

Original article

Norwegian adolescents with asthma are physical active and fit*

Background: Evidence regarding habitual physical activity levels and aerobic fitness of asthmatic compared to nonasthmatic children and adolescents is contradictory, and it is unclear if low physical activity levels can contribute to asthma development. The present study therefore aimed to determine whether adolescents with asthma have reduced physical activity levels and aerobic fitness, or increased energy intake and body fat compared to controls.

Methods: From the environment and childhood asthma study in Oslo, 174 (13- to 14-year old) adolescents, 95 (66 boys) with and 79 (41 boys) without asthma performed maximal running on a treadmill with oxygen consumption measurement (aerobic fitness) and had the sum of four skinfolds and waist circumference recorded (body fat), followed by wearing an activity monitor and registering diet for four consecutive days. Asthma was defined by at least two of the following three criteria fulfilled: (1) dyspnoea, chest tightness and/or wheezing; (2) a doctor's diagnosis of asthma; (3) use of asthma medication. Participants with asthma used their regular medications.

Results: Neither aerobic fitness, total energy expenditure nor hours in moderate to very vigorous intensity physical activity during week and weekend differed between adolescents with and without asthma. Energy intake and body fat was similar in both groups.

Conclusions: Total energy expenditure, aerobic fitness and hours in moderate to very vigorous intensity physical activity were not reduced and energy intake and body fat measured with skinfolds not increased among Norwegian adolescents with asthma.

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The percentage of children and adolescents reported to have had asthma at some time in their lives has increased in the last decades (1), with a 20.2% lifetime prevalence of asthma in Oslo, Norway reported in 2005 (2). The cause of the increase in asthma is thought to be multi-factorial including allergen sensitization, lifestyle changes and environment (3) with increasing attention to 'Western lifestyle', urbanization, unhealthy diet and sedentary lifestyle with decreased physical activity (4). Exercising more than once per week has been found inversely related to new onset of wheeze in adolescents; however, this association disappeared when active smoking was taken into account (5). In addition, participation in moderate and vigorous physical activity may influence aerobic fitness (6), and lower levels of work capacity has been associated with higher risk of developing asthma (7). A number of longitudinal studies have also reported increasing risk of developing asthma or asthma symptoms in obese children and adolescents (8); however, the causality is not known.

Comparisons of habitual physical activity levels of children and adolescents with and without asthma have given inconsistent results with higher (9, 10), lower (11–13) or similar physical activity levels (14, 15) reported in asthmatic subjects. Only two studies reported objectively measured physical activity levels, in which, Firrincieli et al. (13) found lower physical activity levels among children aged 3–5 years with a history of wheezing whereas van Gent et al. (15) found no differences in physical activity levels in children 7–10 years with undiagnosed asthma, diagnosed asthma and controls. At present, only scarce information is available regarding objective measurement of physical activity in asthmatic adolescents 13–18 years of age. The present study therefore aimed to determine whether adolescents with asthma have reduced objectively measured physical activity levels, secondarily to examine differences in aerobic fitness, total energy intake and body fat in adolescents with and without asthma.

Material and methods

Study design

The present nested case-control study is part of the birth cohort 'Environment and Childhood Asthma' study in Oslo, described elsewhere (16). This 13-year follow-up study conducted between October 2005 and June 2006 consisted of 1 day of clinical investigation and 4 days home monitoring including adolescents with current asthma and without asthma at 10 years.

The study was approved by the Data Inspectorate of Norway and the Medical Research Ethics Committee. Written informed consent to take part was obtained from the participating children and their parents.

Subjects

From the 10-year follow up (2), all 147 children with current asthma and 163 controls without lower respiratory disease, born at the same day as adolescents with current asthma, were invited to participate in the present study of which 174 (56%) agreed to participate. Ninety-five (66 boys) of the adolescents had asthma and 79 (41 boys) did not. *Asthma* was defined by at least two of the following three criteria fulfilled (2):

1. Dyspnoea, chest tightness and/or wheezing 0–3 years and/or after 3 years.
2. A doctors diagnosis of asthma.
3. Used asthma medication (β -2 agonists, sodium chromoglycate, corticosteroids, leukotriene antagonists and/or aminophylline) 0–3 years and/or after 3 years.

