectively. VPA doubled the risk of uncontrolled asthma in women: AOR: 1.94 (1.13-3.35)
Westermann et al 2008[49]	Exercise habits, asthma severity, and asthma control (ACQ)	Higher BMI was more closely associated with exercise habits than were asthma control and severity, after adjusting for demographic variables
Yamasaki et al 2017[50]	PA, measures of oxidative stress, and antioxidants in blood, spirometry, FeNO, serum levels of vitamins, dietary vitamin intake	Significant correlations only for PA (activity counts/minute) and FEV_1/FVC
Yawn et al 2015[51]	Volume and intensity of PA, asthma control (APGAR), exacerbations	Low PA associated with asthma control only in SLRA

2MWT, 2-min walk test; *6MWD*, 6-min walk distance; *ACQ*, asthma control questionnaire; *AHR*, adjusted hazards ratios; *AOR*, adjusted odd ratio; *AQLQ*, asthma quality of life questionnaire; *BMI*, body mass index; *CI*, confidence interval; *CRT*, chair raise test; *EE*, energy expenditure; *ER*, emergency room; FEV_1, forced expiratory volume in the first second; *FeNO*, fraction of exhaled nitric oxide; *FVC*, forced vital capacity; *GP*, general practitioner; *hs-CRP*, high-sensitivity C-reactive protein; *LPA*, light PA; *LTPA*, leisure-time PA; *MET*, metabolic equivalent task; *MVPA*, moderate and vigorous PA; *MVRA*, multi-variable regression analysis; *OR*, odds ratio; *PA*, physical activity; *PAL*, physical activity level; *QoL*, quality of life; *RM*, repetition maximum; *SLRA*, simple linear regression analysis; *SOB*, shortness of breath; *ST*, sedentary time; *Steps*, average steps/day; *VPA*, vigorous PA.
*Studies using activity monitors.

DISCUSSION

This review summarizes the literature in relation to the prevalence of physical activity and sedentary time in people with asthma, and the associations between these behaviors and different disease outcomes. We found that people with asthma undertake less physical activity than people without asthma, and that the level of activity in asthma seems to be influenced by age, sex, and disease severity.

We also found that people with asthma average 8390 steps/day. This is almost double the value observed in COPD, where an average of 4579 steps/day were reported ($FEV_1\% < 50\%$ in 55% of studies included).[59] This suggests that although physical activity may be reduced in asthma, the degree of reduction is not as severe as in COPD. Nevertheless, there are subgroups in the asthma population where physical activity is lower.[16-18,21] The 2 studies including people with severe asthma reported a median of around 5800 steps/day.[16,18] Therefore, the estimate of 8390 steps may not be a value applicable to more severe populations. However, considering that this is the first meta-analysis of steps performed in adults with asthma, and that the objective measurement of physical activity in asthma is a fairly recent topic, this value provides a reference that can be updated and developed with future studies.

We found that physical activity seems to be influenced by sex. Several studies reported better activity outcomes in men with asthma compared with women. Similar findings have been reported in children with asthma compared with controls, suggesting that lower levels of activity are only present in women.[60,61] In the general population, it has also been found that both girls[62] and adult females[63,64] do less activity than their male counterparts. However, the fact that the decline in activity in middle-aged and older people with asthma is seen earlier in women[27,30] may suggest that the disease consequences are more severe or have a greater impact on health in females. Supporting this observation is evidence suggesting that among people with similar asthma severity, women tend to have poorer self-reported measures of asthma control and health status[65] and are twice as likely to be admitted to hospital because of acute asthma.[66] From a societal perspective, this sex difference could also be due to changes in physical activity after retirement, with women retiring at an earlier age.[30]

We also identified a potential effect of age on the level of physical activity, showing that the decrease in activity is more pronounced, or even exclusive, in the older asthma population.[27,32,37,46] This is in line with evidence that younger people with asthma engaged in similar[15] or higher[61,67] levels of activity

