Exercise-induced bronchospasm prevalence in collegiate cross-country runners

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ABSTRACT

THOLE, R. T., R. E. SALLIS, A. L. RUBIN, and G. N. SMITH. Exercise-induced bronchospasm prevalence in collegiate cross-country runners. *Med. Sci. Sports Exerc.*, Vol. 33, No. 10, 2001, pp. 1641–1646. **Purpose:** The purpose of this study was to determine the prevalence of exercise-induced bronchospasm (EIB) in collegiate cross-country runners using a protocol involving an intense exercise challenge conducted in the same environment in which the athletes train and compete. **Methods:** One-hundred eighteen collegiate cross-country runners from the Los Angeles, California, metropolitan area participated in the study. All testing took place on a track at the time and location of a normal practice session. The baseline peak expiratory flow rate (PEFR) measurements (best of three) and preexercise heart rate were recorded, after which the athletes ran 2000 m on a track at 85% of maximum heart rate. The postexercise heart rate was recorded and then PEFR measurements at 2, 5, 10, and 30 min after exercise were recorded. The athletes completed a 16-item questionnaire regarding asthma symptoms and health history. Those athletes with a history of asthma and currently taking medications for the asthma were then excluded from statistical analysis of the questionnaire responses. A decrease in PEFR of 15% was considered positive for EIB. **Results:** Of the 114 athletes not currently taking medications for asthma, at least 14% (16 athletes) were EIB positive. There was a poor correlation between reported symptoms of asthma and testing positive for EIB. **Conclusion:** This study demonstrates a high prevalence of EIB in collegiate cross-country runners (at least 14%) and that reported symptoms are a poor predictor of actual EIB. **Key Words:** EXERCISE, RUNNING, SPIROMETRY, ASTHMA

Exercise-induced bronchospasm (EIB) is prevalent in competitive athletes and has recently been investigated with a focus on pathophysiology, diagnosis, management, and prevalence rates (15,17,25,27,29,30). The diagnosis of EIB is important in targeting athletes who would most benefit from effective preventative measures (11,14,18,25). Studies of EIB prevalence in collegiate athletes have suggested a rate of 3% to 19% (9,16,21,28). These initial studies utilized screening questionnaires, indoor treadmill exercise challenge, or methacholine provocation (9,21,28) conducted in controlled laboratory settings and not in the training environment. Recent studies have focused on testing athletes in the varied environments in which they train and have given new insight to EIB prevalence rates (16,22,30). The recent testing protocols are derived from the observation that EIB is most pronounced at high levels of exertion and environmental exposure and that the presence of EIB does not correlate to perceived symp-

college sports, but have not studied the prevalence of EIB in collegiate cross-country running, a sport recognized for its asthmogenic potential (1,5,7,16,22,23). The aim of our study was to determine the prevalence of EIB in collegiate cross-country runners with a protocol utilizing an intense exercise challenge and spirometry measurements performed in the standard training and competition environment of the runners.

MATERIALS AND METHODS

Subjects. One hundred eighteen collegiate cross-country runners from eight Southern California schools participated in the study. Eighty-nine runners were from six schools belonging to the National Collegiate Athletic Association (NCAA) Division III Southern California Intercollegiate Athletic Conference (SCIAC), 9 runners were from a local community college, and 18 runners were from a local National Association of Intercollegiate Athletics (NAIA) college. There were 57 women and 61 men, with an age range of 17–24 yr and a mean age for women of 19.2 yr

The participating schools and coaching staffs agreed to conduct the testing during normal practice times in cross-country season. Informed consent was obtained from all athletes participating in the study. Every athlete consented to voluntary participation and no athlete declined to be tested. In addition to participating in an exercise test, the athletes completed a 16-item questionnaire. All athletes who reported a history of asthma and were also taking asthma medications were evaluated separately from the rest of the

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study population with respect to questionnaire analysis and exercise testing.

Procedures. All cross-country runners were assembled on the track and given a brief introduction to the study protocol. Our protocol included recording baseline peak expiratory flow rate (PEFR); performing a 2000-m run at an intense exertion level; and then recording PEFR measurements at 2, 5, 10, and 30 min after the run. All measurements took place at the respective team's running track during normal practice session times. The air temperature, wind speed and direction, air ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO), Particulate Matter, and Pollution Standard Index (PSI) were all recorded through the South Coast Air Quality Management District (SCAQMD). A portable peak flowmeter (Astech peak flowmeter, Dey L.P., Napa, CA) was used for all PEFR measurements and each athlete used the same meter throughout the test. A portable pulse oximeter (Nonin 850 pulse oximeter, Nonin Medical Company, Plymouth, MN) was used to obtain the preexercise heart rate as well as the postexercise heart rate. The proper use of the peak flowmeter and the pulse oximeter was demonstrated as well as the details of the exercise protocol. The best of three PEFR values was recorded each time the PEFR was measured. A warm-up consisting of stretching was allowed, but the athletes were instructed to refrain from further warm-up with any strenuous activity including running.

