Exercise-induced Bronchospasm in High School Athletes via a Free Running Test*

Incidence and Epidemiology

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Background: Exercise-induced bronchospasm (EIB) affects up to 35% of athletes and up to 90% of asthmatics. Asthma morbidity and mortality have increased over the past several decades among residents of Philadelphia, PA. It is possible that a simple free running test for EIB may serve as a tool to study the factors contributing to recent trends in asthma, and to screen for asthma in athletes in the urban setting.

Objectives: The purposes of this study were to (1) assess a free running test to screen for EIB, and (2) examine prevalence of and epidemiologic factors associated with EIB in high school athletes.

Design: Cross-sectional observational study on the incidence and risk factors for EIB. To validate our method and criteria for the diagnosis of EIB, a repeat test was performed on a portion of the athletes. In a randomized single-blinded fashion, 15 athletes who had demonstrated EIB initially received albuterol or placebo prior to a repeat exercise test.

Setting: Community high school athletic facilities.

Participants: We studied 238 male high school varsity football players.

Intervention: All athletes underwent an acquaintance session with a questionnaire, followed by a 1-mile outdoor run (6 to 8 mins).

Measurements: Peak expiratory flow (PEF) measurements were determined prior to and 5, 15, and 30 min after exercise. Heart rates (HRs) and dyspnea scores were measured. EIB was defined as a decrease of 15% in PEF at any time point after exercise. Associations of EIB with demographic factors were assessed by univariate and multivariate analyses.

Results: Two hundred thirty-eight athletes participated: 92 European-Americans (EA), 140 African-Americans (AA), 5 Hispanics, and 1 Native American. Mean age was 16 ± 1 years. Average HR postexercise was 156 ± 24 beats/min. Twenty-four (10%) reported a history of treated asthma. The prevalence of EIB among the remaining 214 athletes was 19 of 214 (9%). The rate of EIB among AA athletes was higher than among EA athletes: 17/126 [13%] AA vs 2/82 [2%] EA, p = 0.01). During the validation portion of the study, the placebo-treated group (n = 7) demonstrated a consistent drop in PEF after exercise on repeat testing, with a 16 ± 5% fall in PEF on initial testing and a 14 ± 13 drop with placebo. In contrast, the fall in airflow in the albuterol-treated athletes (n = 8) following exercise reversed with albuterol treatment, from a 15 ± 6% fall in PEF at initial testing to an increase in PEF of 6 ± 9% from baseline following albuterol administration. A history of wheezing (p < 0.001), residence in a poverty area (p < 0.0001), race (p = 0.01), remote history of asthma (p < 0.001), and absolute water content of the air on the day tested (p = 0.04) were significantly associated with EIB. By stepwise regression, EIB was most closely associated with a history of wheezing (p = 0.001) and poverty area residence (p = 0.003).

Conclusions: Our findings indicate a substantial rate of unrecognized EIB exists among urban varsity athletes, and suggest that active screening for EIB, especially for students residing in poverty areas, may be indicated to identify individuals at risk for EIB and asthma.

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Key words: airflow hyperreactivity; asthma; athletes; exercise; peak expiratory flow; poverty; race

Abbreviations: A = albuterol; AA = African-American; BMI = body mass index; DS = dyspnea score; EA = European-American; EIB = exercise-induced bronchospasm; HR = heart rate; NS = not significant; P = placebo; PEF = peak expiratory flow; TA = treated asthma
Exercise-induced bronchospasm (EIB) is defined as the occurrence of airways obstruction, immediately to 30 min after moderate exercise.\(^1,2\) The EIB episode, which is usually short lived, is preventable with the use of certain medications.\(^1\) The diagnosis of EIB is typically suggested by a clinical history and a decrease in FEV\(_1\) by at least 15% following a methacholine challenge or 10% with exercise challenge. However, several studies have suggested that a 10 to 25% change in peak expiratory flow (PEF) rate after exercise constitutes EIB.\(^3-5\) The exact relationship of EIB to asthma remains unclear, but up to 90% of known asthmatics report EIB,\(^1\) and EIB is found in up to 35% of selected patient populations without known asthma.\(^4,6\)

Asthma morbidity and mortality have increased over the past several decades among residents of Philadelphia, PA. Rates of asthma mortality are highest in poverty areas with large proportions of African-American (AA) residents.\(^7\) The factors driving these high rates of asthma morbidity and mortality are not fully understood, but they likely include poor access to and utilization of health-care services, substandard patterns of pharmacotherapy employed for the treatment of asthma, indoor allergens and pollutant exposures, and psychosocial factors.\(^8-10\)

