

Asthma and allergy among schoolchildren in a mountainous, dry, non-polluted area in Norway

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The aim of this study was to assess prevalence of asthma and allergy in the non-polluted mountain area of Upper Hallingdal, Norway. All schoolchildren (7–16 years) who in a previous questionnaire survey ($n = 1177$) reported 'sometime' asthma were enrolled in group I ($n = 80$), the 59 who reported asthma-like symptoms in the past 12 months formed group II, and 77 of the healthy controls were randomly selected as group III. All 216 children underwent clinical examination, skin prick test, spirometry, bronchial provocation (PD_{20} metacholine) and treadmill exercise test. Subsequently they were reclassified as (1) healthy, never had asthma or symptoms, (2) symptoms not confirmed as asthma, (3) previous asthma, now healthy, (4) current asthma. Lifetime asthma prevalence was 10.2%. Based upon clinical examination, the specificity and sensitivity of the questionnaire for asthma diagnosis were 88 and 74%, respectively. Forced vital capacity was significantly higher among the asthmatics (group 4 versus 1), whereas forced expiratory volume in one second (FEV_1) and forced expiratory flow at 50% of vital capacity were similar in all groups. More than 10% reduction in FEV_1 following treadmill-run was found in 20% of children. Children with current asthma compared to controls had significantly; lower mean values of PD_{20} (9.1 versus 16.5 μmol), higher eosinophil cationic protein (13.4 versus 7.7 μmol) and more frequent sensitization to animal dander (56% versus 10%). In conclusion, despite a favorable climate, little mite sensitization and low outdoor pollution, asthma prevalence was surprisingly high in Upper Hallingdal. Sensitization to animal dander was the most important contributing factor for current asthma.

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Several recently published epidemiological studies of asthma and allergy have assessed the impact upon atopic disease of various indoor and outdoor environmental exposures (1–3). It has been maintained that the 'western lifestyle' combined with unsatisfactory indoor and outdoor environment are important contributors to the morbidity of asthma. Despite similar indoor allergen exposure in Estonian compared to Scandinavian homes (4), there are reports of lower prevalence of asthma and less allergic sensitization in the Baltic region as well as in the former East Germany compared to western countries in Europe (5,6).

Studies have reported improved clinical condition, improvement in bronchial hyper-responsiveness and lung function and decreased eosinophil mediator release in patients staying in high-altitude areas with dry climate and low mite exposure (7), and a subsequent worsening when moving back to low-altitude areas (8). Studies from different parts of Norway have shown little variation in the prevalence of asthma, most being performed along the coast and/or in cities with low or heavy pollution (9–11). In order to compare the prevalence of asthma in different regions of Norway, a questionnaire survey was conducted in 1994 in Oslo (an urban

area with heavy traffic), Odda (a small town with heavy industry in the south-west of Norway) and Upper Hallingdal (a non-polluted rural mountain area in the middle of south Norway). Surprisingly similar results in Oslo and Upper Hallingdal were found for lifetime prevalence of asthma (9.4 versus 8.5%) and asthma-like symptoms in the past year (13.1 versus 14.4%), whereas the corresponding figures for Odda were 5.4 and 9.0%, respectively (12).

The aim of the present study was to validate the reported asthma prevalence in the questionnaire survey by clinical examinations, and evaluate by objective measures of bronchial hyper-responsiveness, exercise-induced asthma and atopy the characteristics of asthma and atopy in the rural mountain area of Upper Hallingdal.

Subjects and methods

Study design

The present study was performed from October 1995 to May 1997 at Geilomo Children's Hospital (the only hospital in Norway for prolonged stay and rehabilitation of children with asthma), in the high-altitude community Hol in mid-south Norway.

Recruitment of children to the present study was based upon a questionnaire survey from 1994 (International Study of Asthma and Allergies in Childhood (ISAAC), parent-supported, translated into Norwegian) of asthma and allergy in Upper Hallingdal (12). The 1994 questionnaire was distributed to all 1177 children (7–16 years) (48% male) attending primary school from 1st to 9th grade in the three communities Hol, Hemsedal and Ål. The response rate was 88% ($n = 1034$).