There were no significant differences at 10-year follow-up with respect to socioeconomic factors (income and education), body mass index (BMI), lung function, bronchial hyper responsiveness, use of inhaled corticosteroids or β -2 agonist, prevalence of wheeze and exercise induced bronchoconstriction between the adolescents in the present study and those invited, but who did not want to participate.

Exclusion criteria were any other overt disease which might influence the results, respiratory tract infection during the last 3 weeks before attending the visit, and use of medication which could interfere with the tests. Participants with asthma used their regular medications.

Methods

The present study included a parental structured interview including central international study of asthma and allergies in Childhood questions related to airways symptoms (validated in Norwegian language (17)) of the child, in addition to detailed questions of medication use, lifestyle and diseases (2). Information regarding type and frequency of physical activity as well as transportation to school, hours of television viewing and time at computer each day was collected using a physical activity questionnaire.

Anthropometrics. Body mass was measured with the subject wearing light clothing and without shoes (Seca 709, Seca, Hamburg, Germany) to the nearest 0.1 kg. Height was measured to the nearest 0.5 cm by using a stadiometer. BMI was calculated as body mass (kg) divided by height (m) squared. Overweight and obesity were calculated according to Cole et al. (18). The waist circumference was measured to midway between the costal arch and the iliac crest with a metal anthropometric tape to the nearest 0.5 cm at the end of a gentle expiration. Pubertal stage was assessed by means of Tanner

criteria (19). Skinfold thicknesses were measured with a Harpenden fat caliper at the biceps, triceps, subscapular and suprailiac region.

Lung function. Forced expiratory volume in 1 s (FEV_1), forced vital capacity (FVC) and forced expiratory flow at 50% of FVC (FEF_{50}) were measured by maximum forced expiratory flow-volume curves (Masterlab; Erich Jaeger® GmbH & Co KG, Würzburg, Germany) and total lung capacity (TLC), residual volume (RV) and specific airway resistance (sRaw) were measured with a body plethysmograph (Masterlab BodyPro, Erich Jaeger® GmbH & Co KG) according to criteria of European Respiratory Society (20, 21). The predicted values of Zapletal et al. (22) were used for comparisons. All individual flow-volume curves were reviewed for technical acceptability. Response to inhaled salbutamol was measured using 0.4 mg salbutamol (Airomir™ Autohaler™; 3M Pharmaceuticals, Maplewood, MN, USA). A $\geq 12\%$ increase in FEV_1 15 min after inhalation, compared to baseline ($\Delta FEV_1 = (FEV_1 \text{ post} FEV_1 \text{ pre}) / FEV_1 \text{ pre}$) was defined as a reversible airflow-limitation.

Physical activity. Habitual physical activity was measured with SenseWear™ Pro2 Armband (BodyMedia Inc., Pittsburgh, PA, USA). The participants received the monitor during their visit at the laboratory. The recording of physical activity started on a Wednesday or on a Sunday (random order) and included 3 week days and 1 weekend day. The monitor was worn on the right arm over the triceps brachii muscle at the midpoint between the acromion and olecranon processes. The participants and their parents used an additional form to indicate when the monitor was not in use, such as during water activities. Energy expenditure was computed at 1-min intervals. The cut off points defining moderate to very vigorous intensity were three metabolic equivalents (METs). The data from the monitor was downloaded and analysed with software developed by the manufacturer (Innerview Professional Research Software Version 5.1; BodyMedia Inc., Pittsburgh, PA, USA).