The prevalence of asthma also appears to be higher in urban poverty areas in the United States, which contains relatively high proportions of AA and Hispanic-American residents.\(^11-15\)

Studies examining the utility of exercise testing to screen for and study asthma prevalence have been hampered by differences in the clinical definition of EIB and varied testing protocols.\(^16-23\) In addition, the clinical significance of a fall in airflow after exercise as it relates to a diagnosis of asthma is not clear. However, Haby and colleagues\(^34\) have recently shown that a decrease in FEV\(_1\) after exercise may correlate with wheezing history and histamine-induced hyperreponsiveness in children. Thus, it is possible that, if during exercise testing airflow changes can be correlated with clinical disease, it may serve as a tool to study the factors contributing to recent trends in asthma, and to screen for asthma in the urban setting.

The purposes of this study were as follows: (1) to test the ability of a simple free running test to screen for EIB; (2) to evaluate the significance of a decrease in airflow after exercise, as it relates to airflow hyperreactivity (a validation test); and (3) to use this test to examine the incidence of and factors associated with EIB in high school athletes.

**Materials and Methods**

**Study Design**

Two hundred thirty-eight varsity male high school athletes from nine high schools (five public and four parochial, mean size = 1,825 (range, 300 to 3,200) students) in Philadelphia, PA, were asked to run an approximate outdoor mile (five laps around a 120 × 50-yard playing field) as part of their fall football practice. The study was conducted from mid-August to early November 1995 and 1996, in the afternoon (3 to 6 PM) during 12 different testing sessions. Between 6 and 30 athletes participated at any of these sessions. The athletes were arbitrarily selected to participate by the head football coach. Students were unaware testing was going to occur prior to being selected. Of 475 eligible varsity athletes on the active rosters, 238 participated in the study (50%). The remaining athletes did not participate due to absence from practice, injury, or when the 30 slots available for study on a given day were filled. Twenty-four athletes (10%) were identified as having asthma that was being treated medically and were excluded from statistical analyses. As this portion of the study was observational and without therapeutic intervention, informed consent was not necessary in concordance with the approval of the Institutional Review Board of Temple University. The data on the remaining 214 athletes are presented.

Prior to exercising, an acquaintance session was conducted to collect demographic information and to introduce subjects to the study and its field investigators. This session included a two-page, 15-item questionnaire described previously,\(^1,16\) a review of the study protocol, and instruction in the use of a PEF meter (Mini-Wright; Armstrong Medical Industries; Northbrook, IL).

Without warm-up activity, the athletes performed a competitive, outdoor run in groups of four to six. If the athletes were unable to complete the entire run, a minimum exercise time of 6 min was required prior to PEF testing. Heart rates were obtained immediately after completion of the exercise with a portable pulse oximeter (model 950 Healthdyne Technologies; Marietta, GA); PEF measurements were then measured at 5, 15, and 30 min after completion of exercise. The athletes remained sedentary between measurements. A dyspnea score using the visual Borg scale (0 to 100) was also measured at each testing period.

**PEF Measurements**

PEF was obtained using the best of three measurements at each tested time point. All PEF measurements were performed with the subject in the standing position under direct supervision. Without the use of a noseclip, each athlete used the same PEF meter throughout the testing protocol. The percent variability of PEF at each time point was calculated ([maximum PEF – minimum PEF]/maximum PEF) ×100.
Exercise Performance and Testing Conditions

Athletes ran approximately 1 mile. Ideally, exercise should be performed for at least 6 min at 80% of the predicted maximum heart rate (HR),23 which corresponds to approximately 160 to 170 beats/min for 15 to 18 year olds. The mean exercise time was 488 ± 7.5 s (8.1 min), and the average HR obtained immediately after exercise was 156 ± 24 beats/min.

The absolute water content of the air on each day of testing was calculated from temperature and relative humidity measurements obtained from a local weather center. During the days of testing, the absolute water content of the air was 9 ± 3 mg H₂O/L. The mean temperature and relative humidity were 19 ± 4°C (67 ± 9°F) and 56 ± 13%, respectively.

