LEADING ARTICLE

Sports Med 2004; 34 (13): 861-870
0112-1642/04/0013-0861/$31.00/0

Fitness and Physical Activity in Children with Asthma

Liam Welsh,[1,2] *Richard G.D. Roberts*[1] and *Justin G. Kemp*[2]

1 Department of Respiratory Medicine, Royal Children's Hospital and Murdoch Children's Research Institute, Melbourne, Victoria, Australia
2 School of Exercise Science, Australian Catholic University, Melbourne, Victoria, Australia

Abstract

Asthma remains the most common chronic disease in childhood, reportedly affecting up to 25% of children in Western urban environmental settings. There seems to be a common perception that asthmatic children have a reduced capacity for exercise. Surprisingly, there is conflicting evidence in the literature in relation to this position. In this review, we present an overview of the literature in which habitual physical activity and fitness levels, including aerobic fitness, of asthmatic and non-asthmatic children are compared.

There is contradictory evidence regarding the aerobic fitness levels of asthmatic children and adolescents, and it remains unclear whether significant differences exist between asthmatic children and their non-asthmatic counterparts. There is limited information concerning the relative anaerobic fitness of asthmatic children and adolescents; however, this is also conflicting. During childhood and adolescence, asthmatic individuals seem to have physical activity levels comparable with those of the normal paediatric population. However, differences in physical activity levels may develop during the time of maturation from adolescence into adulthood. Accordingly, it is not possible to establish a definitive conclusion about the issue in either children or adults. Further research with well designed methodologies is needed in order to determine whether asthmatic children and adolescents have different aerobic fitness, anaerobic fitness and physical activity levels when compared with the normal paediatric population.

1. Background

Asthma remains the most common chronic disease in childhood,[1] reportedly affecting up to 25% of children in Western urban environmental settings.[2] This is despite the recent suggestions that asthma prevalence among children has either reached a plateau or is undergoing a downturn.[3,4] A considerable proportion of asthmatic children is affected by exercise-induced asthma (EIA), with the prevalence believed to be between 70% and 90%.[5,6] Having a diagnosis of asthma or EIA does not necessarily prevent participation in sporting activities. It is well documented that asthmatic individuals have participated successfully at the elite level of sport, competing in a range of events at both the Winter and Summer Olympics.[7-9] The prevalence of EIA among members of the 1984 and 1996 US Summer Olympic teams was 11% and 20%, respectively, and 23% in the 1998 Winter Olympic athletes.[8] Sixty-seven Olympic athletes with a history of asthma or exercise-induced bronchial symptoms won 41 medals at the 1984 Los Angeles Games.[9]

However, the fear of breathlessness associated with EIA might be expected to deter many asthmatic people, particularly children, from participating in regular physical activity. This has given rise to the common perception that asthmatic people have a reduced capacity for exercise. Surprisingly, there is conflicting evidence in the literature in relation to this position. In this review, we present an overview of the literature in which habitual physical activity and fitness levels, including aerobic fitness, of asthmatic and non-asthmatic children are compared.

1.1 Methodology

In preparing the data used in this paper, literature searches were performed using Medline – National Library of Medicine (1966 to August 2003). Using Endnote 6.0®, [1] searches were carried out using PubMed Medline (c1960 to August 2003), the library catalogue at the University of California (c1960 to August 2003) and the library catalogue at the University of Sydney (c1960 to August 2003). The terms that were searched for included 'maximal/peak oxygen consumption', 'aerobic fitness', 'anaerobic fitness/threshold', 'physical activity', 'asthma' and 'children'. The reference sections of all articles were scanned for further potential inclusions.

Forty-seven potential studies were located that focused on fitness in asthmatic children. Fourteen of these reported baseline (untrained) aerobic fitness in asthmatic children. These investigations either had a comparison of aerobic fitness with a control group of non-asthmatic children, or a comparison with established percentile scales. Studies were included regardless of the method used to estimate aerobic fitness.

Only six studies were located on anaerobic fitness in asthmatic children and, in accordance with the aerobic fitness inclusion criteria, studies were only incorporated if comparisons were made with a non-asthmatic control group. Four studies satisfied this criterion. Again, the method of estimation was not a factor.

Twelve potential studies were located for the physical activity section. However, following the application of the established inclusion criteria, only four of these studies were found to be suitable. Consequently, two adult investigations were also included to provide further evidence and to highlight a possible maturation factor. All articles were included regardless of publication length. Specifically, articles published as abstracts, short reports or otherwise were not excluded.