TABLE V. Activity outcomes from activity monitors

		Steps per day			Volume/intensity of PA or sedentary time (min* or h†/d)		
	N	**Asthma**	**Controls**	***P* value**	**Asthma**	**Controls**	***P* value**
Bahmer et al 2017[16]	SA: 63 MA: 83 C: 29	SA: 6,174 (4,822-9,277) MA: 7,841 (6,534-10,252)	8,912 (6,800-11,127)	**<.001**	MVPA* SA: 125 (68-172) MA: 151 (99-197)	163 (110-207)	**<.05‡**
Bruno et al 2016[17]	A: 24 C: 18	10,434 ± 3,813	10,860 ± 3,042	>.05	PA*: 69.7 ± 84.2 AEE: 335 (380)§ kcal/d	93.2 ± 101 486.7 (435)	**.04** **.04**
Cordova-Rivera et al 2017[18]	SA: 61 C: 61	5,362 (3,999-7,817)	7,817 (6,072-10,014)	**.0002**	ST* 674.4 ± 71 LPA* 193 ± 57.5 MVPA* 21.9 (12.8-37.9)	676.2 ± 65 171 ± 50.6 41.7 (29.3, 65.8)	>.05 **.029** **<.0001**
Moore et al 2015[19]	A: 16 C: 16	11,125 ± 5,487	10,711 ± 2,675	>.05	n/a	n/a	
Scott et al 2013[20]	A: 33	8,341 ± 3,377	n/a		n/a	n/a	
Van't Hul et al 2016[21]	A: 226 C: 201	7,593 (7,155-8,030)	8,795 (8,326-9,263)	**.001**	Sitting†: 8.21 (7.95-8.48) PAL: 1.53 (1.51-1.55) LPA†: 1.7 (1.65-1.88) MPA†: 1.66 (1.58-1.74) VPA†: 0.34 (0.30-0.38)	8.6 (8.29-8.86) 1.57 (1.55-1.59) 1.91 (1.80-2.02) 1.64 (1.55-11.7) 0.45 (0.41-0.49)	>.05 **.034** >.05 >.05 **<.001**
Vermeulen et al 2016[22]	A: 20	10,159 ± 3,751	n/a		MET 0-3 (% time): 87.2 MET 3-6 (% time): 12.07	n/a	
Yamasaki et al 2017[50]	A: 18	n/a	n/a		*Activity counts: 283.3 ± 81.1	n/a	

Results expressed as mean ± standard deviation or median (IQR). Statistically significant results are in bold ($P < .05$).
A, Asthma; *AEE*, active energy expenditure; *C*, controls; *IQR*, interquartile range; *kcal*, kilocalories; *LPA*, light physical activity; *MA*, mild to moderate asthma; *MET 0-3*, metabolic equivalent task of light PA; *MET 3-6*, metabolic equivalent task of moderate PA; *MPA*, moderate PA; *MVPA*, moderate and vigorous physical activity PA/day; *n/a*, not assessed; *PA*, physical activity; *PAL*, physical activity level; *SA*, severe asthma; *ST*, sedentary time; *VPA*, vigorous PA.
*Reported as min/d.
†Reported as h/d.
‡*P* value for the whole asthma sample compared with healthy control.
§Reported as median (IQR) by the authors.

