

Determinants of Physical Fitness in Children With Asthma

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ABSTRACT. *Rationale.* This study was designed to examine the relationships among weight, asthma severity, physical activity, and aerobic fitness in children with asthma.

Subjects and Methods. Sixty-four asthmatic children 8 to 12 years old (53% female) were assessed while attending a summer asthma camp. Measures included height and weight, spirometry, histamine bronchial provocation challenge, maximal aerobic power, and questionnaires to quantify habitual activity, perceived activity limitations due to asthma, perceived competence in physical activity, and attitudes toward physical activity. Asthma severity was determined from spirometric indices (forced expiratory volume during the first second), degree of airway hyperresponsiveness, and amount of medication prescribed.

Results. There was no correlation between asthma severity and aerobic fitness. Only perceived competence at physical activity was found to have a significant correlation with aerobic fitness. Appropriate-weight, overweight, or obese (defined by body mass index) children all had similar results for maximum aerobic power and level of habitual activity. However, overweight or obese children reported greater limitation of physical activity. Their asthma-impairment scores were higher than the scores of appropriate-weight peers, although standard measures of pulmonary function were no different among groups. The higher asthma-severity scores were related to greater medication needs in the overweight or obese children with asthma.

Conclusions. Lower maximum aerobic power in asthmatic children is related more to how capable they perceive themselves than to asthma severity. Overweight asthmatic children experience greater limitation of physical activity and thus are prescribed more medication, although by standard measures of asthma severity, they are very similar to normal-weight peers with asthma. Efforts should be directed at understanding the reasons responsible for reduced exercise tolerance before escalating pharmacologic treatment. *Pediatrics* 2004;113:e225-e229. URL: <http://www.pediatrics.org/cgi/content/full/113/3/e225>; *asthma, exercise, physical activity, obesity.*

ABBREVIATIONS. FVC, forced vital capacity; FEV₁, forced expiratory volume during the first second; ATS, American Thoracic Society; PC₂₀, provocative concentration causing a 20% fall in FEV₁; BMI, body mass index.

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Exercise-induced bronchoconstriction affects a majority of children with asthma,¹ and the resulting unpleasant symptoms may incline the child to refrain from such activity. According to current treatment guidelines, a diagnosis of asthma should not deter a child from physical activity, inasmuch as normal physical activity is a recognized goal of optimal asthma control.² There are conflicting studies regarding fitness levels in children with asthma.³⁻⁸ If children with asthma indeed are less fit than their nonasthmatic peers, then elucidation of the reason(s) responsible would enable clinicians to direct educational and therapeutic effects to enable their patients to participate fully and create a level playing field.

Several factors could influence an asthmatic's ability to perform exercise.⁹ First, the degree of resting airflow obstruction could determine the ventilatory limits for aerobic exercise.¹⁰ Second, the degree of bronchial hyperresponsiveness could impose limitations on exercise tolerance, an effect separate from baseline airway caliber.¹¹ Finally, the level of habitual activity could affect physical fitness, as is the case in healthy adults.¹² Hence, children with asthma disinclined to exercise because of dyspnea could set themselves up for a sedentary lifestyle. Perhaps more tantalizing is the recent surge of interest in the relationship between asthma and obesity.¹³⁻¹⁸ What is cause and what is effect is far from clear, but none of the above possibilities are mutually exclusive, and indeed it is conceivable that a vicious cycle is set into motion in childhood. Over time, unpleasant, past experiences may result in a pattern of physical inactivity, leaving the child with maladaptive attitudes toward and less perceived competence in exercise.¹

This study was designed to examine potential determinants of aerobic fitness in children with asthma. The primary hypothesis was that asthma severity would not correlate with physical fitness. Specifically, we sought to assess level of habitual activity, activity limitations due to asthma, attitudes toward physical activity, perceived competence in performing physical activities, and degree of asthma severity as potential influences on aerobic fitness.

METHODS

Subjects

This study was conducted over two 1-week periods in August 2000 and again in 2001 at the summer asthma camp in rural Nova Scotia. The Lung Association of Nova Scotia sponsors the camp, and each year ~60 to 80 children 8 to 11 years old attend. The only a priori criterion for being selected to attend camp was clinically stable, physician-diagnosed asthma. Written informed consent was obtained from the parent(s) at the time children registered at

the camp. This study received ethical approval from the IWK Health Centre Research Ethics Board.

