

EXERCISE INDUCED BRONCHOSPASM

Prevalence Rate of Exercise-Induced Bronchoconstriction in Annaba (Algeria) Schoolchildren

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Background. We studied the prevalence rate of exercise-induced bronchoconstriction (EIB) in Annaba schoolchildren. No previous assessment of this syndrome had ever been done in Algeria. **Methods.** EIB was evaluated using the 6 min free running test (6MFRT) on 286 children, 87.4% of whom were 10–12 years old. They performed the test in the morning, during the autumn–winter season. Peak expiratory flow rate (PEFR) was measured before, and then 5 and 10 min after the 6MFRT, a 15% or more decrease in post-exercise PEFR being defined as significant. **Results.** EIB was much more frequent in asthmatic than in nonasthmatic children (47.0% vs. 13.9%, $p < .001$) and the drop in PEFR was more marked among the former. EIB was observed more often in a cool temperature ($<8^{\circ}\text{C}$). There were relatively more children who were either eutrophic or overweight among those presenting an EIB. Past histories of nocturnal wheezing and rhinoconjunctivitis presented respectively the best specificity (96.7%) and sensitivity (84.8%). Children of unemployed workers presented the highest occurrence of EIB. Passive smoking appeared as the only factor being related to EIB among the indoor pollutants. The prevalence rate of asthma (6.7%) was higher than in a previous cross-sectional epidemiological survey study performed in the Maghreb. The prevalence rate of EIB (13.9%) was situated in the upper range of the results given worldwide. **Conclusions.** These features of a fairly high bronchial hyperresponsiveness could be facilitated by the polluted environment of the city.

Keywords air pollution, children, exercise-induced bronchoconstriction, free running, peak expiratory flow

INTRODUCTION

Asthma prevalence, after an increase during the second part of the twentieth century, may have plateaued between 1995 and the first years of the present century (1). This stabilization, and even some decrease in asthma prevalence, especially in countries with high baseline rates, was confirmed by the International Study of Asthma and Allergies in Children (2).

Children are more prone to present with exercise-induced asthma (EIA) since they often have a more intense physical activity than adults. The screening of EIA using the 6 min free running test (6MFRT) makes it possible to detect exercise-induced bronchoconstriction (EIB), which ranges from 5.8% to 14.9% (3) in children not known to be suffering from asthma. Moreover, it was observed that asthmatic subjects are more prone to develop EIB (4).

While the prevalence rate of asthma has been evaluated in some countries of the Maghreb through telephone interviews (5), we found only two articles concerning that of EIB in the same area, one performed on Libyan schoolchildren (6) and another one concerning Tunisian athletes (7), which both reported the same prevalence rate of 10%.

Because of the absence of previous studies on EIA/EIB in Algeria, we decided to assess the prevalence rate of EIB in Annaba schoolchildren using the 6MFRT. Annaba is an eastern Algerian industrial town subject to polluting (air, sea and ground) industrial activities (8). This study was performed in the morning during the autumn–winter season. The respective roles of personal, familial, and environmental factors were carefully analyzed.

METHODS

This study was performed in the city of Annaba (Eastern Algeria, 572,000 inhabitants in 2005) during the 2005–2006 autumn–winter season (11/12/2005 to 18/03/2006). Measurements were made in the morning between 8.00 and 11.00 am. Temperature and hygrometry statements were supplied by the meteorological station of Annaba.

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Like other Algerian coastal cities, Annaba's territorial public community (wilaya) presents the wet and mild characteristics of Mediterranean climate, with an average annual temperature varying from 14°C to 19°C. Pluviometry oscillates between 600 and 1200 mm a year, and it is higher during autumn and winter. The industrial potential of the wilaya of Annaba includes three complexes: Ispat (steel industries), Asmidal (phosphate fertilizers), and Ferroviai (metallic transformation). Its geographical situation promotes the dispersion of various wastes and pollutants toward the city.