The distance of 2000 m was chosen as a standard distance that both men and women could complete in 6 to 10 min if run at 85% maximal heart rate. This range of times was selected on the basis of the time required to produce a maximal bronchoconstrictive response after exercise as noted in previous studies (3). The athletes were given their split times every 400 m, and a time was recorded for the completion of the 2000-m run. Immediately after the run, a postexercise heart rate was recorded, and then the athletes were informed that they could rest and stretch but refrain from further running. Three postexercise PEFR values were obtained at 2, 5, 10, and 30 min after the run. The change in PEFR was determined by subtracting the PEFR value at 2, 5, 10, and 30 min after exercise from the best of three baseline PEFR values. The lowest postexercise PEFR value of the four different times was used to calculate the percent change.

The 16-question survey was modeled after the survey used in prior studies of U.S. Olympic athletes sponsored by the American Academy of Allergy and Immunology and is listed in Table 1 (27). EIB-positive athletes were those with a 15% or greater decrease in postexercise PEFR. All other athletes were considered EIB-negative.

Statistical analysis. For each survey question, respondents were separated into EIB-positive and EIB-negative groups, and the fraction of each group that answered the question positively was recorded. A difference-in-proportions Z test was used to see if there was a statistically significant difference between the percentage of the EIB-positive athletes who answered yes and the percentage of EIB-negative athletes who answered yes. The *t*-value for a difference-in-means *t*-test was used to analyze the difference between the EIB-positive and EIB-negative groups in the parameters of "percentage of maximal heart rate achieved" and the time of the 2000-m run. For all statistical comparisons, the level of significance was set as $P < 0.05$. A chi-square test applied to a 2 × 2 contingency table for each survey question gives the same P value as does the difference-in-proportions Z test. The Pearson correlation coefficient was calculated by assigning (arbitrary) numerical values to the yes/no categories and EIB-positive/EIB-negative categories. For the 2 × 2 case considered here, the Pearson correlation coefficient is equal to the square root of the chi-square statistic divided by the sample size. Positive correlation coefficients indicate that those who answer yes are more likely to be EIB-positive. The odds ratio was calculated by taking the ratio of the odds of being EIB-positive for those who answered yes to the odds of being EIB-positive for those who answered no. The odds ratio is greater than 1 if the correlation coefficient is positive and less than 1 if the correlation coefficient is negative. The statistical significance of the correlation coefficient or odds ratio is assessed by the P values calculated from the differ-

studied, 4 had a previous history of asthma or EIB and were currently taking medication (all beta-agonist or steroid metered-dose inhalers (MDIs)) for the asthma. Of these four, only one athlete currently taking medication demonstrated a greater than 15% decrease in PEFR after exercise. This athlete only used a triamcinolone MDI the day of the study and indicated she only used the beta-agonist MDI for asthma symptoms. The other three were all taking beta-agonist MDIs, two with concomitant steroid use, and all three demonstrated no significant postexercise PEFR decrease. There were no athletes reporting a history of asthma and requiring pharmacologic intervention that were not taking any medications for asthma at the time of the study (the four athletes reporting needing asthma medications were taking medications for asthma during the study).

The results of the questionnaire were tabulated as either a positive or negative response ("yes" or "no"). Table 2 compares positive response rates between EIB-positive and EIB-negative athletes. Out of the 16 EIB-positive athletes, 13 (81.25%) demonstrated at least one symptom of asthma or exercise-induced asthma (questions 5, 6, 7, 10, 11, or 14). Forty-nine (50%) out of 98 EIB-negative athletes reported at least one symptom of asthma or exercise-induced asthma. This difference between the two groups was statistically significant ($P = 0.0100$). Of the 16 athletes positive for EIB who were not taking medications, only 3 (19% of those EIB-positive not taking asthma medications) reported a past history of asthma or exercise-induced asthma. This question was not statistically significant in predicting a positive test for EIB ($P = 0.4047$). Of the 98 EIB-negative athletes, 16 athletes (17% of those testing negative) reported a history of asthma or exercise-induced asthma yet none were found to have EIB on testing. Statistical significance for the prediction of those testing positive for EIB was shown only in EIB-negative athletes responded "yes" ($P = 0.0012$).