1.2 Benefits of Improved Fitness

Many health benefits exist for children and adolescents who partake in regular physical activity. Increased aerobic fitness,[10] improved ventilatory capacity and performance,[11] and a lowered body composition[12] are some of these benefits. On the other hand, physical inactivity among young people has been associated with lower levels of aerobic fitness[13] and increased prevalence of overweight and obesity.[14] It would, therefore, be expected that reduced levels of physical activity amongst asthmatic children would lead to reduced aerobic fitness and increase the likelihood of reaching a ventilatory limitation at modest levels of exercise intensity. The sensations associated with reaching such a limitation, usually perceived as being unpleasant, may act as a deterrent to exercise in the asthmatic child[15] and may well manufacture a self-limiting cycle of inactivity. Consequently, an asthmatic child may not be physically equipped to cope with a bout of EIA as well as they may if they possessed an aerobic fitness comparable with that of a physically active non-asthmatic child. Furthermore, children affected in this way would be doubly disadvantaged in that their asthma is likely to be poorly controlled[16] and their prospects for a healthy adult life reduced.[13,14]

1.3 Relationship Between Aerobic Fitness and Physical Activity

Despite considerable evidence linking normal aerobic fitness and physical activity with a number of health benefits, studies investigating the interac-

1 The use of trade names is for product identification purposes only and does not imply endorsement.

tion between aerobic fitness and physical activity have reported contradictory results. There is evidence for a strong association between aerobic fitness and physical activity in adults.[17-20] In children and adolescents, however, there appears to be conflicting evidence concerning this relationship. Whilst Mirwald and Bailey[21] have shown a high level of physical activity to be related to high peak oxygen consumption ($\dot{V}O_{2peak}$) values in boys aged 7–17 years, Andersen et al.[22] reported that young people with different levels of $\dot{V}O_{2peak}$ did not differ significantly in their daily physical activity levels. Furthermore, Al-Hazzaa and Sulaimen[23] and Wong et al.[24] found physical activity and aerobic fitness to be significantly related in 7- to 12-year-old boys and 8- to 12-year-old children, respectively, whilst Janz et al.[25] found no relationship in boys aged 6–17 years. These studies are representative of the available literature.

There may be a number of reasons for these reported discrepancies, ranging from the methodological to the physiological. For example, in larger epidemiological surveys, physical activity is usually assessed by questionnaire, a technique that has inherent inaccuracy, especially in children.[26] When physical activity is measured directly, e.g. accelerometry, it is often difficult to demonstrate that the recording period adequately represents the actual pattern of activity.[27] Although considered to be the 'gold standard' for measuring energy expenditure, the doubly labelled water technique is unable to detect levels of intensity or type. Also, it has been suggested that the poor association between aerobic fitness and physical activity is due to young people not participating in physical activity of sufficient intensity to alter $\dot{V}O_{2peak}$.[28] Furthermore, a number of authors have hypothesised that the high initial level of aerobic fitness in children makes it more difficult to demonstrate trainability.[29,30]

Despite the lack of association between aerobic fitness and physical activity in the normal paediatric population, the concept of asthmatic children having a ventilatory limitation to exercise suggests that a relationship between aerobic fitness and physical activity in this group may be more probable. If there was an initial deficit in aerobic fitness, increasing the level of physical activity would likely result in improvements in aerobic fitness, thereby creating a direct relationship. This rationale may have been the catalyst for a number of studies that have investigated the association between asthma and aerobic fitness as well as between asthma and physical activity, and the interaction between all three of these factors. The effects of aerobic conditioning (training programmes) on aerobic fitness, EIA and asthma symptoms have also been the subject of several investigations.

2. Asthma and Fitness

2.1 Asthma and Aerobic Fitness

As described in section 1.2, a superior level of fitness would likely be protective against an asthmatic episode. Despite this, there is anecdotal information suggesting that asthmatic children are not as aerobically fit as non-asthmatic children. However, several studies also report little or no difference in the fitness levels between asthmatic and non-asthmatic children and adolescents (see table I for participant characteristics in this section).

2.1.1 Comparable Aerobic Fitness

Bevegård et al.[31] assessed the maximal oxygen consumption ($\dot{V}O_{2max}$) of 20 mild to severely asthmatic boys on a cycle ergometer and concluded that "even children with severe asthma have a normal maximal oxygen uptake capacity". Likewise, Hedlin et al.[35] evaluated the working capacity of 16 children with a history of EIA on an electrically braked cycle ergometer and found them to have comparable $\dot{V}O_{2peak}$ values to normal healthy boys of the same age. Moreover, Fink et al.[16] reported no differences in $\dot{V}O_{2max}$ between groups of stable asthmatic and non-asthmatic children stratified into active and inactive groups. They concluded that a sedentary lifestyle was the probable cause for any asthmatic child to have poor aerobic fitness and that their aerobic fitness had the potential to be normalised by training. Also, Thio et al.[41] found 22 from a cohort of 28 mild to moderately severe asthmatic children

Table I. Studies investigating asthma, aerobic and anaerobic fitness in children and adolescents