After approval of the protocol by the Ethics Committee of the Badji Mokhtar University (Pr A. Mira, Legal Medicine, Annaba), an authorization from the Directorate of Education of the wilaya of Annaba was given to the headmaster of each school informing him about the research project. The headmasters in turn invited the parents to a meeting at which they informed them of the project. The survey was conducted after obtaining written consent from the parents.

Subjects

This epidemiological study of transverse type was realized in the 6th year forms of the town of Annaba, on a representative sample of children obtained by cluster sampling, and stratified on the size of schools. Among the 319 pupils selected, 33 were excluded from this study for the following reasons: absence from school ($n = 21$), insufficient strength of the effort ($n = 7$), excessive dyspnea during the effort ($n = 3$), severe fatigue during the effort ($n = 2$). The 12 children who were unable to correctly end the test because of the exhaustion were watched for one hour. They could not execute repeatedly the peak expiratory flow rate (PEFR) measurements during the recovery phase (see below: 'Free running test'). They did not present auscultatory wheeze.

Collection of Data

Data were collected in a room near the school playground where the free running tests took place. After recording their identity and anthropometric data (height, weight, body mass index: BMI) (9), the children filled in a questionnaire with the help of a physician. The French version (10) of the ISAAC (International study of Asthma and Allergies in Childhood) questionnaire was used. Verbal translation into dialectal Arabic was often used during the interviews.

Criteria of Inclusion

- Ten to 15-year-old children of both sexes, living and attending school for more than 1 year in the municipality of Annaba.
- Normal lung function (PEFR >80% of mean predicted value) (11) and clinical examination. The children considered as being asthmatics had to be free from any inhaled medication for at least 24 h. None of them took long-term control medications but only short-acting beta agonists on demand.

Criteria of NonInclusion

- Heart disorders.
- Acute infectious disease, anemia.
- Neuromuscular diseases.
- Tracheal stenosis.

Free Running Test

The 6MFRT were performed according to the usual protocol (12) after a slight modification (13): a 1 min slow running was followed by a 5 min running at the fastest possible speed. This short initial warm-up is intended to improve the tolerance in the test of running. Heart rate at the end of running, assessed by radial pulse palpation, had to be >85% of the maximal predicted value and the decrease in PEFR had to be >15% in order to conclude that the test was positive. PEFR was measured with a Mini-Wright Peak Flow Meter (Clement Clark International, UK). Three reproducible measurements were realized at each step of the free running test, that is, at rest and then at the 5th and 10th min of the recovery phase, the best result of each trial being kept. The children were asked about the occurrence of functional respiratory symptoms, and lung auscultation was performed before the test and again during the recovery phase. In case of a significant bronchospasm, the children were invited to inhale four puffs of salbutamol and their PEFR was measured 10 min later to check that a satisfying recovery had occurred.

Statistical Analysis

After codification, the results of the questionnaires as well as values of PEFR were entered into the EPI INFO 6.04 software and processed. The statistical analysis allowed comparing the observed proportions. The used tests were: the comparison of two percentages, the comparison of two qualitative variables (Pearson Chi-Square Test), the tests of sensibility and specificity. The positive predictive value (PPV) of a symptom was the percentage of children with a positive test among those developing symptoms, while the negative predictive value (NPV) was the percentage of children with a negative EIB among those without symptoms. Sensitivity is the percentage of children having symptoms among those with a positive test, while specificity is the percentage of children having no symptoms among those with a negative test. The significant level of the results was established at $p < .05$.

RESULTS

Prevalence Rate of EIB

Prevalence rate of EIB was 16.1% (46/286) in our population of children. Among them, the children considered as being asthmatics showed EIB during the running tests in a much higher proportion (9/19, i.e. 47%) than the other children (37/267, i.e. 13.9%, $p < .001$).