Aerobic fitness. Aerobic fitness was determined as highest oxygen consumption ($\dot{V}O_{2\text{peak}}$) during treadmill running (Woodway ELG 2, Woodway GmbH, Weil am Rhein, Germany), starting at 5 km/h and an inclination of 5.3%. The speed increased with 2 km/h after 5 min running, thereafter 1 km/h each minute until a maximal speed of 11 km/h was reached. With no increments in speed, the inclination of the treadmill was raised 1% each minute until exhaustion. Heart rate (HR) was recorded continuously (Polar Vantage, Polar Electro KY, Kempele, Finland). Minute ventilation ($\dot{V}_E$), respiratory exchange ratio (RER), oxygen consumption ($\dot{V}O_2$) and carbon dioxide production ($\dot{V}CO_2$) were measured after 4 min running using the Oxycon Champion (Erich Jaeger® GmbH & Co. KG, Hoechberg, Germany). Calibration was conducted before each test period. The main criterion for having reached maximal effort was a subjective assessment by the test leader that the participants had reached his or her maximal effort. The second criterion was a RER above 1.00, HR above 200 beats/min or reporting perceived exertion (RPE) above 17 using the Borg-RPE-Scale (23). A $\dot{V}O_2$ plateau was defined as a change in $\dot{V}O_2$ during the final 2 min of running $\leq 2 \text{ ml/kg/min}$ (24); however, absence of a $\dot{V}O_2$ plateau was not used as exclusion criteria for not reaching maximal effort.

Diet. The participants received four precoded food diaries (25), one for each day. They had to record their food intake and were instructed (verbally and watching a video) how to fill in the diary. The recordings of the diet were performed the same days as the activity recording. Daily intake of energy was computed using the food database and software system (KBS, version 4.9; Department of Nutrition, University of Oslo, Oslo, Norway) developed at the

Department of Nutrition, University of Oslo. In the present study, total energy intake is presented only.

Statistical analysis

Sample size calculations were based on a standard deviation (SD) of daily hours of moderate to very vigorous intensity physical activity of 1.0 h and a significance level of 0.05 to obtain 80% power, 64 subjects were required in each group to detect a mean difference of 0.5 h.

Demographic data are given as mean values and SD unless otherwise stated and results as mean with 95% confidence intervals (CI). Chi-square tests and independent *t*-test were used to analyse differences between groups. Differences in outcome variables between groups were assessed by analysis of covariance adjusting for age, pubertal stage (entered puberty or not) and gender (core set variables). Physical activity data were also adjusted for mean hours each day the Armband was worn. The underlying assumptions of the analysis of covariance were assessed using Jackknife Residuals and Cook's *d*. Further stratifying by gender was not feasible due to small groups. Statistical significance level was set to 5%. Statistical analyses were performed with Statistical Package for Social Sciences Version 15.0 (SPSS, Chicago, IL, USA).

Results

Adolescents with asthma and controls did not differ significantly with respect to body mass, height, reversible airflow limitation, TLC (% of predicted), RV/TLC or sRaw (Table 1); however, adolescents with asthma had significantly lower FEV₁, FEF₅₀ (% of predicted) and FEV₁/FVC compared to controls. Among the adolescents with asthma, 47% used inhaled corticosteroids regularly, 60% used β_2 -agonists regularly and 47% used β_2 -agonists when participating in physical activity. Exercise was reported as the most important symptom provoking factor in 36% of the adolescents with asthma, and 36% of those with asthma reported activity limitations due to their asthma. One of the

adolescents with asthma only reported active daily smoking vs. none of the controls. The mean use of the activity monitor during week days was 21.2 (95% CI; 20.8–21.5) vs 16.4 (15.6–17.2) h/day during weekend days, and not different between the two groups, with recordings for 4 days in 95% of the subjects. During maximal running on the treadmill 51% (controls) and 58% (with asthma) of the adolescents reached a $\dot{V}O_2$ plateau. Highest recorded heart rate was 196 (194–198) beats/min and RER_{peak} was 1.08 (1.06–1.09), and not significantly different between adolescents with and without asthma (*P* > 0.2).

Physical activity, sedentary time and aerobic fitness

Neither total energy expenditure nor hours in moderate to very vigorous intensity physical activity during week and weekend days were different between adolescents with asthma and controls when adjusted for the core set variables (Table 2). Although, both groups had significantly lower total energy expenditure during weekend days (*P* < 0.001), only controls (*P* = 0.001) had significantly smaller quantity of minutes in moderate to very vigorous intensity physical activity during weekends. All participants fulfilled the international physical activity guidelines during week days and 95% of the adolescents with asthma fulfilled the physical activity recommendation vs 87% of the controls (not significant) during weekends. The adolescents participated in exercise or sport activities on average four times a week. Almost 70% of the participants reported the exercise or sport activities as strenuous. The adolescents with and without asthma participated in similar kind of activities. Sixty to seventy per cent of the adolescents participated in

