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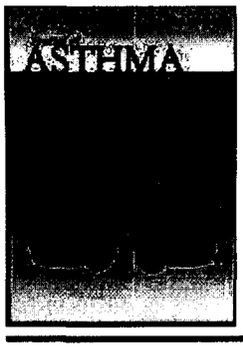

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REVIEW

The difference in amount of physical activity performed by children with and without asthma: A systematic review and meta-analysis

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Abstract

Objective: Despite the benefits of a physically active lifestyle, some studies suggest fear of exacerbations by both children and their parents limit physical activity in children with asthma. We undertook a systematic review to quantify the difference in objectively measured physical activity levels of children and adolescents with and without asthma. *Data Sources*: MEDLINE, PubMed and EMBASE. *Study Selection*: English language observational studies of children and adolescents to the age of 18 that compared objectively measured physical activity (accelerometer or pedometer devices) between those with asthma and without asthma. *Results*: Overall 22,285 articles were retrieved with 12 studies being included in the review: 1 cohort, 1 case-control and 10 cross-sectional. A meta-analysis of accelerometry data from the single cohort study and 8 cross-sectional studies produced an overall mean difference of 0.01 (95% CI: −0.09–0.11) activity counts per minute in children and adolescents without asthma compared to those with asthma. *Conclusion*: We did not find any evidence that children and adolescents with and without asthma engaged in different amounts of physical activity when measured objectively by accelerometers. Children and adolescents with asthma may not require differentially targeted policies to encourage more physical activity, however further longitudinal studies are needed.

Keywords

Physical activity, asthma, systematic review, child

History

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Introduction

Regular physical activity has substantial short- and long- term physical and mental health benefits for all age groups [1]. In children and adolescents, these benefits can endure into adulthood [1]. As a result, the World Health Organisation (WHO) and national health departments recommend that children and adolescents aged between 5 and 17 years should engage in at least 60 minutes of moderate- to vigorous- physical activity daily [2, 3]. However, globally many children and adolescents fail to reach these targets [4].

Whilst there are currently no guidelines for physical activity specifically for children with asthma, a recent update published by the Global Initiative for Asthma (GINA) recommends that children with controlled asthma should be encouraged to exercise [5, 6] because regular aerobic exercise improves the management of asthma symptoms [7, 8] and lung function (peak expiratory flow in one second (PEF), forced expiratory volume in one second (FEV_1), and forced expiratory flow (FEF_{25})) [9], as well as incurring other health benefits including improvement of cardiovascular and bone health and reducing the risk of diabetes, stroke and depression [10].

In enacting these recommendations, it is important to know whether physical activity levels are actually lower in children and adolescents with asthma compared to those without asthma. Some qualitative studies suggest that fear of exacerbations by both children and their parents may limit the duration, frequency and intensity of physical activity in children with asthma [6, 7, 9, 11–13], however the results of these qualitative studies are inconsistent [12, 14–18]. A review published by Williams *et al.* in 2008 also concluded that children with asthma find it difficult to be as physically active as children without asthma [19]. However this review was a narrative rather than systematic review and did not include studies with objective measures of physical activity [19].

To determine the impacts and effects of physical activity on health outcomes, it is necessary to obtain an accurate and reliable assessment of habitual physical activity [20]. Measuring physical activity objectively is important to overcome potential reporting and recall biases associated with subjective measurements such as questionnaires, particularly in children. Physical activity in children tends to occur in brief and intermittent bouts of activity which can be difficult to accurately recall

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and quantify [21–23]. Furthermore a proxy reporter such as a parent or teacher is often called upon in questionnaires to provide an estimate of the child's activity, however, these proxies are unlikely to be able to accurately describe a child's activity profile throughout the whole day [22]. The use of accelerometers can help to overcome some of these pitfalls, and provide a more accurate measure of habitual physical activity in children.

Accelerometers are devices able to detect acceleration produced by the body when in motion [24]. Once an acceleration is detected by a sensor, a proportional voltage signal is generated and recorded as a "raw count" [24]. Several studies have investigated the validity of accelerometers in children, and have found them to be valid against energy expenditure [25–27]. However, whilst they do not eliminate all measurement bias, accelerometers appear to be the best choice for objective measurement of physical activity in epidemiological studies of children [28].

To our knowledge there have been no systematic reviews that have investigated the difference in objectively measured physical activity in children or adolescents with and without asthma. Therefore, in this systematic review we aimed to identify and collate the available scientific evidence of objectively measured physical activity to investigate whether children and adolescents with asthma are less physically active than their peers. If there is evidence that children with asthma engage in less physical activity, there may be a need for specific physical activity recommendations to counter barriers to exercise in this group of children and adolescents.