Question 3, regarding the use of over-the-counter (OTC) herbs, medications, supplements, and vitamins, yielded more positive responses than any other question (see Table 2). This was significantly correlated with testing results ($P = 0.0311$).

Exercise testing results. All of the athletes were tested with exercise challenge and then completed the survey (Tables 3 and 4). Only the 114 athletes not taking medications for asthma were included in the results and statistical analysis of survey questions. Ninety-eight athletes were EIB-negative (47 women and 51 men) and 16 athletes (8 women and 8 men) were EIB-positive. The average baseline PEFR for the 47 EIB-negative women was 423 $L \cdot s^{-1}$; for the 51 EIB-negative men, 605 $L \cdot s^{-1}$. The postexercise percent PEFR change at 2, 5, 10, and 30 min for the EIB-negative runners was an increase of 6%, 4%, 5%, and 5%, respectively. The average of the percent of maximal heart rate achieved in the EIB-negative group was 71.3%. The EIB-negative women ran the 2000-m course in a mean time of 8 min 33 s (8:33); the EIB-negative men, 6 min 48 s (6:48). The average baseline PEFR for the eight EIB-positive women was 411 $L \cdot s^{-1}$; for the eight EIB-positive men, it was 620 $L \cdot s^{-1}$. The average of the percent of maximal heart rate achieved in the EIB-positive group was 70.3%. The postexercise percent PEFR change at 2, 5, 10, and 30 min for the EIB-positive runners was a decrease of 16% for all parameters, with a range of decrease from 15% to 43%. The EIB-positive women ran the 2000-m course in a mean time of 9 min 22 s (9:22); the EIB-positive men, 6 min 43 s (6:43).

The difference between the percent of maximal heart rate achieved by the EIB-positive and EIB-negative group was not statistically significant ($P = 0.407$). The difference of the mean time for the 2000-m run was not significant tions) demonstrated a PEFR decrease of 15% or greater. The results of the environmental conditions as recorded through the SCAQMD are recorded in Table 5.

TABLE 1. Survey questionnaire.

1. List any allergies to any medicine (aspirin, penicillin, sulfa, etc.)
2. Are you allergic to any insect bites/stings or do you have any food allergies?
3. Do you take any medications (over-the-counter herbs, supplements, vitamins)?
4. Do you take any prescribed medications taken on a permanent or semipermanent basis?
5. Have you ever been told that you have/had asthma or exercise-induced asthma?
6. Do you ever have chest tightness?
7. Do you ever have wheezing?
8. Do you ever have itchy eyes?
9. Do you ever have itching of the nose or throat or sneezing spells?
10. Does running ever cause chest tightness or wheezing or prolonged shortness of breath?
11. Have you ever had chest tightness, cough, wheezing, asthma, or other chest (lung) problems that make it difficult for you to perform in sports?
12. Have you ever missed school, work, or practice because of chest tightness or cough or wheezing or prolonged shortness of breath?
13. If you have been told you have asthma, what medications have you taken?
14. Do you have trouble breathing or do you cough during or after activity?
15. Do you have or have you ever had lung disease (pneumonia)?
16. List current medications

TABLE 2. Results of survey questionnaire.

Question	EIB-Positive—Yes Response[a]		EIB-Negative—Yes Response[b]		*P* Value	Pearson Correlation Coefficient	Odds Ratio
	No.	%	No.	%			
1	0	0	10	10.2	0.0905	−0.13	0.00
2	4	25.0	14	14.3	0.1379	0.10	2.00
3	6	37.5	61	62.2	0.0311	−0.18	0.36
4	4	25.0	15	15.3	0.1674	0.09	1.84
5	3	18.8	16	16.3	0.4047	0.02	1.18
6	7	43.8	29	29.6	0.1293	0.11	1.85
7	5	31.2	23	23.5	0.2513	0.06	1.48
8	5	31.2	35	35.7	0.3643	−0.03	0.82
9	6	37.5	30	30.6	0.2913	0.05	1.36
10	6	37.5	28	28.6	0.2346	0.07	1.50
11	6	37.5	21	21.4	0.0805	0.13	2.20
12	3	18.8	2	2.0	0.0012	0.28	11.08
13	3	18.8	13	13.3	0.2791	0.06	1.51
14	7	43.8	33	33.7	0.2168	0.07	1.53
15	2	12.5	6	6.1	0.1772	0.09	2.19
16	6	37.5	11	11.2	0.0031	0.26	4.75

[a] 16 total EIB-positive.
[b] 98 total EIB-negative.