Validation Test: Subjects and Study Design

We assessed the ability of our test to diagnose EIB as a defined drop in airflow after exercise that is reproducible on repeat testing and reversible with a bronchodilator. A 10% drop in PEF was selected to determine eligibility, since it is the lowest reported fall in PEF associated with EIB.24 Fifty-three of the original 238 subjects tested (21%) demonstrated at least a 10% fall in PEF on initial testing and were eligible for repeat testing. Although the athletes with treated asthma (TA) were excluded from epidemiologic analysis, they were available and included in the validation portion of our study. Sixteen subjects agreed to participate and were assigned a study number. Informed consent was obtained in compliance with the Institutional Review Board of Temple University. The remaining subjects were not tested due to a variety of reasons, including lack of consent, absence on the day of repeat testing, and academic failure from high school. The repeat testing was done within 2 months of the original test.

The participating subjects were randomized in a single-blind fashion to receive either albuterol (A) (three puffs, 270 µg) or a placebo (P), using a tube spacer device (Aerochamber; Northgate Technologies Inc; Elgin, IL) with direct physician instruction. The three subjects with a known history of TA did not use medication on the day of testing. Twenty-five minutes after receiving the medication, the participants (eight A and seven P) underwent the same exercise protocol as described previously. There was no significant difference in atmospheric water content between the initial test (8 ± 4 mg H₂O/L) and the subsequent test (9 ± 4 mg H₂O/L). One subject did not finish the test due to nasal irritation and was excluded. The maximal change in PEF from the baseline (before treatment) was used to determine the maximal changes in PEF following exercise. Data for the remaining 15 subjects (8 A and 7 P) are reported.

Data Analysis

The data were analyzed using software (Sigmastat, Jandel Scientific; San Rafael, CA) and software package (SAS Institute Inc; Cary, NC). We defined EIB as a fall in PEF of at least 13% at any time point after exercise, a value based on previous studies examining the incidence of EIB using a free running test21,22 and the results of our validation test. The maximum change in PEF from baseline after exercise was used to determine the presence of EIB. Those athletes residing in a zip code with ≥20% of the population classified in poverty20 according to the 1990 census enumeration for Philadelphia27 were considered poverty area residents. Fisher's Exact Test for independence was used to determine the associations among qualitative factors and EIB. The Wilcoxon rank sum test for independent samples was used to determine associations among quantitative factors and EIB. Stepwise logistic regression was used to determine the factors that in combination were most predictive of EIB. The variables included in the initial logistic regression included race, poverty area residence, questionnaire responses, percent baseline PEF, absolute water content, age, body mass index (BMI), and HR after exercise. Baseline PEF (percent, absolute water content, and an indicator variable for the one school that had an unusually high prevalence of EIB was included in a second logistic model to adjust for the differences at baseline in these parameters. Corrections for predicted PEF measurements were calculated based on the subjects’ height and race, using the equations recommended by the manufacturer of the Wright Mini-Flow Meter (Clement Clarke; Columbus, OH).28 p values of <0.05 were considered statistically significant.

RESULTS

PEF Variability

The overall PEF variability for all collected time points was 5 ± 4%, which is well within the 15% cutoff that we used to define EIB. The percent variability at each time period was 5 ± 3% pretest, 6 ± 5% at 5 min, 5 ± 4% at 15 min, and 5 ± 4% at 30 min.

Airflow Response

Figure 1 demonstrates the PEF response to exercise in the 214 athletes without known asthma or TA. The average change in PEF as a group was a fall of 6 ± 10%. Considering potential definitions of EIB, the prevalence of EIB in this study ranges from 20% (43/214) if a 10% fall in PEF is considered diagnostic for EIB, to 11% (24/214) if a 12.5% fall is diagnostic, to 9% (19/214) if a 15% fall is diagnostic.

Table 1 shows the demographics and performance data of the athletes with and without EIB. Nineteen of 214 (9%) of the athletes demonstrated EIB. There was a significant difference in prevalence of EIB among athletes of different races, with 17 of 126 (13%) AA athletes having EIB, as compared with 2 of 82 (2%) European-American (EA) athletes (p = 0.01). There was no significant difference between the athletes with and without EIB with regard to age, BMI, initial percent predicted PEF, or measured HR after exercise. The athletes with EIB exercised for a longer period of time than those without EIB (513 ± 94 s EIB [+] vs 466 ± 78 s EIB [−], p = 0.03). The absolute water content was lower in the athletes with EIB compared to those without EIB (8 ± 3 mg H₂O/L EIB [+] vs 9 ± 4 mg H₂O/L EIB [−], p = 0.04).