Methods

Search strategy

We conducted an electronic search for publications in 3 databases (MEDLINE, PubMed and EMBASE) to obtain all articles that investigated the relationship between physical activity and asthma from inception to 5th August 2015 for PubMed and Medline, and from inception to 18th August 2015 for EMBASE. A final search of the 3 databases was conducted on 19th December 2015. The key terms employed in the searches were "physical activity", "physical training", "exercise", "sedentary", "asthma", "early life wheeze" and "transient wheeze", and appropriate MeSH terms. Terms were combined using the Boolean operators "OR" and "AND" (see appendix for full details). Reference lists of published articles were checked to ensure that all relevant articles were included.

Screening of articles

Articles were first screened using the inclusion and exclusion criteria specified below by title and abstract. Finally, the full texts of manuscripts were reviewed and excluded if they failed to meet the inclusion criteria. Titles, abstracts and data extraction of the retrieved articles were independently screened by two investigators (RC and BCVS). Disagreements were resolved by a third investigator (MR).

Exclusion and inclusion criteria

We included observational studies where the exposure variable was the presence or absence of asthma, and the outcome was physical activity. We limited the review to include only those studies which measured physical activity objectively by use of an accelerometer or pedometer. Only English language studies that reported associations in children or adolescents with and without asthma between birth and 18 years of age were selected for inclusion in this review. Letters or reviews that did not present original data, and animal and *in vitro* studies were excluded.. There were no restrictions on date of publication.

Confounding variables

Several variables were identified as *a priori* potential confounders of the relationship between asthma and physical activity. The included studies were checked for adjustment for these variables: gender, age, socioeconomic status, parental asthma, number of siblings and pet ownership.

Data extraction

The following information was extracted from each included article: author, date of publication, location of study, the study population age and gender, whether cross-sectional, case-control or cohort design, length of follow up if longitudinal design, definition of the exposure and tool used to measure the exposure, type of accelerometer used to measure the outcome, length of time the accelerometer was worn, measurement units and cut off points for the categorisation of physical activity, level of asthma control, the confounding variables considered in the analysis, the unadjusted and adjusted results, and the author's conclusions. The authors of ten articles were contacted to request mean and standard deviation activity data for children with and without asthma for inclusion in this analysis [14, 29–37]. Four authors responded and provided the requested data [14, 29, 31, 32]. However 2 of these articles [29, 31] used data from a previously identified study [38], hence we only included the primary article that focused on the difference in physical activity between adolescents with and without asthma [38].

Quality assessment

Included papers were assessed using the Newcastle-Ottawa Scale (NOS) [39]. The NOS is a tool to assess the methodological quality of cohort and case-control study designs. The NOS rates studies on several design-specific criteria, including: the definition of the exposed and unexposed groups, selection and representativeness of exposed and unexposed groups, comparability, and assessment of both the exposure and outcome variables of interest. Cohort and case-control studies could be awarded a maximum of nine points. A modified version of the NOS that has been used in other publications [40–42] was then used to assess the cross-sectional studies. Using our modified NOS scale for cross-sectional studies, studies could be awarded a maximum of 8 points.

Meta-analysis

Mean and standard deviation of the mean raw physical activity counts as measured by accelerometer for both children with and without asthma were compared. Where articles presented confidence intervals of the mean, data were transformed into mean and standard deviation. Data were pooled with a both