Procedures

Standing height and weight were measured on a hospital stadiometer/scale combination (Health-o-meter, Continental Scales, Chicago, IL). Subjects performed spirometry to derive forced vital capacity (FVC), forced expiratory volume during the first second (FEV₁), and forced expiratory flow over the middle half of the FVC according to American Thoracic Society (ATS) criteria.¹⁹ These measurements were performed on a portable, pneumotachograph-based spirometer (PrestoFlash, Burdick, Inc, Milton, WI), which was calibrated daily with a volumetric syringe, and expressed as a percentage of predicted value.²⁰ This was followed by a histamine-inhalation challenge to determine airway responsiveness.²¹ Aerosolized histamine in doubling concentrations was generated with a compressor-driven (8 L·min⁻¹) Wright nebulizer and inhaled via the tidal-breathing method through a mouthpiece. The provocative concentration causing a 20% fall in FEV₁ (PC₂₀) was identified by linear interpolation of a semilogarithmic plot of FEV₁ versus histamine concentration. Children who had a negative histamine-challenge test (ie, <20% fall in FEV₁ after the highest concentration of histamine [8 mg·mL⁻¹]) were arbitrarily assigned a PC₂₀ of 16 mg·mL⁻¹. Short-acting bronchodilators were withheld 4 hours before spirometry and histamine challenge, whereas long-acting bronchodilators and oral antihistamines were withheld for 48 hours.

On a different day and at time of day conducive to the child's camp schedule, a progressive bicycle exercise test to voluntary exhaustion was done to determine maximal aerobic power (peak $\dot{V}O_2$). Short-acting, inhaled bronchodilator was given routinely before the exercise test to ensure that exercise-induced bronchoconstriction did not limit exercise. The progressive exercise test consisted of step increments in work rate of either 8 or 16 watts per minute (depending on the subject's size and age) on an electrically braked cycle ergometer. Subjects were encouraged verbally to pedal to symptom-limited exhaustion, which typically meant their legs became too fatigued to continue. Maximal test criteria consisted of visible signs of fatigue (flushing, sweating, and panting), heart rate of ~190 beats per minute, and a respiratory exchange ratio of greater than unity. Ventilation and gas exchange were measured breath by breath with an exercise-testing module (CPX Plus, WE Collins, Braintree, MA) that underwent volume and gas calibrations before and after every test. Heart rate was monitored with a tripolar lead system (model 90623A, SpaceLabs, Redmond, WA), and oxygen saturation was measured continuously (Nelcor N-200, Hayward, CA) by pulse oximetry using a skin reflectance probe placed on the forehead.

Questionnaires

Parents completed 3 questionnaires with their children before the beginning of camp. Habitual activity level was assessed by the Hay Activity Evaluation Scale,²² designed to categorize daily physical activity (hours spent inactive, somewhat inactive, somewhat active, and active). Physical-activity limitation due to asthma was measured with questions modeled after Bukstein et al²³ (degree of limitation from asthma affecting child's 5 favorite physical activities) and Juniper et al²⁴ (limitation from asthma of physical activity in general). After the exercise, study personnel administered 2 additional questionnaires to participating children. Perceived competence in physical activity was assessed by a modified version of the Perceived Competence Scale for Children,²⁵ and attitudes toward physical activity were assessed by the Children's Attitudes Toward Physical Activity questionnaire.²⁶ Numerical scores were calculated for all questionnaire responses, allowing them to be analyzed as continuous variables.

Analysis

Asthma severity was rated according to published guidelines.²⁷ The scoring based on FEV₁ and degree of airway hyperresponsiveness was used as described, but the minimum-medication-needs table was modified for pediatric dose ranges (Table 1). The percent of ideal body weight for each study participant based on their measured height and weight and body mass index (BMI: weight/height²) were derived from global standards.²⁸ Peak $\dot{V}O_2$ was chosen as the indicator of physical fitness and expressed as a

TABLE 1. Minimum-Medication-Needs Table (Modified From Table 3 of ref 27)

Score	Medication
0	No medication
1	Occasional SABA only, not daily
2	SABA and either daily LTRA or daily low-dose ICS ($\leq 500 \mu\text{g}$ of BDP)
3	Daily LTRA and/or daily high-dose ICS ($>500 \mu\text{g}$ of BDP); or low-dose ICS plus LABA or LTRA; or occasional (1–3 per year) course of systemic steroid

SABA indicates short-acting bronchodilator; BDP, beclomethasone dipropionate or equipotent inhaled steroid; ICS, inhaled steroid; LTRA, leukotriene receptor antagonist; LABA, long-acting β -agonist.

percent of predicted maximum oxygen consumption (peak $\dot{V}O_2$) based on results from 77 healthy 7- to 12-year-olds who had performed identical exercise tests previously as part of other studies in our laboratory. Parametric (regression and analysis of variance with posthoc testing using Fisher's least-significant difference) or nonparametric (Spearman correlation and Kruskal-Wallis test) statistical analyses were conducted as appropriate. Stepwise logistic regression analysis was used to examine potential predictors of peak $\dot{V}O_2$. Computations were done on a Macintosh computer using Statview 5.0 (SAS Institute, Cary, NC).

