Prevalence of Bronchial Hyperresponsiveness in Highly Trained Athletes*

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Previous studies indicated that the prevalence of symptomatic asthma is about 4 to 7 percent. No similar studies exist to suggest the prevalence of asthma in highly trained competitive athletes, since asthma is thought to be an uncommon disease in this population. We became concerned, therefore, when a large number of football players developed symptoms consistent with asthma during preparation in California for the Rose Bowl in December 1981. We studied the team and found 12 percent of the football players admitted to a history of asthma, whereas none of the members of the university basketball team and 7 percent of a group of sophomore medical students and physician assistant students gave a history of asthma. Furthermore, 19 percent of the football players indicated that at some time they had chest tightness, cough, wheezing, or prolonged shortness of breath after exercise; 12 percent of the basketball players and 37 percent of the students indicated such a history. We examined each of these three groups for nonspecific bronchial hyperresponsiveness to inhaled methacholine using a modified methacholine bronchoprovocation (MBP) challenge and found that 76 of 151 (50 percent) football players tested had positive tests; 76 percent of those with symptoms had positive results of inhalation tests and 47 percent of those with minimal or no symptoms had positive test results. In addition, four of 16 (25 percent) basketball players and 69 of 167 (41 percent) students had positive MBP tests. These studies indicate that bronchial hyperresponsiveness to inhaled methacholine is much more common in these young adults than has previously been suspected.

The 1972 gold medalist in the 400 meter freestyle swimming competition at the Munich Olympics was disqualified when it was subsequently discovered that he had used ephedrine containing bronchodilators. That event clearly demonstrated that a highly trained athlete may be very competitive in spite of active asthma. It has generally been thought that few competitive athletes have asthma. The prevalence of hyperresponsive airway disease in this population, however, has never been studied.

We became interested in this problem after members of our university football team were noted by team physicians and trainers to have a significant problem with wheezing and chest tightness during pregame preparation in California for the 1982 Rose Bowl. Training had been suspended for about four weeks before the trip, and we wondered whether certain members of the team might have hyperresponsive airway disease that was manifested only when these athletes were out of training and breathing polluted air.

We used a modified methacholine bronchoprovocation (MBP) test and screened team members for nonspecific airway reactivity. We found that one half had positive MBP challenges, but only 12 percent had been diagnosed as having asthma. Nineteen percent recognized symptoms of chest tightness, cough, wheezing, or prolonged shortness of breath at some time. These studies indicate that a positive MBP test is very common in these highly trained athletes. This, coupled with the finding that many have had symptoms of asthma, suggests that mildly symptomatic asthma is common in these athletes.

**Subjects and Methods**

*Asthma Questionnaire and Definitions*

Total symptom scores were determined using the following questions and scores (in parentheses): A history of asthma meant that the individual had been told that he had asthma (4 points). Symptoms of asthma included the following: exercise-induced chest tightness (1 point); exercise induced cough (1 point); exercise-induced wheezing (1 point); exercise-induced prolonged dyspnea (1 point); chest tightness, cough, wheezing or prolonged dyspnea not exercise-related (1 point); upper respiratory infections that led to chest symptoms (1 point); and chest tightness, cough, or wheezing after exposure to cold air, smoke, fumes, dust, mold (1 point). We compared individuals with a symptom score of 3 or less (nonasthmatic group) with those with a symptom score of 4 or greater (asthmatic group). The maximum score was 11.

Nonspecific bronchial hyperresponsiveness meant that the individual had a positive methacholine bronchoprovocation (MBP) test.
Table 1—Prevalence of Asthma Symptoms*