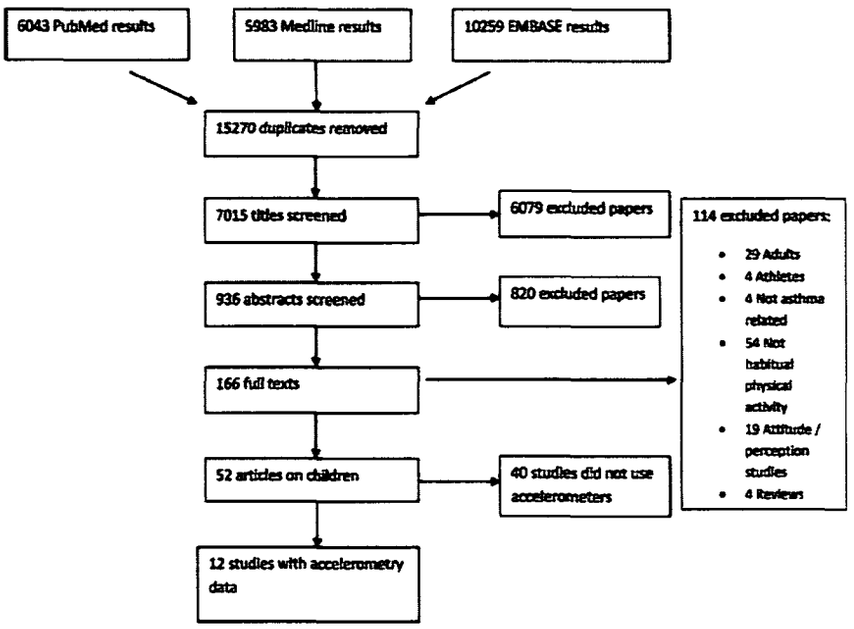

Figure 1. Flow chart of articles through the search process.

fixed and random effect models. An I^2 value of 70% or greater was chosen to indicate a substantial amount of heterogeneity. A meta-regression was not performed due to insufficient number of included studies [43]. A funnel plot was used to investigate potential publication bias. Stata 12 (StataCorp. College Station Texas) statistical package was used for all analyses.

Results

Search results

The 3 databases searched retrieved 22,285 results of which 15,270 duplicates were deleted. Of the 116 full text articles examined, 52 studies were conducted in child or adolescent populations. Ultimately, 12 manuscripts measured physical activity objectively through the use of an accelerometer were included for analysis in this review [14, 30, 32–34, 37, 38, 44–48] (Figure 1).

Description of included studies

Study design

The extracted information from the 12 included articles were collated (Table 1). Ten manuscripts were cross-sectional studies [30, 33, 34, 36–38, 44–47], 1 was a case-control [32] and 1 was a cohort study [14]. This review presents data collected from a total of 5797 children and adolescents between the ages of 2 and 14. Sample sizes ranged from 1614 children in a population based cross-sectional study by van Gent et al. [33] to 2 cross-sectional analyses with 54 children each [30, 49].

Participants

The case-control study [32] and seven of the ten cross-sectional studies were conducted in children and adolescents aged between six and 14 years [33, 34, 36, 38, 45–47]. Three cross-sectional studies were conducted in children between the ages of 3 and 5 years [30, 37, 44]. The cohort study followed children from birth until the age of 5 years [14].

Populations

The included studies were conducted in Brazil [32], Cyprus [47], the Netherlands [14, 33], Denmark [37, 46], Norway [38] and the United States America [30, 34, 36, 44–46]. The cohort study was drawn from a larger, population-based, birth cohort study – the KOALA study- in which information about wheeze and doctor's diagnosis of asthma was collected through questionnaires at the age of seven months, then again at the ages of 1, 2, 4 and 5 years. Accelerometry data were then collected from 305 children at the age of 4 or 5 [14]. The case-control study recruited children who presented with asthma from a hospital as cases, and children of the hospital employees were recruited as healthy controls [32].

Three of the 10 included cross-sectional studies were conducted in subsets of the population: females [34], children with obesity [36] and children with maternal asthma [37]. The remaining cross-sectional studies were conducted on population-based samples [30, 33, 38, 44–47].

Physical activity assessment

Physical activity data were collected by accelerometry in all studies except one, which used a pedometer [34]. The most widely reported outcome measure was raw activity counts [14, 30, 32, 33, 37, 38, 44–47], produced when accelerometers convert accelerations into "counts" and add them over a selected time interval [21]. Other studies transformed accelerometer activity counts into metabolic equivalent values (METs) through the use of regression equations [50] and reported these as well [14, 30, 33, 38, 44–47]. Cut-off points for sedentary activity, light, moderate, vigorous and moderate-to-vigorous levels of physical activity varied greatly between studies (Table 2).

Asthma assessment

Three studies looked and "asthma ever" [30, 37, 48] and 5 looked at "current asthma", usually within the last 12 months

Table 1. Summary of studies that contained accelerometry data for physical activity in asthmatic and control children.