RESULTS

Participants

One hundred thirty children registered for the asthma camp were invited by mail to participate in this study: 75 in the first year and 55 in the second year due to repeat campers. Sixty-eight consent forms were signed and returned (52% response rate), and complete data were available on 64 children (4 families did not complete all necessary questionnaires and were removed from the analysis). Comparison data on medication use and spirometric test results were not available from those who declined to participate. Six children had an asthma-impairment score of zero and were excluded from additional analysis. Ten other children had a negative histamine-inhalation challenge (PC₂₀ > 8 mg/mL), but this alone did not constitute an exclusion criterion, because they had all been given a diagnosis of asthma by their primary care physician. Asthma severity was determined to be mild (class I) for 34 (58%) children, moderate (class II) for 20 (35%) children, and severe (class III) for 4 (7%) children. Anthropometric, spirometric, and exercise data are shown in Table 2. The percent of predicted peak $\dot{V}O_2$ ranged from 51% to 113% and averaged 78.5% of

TABLE 2. Pulmonary Function Characteristics of the Study Sample

Characteristic	Mean (SD)
Male/Female	32:26
Height, cm	140 (8)
Weight, kg	42 (13)
BMI, kg/cm ²	21.7 (5.2)
FEV ₁ , % predicted	95 (13)
PC ₂₀ , mg · ml ⁻¹	1.56 (1.77)
Peak $\dot{V}O_2$, ml · min ⁻¹	1166 (276)
% predicted	79 (13)

SD indicates standard deviation.

* PC₂₀ is expressed as geometric (log₂) mean; peak $\dot{V}O_2$ = maximal aerobic power.

TABLE 3. Results of Regression Analyses (*r* Values) Among Continuous Variables, Using Column Heading as the Dependent Variable and Row Headings as the Predictor

	Peak $\dot{V}O_2$ (% predicted)	Habitual Activity Level
Habitual activity level	.22	
BMI	.47*	.07
Perceived competence	.21	.39†
Attitude toward physical activity	.29‡	.42†

* $P < .0001$; † $P = .02$; ‡ $P = .002$.

predicted in class I (mild) asthma, 80.5% of that predicted in impairment class II, and 85% of that predicted in impairment class III, similar among children in each of the 3 classes of asthma severity.

Asthma Severity, Physical Activity, and Fitness

Responses to the Hay Activity Evaluation Scale showed a large variation in participants' habitual activity levels, but the number of hours per day "active" or "somewhat active" was not correlated with peak $\dot{V}O_2$ (Table 3). The results of both sets of activity-limitation questions were not different among children in each of the 3 categories of degree of impairment due to asthma (Table 4).

Among the psychological measures, perceived competence at physical activity did not correlate with peak $\dot{V}O_2$, but the summary score for children's attitudes toward physical activity did correlate with peak $\dot{V}O_2$ (Table 3). In turn, both of these psychological measures correlated significantly with the level of habitual activity, indicating a direct relation between skills and attitudes and participation in physical activity. On the other hand, there were no differences in either of the psychological scores (competence in and attitudes toward) of physical-activity participation among the 3 classes of asthma impairment (Table 4). Asthma severity, habitual activity level, attitudes toward physical activity, and perceived competence were entered into a stepwise regression model to determine their relative importance in predicting aerobic fitness (peak $\dot{V}O_2$), but only the perceived competence measure achieved significance ($P = .026$).