Strength of Bronchial Response to Exercise

Globally, most children (39/46, i.e. 84.8%) had a mild bronchial response to exercise, characterized by a 15–25% drop in PEFR, but a higher proportion of moderate (26–35% drop in PEFR) or strong (36–50% drop in PEFR) bronchial responses was observed in the children known as being asthmatics (4/9, i.e. 44%, $p < .05$, see Figure 1).

Respiratory symptoms (wheezing, cough, chest tightness, dyspnea) were present after running in most children with EIB (43/46, i.e. 93.5%), but the percentages of each of them were rather low (30.2, 27.9, 25.6, 16.3 respectively).

Environmental Conditions Promoting EIB

The average ambient temperature was cool during the running tests: 9.4 ± 3.0 (SD) °C. EIB was more frequently observed [$p < .0025$; odds ratio: 2.24 (confidence interval at 95%: 1.33–3.78)] when running tests were performed at a cool temperature ($<8^{\circ}\text{C}$) than at a warmer temperature ($>8^{\circ}\text{C}$) (Figure 2).

In this study, average hygrometry was high (81.9 ± 13.5 (SD) %) and did not affect the occurrence of EIB, for a threshold fixed at 60%.

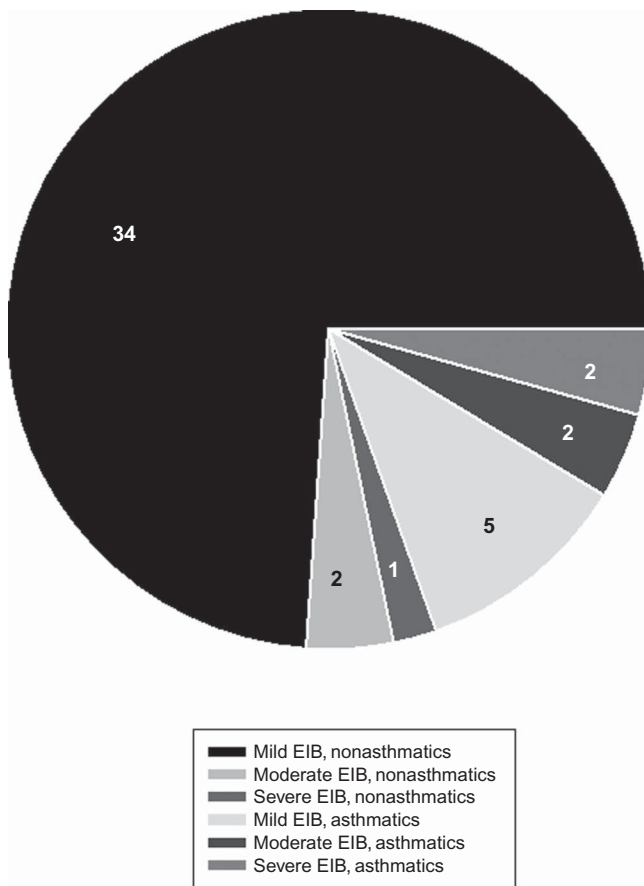


FIGURE 1.—Strength of bronchial response to exercise. The pie chart represents the repartition of EIB among the schoolchildren known as being asthmatics or not.

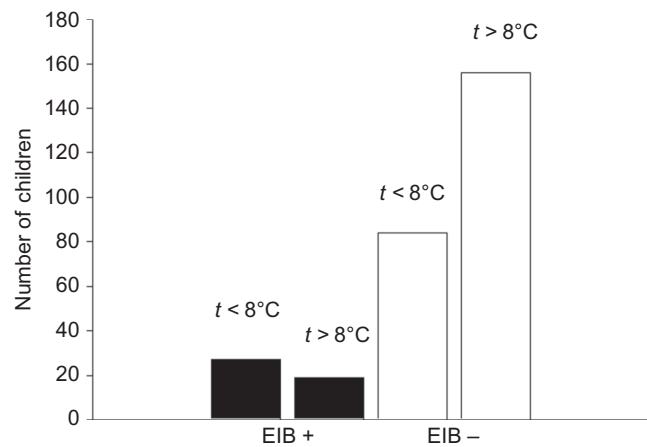


FIGURE 2.—Role of ambient temperature in EIB starting. EIB was more frequently observed (EIB+) when the ambient temperature was lower than 8°C ($p < .0025$).