Study	Participants	Age (y)	Sex	Results
Bevegård et al.[31]	20 AS	8–13	20 M	Normal $\dot{V}O_{2max}$
Boas et al.[32]	22 AS 22 NAS	7–18	22 M 22 M	No difference in $\dot{V}O_{2max}$ between the AS and NAS. No difference in anaerobic fitness
Buttifant et al.[33]	10 AS 11 NAS	15.04 14.53 (mean)	10 M 11 M	No difference in mean or peak anaerobic power; however, lower plasma adrenaline and lactate levels in AS
Counil et al.[34]	19 AS 14 NAS	11.5–15.7	19 M 14 M	AS had 10% lower $\dot{V}O_{2max}$ and lower maximal anaerobic power
Fink et al.[16]	49 AS, 31 NAS	9–16	27 M, 22 F	All active AS had comparable aerobic fitness to NAS
Hedlin et al.[35]	16 AS 9 NAS	10.1–14.3	10 M, 6 F 9 M	No difference in $\dot{V}O_{2max}$ between AS and NAS
Counil et al.[36]	8 AS 7 NAS	12–14	8 M 7 M	Lower mean and peak anaerobic power values in AS
Kukafka et al.[37]	19 AS 195 NAS	14–18	214 M	AS took 10% longer to complete mile run
Riedler et al.[38]	152 AS 70 NAS	13–15	NR	NAS ran 10% further than AS in 6 min run
Santuz et al.[39]	80 AS 80 NAS	7–15	60 M, 20 F	No difference in aerobic fitness
Strunk et al.[40]	76 AS	9–17	42 M, 34 F	91% of AS performed below the 50th percentile in a 9 min run
Thio et al.[41]	28 AS	6–13	17 M, 11 F	22 children had normal $\dot{V}O_{2max}$ 6 children performed below the 5th percentile
Varray et al.[42]	11 AS 11 NAS	11–13	9 M, 2 F 9 M, 2 F	AS recorded lower $\dot{V}O_{2max}$ values compared with the NAS
Welsh et al.[43]	28 AS 200 NAS	10.3–14.6	18 M, 10 F 87 M, 113 F	No difference in 6 min run distance
Wong et al.[24]	57 AS, 1207 NAS	8–12	43 M, 14 F	Reduced $\dot{V}O_{2max}$ in children with asthma and/or bronchitis

AS = asthmatic children; **F** = females; **M** = males; **NAS** = non-asthmatic children; **NR** = not reported; $\dot{V}O_{2max}$ = maximal oxygen consumption.

to possess comparable $\dot{V}O_{2max}$ values with the predicted values of healthy Dutch children of the same age. Santuz et al.[39] reported no significant difference in aerobic fitness between 80 mild to moderately severe asthmatic and 80 non-asthmatic children, as measured by a maximal treadmill exercise test. The study participants were matched for physical activity by their score on the Habitual Level of Physical Activity Questionnaire (HLPA).[44] Matches were also made for age, height and weight. The authors concluded that, as long as physical activity levels are comparable with that of normal children, asthmatic children are capable of achieving a similar level of aerobic fitness. Boas et al.[32] found 22 asthmatic children and adolescents to produce similar values of $\dot{V}O_{2max}$ to 22 age-matched non-asthmatic controls. Furthermore, Welsh et al.[43] recorded a similar finding when assessing the aerobic fitness of 28 stable mild to moderately severe asthmatic children and 200 non-asthmatic children, with no differences found between the groups in the distance covered in a 6-minute run.

2.1.2 Differences in Aerobic Fitness

Contrary to the findings in section 2.1.1, there have been a number of investigations demonstrating reduced aerobic fitness in asthmatic children when compared with non-asthmatic children. Strunk et al.[40] examined the exercise performance of 76 asthmatic children via a 9-minute run and reported that 91% of asthmatic children performed below the 50th percentile, indicating an extreme deficit in aerobic fitness. Varray et al.[42] found 11 asthmatic children had significantly lower $\dot{V}O_{2max}$ values when com-

pared with 11 non-asthmatic children. The children completed a maximal incremental exercise test on a cycle ergometer and were matched for age (11–13 years), sex, height and weight. In a study measuring fitness by a 1.6km (1-mile) run in 16-year-old high-school football players, a statistically significant difference of approximately 10% was reported between those with EIA and unaffected students.[37] These 19 asthmatic adolescents recorded an average time of 513 seconds compared with 466 seconds achieved by 214 non-asthmatic students. Unfortunately, 24 previously diagnosed asthmatic adolescents in this study did not complete the run. Riedler et al.[38] was also able to demonstrate a difference of approximately 10%, when randomly selected non-asthmatic children ran an average distance of 1131m in 6 minutes compared with 1035m by 70 asthmatic children who demonstrated EIA. In these two field studies,[37,38] participants were not premedicated with any preventative drugs. Another difference of around 10% in aerobic fitness was demonstrated by Counil et al.[34] when comparing the cycle ergometer $\dot{V}O_{2max}$ values of 19 asthmatic boys to that of 14 non-asthmatic boys of the same age. In the recent training study of van Veldhoven et al.,[45] most asthmatic individuals from a cohort of 47 performed around or below the 10th percentile for $\dot{V}O_{2max}$ at baseline measurement as measured on a cycle ergometer. In a large epidemiological study of aerobic fitness in Hong Kong Chinese children, Wong et al.[24] estimated $\dot{V}O_{2max}$ to be significantly reduced in children with either asthma or bronchitis compared with those without disease. The Multistage Fitness Test[46] was employed to estimate aerobic fitness while parents completed the ATS-DLD-78 questionnaire[47] to assess disease status and respiratory symptoms. It is important to note, though, that the children with asthma only were not separated from those with bronchitis in the analysis.