Asthma and Weight

Twenty-nine children had a BMI within the normal range, whereas 11 were defined as overweight and 17 as obese according to the classification of Cole et al.²⁸ Peak $\dot{V}O_2$ showed a positive correlation with BMI, whether expressed as a percent of that pre-

TABLE 4. Results of Analysis of Variance (*P* Values) Using ATS Disability Class (I, II, or III) or BMI (Normal, Overweight, or Obese) as the Factor and the Item in the First Column as the Dependent Variable

	Impairment or Severity Class	BMI
Perceived competence	0.17	0.54
Attitude toward physical activity	0.70	0.38
Habitual activity level	0.14	0.46
Favorite-activity limitation	0.11	0.10
General-activity limitation	0.74	0.09

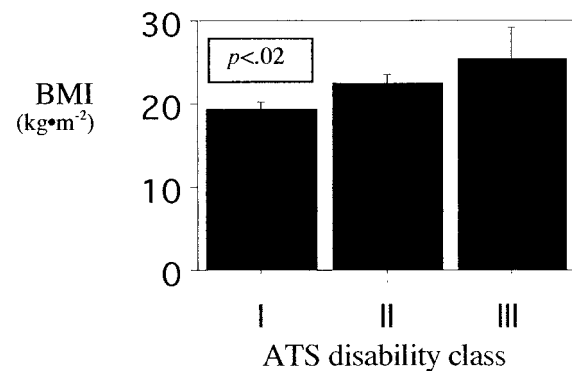


Fig 1. Analysis of variance bar graph (\pm standard error) of BMI versus asthma-severity class.

dicted or in absolute terms (Table 3). Degree of impairment due to asthma (ie, severity) was also related directly to BMI: if BMI was treated as a continuous variable and analysis of variance was conducted, BMI in class I children averaged $19.2 \text{ kg}\cdot\text{m}^{-2}$ vs $22.3 \text{ kg}\cdot\text{m}^{-2}$ in class II vs $25.2 \text{ kg}\cdot\text{m}^{-2}$ in class III (Fig 1). Similarly, if BMI and asthma-severity class were treated as categorical variables, the group proportions were significantly different ($\chi^2 = 11.98$; $P < .02$) (Fig 1).

FEV_1 , PC_{20} , and forced expiratory flow over the middle half of the FVC did not differ significantly among obese, overweight, or normal-weight children with asthma (all P values $> .30$). However, of these measures, only FEV_1 and PC_{20} are considered in calculating the score to rate severity of impairment due to asthma.²⁷ The third component of this scoring system is medication requirement. In this respect, there was a significant trend for medication score to rise with BMI (Spearman's $\rho = .26$; $P = .048$). Overweight or obese children with asthma did not differ from the normal-weight children in terms of level of habitual activity or perceived competence at and attitudes toward physical activity (Table 4). Yet, the obese group, in particular, reported limitation of more of their favorite activities than did the normal-weight children with asthma ($P = .03$). No gender differences were found in BMI, asthma-severity class, or fitness levels.

DISCUSSION

Inasmuch as we failed to find an association between physical fitness (measured as maximum aerobic power) and severity of asthma in a sample of 8- to 11-year-old children with asthma, we confirmed our initial hypothesis. On the other hand, the strongest association with higher peak $\dot{V}O_2$ was found with the psychological predictors of athleticism such as perceived competence at physical activity and attitudes toward physical activity. Thus, we have reaffirmed earlier findings that were published more than a decade ago.^{4,8,10} However, the most tantalizing findings dealt with the association between body weight and asthma, an association that has become the focus of more-recent interest and scrutiny. Obese children with asthma comprised nearly half of the study subjects and were overrepresented in the

group who tallied higher scores when the degree of impairment due to asthma was calculated. This was found although objective measures of airway obstruction and hyperreactivity were no different from other children with asthma in the study. Indeed, it was the amount of medication prescribed to these patients that boosted their severity scores. This begs the question: What is being treated in these children if their asthma is no worse on paper compared with the other children in the study?

Before addressing this question, one cannot ignore the fact that estimation of asthma severity is no easy task, and perhaps the yardstick used in this study is not sensitive enough to track it accurately. We were aware of only 1 multifaceted scale for measurement of asthma in children when our study was conducted, but this 1 scale relied heavily on symptom reporting rather than on objective measures of airway function.²⁹ Given the questionable diagnoses of asthma in some of our campers, we chose the ATS standard over the symptom-based scale. Since our study was completed, another scale has been published, but it too relies heavily on symptoms, medication use, and health care utilization.³⁰ Such scales reflect perhaps more quality of life than they do airway physiopathology. Thus, a comprehensive childhood asthma-severity scale remains elusive.