Figure 2 demonstrates the airflow changes, as percent predicted PEF corrected for race and height, that occurred over the 30 min following exercise. The EIB-positive subjects had a significant decrease in PEF from baseline compared with EIB-negative athletes at each time point tested after exercise.
The athletes with EIB, compared to those without EIB, demonstrated a significant increase in their dyspnea score (DS) at 5 and 15 min after exercise. The 5-min DS was 32 ± 29 EIB (+) vs 16 ± 15 EIB (−), p < 0.001; the 15-min DS was 15 ± 22 EIB (+) vs 7 ± 10 EIB (−), p < 0.01; and the 30-min DS was 6 ± 14 EIB (+) vs 3 ± 8 EIB (−), p = not significant (NS).

Validation Testing

The demographic and baseline study results for the P (n = 7) and A (n = 8) groups are shown on Table 2. There were no significant group differences in race, age, BMI, TA, initial performance (run time and HR after exercise), or subjective DSs after the initial exercise test. Furthermore, the groups displayed a similar initial PEF response to exercise, with the P group demonstrating a fall in PEF of 16 ± 5% and the A group demonstrating a 15 ± 6% fall in PEF.

The P-treated group demonstrated a similar decrease in PEF on repeat testing, with a 16 ± 5% fall in PEF on initial testing and a 14 ± 13% drop with placebo, as shown in Figure 3. In contrast, the A-treated athletes’ fall in airflow following exercise reversed with treatment, changing from a 15 ± 6% fall in PEF at initial testing to an increase in PEF of 6 ± 9% from baseline following A administration. Compared with the placebo group, the percent change in PEF in the A group was statistically significant (+24 ± 67% P vs +157 ± 63% A, p = 0.002). The run times and HR after exercise did not change significantly in either the P- or A-treated groups with the intervention.

Figure 3 also demonstrates the individual PEF responses to exercise on the initial test, and after repeat testing with either P or A treatment. Defining EIB as a 15% fall in PEF, three of four (75%) of the P-treated athletes were considered to have reproducible EIB. The fourth athlete’s PEF went from a 16% fall to a 14% fall after exercise. The three participants who had initial changes in PEF <15% would again not have been considered EIB positive on repeat testing. All participants, regardless of

Table 1—Incidence and Performance Related to EIB

<table>
<thead>
<tr>
<th>Total</th>
<th>EIB(+)</th>
<th>EIB(−)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>214</td>
<td>19 (9)</td>
<td>195 (91)</td>
<td></td>
</tr>
</tbody>
</table>

Race/ethnicity (%)

EA 82 2 (2) 80 (98)
AA 126 17 (13) 109 (87)
Hispanic 5 0 5 (100)
Native American 1 0 1

Agr, yr 16 ± 1 16 ± 1 16 ± 1 NS
BMI, kg/m² 25 ± 5 27 ± 6 25 ± 4 NS
Baseline % predicted PEF 86 ± 12 83 ± 11 87 ± 12 NS

PEF Run, s 470 ± 80 513 ± 94 466 ± 78 0.03
HR after exercise, beats/min 156 ± 23 162 ± 22 156 ± 24 NS
Absolute water content on day tested, mg H₂O/L 9 ± 3 8 ± 3 9 ± 4 0.04
initial PEF changes, showed substantial improvement in PEF following exercise after inhaling A.

**Epidemiology**

Associations of EIB with demographic factors were assessed using the responses to a questionnaire (Appendix). According to univariate analyses, as shown in Table 3, race (p = 0.01), a remote history of asthma (p < 0.001), history of wheezing (p < 0.001), and poverty area residence (p < 0.001) were significantly associated with EIB. The number of estimated days missed from school due to respiratory illness over the year prior to testing (question 16) also correlated with EIB; the EIB (-) students averaging 0.2 ± 1 missed days per year vs 1 ± 3 missed schooldays per year for the EIB (+) athletes (p = 0.02). No other questions correlated significantly with EIB. All the questions had response rates ≥90%. When evaluating each school for EIB prevalence, one school demonstrated a significantly higher rate of EIB than the overall rate for eight other schools combined (p < 0.01). Figure 4 displays rates of EIB among 206 varsity athletes residing in the city of Philadelphia, categorized according to whether they provided a history of wheezing. Among athletes with no history of wheezing, EIB occurred only in those residing in the quintile of zip codes with the highest rates of poverty, while athletes with a history of wheezing displayed a tendency for greater rates of poverty in their zip code of residence.