Author, Date, Country	Population	Physical Activity	Asthma Measurement	Confounders	Results	Author's Conclusions
			Population-based cohort studies			
Eijkemans (2008), The Netherlands [14]	305 children followed from birth to age 5 yrs	Actigraph (Actigraph, FL) Accelerometer worn for 5 days Questionnaire	Reported doctor's diagnosis and use of asthma medications and symptoms (asthma ever and last 12 months)	Gender, parental asthma, mother's education, others	Total activity (counts/min) Boys recent wheeze GMR: 1.02 (0.90–1.14) Boys past wheeze GMR: 1.11 (1.02–1.20) Boys never wheeze GMR: reference; Girls recent wheeze GMR: 0.98 (0.85–1.13) Girls past wheeze GMR: 1.00 (0.92–1.09) Girls never wheeze GMR: reference	No evidence that wheezing children are less physically active.
			Hospital-based case-control studies			
Sousa (2014), Brazil [32]	121 children aged 7–12 yrs	Power Walker (PowerWalker, Yamax, Japan) Accelerometer worn for 6 days	Doctor's diagnosis (last 6 months)	Matched for age, others	Mean (sd) total activity counts/min: Asthmatics: 6171 (2574), Controls: 5700(1865)	Children with good asthma control had DPA levels similar to children without asthma. More asthmatic children were overweight if sedentary as compared to physically active asthmatic children.
			Population-based cross-sectional studies			
Berntsen (2009), Norway [38]	174 adolescents 13–14 yrs	SenseWear Armband (Bodymedia Inc., Pittsburgh, PA) in Accelerometer worn for 4 days and questionnaire	Reported doctor's diagnosis, use of asthma medication or symptoms (current asthma)	Age, gender, others	MPA (mean, 95% CI): Asthma: 39736 (35828–43643), Controls: 35245 (32543–37947); VPA (mean, 95% CI): Asthma: 16351 (13380–19321), Controls: 14291 (12380–16201)	Hours spent in moderate to vigorous physical activity were similar in asthmatics and non-asthmatics.
Brasholt (2010), Denmark [37]	253 children 5 yrs	Actical (Philips Respironics, Murraysville, Pa) Accelerometer worn for 4 weeks	Doctor's diagnosis (asthma ever)	Age, mother's education, others	Boys ARR: 0.88 (0.79–0.97); Girls ARR: 0.9 (0.85–0.97); Non-asthmatics ARR: 0.9 (0.82–0.98)	No association between physical activity and asthma diagnosis.
Fedele (2014), USA [36]	248 obese children 7–12 yrs	Sensewear Armband (Bodymedia Inc., Pittsburgh, PA) in Accelerometer worn for 7 days	Reported doctor's diagnosis (asthma ever)	Age, gender	Time spent in activity, Mean (SD): Obesity only (controls): 117.91 (75.41) Asthma and obesity: 94.98 (47.98)	Children with both asthma and obesity engaged in less physical activity than children with obesity only (though this was not statistically significant).

(*Continued on next page*)

Table 1. (Continued)

Author, Date, Country	Population	Physical Activity	Asthma Measurement	Confounders	Results	Author's Conclusions
Firrincieli (2005), USA [30]	54 children 3–5 yrs	Actiwatch (Mini Mitter Co., Bend, OR) Accelerometer worn for 6–7 days	Reported asthma diagnosis, medication use and symptoms (asthma ever)	None stated	Data not presented (means)	Children with history of wheezing were significantly less active than non-wheezing children.
Rundle (2009), USA [44]	437 children age 4 yrs	Actiwatch (Mini Mitter Co., Bend, OR) Accelerometer worn for 6 days	Reported doctor's diagnosis or wheeze or use of asthma medications (last 12 months)	Age, gender, others	Mean (sd) Total activity counts/min: Asthma: 686.4 (147.5) Controls: 683.4 (151.8)	Asthma symptoms were not associated with physical activity.
Tsai (2012), USA [49]	54 children 9–11 yrs	Actigraph (Actigraph, FL) Accelerometer worn for 7 days	Reported doctor's diagnosis and medication. (unclear)	Gender, others	Mean (sd) total activity counts/ min: Asthma: 650 (202), Controls: 752 (260)	Children with asthma have similar levels of activity as non-asthmatic children.
van Gent (2007), The Netherlands [33]	1614 children 7–10 yrs	PAM (PAM B.V. The Netherlands) Accelerometer and Questionnaire worn for 5 days	Reported doctor's diagnosis, and FEV variability (last 12 months)	None stated	Mean (95%) MPA: Undiagnosed asthma: 86 (76–95), Diagnosed asthma: 78 (66–90), Controls: 78 (71–85); Mean (95%) VPA: Undiagnosed asthma: 22 (15–25), Diagnosed asthma: 21 (14–28), Controls: 20 (14–21)	No difference in daily physical activity or intensity of physical activity between children with diagnosed asthma, undiagnosed asthma or healthy controls.
Vangeepuram (2014), USA [34]	1182 girls 6–8 yrs	Pedometer worn and Questionnaire answered for 7 days (minimum 4 days)	Reported doctor's diagnosis, asthma symptoms or medication. (asthma ever and last 12 months)	Age, level of caregiver education, others	Pedometer steps (mean, sd): Asthma: 9590 (4348) Control: 10359 (4161)	Did not find strong associations between asthma diagnosis and physical activity.
Vahlkvist (2009), Denmark [46]	214 children 6–14 yrs	RT3 (Stayhealthy, Monrovia, CA) Accelerometer worn for 4 weeks	Reported asthma symptoms, and FEV variability (current asthma)	Matched on age, gender	Total PA counts/min (mean, CI): Asthma 348.3 9325.1–371.5) Control: 362.6 (350.5–374.8)	No statistically significant differences between asthmatics and non-asthmatics in overall daily activity, time spent in high or vigorous activity.
Yiallouros (2015), Cyprus [47]	203 children 8–9yrs	Actigraph (Actigraph, FL) Accelerometer worn for 6 days	Reported doctor's diagnosis (asthma ever and in last 12 months)	Gender, parental education, others	Total PA counts/min (means, 95% CI): Control: 509.5 (497.8–521.2) Inactive asthma: 493.6 (478.6–508.7) Active asthma: 500.2 (476.4–524.0)	No difference in sedentary and physical activity levels in asthmatic and non-asthmatic boys. Girls with active asthma are less active than healthy peers.