TABLE 3. Results of 2000-m run in seconds.

	No.	2000-m Time (s)
EIB-negative women	47	513 ± 56
EIB-positive women	8	567 ± 35
EIB-negative men	51	408 ± 25
EIB-positive men	8	403 ± 22

TABLE 4. Results of average percent of maximum heart rate achieved (%MHR) and average percent change in peak expiratory flow rate (PEFR) from baseline PEFR at 2, 5, 10, and 30 min after exercise.

	%MHR	% Change PEFR 2 Min	% Change PEFR 5 Min	% Change PEFR 10 Min	% Change PEFR 30 Min
EIB-negative runners	71.3	+6	+4	+5	+5
EIB-positive runners	70.3	−16	−16	−16	−16

DISCUSSION

EIB prevalence. The goal of our study was to screen collegiate cross-country runners for EIB using a protocol that tested the athletes in the environment of their training at an exertion level at which they commonly trained. We chose runners because the prevalence rate of EIB in runners has been understudied despite the frequently quoted statement that outdoor cross-country running is asthmogenic (1,5). The focus of our study was specifically collegiate runners because prior studies of collegiate athletes have relied on laboratory testing or survey questionnaires to quantify EIB prevalence rates (9,21,28). A further goal was to investigate an opposing supposition that a low EIB prevalence rate would be associated with running at the competitive collegiate level because of a prior negative selection of asthmatic athletes who avoid running and choose instead to compete in less asthmogenic sports.

We did not find a low prevalence of EIB among runners in our study and, in fact, found a prevalence rate of EIB higher than or similar to that found in previous studies of EIB in collegiate athletes (9,21,28). The results of our study demonstrate the prevalence rate of EIB in collegiate runners not on medications for asthma or EIB to be at least 14% using the criteria of a 15% postexercise decrease in PEFR as an indicator of EIB. Including the athletes with a prior history of asthma and/or EIB currently taking asthma medications, we found the prevalence rate of EIB could be as high as 16.7%. We included the four athletes with a current history of asthma for this prevalence rate on the basis of past observations that most asthmatics will experience EIB at intense exertion levels (15,29). Some authors have suggested using a 10% decrease as the cutoff for EIB diagnosis, as any appreciable airway obstruction could be detrimental to athletic performance (12,24). Using the criteria of a 10% decrease in PEFR as diagnostic of EIB, we found a prevalence rate of 25.8%. The 14% prevalence rate is higher than previous studies performed with screening questions and

softball, and soccer athletes demonstrating a 15% incidence of EIB as demonstrated through an outdoor running exercise challenge (16).

Exercise challenge protocol. Our exercise protocol was developed to test for EIB in the context of a typical cross-country running practice session in the standard training environment. The coaching staffs were contacted to help develop a testing protocol that would be effective, practical, and applicable to test for EIB in a large group of athletes. The standard testing protocol for EIB has been to test athletes with an exercise load of 85% of maximum heart rate for 6 to 10 min (2,3,6). Recent protocols have suggested testing athletes at an even higher level of exertion (15,22,30). We encouraged the athletes to run at a pace at least 85% of maximum heart rate. The exercise protocol we developed was to run a 2000-m course. Most collegiate runners are able to run 2000 m within 6 to 10 min, and 2000 m is a distance cross-country athletes often run when running intervals on the track. The approximate time to complete the 2000-m run would meet the criteria of an exercise challenge lasting 6 to 10 min and produce a maximal bronchoconstrictive response.

It has been noted that athletes develop bronchospasm most readily after the cessation of exercise, and the time of onset of bronchoconstriction can vary (2–4,15). Accordingly, protocols have suggested testing periodically for up to 30 min after cessation of exercise (3,4). This observation has been supported by work on the pathophysiology of EIB relating to airway rewarming and bronchial hyperemia after the cessation of exercise (15). In our study, we tested athletes at 2, 5, 10, and 30 min after the exercise challenge and, in the EIB-positive group, found the average PEFR decrease was 16% at each of the testing times.