Three groups of children were selected and invited to participate in the present clinical case-control study. Asthma-like symptoms were recorded on the basis of the following questions: 'have you ever, and in particular in the last 12 months, experienced chest tightness, whistling breath sounds, shortness of breath when exercising, cough during the night or frequent episodes of the common cold?'

Clinical examination and investigations were performed out of the pollen season on two separate days 1–2 weeks apart, consisting of clinical history and examination by a paediatric allergologist, spirometry, skin prick test, bronchial metacholine provocation test and blood samples on day 1 and an exercise test on day 2.

The diagnosis of asthma was re-assessed after clinical examination and careful medical history,

using at least three episodes of wheezing, prolonged cough/night cough or recurrent lower respiratory tract infections as criteria. Bronchoconstriction by exercise was classified as asthma of mild degree.

Ethics

Signed, informed consent from the children and their parents was obtained prior to inclusion, and the study was approved by the regional ethics committee.

Subjects

Based upon the 1994 questionnaire, three groups of children were recruited for further investigation in the present study. The first group consisted of 80 of the 88 children (91%) whose parents had reported a previous asthma diagnosis. Of the 65 children reported to have experienced episodic symptoms of wheeze or shortness of breath during the last 12 months, 59 (91%) agreed to participate. The control group comprised 77 of the 100 children (77%) randomly selected from the remaining study population who did not report a diagnosis of asthma or symptoms suggestive of asthma in the last year. Demographic data for the 216 included children are shown in Table 1.

After clinical examinations and interview of the children and their accompanying parents, the three groups initially selected according to the questionnaires were reclassified into four categories: (1) healthy, no asthma or symptoms ever, (2) symptoms not confirmed as asthma, (3) previous asthma, now healthy, (4) confirmed asthma. The severity of asthma was determined according to the classification in Table 2 (13,14).

Geographic areas and general climate observations

The three communities are situated in the upper part of Hallingdal in the mid-south of Norway with population settlements varying from 340 to 900 m above sea level. The majority of inhabitants live more than 600 m above sea level. The climate is generally dry and cold (normal mean temperature during the six summer months (May–October) 7.3°C and that in the six winter months (November–April) –5.2°C).

The main occupations are within tourism and farming, with no industrial air pollution. Dwellings are widely scattered, and domestic animals (farming and pets) are common.

Table 1. Demographic details of the study groups

Variable	Case group (n = 80)	Symptom group (n = 59)	Control group (n = 77)
Age (years)*	13.4 ± 2.8	13.2 ± 2.7	13.0 ± 2.4
Gender (M/F)	35/45	23/36	39/38
Height (cm)*	158.8 ± 14.2	159.9 ± 12.2	159.0 ± 14.0
Weight (kg)*	54.0 ± 17.5	53.5 ± 12.7	51.2 ± 14.8

*Values are given as mean ± standard deviation. There were no significant differences between groups.

Methods

Skin-prick test (SPT) was performed by two trained nurses following the Nordic guidelines and standards and European consensus (15,16) with the following allergens: house dust mite (*Dermatophagoides pteronyssinus*); mould (*Cladosporium herbarum*); dander from dog, cat, horse, cow and guinea-pig; birch pollen; grass pollen (timothy); mugwort pollen; and five food allergens [cow's milk, hen's egg, fish (cod), hazelnut and peanut] (Soluprick, ALK, Copenhagen, Denmark). A histamine chloride solution (10 mg/ml) was used as a positive control and the allergen diluent as a negative control. Weal size was measured after 15 min, and the size corresponding to that produced by the histamine prick was set to 3+ (and its size registered as half the value of the longest plus the shortest diameter), half of that size to 2+. A reaction was considered positive if 2+ or greater, and this was used as the definition of allergy in the study population.