PA = Physical activity, MPA = moderate physical activity, VPA = vigorous physical activity, MVPA = moderate-to-vigorous physical activity, BMI = body mass index, GMR = geometric mean ratio.

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Table 2. Definitions for sedentary, light, moderate, vigorous and moderate to vigorous physical activity levels used by the studies included in this review.

Study	Sedentary	Light Physical Activity (LPA)	Moderate Physical Activity (MPA)	Vigorous Physical Activity (VPA)	Moderate-Vigorous Physical Activity (MVPA)
Berntsen (2009) [38]			Not defined		
Brasholt (2010) [37]			Not defined		
Eijkemans (2008) [14]	0 – 363 counts/15sec	364 – 811 counts/15sec	812 – 1234 counts/15sec	>1234 counts/15sec	ND
Fedele (2014) [36]	ND	ND	ND	ND	≥ 3 METs
Firrincieli (2005) [30]	ND	ND	ND	>2000 activity units	ND
Rundle (2009) [44]	≤598 counts/min	599 – 685 counts/min	686 – 773.5 counts/min	>773.5 counts/min	ND
Sousa (2014) [32]	ND	Boys: >15000 steps/day Girls: >12000 steps/day	ND	ND	ND
Tsai (2012) [45]	0 – 49 counts/min	50 – 699 counts/min	700 – 2499 counts/min	>2500 counts/min	ND
Vahlkvist (2009) [46]	ND	ND	3 – 5 METs	≥6 METs	ND
Vangeepuram (2014) [34]	ND	ND	ND	ND	>4.5 MET-hours
van Gent (2007) [33]	ND	ND	3 – 6 METs	>6 METs	ND
Yiallouros (2015) [47]	0 – 99counts/sec	100 – 3200counts/sec	ND	ND	>3200 counts/sec

ND = not defined; METs = metabolic equivalent values.

[32, 33, 38, 44, 46]. Three of these studies looked at both asthma ever and current asthma [14, 34, 47]. With the exception of 2 studies in which physicians diagnosed asthma in participants 37], other included studies relied on parental/child reports of a doctor's asthma diagnosis in conjunction with reports of asthma symptoms and/or use of asthma medication [14, 32, 30, 38, 44, 45, 47]. Two studies measured Forced Expiratory Volume (FEV) variability in addition to reported doctor's diagnosis and reported asthma symptoms [33, 46].

Asthma control

Nine of the 12 included studies mentioned asthma control or severity in their study populations [32–34, 30, 37, 38, 45–47]. Four studies reported good asthma control: two had a range of disease severities but good control [32, 37], one study reported good or partially controlled asthma [45], and one reported good asthma control but did not discuss asthma severity [38]. One study used the ISAAC questionnaire to look at asthma severity [30]. Two studies stratified by diagnosed and undiagnosed asthma [33] or stratified by active and inactive asthma [47] but did not discuss this in terms of asthma severity or control. One study reported the use of asthma controller medications, but did not describe the level of asthma control or severity in their population [34]. One study used the childhood asthma control test (C-ACT) and reported that asthma was not optimally controlled in the study population [46]. Two studies had no discussion of asthma control or severity [14, 44], and one was unable to assess asthma severity [36]. We were unable to perform a meta-analysis that stratified by asthma control due to the high degree of heterogeneity between studies.