<table>
<thead>
<tr>
<th></th>
<th>Group A: Football Players (n = 156)</th>
<th>Group B: Basketball Players (n = 16)</th>
<th>Group C: Students (n = 167)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (mean ± 1 SD)</td>
<td>18.8 ± 1.2</td>
<td>19.4 ± 1.1</td>
<td>24.5 ± 2.3</td>
</tr>
<tr>
<td>Sex (% male)</td>
<td>100</td>
<td>100</td>
<td>65</td>
</tr>
<tr>
<td>Family history of allergic disease (%)</td>
<td>44</td>
<td>31</td>
<td>57</td>
</tr>
<tr>
<td>Asthma history</td>
<td>18 (12)</td>
<td>0 (0)</td>
<td>12 (7)</td>
</tr>
<tr>
<td>Exercise-induced chest tightness</td>
<td>14 (9)</td>
<td>2 (12)</td>
<td>25 (15)</td>
</tr>
<tr>
<td>Exercise-induced cough</td>
<td>31 (14)</td>
<td>0 (0)</td>
<td>28 (17)</td>
</tr>
<tr>
<td>Exercise-induced wheezing</td>
<td>11 (7)</td>
<td>0 (0)</td>
<td>15 (9)</td>
</tr>
<tr>
<td>Exercise-induced prolonged dyspnea</td>
<td>10 (6)</td>
<td>0 (0)</td>
<td>10 (6)</td>
</tr>
<tr>
<td>Ever have chest tightness, cough, wheezing, or prolonged dyspnea</td>
<td>30 (19)</td>
<td>6 (12)</td>
<td>61 (37)</td>
</tr>
<tr>
<td>Chest symptoms with irritants</td>
<td>54 (35)</td>
<td>6 (38)</td>
<td>53 (32)</td>
</tr>
<tr>
<td>Chest symptoms after URI</td>
<td>17 (10)</td>
<td>4 (25)</td>
<td>25 (15)</td>
</tr>
</tbody>
</table>

*There were no statistically significant differences between football players and students, between basketball players and students, or between football players and basketball players.

Subjects and Design (Table 1)

Group A (football players). All members of the University of Iowa athletic teams are required to have a history, physical examination, and laboratory testing in order to participate in a National Collegiate Athletic Association sport. Ninety members of the University of Iowa football team completed the questionnaire and performed a MBP challenge in August 1982. A subset of this group (40 players) was again examined in January 1983, for methacholine reactivity using the standard MBP test. Two additional groups of 29 and 37 football players were examined as freshmen in August 1983 and August 1984, respectively, on the day that they reported for physical examination prior to practice.

Football players are recruited from a large number of locations throughout the United States, although most are from midwestern states (Iowa, Minnesota, Nebraska, Missouri, and Illinois), New York, and New Jersey. They range in age from 17 as freshmen to 23 as "red-shirt" seniors. Most participated in more than one sport in high school but limit their participation to football in college. They reside together on the same floor of a dormitory at the University, except for the married students. None of the members of the team admitted to a history of smoking.

Group B (basketball players). Sixteen basketball players were similarly questioned and examined in September 1983.

All of the athletes (groups A and B) were asked if they had ever had chest tightness, cough, wheezing, asthma, or other chest problems in the past that made it difficult for them to perform on the athletic field.

Group C (students). 167 sophomore medical students and physician assistant students out of a class of 184 students performed a modified MBP test on each other during a portion of their Introduction to Clinical Medicine course in February, March, and April 1984, to demonstrate how a MBP challenge is performed and interpreted. None of these students underwent a second challenge. Students were excluded from this test if they had overt asthma. Their participation was entirely voluntary. Students also completed the asthma questionnaire which was used to demonstrate how symptoms may correlate with the clinical evaluation of asthma. None of the students was taking any medication for asthma. All data were coded so that no student could subsequently be identified since the primary purpose was educational.

Methacholine Bronchial Provocation (MBP) Test

Methacholine was obtained and diluted to 25 mg/ml in a solution that consisted of 0.5 percent NaCl, 0.275 percent NaHCO₃ and 0.4 percent phenol.

The standard MBP challenge was done as previously described. The modified MBP challenge is similar to the challenge described by Frigos et al. Individuals with a past history of asthma or a past history of symptoms that suggested asthma were included. Those individuals with active asthma were excluded from testing. Spirometry was performed using a Jones Pulmonor Model 2.