Our protocol did not control running speed, minute ventilation, or exact time to complete the 2000-m run. The athletes were under the observation of their coaching staff and were under instruction to run a 2000-m run at least at

TABLE 5. Environmental data at specific test sites.

Location	Date	Time	Temp (°F)	RH %	RWS MPH	RWD Deg	O_3 PPHM	CO PPM	SO_2 PPHM	NO PPHM	NOX PPHM	NO_2 PPHM	PM 10 UC/M3
Claremont, CA	09/20/99	1630	80	44	4	279	2	2	0	1	11	10	48
Claremont, CA	09/27/99	1630	72	67	4	251	2	1	0	1	6	5	39
Claremont, CA	10/05/99	0730	73	55	1	187	1	3	0	20	32	12	103
Thousand Oaks, CA	10/20/99	1630	82	15	1	350	1	2	0	4	9	5	37
La Verne, CA	11/15/99	1530	68	68	6	253	0	3	0	1	3	2	143
Redlands, CA	11/17/99	1700	61	48	3	225	1	1	0	1	5	4	33
Riverside, CA	12/01/99	0730	49	83	1	174	0	2	1	27	36	6	85
Riverside, CA	12/01/99	1530	60	62	3	280	0	2	1	1	5	4	101

heart rate achieved/220 − age) is a variable estimate and could misrepresent the percentage of maximum heart rate the runners actually achieved. Our results indicated a level of exertion lower than the optimal goal of 85% of maximum heart rate. This could be accounted for by our testing methods of checking the postexercise heart rate with pulse oximeters after the run. Although the heart rate monitor function on a pulse oximeter is normally faster, easier, and possibly more accurate than manually counting the heart rate for a given time, we found that occasionally athletes would wait in line to get a heart rate check when a large group of runners finished at the same time. The recorded value (71.3% in the EIB-negative group and 70.3% in the EIB-positive group) was most likely lower than during and directly after the completion of the run. The coaches subjectively commented that the pace and times of the athletes were similar to those achieved during a standard interval-training workout. On the basis of recent studies testing athletes for EIB using higher levels of exertion, it is possible the prevalence rate of EIB in our study population could have been higher if the athletes had run at a higher level of exertion (15,22,30).

The use of peak flowmeters was chosen because of their practicality of use for a large group of athletes in the field environment. We noted that evaluating the FEV_1 is an accepted value but full spirometry evaluation was not practical and the PEFR can give a reasonable indicator of bronchoconstriction, as suggested in other studies (16,24). The PEFR value was effort-dependent and error was minimized through careful instruction and practice of correct peak flowmeter use and by recording the best of three PEFR values. We found the peak flowmeter was a practical and economical method of testing a large group of athletes. The athletes were able to learn its proper use easily and the method was quick, noninvasive, and allowed for the testing to be performed efficiently.

There was no significant difference (P = 0.299) in the 2000-m run time between the EIB-positive and EIB-negative men, but the EIB-positive men actually ran a mean time of 5 s faster than the EIB-negative men. The EIB-positive women ran a mean difference of 53 s (P = 0.0053) slower than the EIB-negative group. This finding is interesting from an observational standpoint, and further studies would be needed to investigate these findings. Previously undiagnosed EIB-positive runners who initiate pharmacologic treatment for EIB.

Survey questionnaire. Recent studies regarding the screening and diagnosis of EIB have focused on testing the athlete in the environment of competition (16,22,30). The importance of performing testing instead of relying on symptoms, lack of symptoms, or surveys as a method of EIB diagnosis or exclusion has been emphasized because of a lack of correlation between subjective symptomatic parameters and testing positive for EIB (7,10,13,14,21–23). In analyzing the survey results to correlate those testing positive for EIB and giving a positive response to survey questions, we found a positive correlation with only one question: "Have you ever missed work or school because of chest tightness or shortness of breath?" This finding correlates with a study by the Sports Medicine Committee of the American Academy of Allergy and Immunology (27). The remainder of the questions did not correlate to those testing positive and reconfirms the findings of others suggesting that reported symptoms do not correlate with either the presence or absence of EIB (7,10,13,14,21–23).

The other questions that were positively correlated both dealt with current medications. One large team (with 35 members) was taking supplements as recommended by the coaching staff, so the statistically significant finding concerning current use of medications and OTC herbs, supplements, and vitamins may have been spurious. We found significance to the reporting of at least one symptom of asthma and/or EIB, as 13 of 16 EIB-positive athletes answered "yes" to at least one of six questions regarding symptoms of EIB. One half (49 of 98) of the EIB-negative athletes also reported at least one symptom of EIB, however, demonstrating the lack of specificity of reported EIB symptoms.