Blood was collected into Vacutainer® SST® tubes (with clot activator and gel for serum separation) through a venous puncture, stored at room temperature for 60 ± 10 min and subsequently spun at 1300×g for 10 min to separate serum (manufacturer's instructions for eosinophil cationic protein (ECP); Pharmacia Upjohn, Uppsala, Sweden). The serum was stored at -20°C, before the ECP analysis was performed by the Pharmacia CAP system ECP fluoro-enzyme immunoassay (FEIA) method. Total and specific serum IgE, and serum allergen panels (Phadiatop and Fx5) were analyzed by the CAP system (Pharmacia Diagnostics AB, Uppsala, Sweden).

Lung function was measured by maximum expiratory flow volume loops (MasterScreen

Pneumo version 4.0, Erich Jaeger GmbH, Wurtzburg, Germany). The following parameters were recorded: forced vital capacity (FVC), forced expiratory volume in one second (FEV₁) and forced expiratory flow at 50% of vital capacity (FEF₅₀), using predicted values according to Zapletal et al. (17).

Bronchial responsiveness to metacholine as provocation dose eliciting a 20% fall in FEV₁ (PD₂₀ methacholine) was measured if baseline FEV₁ exceeded 60% of predicted. A breath-actuated dosimeter (APS dosimeter, version 2, Erich Jaeger, Germany) was used for doubling doses of inhaled metacholine. The post-saline (0.9% solution) FEV₁ was used for calculation of any subsequent change in FEV₁. The dose of metacholine causing a 20% fall in FEV₁ (PD₂₀) was determined by linear logistic interpolation of the semi-logarithmic dose-response curve (18). All lung function tests, PD₂₀ and treadmill tests were performed by one investigator only.

An exercise test was performed during visit 2, scheduled within 1–2 weeks of visit 1. The child ran for 8 min on a treadmill (Powerjog, E.G. 30, Power Sport Int. Ltd, Cardiff, UK), with an incline of 5.5% and speed adjusted to obtain an exercise load of 85% of calculated maximum, obtaining a steady heart rate for the last 4 min between 180 and 200 beats/min. The maximum exercise load was assessed by heart rate, calculated from 220 minus the age of the patient. The heart rate was recorded electronically (Sport-Tester PE 3000 with memory function; Polar Electro, Kempele, Finland). Lung function was measured before, immediately after and 3, 6, 10, 15 and 20 min after finishing the treadmill run. A 10% reduction in FEV₁ compared to baseline was defined as a positive test. After completing the

Table 2. Asthma severity score

	Frequency of episodes	Duration of episodes	Treatment
Mild*	< 10/year	< 1 week	Only short-acting β_2 -agonists**
Moderate	≥ 10/year	1–2 weeks	DSCG or moderate high dose ICS < 800 µg/day
Severe	Almost daily	> 4 weeks or chronic	ICS ≥ 800 µg/day and long-acting β_2 -agonists or frequent use of short-acting β_2 -agonists

*Exercise-induced bronchoconstriction as only symptom included. ** β_2 -agonists, oral or inhaled. DSCG, disodiumcromoglycate; ICS, inhaled corticosteroids.

test, all children received inhaled nebulized salbutamol 0.05 mg/kg body weight, 10 min after which lung function measurements were repeated.

Before each visit, regular medication was withheld according to the following criteria: short-acting inhaled β_2 -agonists for 8 h, long-acting inhaled β_2 -agonists for 24 h, oral β_2 -agonists for 12 h, slow-release oral β_2 -agonists and theophylline for 72 h and anti-histamines for one week. Disodium cromoglycate was withheld on the days of examinations.

Statistical analysis

The Statistical Packages for Social Sciences (SPSS release 8.0 for Windows; SPSS Inc., Chicago, Illinois, USA, 1997/1998) was used for statistical analyses. Demographic data are given as mean with standard deviation (SD), differences between groups were analyzed by independent-samples *t* test, and the χ^2 test was used for frequency tables. Logistic regression was used to estimate odd ratios for factors influencing asthma diagnosis, presented with 95% confidence intervals (CI). To calculate correlations, Pearson's correlation factor (interval by interval) was applied. The sensitivity of the questionnaire was defined as the proportion of children with asthma correctly identified among the children originally categorized to the asthma group. The specificity of the questionnaire was defined as the proportion of healthy children without asthma correctly identified among the children originally categorized in the control group.