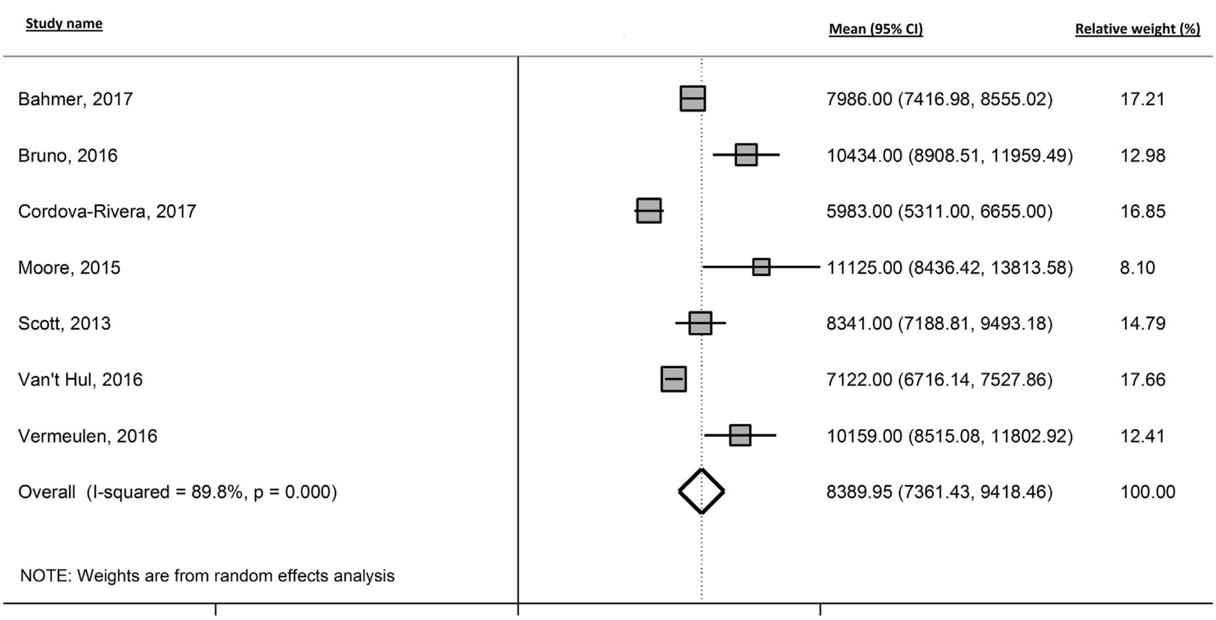

FIGURE 2. Forest plot of standardized mean (95% CI) for steps/day. Authors Bahmer et al, Scott et al, and Van't Hul et al were contacted, and they provided the mean and standard deviation of their results.

compared with their age-matched controls. Plausible biological reasons could relate to the age-related changes in the lung leading to an increased work of breathing that are more extreme in people suffering from respiratory morbidity. Furthermore, older people with asthma are likely to have a longer duration of disease, and therefore, may have more airway remodeling resulting in incomplete reversibility of airflow limitation.[68] It is also worth mentioning that in the last 30 years, there has been a growing body of evidence that supports the adherence to exercise in people with asthma. This contradicts previous beliefs that people with asthma should avoid exercise and physical activity.[69] It is likely that the age effect identified in this review is linked to this paradigm shift. Finally, people more than 50 years of age with obstructive airway disease show a high degree of overlap in features of both asthma and COPD,[68] so it is possible that the activity levels of older people with asthma could be similar to that of COPD populations,[5,6,59] a finding that requires further investigation and may focus on physical activity interventions to an older age group.

In terms of the associations with physical activity, there was a trend showing that higher physical activity was modestly associated with better lung function in people with asthma. In 2 longitudinal studies, a trend toward a slower lung function decline in active people with asthma compared with inactive people was reported.[53,55] Studies carried out in the general population[70,71] have suggested that this positive impact may be due to the counteracting effect that physical activity may have on the age-related chest wall stiffening,[70] or to a potential positive impact on inspiratory muscle endurance.[72] Among the cross-sectional studies, the results were less consistent. Interestingly, in 2 of the studies reporting a positive association between spirometric values and physical activity,[17,42] participants were relatively young (mean age <39 years), with moderate disease severity, whereas studies in severe or uncontrolled asthma population did not find an association.[16,21] A systematic review of RCTs of physical training in asthma[73] concluded that exercise was not significantly associated with spirometric parameters. Similarly, in COPD, spirometric values have shown a weak-to-moderate association with physical activity.[74] Bahmer et al[16] reported that airway resistance and small airway dysfunction were better markers of physical activity than spirometric values in moderate and severe asthma participants. Whether the association between airflow limitation and physical activity is modulated by time since diagnosis or disease severity needs further investigation.