Confounding variables

Seven of the included studies adjusted or matched for age [32, 34, 36–38, 44, 46] and gender [14, 36, 38, 44–47]. Four studies adjusted for parent or caregiver education as a proxy for socioeconomic status [14, 34, 37, 47]. One study adjusted for parental asthma [14]. None of the included studies adjusted for number of siblings or pet ownership. Two studies did not report adjustment for any covariates [30, 33].

Findings of the studies included in the systematic review but not the meta-analysis

Three cross-sectional studies could not be included in the meta-analysis as they did not present information regarding the number of children with and without accelerometry data, the mean and standard deviation or confidence interval of the mean [30, 34, 36]. Two of these 3 cross-sectional studies found that children with asthma or wheeze were less active than those without asthma or wheeze [30, 36]. This result was significant in the study by Firrincicli et al. [30] but was not statistically significant in the study by Fedele et al. [36]. Both of these studies were conducted in the United States. The study conducted by Firrincieli et al. had a small sample size of 54 children aged between 3 and 5 years [30], while Fedele et al. had a sample size of 248 children with obesity aged 7 to 12 years [36]. The third study was an analysis of 558 female children conducted in the United States, which found no association between asthma diagnosis and physical activity [34].

Quality assessment of included studies

The cohort [14] scored 8 out of 9 and the case-control [32] scored 7 out of 9 using the NOS. Study scores for the cross-sectional designs ranged from 4 [30] to 8 [47] out of 8 points. Four studies scored 7 [34, 37, 38] or above [47] out of 8, again indicating acceptable quality. The 3 studies that could not be included in the meta-analysis scored 4 [30], 6 [36] and 7 [34] out of 8 points. This suggests that with the exception of Firrincieli et al. [30], 2 of the 3 studies excluded from meta-analysis were of reasonable quality. Table 3 presents the NOS point allocation for each of the included studies.

Results of meta-analysis

Nine studies (8 cross-sectional and 1 cohort) presented mean and standard deviation data (or data from which these measures could be derived) for the amount of physical activity performed by children with and without asthma, as measured by accelerometer and were pooled in a meta-analysis [14, 32, 33, 37, 38, 44–47] (Figure 2). There was no significant difference in mean physical activity level between children with and without asthma (both the fixed and random effect estimate =

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Table 3. Presentation of the allocation of Newcastle-Ottawa Scale (NOS) points for each study.

Study, >Design	Berntsen (2009), Cross-sectional [38]	Brasholt (2010), Cross-sectional [37]	Fedele (2014), Cross-sectional [36]	Firrincieli (2005), Cross-sectional [30]	Rundle (2009), Cross-sectional [44]	Tsai (2012), Cross-sectional [45]	Vahlkvist (2009), Cross-sectional [46]	Vangeepuram (2014), Cross-sectional [34]	van Gent (2007), Cross-sectional [33]	Yiallouros (2015), Cross-sectional [47]	Sousa (2014), Case-control [57]	Eijkemans (2008), Cohort [14]
Points	7/8	7/8	6/8	4/8	6/8	6/8	6/8	7/8	5/8	8/8	7/9	8/9
Representativeness	1	1	1	1	1	1	0	1	1	1	1	1
Sample size	0	0	0	0	0	0	0	0	0	1	N/A	N/A
Comparability	2	2	2	0	2	2	2	2	0	2	2	2
Statistical Test	1	1	1	0	0	1	1	1	1	1	N/A	N/A
Non-response rate	1	1	0	1	1	0	1	1	1	1	0	N/A
Ascertainment of outcome	2	2	2	2	2	2	2	2	2	2	N/A	1
Selection of controls/ non-exposed cohort	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	1
Ascertainment of exposure	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	0
Definition of controls	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A
Same method of ascertainment for both cases and controls	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A
Case definition	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A
Outcome not present at start of study	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0
Adequate follow up time	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1
Adequacy of follow up of cohort	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1

N/A (not applicable) was allocated when the scale did not include that criterion for a specific study design.