Results

Eight of the initial 80 children in the asthma group were presently healthy (no asthma symptoms for several years) and reclassified to the 'previous' asthma group. Two children were reclassified to the healthy group as they were initially incorrectly classified as asthma.

Three of the 77 control children had received a doctor's diagnosis of asthma after the 1994 survey, and one child was classified as 'present' asthma during clinical examination due to asthma-like symptoms during the past year. All four children were reclassified into the asthma group. Two further children reported 'symptoms' not suggestive of asthma.

Among the 59 children with asthma-like symptoms during the last 12 months prior to the 1994 survey, 51 (86%) still had symptoms during the last 12 months of the present study. Of these, five children had received a doctor's

diagnosis of asthma since 1994, two had wrongly ticked the 'symptoms' box in the first survey when, in fact, they had asthma, and 16 were interpreted as having asthma. The most commonly found characteristics in these 16 children were positive family history of atopy ($n = 14$), multiple allergies ($n = 13$), a history of lower respiratory disease ($n = 11$) and asthma-like symptoms induced by exercise ($n = 12$), cold weather ($n = 8$), animal exposure ($n = 7$) and respiratory infections ($n = 4$).

The lifetime prevalence of asthma in the three communities increased from 8.5% (88/1034) in the questionnaire to 10.2% (105/1034) after the paediatric clinical assessment. The specificity and sensitivity of the 1994 questionnaire were 88 and 74%, respectively. However, accounting for the children who developed asthma or asthma-like symptoms during the time between the questionnaire and the clinical study, the figures change to 97 and 81%, respectively. A flow chart of the initial groups and subsequent present reclassification is shown in Fig. 1. In the following analysis, the eight children in the symptom group who did not report symptoms in the last 12 months prior to the clinical study remained in the reclassified symptom group.

Lifetime asthma tended to be more frequent among girls, 10.9 (59/543), than boys, 9.4% (46/491), but the difference was not significant ($p = 0.43$).

All but three children (94/97, 97%) in the 'present asthma' group reported having symptoms of asthma during the last 12 months. Type of symptoms and gender differences are shown in Table 3.

Current treatment for asthma was reported by 7.3% of all children. Twenty children (21% of the asthma group, 1.9% of all children) reported current use of inhaled corticosteroids, of whom five used a low dose ($< 400 \mu\text{g/day}$) and 15 a medium dose (400–800 $\mu\text{g/day}$). Six children used

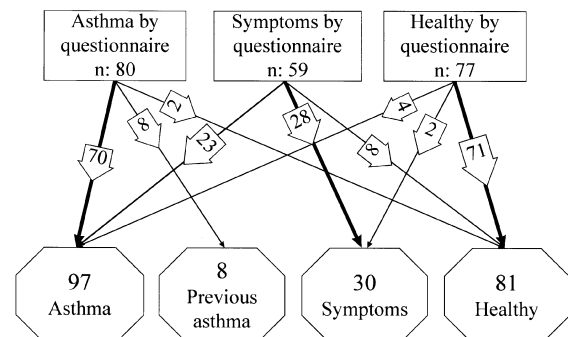


Fig. 1. Flow chart showing the changes from the questionnaire diagnostic groups to the reclassified groups after the doctor's evaluation.

Table 3. Asthma related factors split into age groups regarding current symptoms (last 12 months) and sex

Asthma-related factors	9–11 years	12–14 years	15–18 years	Total (n = 97)
Exercise-induced dyspnea	24	24	28	76 (78%)
Chest tightness	27	24	25	76 (78%)
Night cough	24	21	16	61 (63%)
Wheezing	18	21	20	59 (61%)
Frequent common colds	11	18	16	45 (46%)
Sex distribution of asthma (F/M)*	0.86	1.1	2.3	1.3 (NS)
Asthma distribution (n = 216)	34/67	30/77	33/72	97/216 (NS)
Percentage of age group	51%	39%	46%	

*Adjusted for total sex distribution in each age-group.

inhaled corticosteroids only periodically during exacerbations or during the pollen season. Nebulizers were used periodically by 22 children (2%).