Some studies reported a positive association between physical activity and asthma control[18,21,24,35,47] or health status,[18,33] which is in line with studies reporting the beneficial impact of exercise protocols on these clinical outcomes.[75-78] In some studies, however, the strength of these associations was attenuated to the null when confounders such as BMI were included,[24,49,51,57] which suggests that the association between obesity and asthma control is stronger than the association between activity and asthma control. Studies addressing the relationship between current or incident asthma, BMI, and physical activity have shown similar results.[25,58] Nevertheless, another study found that the association between asthma control and MVPA was still significant after adjusting for BMI, among other confounders.[18] This suggests that MVPA may still have a modest but independent positive effect on asthma control, in addition to its important role in weight management.[79] Some authors also found an increase in asthma symptoms due to engagement in vigorous physical activity.[42,47,57] Similar findings have been previously reported, especially in females.[61,67] A link between strenuous exercises (a component of vigorous physical activity) and the development of EIB or exercise-induced asthma symptoms has been well documented in the literature.[80,81] In fact, a dose-response relationship has been proposed, where both very low levels of activity (inactivity) and vigorous activity are associated with higher risk of asthma symptoms, whereas exercise carried out at a moderate level shows a protective effect.[81]

In terms of the association with asthma exacerbation and health care use, Garcia-Aymerich et al[56] found a longitudinal dose-related protective effect of physical activity on risk of hospital admission for asthma exacerbation. Fisher et al[54] did not observe a significant association between activity engagement and risk of readmission in people with asthma. However, they observed the same pattern in the COPD population, and attributed this lack of association to the small number of participants with asthma and COPD at baseline. Longitudinal studies in COPD have found that physical inactivity is strongly related to acute exacerbations resulting in hospitalization, reduced length of time until admission for an exacerbation, and increased all-cause mortality.[7-10] The body of evidence for asthma is considerably less, and unlike studies conducted in COPD,[9,10] very few have relied on objective physical activity measures to assess the associations of this behavior with disease outcomes.

Data on exercise capacity were scarce,[18,40] but the available evidence suggests that physical activity, especially steps, is positively associated with functional exercise capacity. Interestingly, a weaker effect was observed for MVPA that may suggest that the biggest benefits are obtained by engaging in light to moderate, but more continuous physical activity, rather than shorter but intense periods.[18] Exercise training in patients with asthma can improve cardiopulmonary fitness, assessed by the direct oxygen consumption,[73] and exercise capacity measured by the 6-minute walk distance improves immediately after a 6-week exercise program (3 weekly supervised sessions of walking training and strength exercises) and at 3 months' follow-up.[77] In an RCT, improvement in aerobic capacity and weight loss were independently associated with improvements in asthma control.[82] This highlights the potential benefit of promoting physical activity as a way to improve different impairments in asthma, which despite of being assessed as different clinical outcomes, still affect the person in multiple dimensions of the disease.

Fewer studies have examined sedentary time in asthma. Both studies using activity monitors did not find significant differences between people with asthma and controls,[18,21] but both groups were highly sedentary. A third study[28] reported that people with asthma had higher time watching television than controls. However, in this study, a self-reported proxy of sedentary time was used. Higher sedentary time was associated with decreased exercise capacity, lung function, and asthma control,[18] but these associations were attenuated to the null when physical activity was included as a confounder. This suggests that the deleterious effect of sedentary time may be overcome when engaging in some physical activity.[83] Nevertheless, promoting frequent and longer breaks of sedentary time may be a more achievable goal than increasing activity levels in people with obstructive airway disease. In COPD, there are data linking objectively measured sedentary behavior as an independent predictor of mortality.[84] Studies measuring sedentary time with postural-based accelerometers[85] are required to explore to what extent sedentary time is occurring in asthma and whether it is associated with poorer asthma outcomes.