2.1.3 Summary

We have identified seven studies in which aerobic performance is significantly lower in asthmatic children compared with non-asthmatic children; another seven have also been described in which no difference could be established. Therefore, it remains unclear whether significant differences exist between asthmatic individuals and their non-asthmatic counterparts. There are three main areas that have contributed to this problem, namely sample selection, methodological variations and statistical analysis. Most studies where fitness is measured directly have used relatively small sample sizes,[31,32,34,35,41,42,45] and the larger numbers generally cited in field studies do not always compensate for the increased variability of the data.[16,39] Often, the non-asthmatic control groups have not been randomly selected and the sex and age distribution in these groups are not reflected in the asthmatic test group.[16,31,32,34,35,37,39-41,43,45] Furthermore, there have been few attempts to look at the full range of asthma severity in a single study.[31] Particularly important is the need to assess fitness in the more severe patients compared with those at the trivial to mild end of the severity spectrum.[31] Methodological difficulties arise from estimating fitness from field studies[37,38,40,43] compared with direct measurements of $\dot{V}O_{2peak}$ and peak anaerobic power. Anecdotal information suggests that testing asthmatic children with and without premedication affects $\dot{V}O_{2peak}$; however, to our knowledge, no such study exists. Finally, a number of studies have not utilised an appropriate statistical analysis, thereby limiting the validity of conclusions.[24,35] These deficiencies in the literature highlight the fact that more research controlling for these variables is needed.

2.2 Asthma and Anaerobic Fitness

There are several measures by which anaerobic performance can be assessed. These fall into three main categories: (i) tests of anaerobic alactacid or phosphagen power using Margaria's single stairs run;[48] (ii) the Wingate Anaerobic Test (WanT) developed by Ayalon and colleagues;[49] and (iii) the force-velocity (FV) test.[50] The single stairs run appears not to have been used in tests of fitness of asthmatic children; however, there are a few published studies where the other tests have been used.

Mean and peak anaerobic power of ten healthy and active asthmatic adolescents were found to be comparable with the values recorded by 11 healthy

and active non-asthmatic adolescents after performing three modifications of the WanT.[33] However, despite the similarities in performance, asthmatic adolescents produced significantly lower plasma adrenaline and lactate levels after completing two of the three WanTs.

When performing the 30-second all-out WanT, Counil et al.[36] reported reduced performance in eight asthmatic boys compared with seven non-asthmatic boys matched for age, anthropometric characteristics and physical activity. Significantly lower peak and mean power values were produced by the asthmatic participants who also demonstrated lower venous blood lactate values following the test. The authors suggested that a reduced anaerobic capacity existed in children with asthma.

By comparison, Boas et al.[32] found no differences in any of the measures derived from performance of the WanT in a group of 22 clinically diagnosed asthmatic males aged 7–18 years compared with an age- and maturation-matched non-asthmatic group.

In a more recent study, Counil et al.[34] examined anaerobic fitness in 19 asthmatic boys using the FV test. These patients were compared with a control group of 14 non-asthmatic boys who were matched for age, anthropometric characteristics, pubertal stage and weekly physical activity. The asthmatic boys had significantly lower maximal anaerobic power than the control group. When divided into subgroups on the basis of asthma severity, boys with moderate levels of asthma had lower levels of anaerobic power than those with mild asthma.

2.2.1 Summary

There is limited information concerning the anaerobic fitness of asthmatic children and adolescents, thereby making it difficult to forward any definitive conclusion as to whether asthmatic children and adolescents have reduced anaerobic fitness compared with their unaffected peers. In particular, with a small number of published studies conflicting in relation to the WanT and with sample size limitations including control group selection, range of asthma severity and single sex, there is a clear need for further well designed, comprehensive studies to provide more data on this topic. Added to this, the suggestion that reduced aerobic abilities in asthmatic children may influence their relative anaerobic metabolism during exercise also needs to be addressed in greater detail.[36]

3. Asthma and Physical Activity

Anecdotal information suggests that children with asthma, particularly those with EIA, are not as physically active as non-asthmatic children. Whether it is because asthma is likely to be precipitated by exercise or that the asthmatic child has chronic airway obstruction, the suggestion is that the experience of exercise is not as rewarding as it is for non-asthmatic children. Despite the amount of speculation, only a limited number of studies have assessed the physical activity levels of asthmatic children, and those that have report differing results. The inherent difficulties associated with accurately recalling habitual levels of physical activity by questionnaire, particularly in children,[51] may substantially affect the quality of the measurement (see table II for participant characteristics from this section).