The children with present asthma (within the last 12 months) were classified into suffering from mild asthma (73.2%), moderate asthma (20.6%), or severe asthma (6.2%). The prevalence of asthma severity among the whole survey population was consequently: mild disease 6.9% (71/1034), moderate disease 1.9% (20/1034) and severe disease 0.6% (6/1034). In the group of moderate asthma, there was an excess of girls (17 versus three boys), whereas gender distribution was relatively similar in the other groups. Most of these children were treated by their general practitioner.

The age at which a doctor diagnosed asthma was beyond the age of 5 years in 44 children, prior to 5 years in 33 children and before the age of 2 years in only 12 children. Age of diagnosis was unknown in 28 subjects.

Lung function results for the 212 approved tests are given as predicted percentage mean (with 95% CI) in Fig. 2 for FVC, FEV₁ and FEF₅₀. Four children did not manage to perform forced expiratory maneuver and were thus excluded. The means of predicted values were within 100 ± 10% in all groups. The only significant difference found was a higher FVC in the asthma group than in the healthy group ($p < 0.001$).

The results as well as the relationship between metacholine bronchial provocation tests (PD₂₀) and fall in FEV₁ after exercise tests (n = 88) for the present asthma group are shown in Fig. 3. All tests with a fall in FEV₁ > 20% corresponded to PD₂₀ < 2.5 µmol. The correlation between PD₂₀ and fall in FEV₁ in the group of asthmatic children was $r = -0.437$ ($p < 0.001$).

Total serum IgE exceeded 2 SD for age in 29% of all children (blood tests missing in one child), whereas the corresponding figures within the groups were 42% in the asthma group, 24% in the

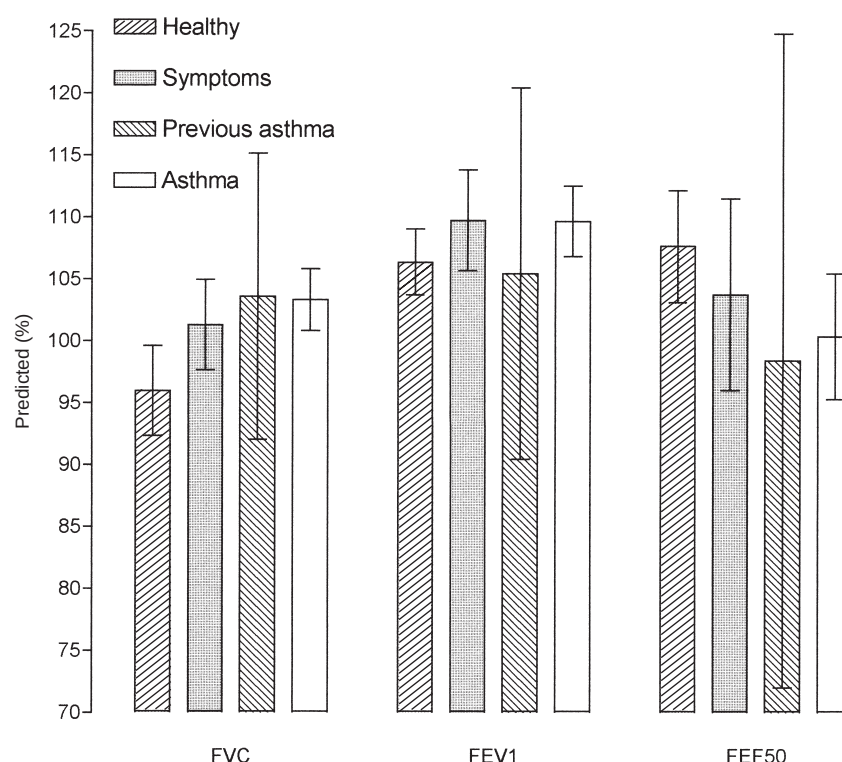
symptom group, 14% in the healthy group and 50% in the group of previously asthmatic children. Geometric mean IgE as well as mean ECP with 95% CI in the four reclassified groups are shown in Table 4; both values were significantly higher in the current asthma compared to the healthy group ($p < 0.001$).