It is not known yet whether obese children are predisposed to asthma, whether asthmatic children are predisposed to obesity, or whether there is some combination of genetic, environmental, and iatrogenic factors responsible for the association. There are a number of reasons why obese children may be predisposed to receiving a diagnosis of asthma. They may complain of shortness of breath on physical exertion before their nonobese peers,³¹ or they may actually experience more exercise-induced bronchoconstriction than nonobese children.¹⁸ Epidemiologic evidence in adults indicates that obesity is a risk factor for dyspnea but not airflow obstruction¹⁷ and for doctor-diagnosed asthma and wheeze but not airway hyperresponsiveness.¹⁶ Indeed, Schacter et al¹⁶ found that there was little objective evidence to support the diagnosis of asthma in these individuals. Furthermore, weight reduction through dieting in obese adult asthmatics significantly improved lung function and reduced the use of rescue medication.³² The same misdiagnosis could occur in children who present with exertional dyspnea. There is emerging evidence of a similar association between asthma symptoms and obesity in children^{14,15} and of greater symptom burden and medication use in obese children.^{33,34} At least part of this may be related to up-regulation of the immune system in obesity,³⁵ although it seems clear that this inflammatory process is not of the atopic or eosinophilic type.¹⁴ That said, it is conceivable that the symptoms on which a diagnosis of asthma was based in some of our children may have been related to other causes of airway inflammation (eg, infection) that resulted in slowly resolving symptoms. This could explain our finding of 10 children with a negative histamine-challenge test by the time summer arrived. We queried whether these children indeed had asthma, but be-

cause they were still on medication, we included them, reasoning that they, their parents, and their doctor(s) all believed that they were asthmatic.

If the problem is not one of overdiagnosis of asthma in an obese child, then is there a physiologic explanation for increased risk of asthma in obese children? Obesity is known to reduce functional residual capacity, and this change alone can increase airway hyperresponsiveness in normal subjects.^{36,37} These effects are believed to be mediated through the effects of lung inflation (volume) on airway smooth muscle tone.^{38,39} Somatic growth and size seem to influence bronchial hyperresponsiveness, inasmuch as most infants exhibit airway reactivity,⁴⁰ and girls seem to have greater airway hyperreactivity than women.⁴¹ The picture becomes yet more complicated in the overweight infant wheezer. It has been postulated that expiratory glottic narrowing explains the recurrent wheeze in this population,⁴² a population whose degree of airway hyperresponsiveness was no different from infants without history of wheeze.⁴³ Thus, it is plausible that obesity in early life can affect airway wall mechanics adversely and predispose one to wheeze.

On the other hand, there are also reasons why asthmatic children may be at increased risk of becoming obese subsequent to their developing asthma. Those children with severe asthma requiring oral steroids to control flare-ups will be at increased risk for weight gain as a result of even short courses of therapy. Symptoms of asthma will not be reported by toddlers and may be missed by the parent(s). This may leave the child experiencing dyspnea continually that may incline him or her to choose less-strenuous activities to avoid such unpleasant sensations, eventually adopting a sedentary lifestyle. The constellation of poor control of exertional symptoms, BMI >25, high stress, and negative parental expectations seem to characterize children with more-recalcitrant asthma (D.A. Bukstein, MD, written communication, 2003). We did not find an association between level of habitual activity and peak $\dot{V}O_2$ in our study. There are 2 likely explanations for this that are not mutually exclusive. First, the scant evidence that a more physically active lifestyle leads to higher peak $\dot{V}O_2$ in children does not support this notion,⁴⁴ unlike in adults. The other is that the validity of questionnaires as a measure of physical activity, particularly proxy questionnaires completed by parents, has been cast into doubt when compared with objective measures such as motion sensors.⁴⁵

Another popular misconception is that obese children are "out of shape." Our findings echo those of others^{46,47} who concluded that maximal aerobic power does not differ in obese compared with normal-weight children, provided one chooses an appropriate means to normalize peak $\dot{V}O_2$. Nevertheless, it seems likely that the demands on muscles (both ventilatory and those of the exercising limbs) of an increased body mass will result in greater perceived effort and dyspnea.⁴⁸ This could have resulted in the heavier children in our study having higher medication subscores on the scale used to estimate degree of impairment due to asthma, although ob-

jective measures of lung function were similar to their peers with lower-severity scores. Indeed, we contend that the overweight and obese patients in this study may have been caught in a spiral, wherein increasing numbers or dosages of medications were prescribed because of such symptoms. This potential iatrogenic contribution to the development of obesity in children with asthma-like symptoms underscores the importance of keeping an open mind in managing children with asthma-like symptoms and conducting a thorough assessment of pulmonary function.

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