Multivariate analysis by stepwise logistic regres-
sion revealed that EIB was most closely associated with a history of wheezing and poverty residence with adjusted odd ratios of 12.5 and 7.8, respectively (p = 0.001 and p = 0.003, respectively). When baseline PEF, absolute water content, and the indicator variable for the one high school with the highest rate of EIB were added to the logistic regression model, the adjusted odds ratios for wheezing and poverty were 12.7 and 10.5, respectively (p = 0.004 and p = 0.001, respectively).

**Table 3—Influence of Factors on the Occurrence of EIB**

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>EIB(+)</th>
<th>EIB(−)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Race, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EA (n = 82)</td>
<td>2</td>
<td>6</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td>AA (n = 125)</td>
<td>14</td>
<td>29</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Poverty area residence, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes (n = 77)</td>
<td>20</td>
<td>20</td>
<td>NS</td>
</tr>
<tr>
<td>No (n = 135)</td>
<td>3</td>
<td>3</td>
<td>&lt;0.0001†</td>
</tr>
<tr>
<td>Questionnaire responses†</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>History of hay fever, %</td>
<td>21</td>
<td>20</td>
<td>NS</td>
</tr>
<tr>
<td>History of asthma or childhood asthma, %</td>
<td>26</td>
<td>6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>History of wheezing, %</td>
<td>63</td>
<td>17</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Household smoke, %</td>
<td>33</td>
<td>55</td>
<td>NS</td>
</tr>
<tr>
<td>Tobacco use, %</td>
<td>10</td>
<td>5</td>
<td>NS</td>
</tr>
<tr>
<td>Any other question (see Appendix)</td>
<td></td>
<td></td>
<td>NS</td>
</tr>
</tbody>
</table>

*Risk for EIB between athletes based on racial difference.
†Comparison of EIB rates living inside and outside of a poverty area (defined as zip code in which ≥20% of residents are classified in poverty).
‡All questions had ≥90% response rates of the 214 participants. Questions 14 and 15 were asked to the last 173 participants.

**Figure 3.** PEF response to exercise before and after pretreatment with P (n = 7) and A-treated athletes (n = 8). The mean ± SE percent changes are shown next to each group. The treatment effect of the P and A (expressed as percent change) was significantly greater in the A-treated athletes (p = 0.002).

**Discussion**

We found a substantial incidence of EIB in undiagnosed and untreated varsity football players in the Philadelphia area. PEF measurements taken in a "field setting" were easily accomplished and helped to verify the diagnosis of EIB, first by reproducibility of measurement and then by showing a reversal of airflow obstruction following bronchodilator therapy. Our findings demonstrate that EIB is common among varsity athletes and is most closely associated with a history of wheezing and poverty area residence, each of which contributes independently to EIB.

Several studies have examined the incidence of EIB in college and high school athletes with varied results, seemingly dependent on study design. Resting lung function, patient questionnaires, and health-care provider interviews have been common screening modalities. Rice and colleagues initiated...
tially reported a 2.8% incidence of EIB in college athletes. In a similar group, Huftel and colleagues\textsuperscript{20} found that 17% of athletes without a history of asthma had a decline in FEV\textsubscript{1} of at least 15% when undergoing methacholine challenge, and 5% were subsequently diagnosed as having asthma. Rupp et al\textsuperscript{19} found EIB in 29% of urban AA middle-school and high-school-age athletes, with exercise provocation. These students had previously undiagnosed conditions and either reported a clinical history consistent with asthma via a questionnaire or had abnormal baseline spirometry findings. In a follow-up study with the same group of students, Rupp et al\textsuperscript{16} found a 13% incidence of EIB in middle-school and high-school-age athletes, 64% of whom had normal screening by history and baseline spirometry. The basis for a diagnosis of EIB in these studies was a significant drop in FEV\textsubscript{1} either by exercise provocation or methacholine challenge. Recently, Feinstein et al\textsuperscript{30} described the utility of a submaximal step test with spirometry, and found a decrease in airflow in 20 to 44% of football players tested. The incidence depended on whether a fall in PEF or FEV\textsubscript{1}, or both, was utilized to diagnose EIB. These reports, and our finding of a 9% incidence of EIB, suggest that EIB may be common and warrant extensive screening of athletes at risk.