Positive SPT was found in 51.5% of the boys and 43.7% of the girls. In the asthma group, positive SPT was found among 68, 65 and 50% of those who had mild, moderate asthma and severe asthma, respectively. In the healthy and the symptomatic groups, 25% and 39% had positive SPT, respectively. The dominant allergens were animal dander, accounting for about 50% of the positive responses, followed by grass and birch pollen, with the other allergens only infrequently positive (Table 5). Mite allergy was found in only four children (two healthy, one with mild and one with moderate asthma). Most of the children with asthma had more than one positive SPT; only eight of those having mild asthma had a single allergy. Despite animal allergy in 56% of the asthmatic children compared to only 10% of the healthy group, 59% of their families kept animals at home (including both pets and farm animals).

A logistic regression analysis with asthma as the outcome variable demonstrated that the most dominant independent variable was animal allergy and an increased IgE for age, but a positive family history of atopy and smoking at home were also significant risk factors. Wall-to-wall carpeting significantly negatively influenced the risk of having asthma, which was interpreted as a result of common advice to asthmatic families to avoid or remove such carpets in Norway (Table 6).

Atopic eczema was reported by 65 of the 216 children, but only 18 of these children presented active eczema at the clinical examination. Rhinoconjunctivitis elicited by pollen exposure was reported in 72 pupils, of which 54% (52/97)

Fig. 2. Mean lung function with 95% confidence intervals for the healthy group, symptom group, previous asthma group, and current asthma group. FVC, forced vital capacity; FEV₁, forced expiratory volume in 1 second; FEF₅₀, forced expiratory flow at 50% of vital capacity.



were classified with asthma, 34% (13/38) were in the symptom group and 7% (5/73) in the healthy group.

Air pollen counts at Geilo during 1994 (independent of the present study) were very low for both birch and grass. On only two days were birch pollen counts higher than 10 per m³ air/day. The total grass pollen counts represented 12% of the Oslo counts for that season (Ramfjord, unpublished data).

Discussion

The present case-control study confirms a life-time prevalence of asthma in upper Hallingdal of approximately 10% among schoolchildren. Allergy to animals and a positive family history of atopy were the most frequent findings among the asthmatic children. The prevalence of asthma was independent of age, but the female ratio increased with age.

The asthma prevalence of 10% was surprisingly high for this geographical area, renowned for its good climate and low allergen load because of low pollen and mite concentrations. Since the study included all asthmatics in the actual population, the participation was 85% and all the children were examined by an experienced paediatric allergologist, the present results are expected to be more reliable than a questionnaire study.

The prevalence of asthma is consistent with Norwegian studies performed during the last 5–10 years in other parts of the country, with either higher environmental humidity, higher pollen counts or increased pollution (9–11).

Allergy to animals was a major factor associated with the high asthma prevalence, as shown by the OR for asthma of 3.6. Five of the six factors with increased odd ratios for asthma involved atopy. The sixth factor was indoor smoking. A high percentage of the families had animals at home, and thus a high level of allergen

Table 4. Geometric mean IgE and mean ECP with 95% confidence intervals are shown for the following groups of schoolchildren: healthy, symptom, previous asthma and current asthma

	Healthy group (n = 73)	Symptom group (n = 38)	Previous asthma group (n = 8)	Asthma group (n = 96)
Geometric mean IgE (U/ml)	33.5	62.4	170.7	127.3
95% CI	23.3–48.3	36.7–106.4	36.0–810.6	93.5–173.3
Mean ECP (μmol)	7.7	9.3	12.0	13.4
95% CI	5.9–9.4	6.6–12.1	0–24.3	11.1–15.7

Table 5. Positive skin-prick test results in 216 schoolchildren living in Upper Hallingdal.