Methacholine was aerosolized using a Rosenthal-French dosimeter and a DeVilbiss No. 42 or No. 646 nebulizer. The average duration of aerosol generation was 0.5 to 0.6 seconds at a pressure of 20 psi. Each of 16 athletes inhaled breaths of saline solution to determine the average amount of methacholine inhaled per breath. We added 1.0 ml of saline solution to the nebulizer, had each of the 16 inhale 20 breaths, removed and measured the remaining saline solution, and calculated that each breath provided 0.88 mg ± 0.2 mg of methacholine. Thus, after one breath, 0.88 mg, and after six breaths, 5.28 mg, of methacholine was delivered to the patient. One breath unit is defined as one breath of solution at 1 mg/ml.

For the modified MBP, baseline values for forced vital capacity (FVC) and forced expiratory volume in one second (FEV₁) were established. One breath of methacholine (25 mg/ml) was then administered and spirometry was repeated five minutes later. If the FEV₁ remained greater than 80 percent of the initial FEV₁, five more breaths of methacholine at the same concentration were given, and spirometry was repeated five minutes later. Therefore, 25 breath units were administered after the first breath and 125 more after the subsequent breaths for a maximum possible total of 150 breath units.

The test was considered positive when the FEV₁ decreased to less than 80 percent of the initial FEV₁. If an individual became symptomatic after administration of the methacholine, he was given albuterol to reverse the bronchospasm.

Statistical Evaluation

Exact probabilities (Tables 1 through 3) were determined using an IMSL subroutine (NHEXT) (IMSL, Reference Manual, Edition 8, Houston, TX). Where these tables were 2 × 2, this is the Fisher exact test. These exact probabilities were compared to a threshold level of 0.05. The chi-square test for linear trends on the proportion of the first row with one degree of freedom was used to test for linear trend in Table 4. The SAS Software System was used to calculate and test a t statistic for values with unequal variants in Figure 1.

Results

One hundred fifty-six football players, 16 basketball

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players, and 167 sophomore medical students and physician assistant students completed the history questionnaire. All received a modified MBP challenge except five football players who had a history of recent asthma. Forty football players were rechallenged five months later with a standard MBP.

Asthma Symptom Scores (Table 1)

Twelve percent of the football players indicated having been told they had asthma. None of the basketball players and 7 percent of the students admitted a history of asthma. Approximately equal percentages of football players and students admitted to having exercise-induced chest tightness, cough, wheezing, or prolonged shortness of breath. Only two basketball players noted chest tightness after exercise. In addition, 19 percent of the football players, 12 percent of the basketball players, and 37 percent of the students had a history of these symptoms in the past. There was no difference in the history of irritant (cold air, smoke, fumes, dust) induced chest tightness, coughing, or wheezing in the three groups.

Prevalence of Positive MBP Challenge (Table 2, Fig 1)

Of the 151 football players challenged, 76 (50 percent) had a positive MBP. Four of the sixteen (25 percent) basketball players and 69 of 167 (41 percent) students had positive results of challenges. There were no complications to the administration of the methacholine and in all cases bronchospasm reversed promptly. A positive MBP challenge correlated with a positive history in the football players, although 24 percent of those with a positive history had a negative challenge (Table 2). In comparison, 47 percent of those with a symptom score less than 4 had a positive modified MBP test. A symptom score of 4 meant that a patient had a previous diagnosis of asthma or that the patient had sufficient symptoms to warrant a clinical diagnosis of asthma as described in the "Subjects and Methods" section. A9 Many individuals without symptoms had positive MBP test results and some with symptoms had negative test results.

Relationship Between Nasal Symptoms and MBP (Table 3)

Football players without nasal symptoms (allergic rhinitis or hay fever) were less likely to have a positive modified MBP test (42 percent) than those with symptoms (70 percent). Among basketball players, 18 percent without nasal symptoms had a positive modified MBP, and 40 percent of those with symptoms had a positive modified MBP challenge. In the student group, 40 percent of those without and 57 percent of those with nasal symptoms had a positive modified MBP.