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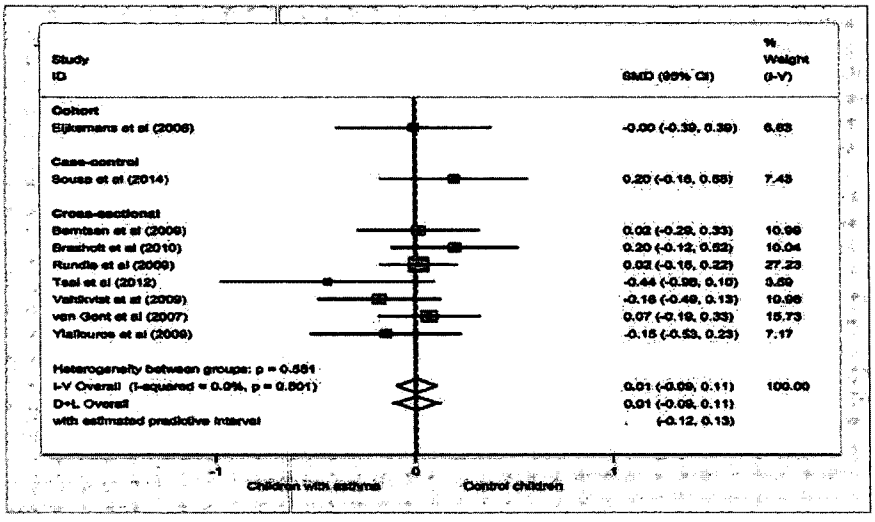

Figure 2. Meta-analysis of mean difference (SMD) in physical activity between children with and without asthma, as measured by accelerometer. SD = standard deviation of the mean.

0.01 activity counts per minute 95% CI: −0.09, 0.11, $p = 0.50$, $I^2 = 0.0\%$). There was no overt evidence of small study bias as demonstrated by the funnel plot (Figure 3).

Discussion

This is the first systematic review and meta-analysis of evidence surrounding objectively measured physical activity level of children with asthma and without asthma. The meta-analysis of 9 studies including 3375 children showed no significant difference in physical activity level between children with asthma and those without the condition [14, 32, 33, 37, 38, 44–47]. This result was supported by 1 of the 3 studies that were not included in the meta-analysis [34]. The remaining two studies that were not included in the meta-analysis had contradictory findings, concluding that children with asthma were less active than their peers [30, 36].

It is unlikely that the 3 studies that did not provide estimates for inclusion in the meta-analysis would have greatly affected the result of this analysis, despite 2 of these concluding that children with wheeze or asthma were less active. The first study had a small sample size and therefore is unlikely to have had sufficient power to influence the estimate [30]. Despite the relatively large sample size of the second article, they reported that the trend for less activity in children with asthma was not statistically significant [36]. In addition, this study was conducted in a population of obese children with and without asthma [36]. The co-morbidity of obesity may have altered the difference in amount of activity performed between those with and without asthma, therefore the implications of this finding to the wider population (including non-obese children) are not clear.

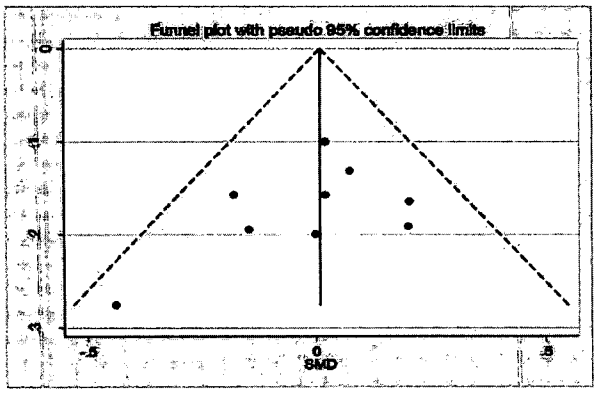

Figure 3. A funnel plot of included studies.

Our results are discordant with the previous review by Williams et al. who concluded that individuals with asthma are less likely to participate in physical activity than individuals without asthma [19]. The conflicting conclusions may be due to several fundamental differences. The present review included only studies that measured physical activity with accelerometry, thereby excluding more subjective measurements. In contrast, Williams et al. did not include any studies that measured physical activity objectively through accelerometry [19]. Second, the review by Williams et al. was a narrative review rather than a systematic review.

A major strength of this review is that only studies that objectively measured physical activity through an accelerometer were included, as these measures of physical activity are more reliable and accurate than self-reporting, or parental reports of frequency and intensity of physical activity, particularly in children [22, 51]. However, it is difficult to establish standard thresholds for categories of physical activity [22]. This is evident in the varied cut-off points for low, moderate and vigorous physical activity used by the included studies.