Allergens	Sum of positive prick tests (n = 216) given as absolute numbers
Grass pollen (timothy)	72
Cat dander	66
Birch pollen	57
Horse dander	41
Dog dander	37
Hazelnut	21
Rabbit dander	19
Cow dander	11
Peanut	7
Mugwort pollen	7
Guinea-pig dander	6
Fish (cod)	4
Mite	4
Cladosporium	3
Eggwhite	3
Cowmilk	0

exposure probably contributed to the high prevalence of allergy and asthma. This is supported by other studies where different types of environmental exposures have been implicated in the prevalence of asthma and other atopic diseases (19,20). Increases in atopic diseases with higher prevalence in the Northern compared to the Southern part of Sweden have been explained by more 'tight', less ventilated houses in the north, combined with more time spent indoors in the poor air quality (1,21). Mite sensitization in the present study was negligible compared to studies from Europe and elsewhere (22,23), but consistent with findings from high-altitude areas (24).

The present study demonstrated a positive association between the number of positive SPT and the severity of asthma. Eight children with mild asthma had only one positive SPT, whereas all the children with moderate and severe asthma had two or more positive SPT. These findings are in agreement with studies demonstrating the

importance of actual allergy load for the development of allergic asthma (25,26), and reports of increasing severity of asthma with increasing allergen load (27).

Allergic rhinoconjunctivitis was reported in 72 children (33%) in the study population. Pollen counts recorded in the actual area in 1994 were very low for both birch and grass pollen, but many families spend their summer holidays in places with higher pollen concentrations. The high prevalence of pollen allergy may be the result of allergen exposure outside the present geographical area. On the other hand, Charpin et al. found that hay fever and positive SPT to grass were significantly higher in the Alps than at sea level (24). The present study demonstrated allergy to cat in 45 children (46%) and to dog in 29 children (30%) with asthma. We therefore believe that domestic animals are major causes of allergen sensitization in children in Upper Hallingdal, with a subsequent important role in asthma development. Very similar results were reported from the Los Alamos study, where Sporik et al. concluded that in a mite-free area with low outdoor air pollution, asthma was nevertheless a major cause of morbidity among schoolchildren. Furthermore, asthma was strongly associated with elevated IgE and sensitization to other indoor allergens, in particular those derived from cat (68% of the asthmatics) (28).

The association between physical activities outdoors in the cold climate and development of asthma is not clearly established. Cross-country skiing and alpine sports are popular among schoolchildren in this region owing to excellent skiing facilities combined with a relative lack of indoor sport facilities. A negative effect of cold air on the airways in young skiers with consequent increased bronchial reactivity is reported in other Norwegian studies (29). High intensity training by athletes can also negatively influence the bronchial responsiveness (30). Increasing physical activity with age combined with cold air may partly explain the findings of the present study. On the other hand, young skiers training at high intensity may be more aware of respiratory symptoms which could subsequently bias the results. However, recently published data reported an increasing fall in FEV₁ at the same exercise load with cold air compared to room air in asthmatic children (31). As further support for cold air adversely influencing the airways, Koskela et al. found that even moderate exercise in adult asthmatics could cause severe bronchoconstriction in climate conditions similar to the Scandinavian winter (32).

Table 6. Odd ratios (OR) with 95% confidence intervals (CI) for having asthma diagnosis by animal allergy, pollen allergy, mite allergy, family atopy, increased IgE, animal at home, indoor smoking, wall-to-wall carpeting at home and gender with level of significance.

Variable	OR	95% CI	Significance (p)
Animal allergy	3.6	1.6–8.1	0.003
Pollen allergy	1.1	0.5–2.5	0.88
Mite allergy	0.7	0.1–5.8	0.76
Family atopy	1.8	0.8–4.1	0.17
IgE increased	2.9	1.2–6.4	0.01
Animal at home	1.2	0.6–2.4	0.55
Smoking indoors	1.9	0.9–3.9	0.07
Wall-to-wall carpeting	0.4	0.2–0.7	0.003
Gender (M/F)	0.6	0.3–1.1	0.13