Table 1. Descriptive data of the participating subjects presented by asthma and controls

	Asthma (<i>n</i> = 95)	Controls (<i>n</i> = 79)	<i>P</i> -value**
Age (years); mean (min–max)*	13.6 (12.8–14.3)	13.6 (12.6–14.3)	0.96
Weight (kg)	53.2 (10.8)	50.5 (9.7)	0.09
Height (cm)	164 (9.0)	162 (7.2)	0.16
FEV ₁ (% of predicted)	100 (12.6)	104 (12.5)	0.04
FEF ₅₀ (% of predicted)	86 (20.8)	98 (21.8)	<0.001
FEV ₁ /FVC	85 (6.7)	87 (6.0)	0.008
FEV ₁ reversibility (% increase)	4 (5.0)	3 (4.5)	0.21
TLC (% of predicted)	104 (13.1)	104 (11.7)	0.85
RV/TLC (%)	27 (7.0)	26 (5.6)	0.37
sRaw (kPa s)	0.84 (0.27)	0.81 (0.27)	0.46

FEV₁, forced expiratory volume after 1 s; FVC, forced vital capacity; FEF₅₀, forced expiratory flow at 50% of FVC; TLC, total lung capacity; RV, residual volume; sRaw, specific resistance of airways; min, minimum; max, maximum.

*Data are given as mean and SD in parentheses unless otherwise stated.

***P*-values for any differences between groups.

Table 2. Adjusted* hours in moderate to very vigorous intensity physical activity, total energy expenditure and total energy intake at week and weekend days, and highest recorded oxygen uptake presented by asthma and controls

	Asthma (<i>n</i> = 95)	Controls (<i>n</i> = 79)	<i>P</i> -value**
MVPA (h/day)			
Week	4.4 (4.0–4.8)	4.6 (4.2–5.0)	0.41
Weekend	3.8 (3.4–4.3)	3.5 (3.0–4.0)	0.32
Total energy expenditure (kcal/day)			
Week	2446 (2336–2556)	2386 (2269–2503)	0.41
Weekend	1992 (1862–2121)	1860 (1719–2001)	0.13
Total energy intake (kcal/day)			
Week	1909 (1782–2036)	1911 (1776–2047)	0.98
Weekend	2043 (1841–2246)	2145 (1931–2359)	0.44
$\dot{V}O_2$ (ml/kg/min)	52.1 (50.1–54.1)	53.1 (51.1–55.1)	0.40

Data are given as adjusted means with 95% CI in parentheses.

MVPA, hours in moderate to very vigorous intensity physical activity; $\dot{V}O_2$, highest recorded oxygen uptake during treadmill test; week, during weekdays, Monday to Friday; weekend, during weekend days, Saturday and Sunday.

*Adjusted for age, pubertal stage (entered as puberty or not), gender and mean hours each day the armband was worn (physical activity data only).

***P*-values for any differences between groups.

endurance training or ball game activities at least weekly. Sixty-four per cent of the adolescents had at least 3 h of physical education per week at school, and 78% participated in PE every time.

Neither hours playing computer nor television watching differed between groups. Twenty-seven per cent of the adolescents watched television for at least 2 h during week days, while 38% of the adolescents spent at least 2 h in front of the computer each day.

Adjusted $\dot{V}O_{2peak}$ did not differ between adolescents with asthma and controls (Table 2). $\dot{V}O_{2peak}$ was approximately 8% lower ($P < 0.001$) for girls compared to boys (pooled data).

Energy intake and body fat

Adjusted energy intake was not significantly different during week and weekend days between adolescents with asthma and controls (Table 2). None of the groups had significantly higher energy intake during weekend vs week days.

Adjusted sum of skinfolds was not significantly different between groups [38.6 (35.5–41.7) mm in adolescents with asthma vs 37.0 (33.7–40.2) mm in controls]; however, adjusted waist circumference was significantly higher ($P = 0.04$) in adolescents with asthma [73.4 (71.6–75.3) vs 71.0 (69.0–73.0)], and 16% of the adolescents with asthma were classified as overweight, according to cut-off points developed by Cole et al. (18), compared to 10% of the controls ($P = 0.053$). Prevalence of obesity were not significant different between adolescents with asthma and controls.