3.1 Comparable Physical Activity Levels

Nystad[56] assessed the physical activity levels in a paediatric cohort of asthmatic and non-asthmatic children by administering the ISAAC (International Study of Asthma and Allergies in Childhood)[57] questionnaire to 4021 school children in three different areas of Norway. No differences were found between the exercise frequency in children who reported ever having asthma or those with current asthma when compared with non-asthmatic controls. Also, there were no differences in the number of hours spent exercising per week between the groups. Using the ATS-DLD-78 questionnaire[47] to estimate physical activity, Wong et al.[24] were unable to establish any significant association between physical inactivity and respiratory disease or symptoms, including asthma. However, the authors suggest that Hong Kong Chinese children participate in low levels of physical activity, which may contribute to the lack of measured difference. Likewise,

Table II. Studies investigating asthma and physical activity

Study	Participants	Age (y)	Sex	Results
Weston et al.[52]	65 AS, 343 NAS	11–13	NR	AS more frequently active than NAS
Crocker et al.[53]	4021	7–16	2030 M, 1991 F	Suggest AS have comparable PA levels to NAS
Ford et al.[54]	12 489 AS 4892 former AS 147 742 NAS	18–70+	82 727 M 82 396 F	AS had lower PA levels than former AS and NAS
Mälkiä and Impivaara[55]	7193	30–89	3251 M, 3942 F	AS M and F recorded significantly lower PA questionnaire scores
Welsh et al.[43]	28 AS	10.3–14.6	18 M, 10 F	No difference in PAQ-C scores
	200 NAS		87 M, 113 F	
Wong et al.[24]	57 AS, 1207 NAS	8–12	43 M, 14 F	No differences found between children with AS and/or bronchitis and NAS

AS = asthmatic; **F** = females; **M** = males; **NAS** = non-asthmatic; **NR** = not reported; **PA** = physical activity; **PAQ-C** = Physical Activity Questionnaire for Children.

Welsh et al.[43] found no differences in the physical activity levels of 28 stable mild to moderately asthmatic children and 200 non-asthmatic children. Physical activity in this study was estimated from responses to the 7-day recall Physical Activity Questionnaire for Children (PAQ-C).[53]

3.2 Differences in Physical Activity Levels

Conversely, Weston et al.[52] found 65 asthmatic children to be more frequently active than 343 non-asthmatic children as measured by a self-administered questionnaire. Although asthmatic children were found to experience higher degrees of anxiety prior to exercise, they reported higher school and all day physical activity levels. To our knowledge, there appear to be no paediatric studies that have found asthmatic children to have lower physical activity levels than non-asthmatic children.

An adult study conducted by Mälkiä and Impivaara[55] investigated the level of intensity of physical activity in 8000 Finnish adults with and without bronchial asthma. Physical activity levels at work, during leisure time and whilst commuting were recorded using a questionnaire.[58,59] Asthmatic men and women both recorded significantly lower levels of physical activity in each of the three time periods studied when compared with their non-asthmatic counterparts. In a study of US adults,[54] participants with current asthma had significantly lower energy expenditure than former asthmatic individuals who, in turn, had significantly lower energy expenditure than non-asthmatic respondents. Only 27% of the current asthmatic individuals were meeting the recommended physical activity requirements.[60]

3.3 Summary

These data suggest that during childhood and adolescence, asthmatic individuals have physical activity levels comparable with those of the normal paediatric population. The findings of Mälkiä and Impivaara[55] and Ford et al.[54] suggest that differences in asthmatic and non-asthmatic physical activity levels may develop during the time of maturation from adolescence into adulthood. However, there are no published studies that have: (i) utilised similar methodology; (ii) included an asthmatic group; and (iii) investigated physical activity over the range of early childhood into adulthood. In order to make definitive conclusions about the situation in either children or adults, studies such as these need to be carried out.