"Field testing" for EIB using a PEF meter has been studied in the pediatric population. Free running with subsequent PEF monitoring has been the most widely used technique. Tsanakas and colleagues\textsuperscript{21} found a 3% incidence of EIB, using a 15% drop in PEF as diagnostic, in secondary school children. Others have had similar results, with the incidence ranging from 3%\textsuperscript{22} to a recent report by Jones and Brown\textsuperscript{23} showing 9%, 58% of whom developed asthma over the subsequent 6 years. Thus, it appears that a "free run" or "field test" such as ours may have a role in screening for EIB and potentially for asthma.

We found that a history of wheezing and a remote history of asthma were significantly associated with EIB, while other questionnaire responses demonstrated no predictive value. The inability of similar questionnaires to predict EIB has been reported.\textsuperscript{1,16} Rupp et al\textsuperscript{16} found that a routine questionnaire predicted EIB with a 36% sensitivity and a 85% specificity in middle school athletes. Randolph and Fraser,\textsuperscript{18} in a younger pediatric population, found that questionnaire responses correlated with EIB, which then was diagnosed via a free running test with a 72% sensitivity and a 50% specificity. Our questionnaire results are compatible with these findings. The ability of our one question on wheezing to so strongly predict EIB may reflect the nature of the population we tested. Our population consisted of a large number of impoverished urban youths. This population has been shown to have higher rates of asthma morbidity that may reflect lack of access to medical care and/or lack of medical compliance.\textsuperscript{11–15} We suspect that this question may have identified a group of athletes with asthma who had not seen physicians and did not identify themselves as asthmatic.

Our findings indicate that a substantial rate of unrecognized EIB exists among urban varsity athletes, and suggest that active screening for EIB—especially for athletes residing in poverty areas—is required in order for these individuals to receive appropriate management. As few whites living in poverty area zipcodes were included in our study, additional investigation focusing on whites residing in urban poverty areas will be required to determine whether greater risk for EIB also extends to white youths. Keeley et al\textsuperscript{30} found higher rates of EIB among schoolchildren in Zimbabwe in association with residing in an urban affluent area compared with urban poor or rural areas, but not in association with race. A recent report from Ghana\textsuperscript{31} also found that the incidence of EIB was significantly higher among 9- to 16-year-olds residing in urban affluent areas compared with urban poor or rural areas. Our findings also imply that the potential to exhibit EIB is influenced by environmental factors—for which, in the United States, residing in an urban poverty area may be the best marker. Greater severity (rates of mortality and hospitalization) and prevalence of asthma have previously been associated with mea-
asures of poverty such as lower income, crowding, and living in inner-city areas where unfavorable health-care access and utilization patterns exist. The multiple environmental factors present in urban poverty areas can influence care-seeking behavior. Cunningham et al found that among Philadelphia schoolchildren aged 9 to 11 years, AA race significantly predicted active asthma, but not persistent wheezing—suggesting that a propensity to obtain care in emergency departments may promote a differential tendency to acquire a label of “asthma.” Our data clearly associate incidence of EIB with poverty area residence (while controlling for race), demonstrate a striking rate of EIB among varsity athletes residing in poverty area zipcodes, and suggest that this likely reflects a high rate of undiagnosed asthma among the youths who live in these areas.

Previously, the diagnosis of EIB has been hampered by varying definitions of and testing protocols for this condition. A commonly used criterion for diagnosis is a 15 to 20% drop in FEV₁ after at least 5 min of exercise (usually in a controlled, laboratory setting) at 90% of the predicted maximal HR. This is a cumbersome, time-consuming, and expensive process that precludes the ability to test large numbers of athletes. Alternatively, the measurement of PEF changes after exercise is easy to perform and entails fewer technical constraints. However, the correlation of PEF changes after exercise in a free running test such as ours to changes achieved through protocols such as those noted above is unknown.

Overall, our screening method was easy to perform and our outdoor run produced an average exercise duration that could reasonably be expected to produce EIB, despite the noted difference between athletes with and without EIB. As our average HR postexercise did not reach the 90% predicted maximum level, we may have underestimated the incidence of EIB. We note that the EIB (+) athletes ran significantly slower than their EIB (−) counterparts (p = 0.03), without a significant difference in HR. We suspect this may be due to exercise limitations from EIB. However, alternative explanations, including lack of effort and worse physical conditioning, are possibilities that cannot be excluded. The degree of variability of the PEF meter measurements were well within our 15% cutoff for a diagnosis of EIB. For these reasons, we believe that our method looks promising to examine for EIB; however, further studies on its sensitivity and specificity are needed.