Reproducibility of MBP (Fig 2)

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Table 2—Overall Asthma Symptom Score vs Modified MBP Challenge*

<table>
<thead>
<tr>
<th>MBP Challenge</th>
<th>Football Players (n = 151)†</th>
<th>Basketball Players (n = 16)</th>
<th>Students (n = 167)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptom Score</td>
<td>0-3 4-11</td>
<td>0-3 4-11</td>
<td>0-3 4-11</td>
</tr>
<tr>
<td>Positive</td>
<td>63/134(47%)‡</td>
<td>4/16(25%)</td>
<td>54/143(37%)§</td>
</tr>
<tr>
<td>Negative</td>
<td>71/134(53%)</td>
<td>12/16(75%)</td>
<td>89/143(63%)</td>
</tr>
</tbody>
</table>

*There were no statistically significant differences between football players and basketball players or between football players and students in given symptom score class or challenge class.

†Five of the 156 football players were not challenged because of recent symptoms of asthma.

‡p<0.05.

§p<0.05.
Table 3—Nasal Symptoms vs MBP Challenge

<table>
<thead>
<tr>
<th>MBP Challenge</th>
<th>Football Players (n = 151)</th>
<th>Basketball Players (n = 16)</th>
<th>Students (n = 167)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Sx</td>
<td>Some Sx</td>
<td>No Sx</td>
</tr>
<tr>
<td>Positive</td>
<td>44/105 (42%)*</td>
<td>32/46 (70%)*</td>
<td>2/11 (18%)</td>
</tr>
<tr>
<td>Negative</td>
<td>61/105 (58%)</td>
<td>14/46 (30%)</td>
<td>9/11 (82%)</td>
</tr>
</tbody>
</table>

*p < 0.05 using Fisher's exact test. †p < 0.05 using Fisher's exact test.

Four to five months after the first modified MBP challenge, which occurred at the height of the ragweed season, 40 of the initial 90 football players received a second MBP challenge using the standard protocol. In most cases, the positivity or negativity to methacholine did not change (Fig 2). Since the standard MBP was used for rechallenge, the rate of decrease in FEV₁ was not as great on rechallenge. Each individual was asked prior to MBP challenge as to whether he or she was having symptoms of the common cold at the time of challenge. The incidence of an upper respiratory infection did not correlate with a positive challenge. Among the students who were examined during the “upper respiratory infection months” of February, March, and April, 36 of 87 (41 percent) without a current or recent upper respiratory infection had a positive MBP challenge and 33 of 80 (41 percent) with such a history had a positive challenge.

Relationship Between Team Position and Bronchial Reactivity

We hypothesized that certain positions might preclude an individual with asthma from performing competitively; for example, a lineman might endure asthma and perform well since much of his work is isometric, but a wide receiver may run many yards on a play and be unable to tolerate asthma. However, we found that there was no correlation between a player's position and the presence of hyperresponsive airways or chest symptoms.

Discussion

The incidence of clinical asthma in highly trained competitive athletes has not been studied. The incidence of asthma in the general population is said to be about 4 to 7 percent. Our studies (Table 1) suggest that a history of asthma in one group of highly trained athletes, football players, is 12 percent, in comparable age matched students is 7 percent, and in college basketball players is 0 percent.

The prevalence of nonspecific hyperresponsiveness to inhaled methacholine was very high in each of the groups that we studied (Table 1 and Fig 1), occurring in 50 percent of the football players, 25 percent of the basketball players, and 41 percent of the students. These data clearly indicate that a large number of young adults have nonspecific bronchial hyperresponsiveness without clinical asthma.

We utilized the modified MBP as described by Frigas et al because this method of administering methacholine is rapid and can be used to screen a large group of individuals quickly. This modified challenge differs from the standard challenge in that low concentrations of methacholine are not administered and a lower total dose is given. In none of the 339 individuals who received this modified challenge were there any complications. In the modified MBP test, we first administered 25 breath units of methacholine, and if there was not a significant drop in FEV₁, 125 more breath units of methacholine. One hundred fifty breath units has been reported to be the dose which provides the maximum degree of specificity and sensitivity. The modified MBP challenge results at the
Table 4—Comparison of Magnitude of Symptom Score and Number of Positive MBP Tests in Football Players