Strength and limitations

This review followed a structured search protocol and used several electronic databases. Since the review of Eijkemans et al,[14] there have been a growing number of studies addressing the prevalence of physical activity in asthma. In addition, the use of activity monitors in asthma is a relatively new topic, and was not addressed in the previous review. Our review also adds to the literature summarizing the evidence of the impact of physical activity on different asthma outcomes. Furthermore, to our knowledge, there is no review reporting measures of sedentary time in people with asthma. However, there are some limitations that need to be considered. Our analysis was restricted to studies published in English, and thus we may have missed literature published in other languages. In addition, because we only included studies conducted in adults, these results should not be generalized to children. In terms of the studies included, there was a great deal of heterogeneity in the clinical asthma and activity outcomes measures, as well as population characteristics. Furthermore, most of the studies were of cross-sectional design. Therefore, reverse causation of the associations reported must be considered as a possibility. Finally, most of the studies were performed either in mild or moderate asthma populations, or severity was not reported. As such, the severe asthma population may be underrepresented in this review, but this highlights the need for further research in this more complex population. Nevertheless, this review provides a complete update of prevalence and associations of these 2 behaviors in people with asthma and provides insight of the gaps in the literature that need to be addressed in future studies.

CONCLUSIONS

People with asthma appear to engage in lower levels of physical activity compared with controls. Disease outcomes seem to improve as the volume or intensity of physical activity increase. However, studies that use objective measures of activity, participants with asthma diagnosed according to guidelines,[1] and more standardized measures of clinical asthma outcomes are needed. Also, further studies addressing sedentary time in asthma might help to understand whether this behavior is present, and to what extent it is associated with poorer asthma outcomes. Specifics subgroups, such as those more than 50 years old, and those with severe asthma are underresearched, and an understanding of how age and severity interact in the relationship between activity and asthma clinical or biological outcomes is needed. Longitudinal studies and RCTs exploring the direction of the relationships between physical activity and asthma outcomes are also needed to improve the consistency of the evidence. The results of this review strongly support the need to undertake this research.

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ONLINE REPOSITORY
ASSOCIATIONS BETWEEN PHYSICAL ACTIVITY AND SEDENTARY TIME AND ASTHMA HEALTH OUTCOMES

Twenty-seven studies reported associations between the level of activity and asthma health outcomes. Five were longitudinal.[E1-E5] Associations with sedentary time were addressed in 3 studies.[E6-E8] Table IV reports the main findings of these studies.

LUNG FUNCTION

The relationship between physical activity and lung function was assessed in 10 studies.[E1,E3,E8-E15] Weak but significant associations were reported in 8 studies,[E1,E3,E8,E9-E13] from which 2 were of longitudinal design.[E1,E3] Brumpton et al[E1] reported that active people with asthma had a slower decline in lung function at follow-up compared with inactive individuals. The mean decline in the forced expiratory volume in 1 second/forced vital capacity ratio was 0.36% and 0.22% per year among inactive and active participants with asthma, respectively ($P = .03$). Bahmer et al[E9] reported that fewer steps/day were associated with increased airway resistance and small airway dysfunction. Van't Hul et al[E14] did not find any correlation between measures of physical activity and spirometric assessments.

ASTHMA CONTROL AND HEALTH STATUS

Measures of asthma control or asthma-related health status were reported in 13 studies,[E5,E7,E8,E12,E14-E22] 12 of them of cross-sectional design.[E7,E8,E12,E14-E22] The results suggest that higher levels of moderate and vigorous physical activity (MVPA) were associated with better asthma control. However, vigorous physical activity was also associated with more asthma symptoms.[E5,E7,E12] Bacon et al[E16] concluded that participants who engaged in the recommended levels of activity were almost 2.5 times more likely to have good asthma control compared with less active participants (adjusted odds ratio [OR] 2.47; 95% confidence interval [CI] 1.06, 5.73). Cordova-Rivera et al[E8] also found a positive association between higher volume of MVPA and better asthma control even after adjusting for the time spent sedentary and confounders such as body mass index (BMI), age, and smoking status. The authors report that a 15-minute increase in MVPA was associated with an improved asthma control questionnaire score of −0.29 units ($P = .032$, adjusted R^2 for the model: 0.18). Russell et al[E5] found that physical activity was positively associated with asthma symptoms only in participants with normal weight (BMI < 25), whereas this was not observed in participants with a BMI ≥25. In addition, in their longitudinal analysis, the relationship between baseline light activity and follow-up current asthma (defined as reporting asthma symptoms, taking asthma medication, or having an asthma exacerbation in the last 12 months) was attenuated to the null after adjusting for BMI.