4. Interaction Between Aerobic Fitness, Physical Activity and Asthma

Although there are several studies focusing on physical activity levels and aerobic fitness of individuals with asthma, there is little information in the literature assessing the interaction between physical activity, aerobic fitness and paediatric asthma. A number of studies that have measured aerobic fitness in asthmatic children and non-asthmatic control groups have taken into account physical activity;

however, the participants recruited have been matched for physical activity, thereby preventing any an evaluation of whether a relationship between asthma, physical activity and aerobic fitness exists. The results of these studies have been equivocal, with some showing reduced fitness[34] and others no difference in aerobic performance.[39]

The study by Fink et al.[16] is one of only three to have assessed physical activity and aerobic fitness in asthmatic and non-asthmatic children without matching either variable. After being recruited, asthmatic children were divided into three categories: sedentary, inactive and active. The control group consisted of only inactive and active participants. No significant differences were found between the exercise performances of asthmatic and non-asthmatic participants. However, the sedentary asthmatic participants had significantly lower aerobic fitness compared with the inactive asthmatic and control groups suggesting a possible dose-related effect. Similarly, Welsh et al.[43] found no difference in physical activity or aerobic fitness between asthmatic children and their counterparts; however, the asthmatic children displaying the lowest physical activity levels also recorded the lowest aerobic fitness levels, indicative of a possible relationship. Interestingly, Wong et al.[24] reported children with either asthma or bronchitis to have lower $\dot{V}O_{2max}$ values compared with non-asthmatic children. They reported a significant relationship between $\dot{V}O_{2max}$ and physical activity, but could not confirm an association between physical activity and respiratory disease or symptoms.

One factor that may be influencing the relationship between aerobic fitness, physical activity and asthma is the observation that asthma and obesity in children may be linked.[61] Immune modification together with the genetic, mechanical and sex-specific effects of obesity are all believed to contribute to the association.[61] For a comprehensive review of this association see Rossner.[62] However, environmental factors such as diet and physical activity are also thought to exacerbate the condition.[62,63] Gilliland et al.[64] examined 3792 school-age children to determine if an interaction existed between obesity and new-onset asthma. The relative risk of a new diagnosis of asthma increased in the upper body mass index (weight [kg]/height^2 [m]) percentiles for both boys and girls. The authors concluded that being overweight significantly increased the relative risk of developing new-onset asthma in boys and nonallergic children.

5. Conclusion

The literature regarding the aerobic fitness of asthmatic children and adolescents is inconclusive. Whether asthmatic children have different levels of aerobic fitness compared with their non-asthmatic counterparts remains unclear. Methodological differences have most probably contributed to the contradictory nature of the evidence, highlighting the need for further research, particularly concerning the full spectrum of asthma severity.

The limited published data suggest that physical activity levels of asthmatic children and adolescents are equivalent with non-asthmatic children and adolescents. Whilst differences reported in adults suggest a decrease in physical activity with maturity, the methodological limitations of questionnaires and the need to account for asthma severity makes it impossible to assess whether there is any difference in physical activity levels between asthmatic and non-asthmatic children. Again, there is a need for further work in this area using the more accurate techniques of activity monitoring (e.g. accelerometry) rather than questionnaires in larger study groups.

Acknowledgements

Liam Welsh is funded by the Australian Research Council for an Australian Postgraduate Award with Industry (APAI) grant. The authors have no conflicts of interest that are directly relevant to the content of this review.

References

1. Kun HY, Oates RK, Mellis CM. Hospital admissions and attendances for asthma: a true increase? Med J Aust 1993; 159: 312-3
2. Robertson CF, Dalton MF, Peat JK, et al. Asthma and other atopic diseases in Australian children: Australian arm of the International Study of Asthma and Allergy in Childhood. Med J Aust 1998; 168 (9): 434-8