Characteristics of the Subjects and EIB

The ages of the children presenting an EIB covered a narrow range (87.4% of them were 10–12 years old, see Figure 3A). The prevalence rate of EIB did not depend on the sex of the children (Figure 3B). Their BMI were abnormally high ($>25 \text{ kg/m}^2$) in only 2/46, that is, 4.4% of them, but there were relatively more children of normal weight or overweight among those presenting an EIB ($p < .04$) (Figure 3C).

The assessment of usual symptoms by the ISAAC questionnaire showed that past histories of nocturnal wheezing and rhinoconjunctivitis presented, respectively, the best specificity and sensitivity (96.7% and 84.8% respectively, Table 1).

EIB and Family Environment

In our population, most mothers were housewives (89%).

A significant difference was observed between children with or without EIB as far as their parent's professions were considered ($p < .001$). The highest occurrences of EIB were observed in children of unemployed workers (13/46, i.e. 28.3%) and middle managers (9/46, i.e. 19.6%).

The occurrence of EIB was not significantly related to the types of houses (apartment in a building, collective house, individual house, precarious house or 'gourbi') or the number of rooms inside (from 1 to >4), but the highest percentages of children presenting an EIB were noted among those living in precarious habitations (prevalence rate: 25.0%) or small habitations including only one room (prevalence rate: 26.1%). When the main house allergenic and polluting agents were inventoried by children's interview, passive smoking appeared to be the only factor being significantly related to EIB ($p < .001$) (Table 2).

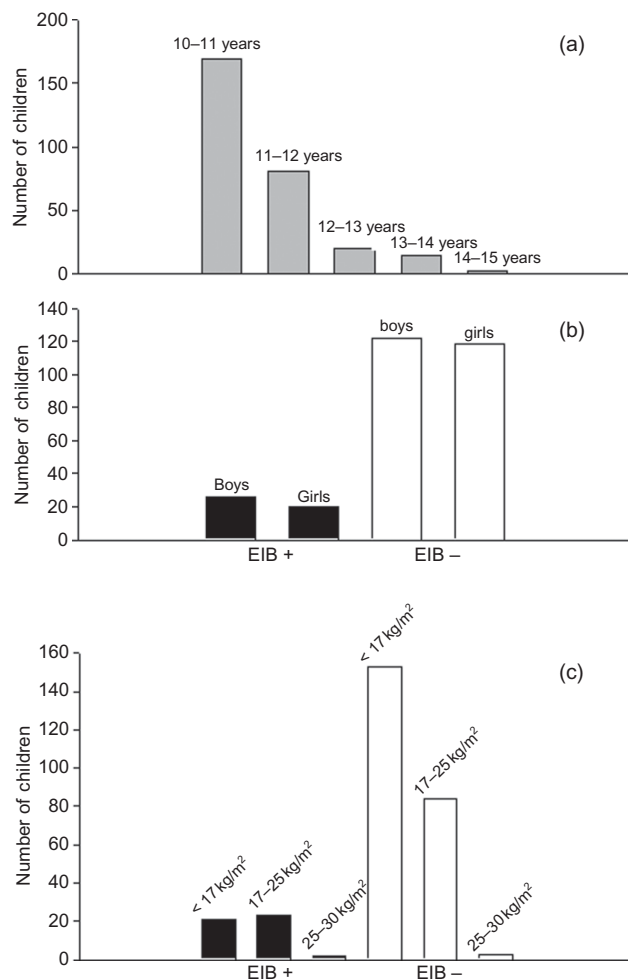


FIGURE 3.—Characteristics of the subjects. (a) Most children were 10–12 years old. (b) The prevalence rate of EIB did not depend on the sex of the children. (c) Being overweight was rare (4.4%) among the children presenting an EIB (EIB+). There were relatively more children of normal weight or overweight among those presenting an EIB ($p < .04$).