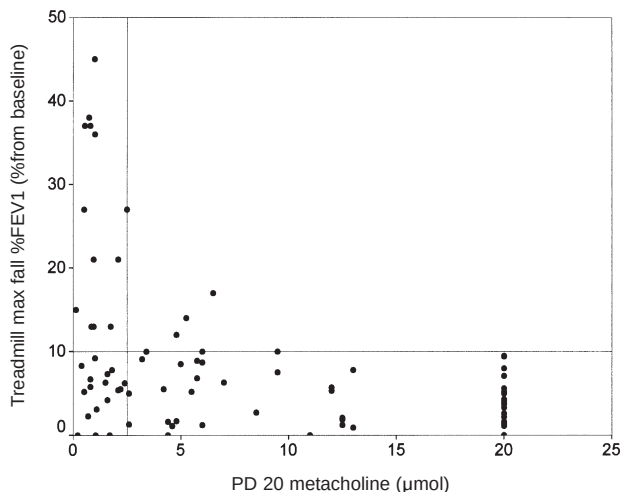


Fig. 3. Relationships between the results from the treadmill test (% fall in FEV₁ from baseline) and metacholine PD₂₀ values for the rediagnosed current asthma groups. The reference line for positive treadmill test is set at a reduction in FEV₁ of 10% and PD₂₀ value of 2.5 µmol. Metacholine inhalation tests without a reduction in FEV₁ of 20% at the highest inhaled dose of metacholine (16 µmol) are marked at a value of 20 µmol.

The gender differences in the present study are in accordance with other studies, showing an increasing proportion of girls with asthma as they reach puberty (33,34).

In the present study, only 7.6% (8/105) of the asthmatic children had outgrown their asthma at the time of investigations. Furthermore, in the separate age-groups 9–11, 12–14 and 15–18 years, the asthma prevalence was quite similar. Late onset of asthma and increasing wheeze with age and exercise are characteristics of the asthmatic children in Upper Hallingdal, contrary to other recent reports (11).

Assessing the severity of asthma is important in relation to interpreting the burden of asthma on individuals and society, but is infrequently done. The percentage distribution of mild, moderate and severe asthma in our asthma group was quite similar to the findings of Steen-Johnsen et al. in Telemark, Norway: 71, 20 and 6% in Hallingdal, compared with 67, 29 and 4% in Telemark, respectively (10). Treatment in general complied with the national and international guidelines, although some children were under-treated.

Except for a significantly higher FVC among the asthma group compared to healthy children, lung function parameters did not differ significantly between the groups. We cannot dismiss the possibility that this was caused by relatively better technique among the asthma children who, in contrast to the others, had performed spirometry previously. Mean values of lung function parameters close to 100% predicted indicate that

the asthma patients in general were well controlled.

As expected, PD₂₀ metacholine was significantly lower in the asthmatic group. However, bronchial hyper-reactivity was quite similar among children with severe compared to moderate asthma (data not shown). This may be explained by a higher dose of inhaled corticosteroids among those with severe disease. A similar trend was seen for ECP.

The exercise test was positive in only 20% of the children with asthma. This was surprisingly low compared to earlier reports (35); however, treatment with inhaled corticosteroids attenuates this reaction (36). Furthermore, it is possible that the majority of children had such mild asthma that wheeze and cough were elicited only by a combination of cold air and hard physical training, and not during standard exercise testing (31).

Bronchial hyper-responsiveness measured by the metacholine PD₂₀ test correlated only moderately with exercise test. Only six patients with PD₂₀ > 2.5 µmol metacholine had a positive exercise test, while the nine children with a > 20% fall in FEV₁ had PD₂₀ < 2.5 µmol. Thus the children with lowest PD₂₀ values had the greatest fall in FEV₁ after exercise, as expected.

In conclusion, this study confirms a relatively high prevalence of both lifetime asthma and especially current asthma in schoolchildren living in Upper Hallingdal. The most frequently identified allergy was associated with domestic animals, whereas mite allergy was rarely found. The high prevalence of asthma may be associated with a high incidence of keeping animals at home combined with frequent heavy physical activity in cold weather.

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