3. Ng K, Toelle BG, Belousova EG, et al. Trends in the prevalence of asthma over 20 years in Belmont, NSW, Australia. Respirology 2003; Suppl. 8: A31
4. Akinbami LJ, Schoendorf KC. Trends in childhood asthma: prevalence, health care utilization, and mortality. Pediatrics 2002; 110 (2): 315-22
5. Johansson H, Foucard T, Petterson LG. Exercise tests in large groups of children are not a suitable screening procedure for undiagnosed asthma. Allergy 1997; 52 (11): 1128-32
6. Wilkerson LA. Exercise-induced asthma. J Am Osteopath Assoc 1998; 11 (4): 322-31
7. Wilber RL, Rundell KW, Szmedra L, et al. Incidence of exercise-induced bronchospasm in Olympic winter sport athletes. Med Sci Sports Exerc 2000; 32 (4): 732-7
8. Rundell KW, Wilber RL, Szmedra L, et al. Exercise-induced asthma screening of elite athletes: field versus laboratory exercise challenge. Med Sci Sports Exerc 2000; 32 (2): 309-16
9. Helenius I, Haahtela T. Allergy and asthma in elite summer sport athletes. J Allergy Clin Immunol 2000; 106 (3): 444-52
10. Mirwald RL, Bailey DA, Cameron N, et al. Longitudinal comparison of aerobic power in active and inactive boys aged 7 to 17 years. Ann Hum Biol 1981; 8 (5): 405-14
11. Åstrand PO, Rodahl, K. Textbook of work physiology. New York: McGraw Hill, 1986
12. Craig SB, Bandini LG, Lichenstein LH, et al. The impact of physical activity on lipids, lipoproteins, and blood pressure in preadolescent girls. Pediatrics 1996; 98: 389-95
13. NIH develops consensus statement on the role of physical activity for cardiovascular health. Am Fam Physician 1996; 54 (2): 763-4
14. Yu CW, Sung RY, So R, et al. Energy expenditure and physical activity of obese children: cross-sectional study. Hong Kong Med J 2002; 8 (5): 313-7
15. Oseid S, Haaland K. Exercise studies on asthmatic children before and after regular physical training. In: Eriksson BO, Furberg B, editors. Swimming medicine IV. Baltimore (MD): University Park Press, 1978: 32-41
16. Fink G, Kaye C, Blau H, et al. Assessment of exercise capacity in asthmatic children with various degrees of activity. Pediatr Pulmonol 1993; 15 (1): 41-3
17. Garfinkel SK, Kesten S, Chapman KR, et al. Physiologic and nonphysiologic determinants of aerobic fitness in mild to moderate asthma. Am Rev Respir Dis 1992; 145: 741-5
18. Gossard D, Haskell WL, Taylor CB, et al. Effects of low- and high-intensity home-based training on functional capacity in healthy middle-aged men. Am J Cardiol 1986; 57 (6): 446-9
19. Seals DR, Sinacore DR, Hurley BF, et al. Failure of endurance training to alter the cardiovascular response to static contraction. Clin Physiol 1983; 3 (3): 219-26
20. Blumenthal JA, Matthews K, Fredrikson M, et al. Effects of exercise on cardiovascular function and plasma lipid, lipoprotein, and apolipoprotein concentrations in premenopausal women. Arterioscler Thromb 1991; 11 (4): 912-7
21. Mirwald RL, Bailey DA. Maximal aerobic power. London: Sports Dynamics, 1986
22. Andersen KL, Ilmarinen J, Rutenfranz J, et al. Leisure time sport activities and maximal aerobic power during late adolescence. Eur J Appl Physiol 1984; 52 (4): 431-6
23. Al-Hazzaa HM, Sulaimen MA. Maximal oxygen uptake and daily physical activity in 7 to 12 year old boys. Pediatr Exerc Sci 1993; 5: 357-66
24. Wong TW, Yu TS, Wang XR, et al. Predicted maximal oxygen uptake in normal Hong Kong Chinese Schoolchildren and those with respiratory diseases. Pediatr Pulmonol 2001; 31: 126-32
25. Janz KF, Golden JC, Hansen JR, et al. Heart rate monitoring of physical activity in children and adolescents: the Muscatine Study. Pediatrics 1992; 89: 256-61
26. Baranowski T. Validity and reliability of self report measures of physical activity: an information-processing perspective. Res Q Exerc Sport 1988; 59: 314-27
27. Cooper A. Objective measurement of physical activity. In: McKenna J, Riddoch C, editors. Perspectives on health and exercise. New York: Palgrave, 2003: 104
28. Armstrong N, Welsman J. Young people and physical activity. New York: Oxford University Press, 1997
29. Lussier L, Buskirk ER. Effects of an endurance training regimen on assessment of work capacity in prepubertal children. Ann N Y Acad Sci 1977; 30: 734-47
30. Sady SP. Cardiorespiratory exercise training in children. Clin Sports Med 1986; 5: 493-514
31. Bevegård S, Eriksson BO, Graff-Lonnevig V, et al. Circulatory and respiratory dimensions and functional capacity in boys aged 8-13 years with bronchial asthma. Acta Paediatr Scand 1971; Suppl. 217: 86-9
32. Boas SR, Danduran MJ, Saini SK. Anaerobic exercise testing in children with asthma. J Asthma 1998; 35 (6): 481-7
33. Buttifant DC, Carlson JS, Naughton GA. Anaerobic characteristics and performance of prepubertal asthmatic and nonasthmatic males. Pediatr Exerc Sci 1996; 8: 268-75
34. Counil FP, Karila C, Varray A, et al. Anaerobic fitness in children with asthma: adaptation to maximal intermittent short exercise. Pediatr Pulmonol 2001; 31: 198-204
35. Hedlin G, Graff-Lonnevig V, Freyschuss U. Working capacity and pulmonary gas exchange in children with exercise-induced asthma. Acta Paediatr Scand 1986; 75 (6): 947-54
36. Counil FP, Varray A, Karila C, et al. Wingate test performance in children with asthma: aerobic or anaerobic limitation? Med Sci Sports Exerc 1997; 29: 430-5
37. Kukafka DS, Lang DM, Porter S, et al. Exercise-induced bronchospasm in high school athletes via a free running test. Chest 1998; 114 (6): 1613-22
38. Riedler J, Reade T, Dalton M, et al. Hypertonic saline challenge in an epidemiological survey of asthma in children. Am J Respir Crit Care Med 1994; 150: 1632-9
39. Santuz P, Baraldi E, Fillippone M, et al. Exercise performance in children with asthma: is it different from that of healthy controls? Eur Respir J 1997; 10: 1254-60
40. Strunk RC, Rubin D, Kelly L, et al. Determination of fitness in children with asthma. Am J Dis Child 1988; 142 (9): 940-4
41. Thio B, Nagelkerke AF, Ketel AG, et al. Exercise-induced asthma and cardiovascular fitness in asthmatic children. Thorax 1996; 51: 207-9
42. Varray A, Mercier J, Ramonatxo M, et al. Maximal exercise in asthmatic children: aerobic limitation or anaerobic compensation [in French]? Sci Sports 1989; 4: 199-207
43. Welsh L, Roberts RGD, Kemp JG. Aerobic fitness, physical activity and asthma in Australian school children [abstract]. Am J Respir Crit Care Med 2002; 165 (8): A740
44. Santuz P, Baraldi E, Zaramella P, et al. Factors limiting exercise performance in long-term survivors of bronchopulmonary dysplasia. Am J Respir Crit Care Med 1995; 152: 1284-9
45. van Veldhoven NH, Vermeer A, Bogaard JM, et al. Children with asthma and physical exercise: effects of an exercise program. Clin Rehabil 2001; 15 (4): 360-70