TABLE 1.—ISAAC questionnaire and prediction of EIB.

Indoor allergens and pollutants	PPV (%)	NPV (%)	Sensitivity (%)	Specificity (%)
Wheezing	52.9	91.9	58.7	90.0
Wheezing/12 last months	56.7	88.7	37.0	94.6
Nocturnal wheezing	74.2	91.0	50.0	96.7*
Asthma	47.4	86.1	19.6	95.8
Exercise-induced asthma	43.0	94.2	73.9	81.3
Rhinoconjunctivitis	24.4	94.4	84.8*	49.6
Familial asthma	23.0	86.3	37.0	76.3

Notes: Positive and negative predictive values (PPV and NPV), sensitivity and specificity of respiratory symptoms observed in the everyday life to predict EIB. The highest sensitivity and specificity concerned, respectively, rhinoconjunctivitis and nocturnal wheezing.

* $p < .001$.

DISCUSSION

Value of the ISAAC Questionnaire Confronted to the Free Running Test

Most children having no symptoms of nocturnal wheezing did not present EIB (specificity = 96.7%). In a previous

TABLE 2.—House allergenic and polluting agents and EIB.

Indoor allergens and pollutants	EIB +	EIB -
Passive smoking	27	19
Dampness	23	23
Mold	9	37
Cockroaches	9	37
Cat	6	40
Dog	6	40
Bird	8	38

Note: Passive smoking constituted the only factor significantly related to EIB ($p < .001$).

work analyzing usual symptoms related to EIB, wheezing also presented the highest specificity (3).

On the other hand, most children having symptoms of rhinoconjunctivitis presented EIB (sensitivity = 84.8%). It was demonstrated that rhinitis promotes the subsequent development of asthma in both atopic and nonatopic individuals (14). We did not find data relating a link between rhinitis and EIB, but it seems logical that impairment in nasal conditioning of inspired air can promote bronchial cooling and dehydration during exercise-induced hyperventilation, and result in an aggravation of bronchial constriction and edema.

Prevalence Rate and Strength of EIB

In this study, 16.1% of the pupils showed bronchoconstriction induced by the free running test. If we set apart the asthmatic children, who represented 6.6% of the pupils and among whom a strong proportion (47%) presented with EIB, we may consider that EIB was thus detected by the running test in 13.9% of the nonasthmatic children. It may be noted that the prevalence rate of asthma in our population was situated in the low range of those observed in the world, which vary from quite low values (2–4%) in Asian countries to very high ones (15–20%) in the United Kingdom, Canada, Australia, New Zealand, and other developed countries (15). However, it is higher than that reported in the Maghreb by the Asthma Insights and Reality in the Maghreb (AIRMAG) study (5): for instance, an average value of 4% was reported in less than 16 year-old children, living in Algeria. The authors signaled that the highest rates were observed in the densely populated coastal strip around Algiers and the lowest in the desert of the South.

In our study, the percentage of EIB is situated in the upper range of the data reported in children and teenagers (5.8%–14.9%) (3), by using the same challenge and the same PEFR threshold. It is also somewhat higher than that reported (10%) in Libyan schoolchildren (6) or Tunisian athletes (7).

The presence of EIB in nonasthmatic pupils reflects the inflammatory process described in the airways after exercise or hyperventilation challenge, from endobronchial biopsy specimens (16,17) or bronchoalveolar lavage fluid (18).

It is a well-known fact that asthmatic subjects are more prone to develop EIB (4): the airways of 50%–90% of

all individuals with asthma are hyperreactive to exercise. This high frequency was verified in our series, where the asthmatic children presented a higher proportion of moderate or strong drop in PEF than the nonasthmatic ones. The basal inflammatory state of airways in asthma may underlie their hyperreactivity to high level ventilation during exercise (19). This may explain why inhaled corticosteroids significantly attenuate EIB (20), as these medications decrease the number of epithelial eosinophils in bronchi (21).