Among studies reporting negative effects of activity, Verlaet et al[E7] found that vigorous activity doubled the risk of uncontrolled asthma in females (adjusted OR [95% CI] 1.94 [1.13, 3.35]; $P < .05$), and in their longitudinal analysis, Russell et al[E5] found a nonsignificant negative trend on current asthma from higher engagement in vigorous physical activity (adjusted OR [95% CI]) of current asthma for 1 to 2 vigorous activity sessions/week: 0.75 (0.38, 1.46) versus >3 sessions/week: 1.03 (0.42, 2.49).

In terms of health status, Ford et al[E18] reported that inactive people with asthma were more than twice as likely to report poor or fair health compared with those doing regular vigorous activity (OR [95% CI] 2.36 [1.72, 3.22]).

EXACERBATION AND HEALTH CARE USE

Measures of health care utilization were evaluated in 6 studies,[E2,E4,E6,E21,E23,E24] 2 of which were longitudinal cohorts.[E2,E4] In 4 studies, less physical activity was associated with increased exacerbation and/or higher health care utilization.[E4,E6,E23,E24] A longitudinal study involving women with asthma[E4] demonstrated that the higher the level of activity performed, the lower the risk of admission for exacerbation ($P = .05$ for trend). Strine et al[E23] reported that inactive people with asthma were more likely to have ≥3 visits to the emergency department for asthma in the last year (adjusted OR [95% CI] 2.4 [1.6, 3.6]) compared with their active peers.

Conversely, Fisher et al[E2] did not find any association between readmission for asthma (mean follow-up 16 years) and participation (yes/no) in physical activity. However, they reported a nonsignificant trend in the association between readmission for asthma and the time spent in activity. Participants engaging in >4 hours/week of gardening and cycling had a 10% and 22% reduced risk of readmission for asthma, respectively, compared with participants spending <4 hours (hazard ratio [95% CI] for gardening 0.90 [0.58, 1.39] and cycling 0.78 [0.49, 1.25]).

EXERCISE CAPACITY

Measures of exercise capacity were evaluated in 2 cross-sectional studies.[E8,E15] Cordova-Rivera et al[E8] found that steps/day were strongly associated with the 6-minute walk distance, even after adjustment for sedentary time and other confounders. The authors reported that every 1000-step/day increase was associated with an increased 6-minute walk distance of 20 m ($P = .01$, adjusted R^2 for the model: 0.35).

BIOLOGICAL MARKERS

There was a significant association between steps/day and systemic inflammation (high-sensitivity C-reactive protein [hs-CRP]) in one of the studies. The authors report that every 1000-step increase was associated with a decrease of hs-CRP of 17%, after adjusting for sedentary time and other confounders. The same study did not find a significant association between MVPA and hs-CRP. No significant association was found between physical activity and measures of eosinophilic airway inflammation.[E8]

SEDENTARY TIME AND HEALTH OUTCOMES

Detrimental associations between sedentary time and outcomes such as exercise capacity, lung function, and asthma control were reported in one cross-sectional study.[E8] However, these associations were no longer significant after adjustment for physical activity. Doggett and Dogra[E6] reported an increased OR (95% CI) for GP consultations, 2.59 (2.34, 2.87), and hospitalizations in the past year, 1.95 (1.82, 2.08), and past 5 years, 1.13 (1.07, 1.18) ($P < .001$ for all results), for people who reported >10 hours of television time a week compared with those who reported ≤10 hours.

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