<table>
<thead>
<tr>
<th>Symptom Score</th>
<th>Positive MBP Challenge* (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>31/83 (37%)</td>
</tr>
<tr>
<td>1</td>
<td>17/26 (61%)</td>
</tr>
<tr>
<td>2</td>
<td>12/19 (63%)</td>
</tr>
<tr>
<td>3</td>
<td>3/4 (75%)</td>
</tr>
<tr>
<td>4-6</td>
<td>7/10 (70%)</td>
</tr>
<tr>
<td>7-8</td>
<td>3/4 (75%)</td>
</tr>
<tr>
<td>9-11</td>
<td>3/3 (100%)</td>
</tr>
</tbody>
</table>

*Chi-square = 12.17, p<0.001.

height of the ragweed season were comparable to those obtained with the standard MBP in January (Fig 2).

A majority of football players and medical students with symptom scores of 4 or higher had positive MBP challenges (Table 2); none of the basketball players had a symptom score above three. Although 31 percent of the individuals tested with symptom scores of 4 or greater did not react to methacholine, the data show that the higher the symptom score, the more likely it is that an individual will have a positive MBP challenge (p<0.001) (Table 4).14

The significance of a positive MBP test in a totally asymptomatic individual cannot be determined from this study. Several questions are raised: Are these individuals more likely to develop clinical asthma or other pulmonary impairments in the future? Are these individuals particularly prone to develop chronic obstructive lung disease if they are exposed to cigarette smoke or industrial fumes? Are these individuals more liable to have a positive exercise challenge? Future prospective studies will be needed to address these questions. Presently, we believe that it is important to recognize that a positive MBP challenge is very common in young asymptomatic adults.

We hypothesize that in the football players, clinical bronchospasm may only occur in a polluted environment, when athletes are out of condition, when athletes have allergic rhinitis, following viral infections, or when athletes practice during the height of the ragweed pollen season or during cold weather.15,16 Contrary to previous studies, we found that athletes and students with current or recent upper respiratory infections were as likely to have a positive MBP as those without.17 Individuals with chronic nasal symptoms, however, were more likely to have a positive MBP challenge (Table 3), a finding which is consistent with previous observations.18

These studies indicate that most highly trained athletes who are in peak condition are able to perform with few symptoms in spite of airway hyperresponsiveness to cholinergic stimuli. In some cases, however, asthma has clearly interfered with athletic performance. We have treated six football players with severe asthma who required chronic medication. In one case, a varsity athlete was unable to walk up more than one flight of stairs without developing severe chest tightness, wheezing and cough, and a reduction in FEV1. Nevertheless, this athlete had competed in high school well enough to be selected to the all-state team and had won a full scholarship to the University. His inability to perform had been attributed in the past to "nervous problems" by coaches.

We conclude from these studies that 1) nonspecific bronchial hyperresponsiveness is very common in young adults since 45 percent had a positive modified MBP, 2) clinical asthma is also common in young adults, and 3) the MBP test may not be as useful as previously thought because of a lack of specificity. No other large study exists in which such a large number of normal young adults were examined for MBP reactivity. Taken together, the data presented here suggest that mildly symptomatic asthma is a common problem in young adults unrecognized by the individual, coach, or physician, with symptoms occurring only after strenuous exercise, during the height of the pollen season, or while breathing in polluted air.

ACKNOWLEDGMENTS: We wish to acknowledge the large number of individuals who made this study possible: Coach John Hayden Fry for his support in these studies; athletic trainer John Strief and the many other athletic trainers and student trainers who helped in these studies; Doctors Hal B. Richerson and Philip Halverson and Kevin Kregel, Roger Medsker, Bruce Packard, Stephen Binderknecht, Colleen Towns and Kay Weiler for the many MBP challenges; Doctors Tom Casale and Hal B. Richerson for reviewing this manuscript; and C. K. Brown who provided statistical consultation.

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4 Prescott LM. Air pollutants might aggravate athletes’ asthma, allergies. JAMA 1984; 215:2496

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Bronchial Hyperresponsiveness in Highly Trained Athletes (Weller et al)