Respiratory Symptoms after 6MFRT in Children Presenting an EIB

We noted that, when considered individually, clinical signs and symptoms were not good predictors of a positive free running test, as previously reported (3).

Environmental Conditions during 6MFRT and EIB

In the population studied, running tests were performed in the morning from the end of autumn to the end of winter, that is, in rather cool ambient conditions. It appears that EIB was facilitated by cool ambient air ($\leq 8^{\circ}\text{C}$), which corroborates carefully controlled studies (22). However, there might be a bias in the distribution of the sampling, because the tests were performed about twice more often at a temperature $> 8^{\circ}\text{C}$ in the children having a negative running test, while the distribution was more homogeneous in those having a positive running test.

The facilitating influence of low humidity on EIB, which has also been demonstrated (23,24), could not be verified in this work and it was rather minimized. Indeed, the threshold was chosen at a fairly high value (60%) because, as stated in the methods, Annaba is situated in a wet region of Algeria. As running tests were performed in damp meteorological conditions (mean humidity $\sim 80\%$), it is not surprising that the influence of humidity could not be brought to light.

Characteristics of the Subjects and EIB

Neither age nor sex could be shown to affect EIB in the population studied.

It seems that obesity does not increase EIB frequency in asthmatic or nonasthmatic children, but it does worsen postexercise bronchospasm and lengthen the recovery period (25).

BMI was marked in very few children of our sampling (5/286, i.e. 1.7%), among which most were thin or of normal weight, but there were relatively more children either eutrophic or overweight among those presenting with EIB. However, children with known asthma were eutrophic. As a whole, being overweight could not be considered as a risk factor in the development of EIB in our population, which does not reflect the childhood obesity epidemic observed in richer countries, where 6–28.7% children present as overweight or with obesity (26). Moreover, the low prevalence rate of asthma reported in our work (6.6%), may be explained, at least

in part, by the unusual rate of being overweight among the schoolchildren.

EIB and Socioeconomic Status

In our population, most mothers were housewives (89%). The children whose fathers were unemployed were more prone to develop EIB. A nonsignificant tendency toward a more frequent prevalence of EIB was observed in children of families living in precarious and small habitations. These data seem to corroborate recent works showing that childhood asthma is more frequent in families with a low socioeconomic status (27). Several hypotheses have been brought forward to explain this fact (27): later recognition of wheezing, increasing risk of sensitization particularly to food allergens, prolonged maternal stress leading to sustained excessive cortisol secretion affecting the developing immune system. Our data suggest a link between EIB and precarious living conditions.

EIB and Passive Smoking

Our data showed that passive smoking was the only indoor pollutant able to promote EIB. Many studies have demonstrated that passive smoking in the home has a harmful effect on children's lung function and it increases their life-long risk of asthma (28). One work reported also that environmental tobacco exposure could increase the occurrence of EIB in children (29). The increase in asthma risk due to tobacco exposure probably results from several factors: an impairment of lung function in childhood, an increased number of lower respiratory tract infections, a minor increasing effect on airway responsiveness (30), and also a possible genetically determined risk of asthma in children exposed to tobacco during pregnancy (31).

In conclusion, the prevalence rate of asthma in Annaba was higher than that reported in other studies performed in the Maghreb, and the prevalence rate of EIB was situated in the upper range of that normally obtained worldwide. This relatively high bronchial hyperresponsiveness might be the consequence of ambient industrial pollution rather than that of individual characteristics and/or family environment. The association of the ISAAC questionnaire and free running test could be a first step to detect and treat EIB in children prone to develop this syndrome. The use of these tools should reduce the frequency of inaccurate or missed diagnoses (32), and expedite preventive care of EIB.

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DECLARATION OF INTEREST

The authors report no competing interests. The authors alone are responsible for the content and writing of this paper.

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