To our knowledge, our study is the first to examine the clinical significance of a screening test for EIB by using airflow reversibility following inhaled albuterol as a diagnostic standard for EIB. Our method is a logical extension of the recent findings by Hahn and colleagues, who demonstrated that a free running test in school children correlated well with a standardized histamine challenge, and might be utilized as an epidemiologic tool to examine EIB and asthma. Complete reversal of postexercise airflow obstruction implies that the PEF changes we noted truly represent EIB. For this reason, although the validation portion of our study involved a small number of subjects and we could not assess group specificity, we believe that our screening test is an effective screening method for diagnosing EIB and studying the various epidemiologic factors mentioned.

We recognize that factors such as weather conditions and length and intensity of exercise are important in the prevalence of EIB. Hahn and colleagues have suggested that the osmotic effects of inspired air influence the prevalence and degree of EIB more than airway cooling. Thus, the absolute water content of the air seems to be the most important weather factor, more inflammatory than either temperature or relative humidity. It appears that an absolute water content of ≤10 mg H₂O/L enhances the prevalence and severity of EIB, whereas a level of >20 mg H₂O/L reduces the likelihood for EIB and makes conditions less optimal for identifying this condition. As we were unable to control for weather, our results may have been biased. However, most of our athletes (75%) were tested under conditions with absolute water contents ≤10 mg/dL, and our multivariate analysis showed that water content did not appear to significantly influence the occurrence of EIB.

The incidence of EIB was found to be significantly higher in one of nine schools tested. It was not possible to account for individual biases that might be present at that particular school (training methods and environmental factors that theoretically could have affected performance), and thus could have affected our results. However, the athletes tested at this location were all varsity athletes who routinely perform the same level of activity as the athletes at the other schools. On the contrary, this one school consisted of athletes who were predominantly AA who resided predominantly in the most extreme poverty areas. Thus we believe that this school highlights our findings that athletes residing in lower poverty areas are at greatest risk for EIB and are more commonly participating in similar athletic activities as are their higher socioeconomic counterparts without proper treatment.

We have shown a substantial rate of untreated asthma, manifested in a higher rate of EIB, that is most closely associated with residing in poverty area. We devised and verified an easy-to-perform
screening test for EIB. Given the increase in urban asthma and our findings of a significant relationship between EIB and poverty, several important issues need to be addressed: (1) there should be more field screening for EIB, especially for populations at high risk, to improve asthma recognition and treatment; (2) the utility of "field tests" as epidemiologic tools to study asthma needs to be examined; and (3) the observations noted in this study need further examination in a larger population of athletes in different cities. If these observations are again confirmed, large-scale screening might be considered.

APPENDIX QUESTIONNAIRE

1. Do you have any allergies? □ YES □ NO
2. Are you allergic to inhalants, such as dust, pollen, or animal hair? □ YES □ NO
3. Have you ever had hay fever? □ YES □ NO
4. Do you take any medications, medicine, drugs, or vitamins on a regular basis? □ YES □ NO
   Names of meds: __________
5. Have you ever had asthma, even as a child? □ YES □ NO
6. Have you ever had wheezing? □ YES □ NO
7. Have you ever had pneumonia or other lung problems? □ YES □ NO
8. Have you ever been hospitalized overnight at any time in your life? □ YES □ NO
   Explain: __________
9. Do you smoke cigarettes, pipe, or cigar? □ YES □ NO
10. Have you to stop when running 1/2 mile (twice around the track)? □ YES □ NO
11. Do you have trouble with breathing after running 1 mile and resting? □ YES □ NO
12. If I sent you out to run 1 mile and then sat you down in a chair and had you rest for 10 or 15 min, would your breathing get worse while resting, your chest get tighter while resting, or would you experience coughing? □ YES □ NO
13. Have you had a cold, sore throat, runny nose or cough within the last 2 weeks? □ YES □ NO
14. Does anyone in your family have asthma? □ YES □ NO
15. Does anyone in your household smoke at home? □ YES □ NO
16. How many days of school did you miss last year because of breathing problems? __________

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