Discussion

Norwegian adolescents with asthma had not reduced aerobic fitness, total energy expenditure and hours in moderate to very vigorous intensity physical activity compared to adolescents without asthma. The adolescents with asthma participated in similar sport activities as controls. Total energy intake and sum of skinfolds were similar, whereas waist circumference was higher among adolescents with asthma. Prevalence of overweight tended to be higher among adolescents with asthma.

The corresponding physical activity levels in adolescents with asthma compared to controls in the present study are supported by others (14, 15), although few studies have included objective physical activity measures. In contrast Ownby et al. (9) found higher levels of physical activity among children with asthma and, Kitsantas and Zimmerman (12) and Lang et al. (11) reported that children and adolescents were less active than controls. Inconsistence between studies may be related to different methodologies and inclusion criteria. For a given subject the measured time in moderate to

vigorous intensity physical activity varies substantially among physical activity monitors used (26). The relative high physical activity level in adolescents with asthma in the present study could be due to the use of asthma medications and good asthma control. Approximately half of the adolescents with asthma used inhaled corticosteroids regularly. Including encouragement of participation in regular physical activity plays an important role in the management of individuals with asthma (27).

Similar aerobic fitness in adolescents with and without asthma is in agreement with others (28); however, the aerobic fitness of the participants in the present study are approximately 10 ml/kg/min higher compared to Santuz et al. (28). Varray et al. (29) found aerobic fitness to be limited in adolescents with severe asthma. This is in contrast to Pianosi and Davis (30) who found no correlation between asthma severity and aerobic fitness. These findings may highlight the importance of not considering children and adolescents with asthma as a homogeneous group. Lower aerobic fitness in adolescents with asthma appears to be related to the degree of inactivity and can be potentially normalized (31). Participation in physical activity with vigorous intensity may influence aerobic fitness in the same manner as in those without asthma (6).

Corresponding daily energy intake in adolescents with asthma compared to controls are supported by others (32), although few studies have included estimates of daily energy intake.

The tendency of a higher prevalence of overweight in adolescents with asthma using the BMI cut-off points developed by Cole et al. (18) is supported by others (8). The higher waist circumference but not sum of skinfolds in the present study is; however, contradictory. Maffei et al. (33) showed waist circumference to be a better predictor of overweight in children than skinfold measurements. Small groups may explain the inconsistent results regarding estimates of body fat.

It is reported that overweight children with asthma experience greater limitation of physical activity (30). In the present study, 36% of those with asthma reported activity limitations due to their asthma. Due to small groups, stratifying by overweight was not possible; however, motivation and introducing active play may increase participation in physical activity in leisure time and result in weight reduction, improve lung function, asthma symptoms, morbidity and health status (34).

The main strengths of the present study are the objective measurements of physical activity and direct and maximal testing of aerobic fitness. Physical activity monitors give reliable measures of physical activity and having advantages compared to self reports with recall biases (35). The adolescents were also recruited from the same population based birth cohort. The inclusion criteria are the same except for asthma which is required to be a case.

Sample size calculations were based on the variable daily hours in moderate to very vigorous intensity physical activity and a sample of 64 subjects in each group were required; however, we can not rule out type II errors for other variables. In addition participation in an ongoing cohort may influence lifestyle due to knowledge regarding asthma management and, the adolescents may not be representative of the general European youth population. It cannot be ruled out whether other groups of children or adolescents with asthma have lower physical activity levels and aerobic fitness or higher amount of body fat. Still, there were no significant differences at 10-year follow up with respect to socioeconomic factors, BMI, lung function, bronchial hyperresponsiveness, use of inhaled corticosteroids or β -2 agonist, prevalence of wheeze and exercise induced bronchoconstriction between the adolescents in the present study and those did not participated.

In conclusion, aerobic fitness, total energy expenditure and hours in moderate to very vigorous intensity physical activity were not reduced in Norwegian adolescents with asthma. The adolescents with asthma participated in the same kind of sport activities as controls. Total energy intake and sum of skinfolds were not increased either, whereas waist circumference was higher among adolescents with asthma. There was a tendency that the prevalence of overweight was higher among adolescents with asthma.

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