A limitation of this review is participant behaviour modification within the included studies. Participant behaviour modification due to the knowledge of their participation could influence the study results (the Hawthorne effect). However, this potential behaviour modification is unlikely to alter the behaviour of children or adolescents if the activity is tracked for more than 1 day [22] and all the studies in this review all measured physical activity for more than a single day. A second issue with accelerometry is the potential underestimation of physical activity data due to the removal of the device for water-based activities where the devices are not water resistant. The removal of the accelerometer for water based activity

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could potentially bias the results if children with asthma perform more water-based activity than children without asthma; however there is insufficient evidence to demonstrate that this is true.

We were unable to perform subgroup analyses to investigate the effects of asthma control or severity on the relationship between asthma and physical activity. This was due to the limited number of articles that accounted for or stratified by level of asthma control or severity in their studies. Future studies should also investigate the role of body mass index (BMI) in their analyses, since BMI is a potentially important variable that could act as either a confounder, mediator or as an effect modifier in the relationships between asthma and physical activity. BMI was not included in this review as few articles included it as a confounder in their analyses. For this reason we were unable to meta-analyse or stratify the results by BMI.

It is conceivable that these results present similar levels of physical activity for children with and without asthma since the included studies stem primarily from countries such as the United States, the Netherlands and Norway, which share similar and sophisticated asthma management programs. In fact, many of the included articles reported good asthma control in their study populations [32, 37, 38, 45]. For this reason, the results of this review may not be applicable to populations in which asthma medication and education is inaccessible or inadequate. In future, stratification by level of asthma control or severity may add valuable insight into the effect of poor asthma control on children's physical activity, with implications for the improvement of asthma programs to encourage more active lifestyles.

Cross-sectional studies cannot be relied upon to determine temporality of the association, and introduce the possibility of reverse causation. Therefore, longitudinal studies that objectively measure sustained and habitual physical activities over time, as well as symptoms of wheeze and asthma, are required to investigate causality and the temporal relationship between asthma and physical activity. That is, to distinguish whether physical inactivity leads to the development of asthma, or whether asthmatics are more prone to a sedentary lifestyle due to fear of asthma exacerbations or a reduced capacity for physical activity. In this review, the included cohort study did not find differences between the levels of physical activity attained by children with and without asthma. However further longitudinal studies are required to investigate these intricacies.

As recommended [52], we performed an evaluation of included studies through the use of the Newcastle-Ottawa Scale (NOS) [39]. Despite the availability of other tools, there is not yet any single tool that is an obviously better option than the others [53]. Use of the NOS scale, however, remains controversial, as critical reviews of the scale itself found that it has low inter-rater reliability [54], questionable validity [55] and low agreement between reviewers and authors [56]. For this reason, we did not attribute much weight to the NOS tool ratings; we merely used the ratings as an indication of study quality and to highlight areas that future research studies should focus on to improve quality.

Based on the available evidence using objective measurements of physical activity, there appears to be no need for physical activity programs to specifically target children and adolescents with asthma in countries with developed asthma care systems. However, these results may not apply to countries with less developed asthma management programs. Efforts should continue to promote habitual physical activity in children in accordance with World Health Organisation guidelines.

Conclusion

This systematic review and meta-analysis did not find evidence that children and adolescents with asthma engaged in less physical activity, when measured objectively, than their peers without asthma. Therefore, public health policies that encourage children and adolescents to increase their level of physical activity do not need to differentially target children with asthma in settings where effective asthma campaigns have been established.

Declaration of interest

The authors report no conflict of interest. The authors alone are responsible for the content and writing of the article.

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Appendix

Search strategy

Medline: "physical activity."af., "physical activity."sh., "physical training."af., "physical training."sh., exercise.af., exercise .sh., sedentary.af., sedentary.sh., asthma.af., asthma.sh., "early life wheeze."af., "early life wheeze."sh., "transient wheeze."af., "transient wheeze."sh

PubMed: ((((("physical activity"[All Fields] OR "exercise"[All Fields]) OR "exercise"[MeSH Terms]) OR "physical training"[All Fields]) OR "sedentary"[All Fields]) AND ("asthma"[MeSH Terms] OR "asthma"[All Fields] OR "early life wheeze"[MeSH Terms] OR "early life wheeze"[All Fields] OR "transient wheeze"[MeSH Terms] OR "transient wheeze"[All Fields])

Embase: ("physical activity."mp. or exp exercise/ or exp physical activity/) or ("physical training."mp. or exp training/) or (exp exercise/ or exercise.mp.) or (exp exercise/ or exp sedentary lifestyle/ or sedentary.mp. or exp physical activity/) and (exp asthma/ or asthma.mp.) – excluding Medline journals.