46. Brewer J, Ramsbottom R, Williams C. Multistage fitness test. Leeds: National Coaching Foundation, 1988: 5-7
47. Ferris BG. Epidemiology standardization project. Am Rev Respir Dis 1978; 118: 1-88
48. Aghemo P, Rovelli E. Measurement of muscular power (anaerobic) in man. J Appl Physiol 1966; 21: 1662-4
49. Ayalon A, Inbar O, Bar-Or O. Relationships among measurements of explosive strength and anaerobic power. In: Nelson RC, Morehouse CA, editors. International series on sport sciences. Vol. 1. Biomechanics IV. Baltimore (MD): University Park Press, 1974: 572-7
50. Vandewalle H, Pérès G, Heller J, et al. All out anaerobic capacity test on cycle ergometers. Eur J Appl Physiol 1985; 54: 222-9
51. Kowalski KC, Crocker PRE, Faulkner RA. Validation of the physical activity questionnaire for older children. Pediatr Exerc Sci 1997; 9: 174-86
52. Weston AR, MacFarlane DJ, Hopkins WG. Physical activity of asthmatic and non-asthmatic children. J Asthma 1989; 26 (5): 279-86
53. Crocker PR, Bailey DA, Faulkner RA, et al. Measuring general levels of physical activity: preliminary evidence for the Physical Activity Questionnaire for Older Children. Med Sci Sports Exerc 1997; 29 (10): 1344-9
54. Ford ES, Heath GW, Mannino DM, et al. Leisure-time physical activity patterns among US adults with asthma. Chest 2003; 124: 432-7
55. Mälkiä E, Impivaara O. Intensity of physical activity and respiratory function in subjects with and without bronchial asthma. Scand J Med Sci Sports 1998; 8: 27-32
56. Nystad W. The physical activity level in children with asthma based on a survey among 7-16 year old school children. Scand J Med Sci Sports 1997; 7: 331-5
57. Asher MI, Keil U, Anderson H, et al. International Study of Asthma and Allergies in Childhood (ISAAC): rationale and methods. Eur Respir J 1995; 8: 483-91
58. Saltin B, Grimby G. Physiological analysis of middle-aged and old former athletes. Circulation 1968; 38: 1104-15
59. Wilhelmsen L, Tibblin G, Fodor J, et al. A multifactorial primary preventative trial in Gothenberg. In: Larsen OA, Malmorg RO, editors. Coronary heart disease and physical fitness. Copenhagen: Munksgaard, 1971: 266-79
60. Pate RR, Pratt M, Blair SN, et al. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. JAMA 1995; 273: 402-7
61. Tantisira KG, Weiss ST. Complex interactions in complex traits: obesity and asthma. Thorax 2001; 56 Suppl. II: ii64-74
62. Rossner S. Obesity: the disease of the twenty-first century. Int J Obes Relat Metab Disord 2002; 26 Suppl. 4: S2-4
63. Metcalf BS, Voss LD, Wilkin TJ. Accelerometers identify inactive and potentially obese children (EarlyBird 3). Arch Dis Child 2002; 87 (2): 166-7
64. Gilliland FD, Berhane K, Islam T, et al. Obesity and the risk of newly diagnosed asthma in school-age children. Am J Epidemiol 2003; 158: 406-15

Correspondence and offprints: Dr *Richard G.D. Roberts*, Department of Respiratory Medicine, Royal Children's Hospital, Flemington Rd, Parkville, VIC 3052, Australia.
E-mail: ric.roberts@rch.org.au