Environmental testing. The location of exercise testing for EIB has been examined recently, and an emphasis has been placed on testing athletes in the environment in which they compete (16,22,30). At issue is the potentially asthmogenic nature of the air in the environment in which athletes actually compete and train. Athletes may be especially sensitive to allergens, colder temperature, air pollutants, and other environmental triggers, and may demonstrate bronchospasm when exposed to these variables (8,19,20,26). This is a practical observation because athletes are concerned with increasing performance where they train and compete, and not in an artificial environment such as a temperature-controlled laboratory setting. Performing the exercise challenge in the environment was of specific interest in our study population of local collegiate athletes, as the Los Angeles metropolitan area and Inland Empire have a reputation of poor air quality and many out-of-town athletes complain of asthma and allergy-like symptoms on arrival to the area.

Interestingly, during the testing there were no smog alerts and the air quality was reported as good to moderate. For Although the temperature, humidity, and air parameters were similar in all locations as measured by proximate SCAQMD monitors, controlling and recording acute changes in air quality, temperature, and allergens is difficult. Testing in the training environment was a strength of our study, yet it may have been a confounding variable across training sites. It is known that cold, dry air will produce an increased asthmogenic response, and if the athletes were preparing to compete in a colder or drier climate, it would be advantageous to test the athletes in those climatic extremes in order to determine the true positive rate (13,14,30).

CONCLUSION

This study demonstrated a prevalence rate of EIB among collegiate cross-country runners not taking medications for asthma or EIB to be at least 14%. This value suggests that a significant percentage of collegiate runners will develop bronchospasm if exposed to an intense exercise challenge. This study also demonstrated a lack of correlation between those testing positive for EIB to positive responses on a screening questionnaire. It is possible that athletes do not recognize or ignore symptoms of bronchoconstriction and accordingly do not seek out medical assistance for a diagnosis or intervention. Using an easily implemented screening protocol such as the one we used in this study, athletes can be evaluated for EIB and, if indicated, started on an effective treatment program that may optimize training and performance.

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REFERENCES

1. Bar-Yishay, E., I. Gur, O. Inbar, et al. Differences between swimming and running as stimuli for exercise induced asthma. *Eur. J. Appl. Physiol.* 48:387–397, 1982.
2. Beck, K. C., R. E. Hyatt, P. Mpougas, and P. D. Scanlon. Evaluation of pulmonary resistance and maximal expiratory flow measurements during exercise in humans. *J. Appl. Physiol.* 86: 1388–1395, 1999.
3. Beck, K. C. Evaluating exercise capacity and airway function in the athlete. In: *Allergic and Respiratory Disease in Sports Medicine*, J. M. Weiler (Ed.). New York: Marcel Dekker, 1996, pp. 35–64.
4. Brudno, D. S., J. M. Wagner, and N. T. Rupp. Length postexercise assessment in the determination of exercise-induced bronchospasm. *Ann. Allergy* 73:227–231, 1994.
5. Bundgaard, A., T. Ingemann-Hansen, A. Schmidt, and J. Halkjaer-Kristensen. Exercise-induced asthma after walking, running, and cycling. *Scand. J. Clin. Invest.* 42:15–18, 1982.
6. Eggleston, P. A. Methods of exercise challenge. *J. Allergy Clin. Immunol.* 73(5 pt 2):666–669, 1984.
7. Feinstein, R. A., J. Larossa, A. Wang-Dohlman, and A. A. Bartolucci. Screening adolescent athletes for exercise-induced asthma. *J. Clin. Sports Med.* 6:119–123, 1996.
8. Helinius, I. J., H. O. Tikkanen, and T. Haahtela. Occurrence of exercise-induced bronchospasm in elite runners: dependence on atopy and exposure to cold air and pollen. *Br. J. Sports Med.* 32:125–129, 1998.
9. Huftel, M. A., J. N. Gaddy, and W. W. Busse. Finding and managing asthma in competitive athletes. *J. Respir. Dis.* 12:1110–1122, 1991.
10. Kufka, D. S., D. M. Lang, and S. Porter. Exercise-induced bronchospasm in high school athletes via a free running test: incidence and epidemiology. *Chest* 114:1613–1622, 1998.
11. Leff J. A., W. W. Busse, D. Pearlman, et al. Montelukast, a leukotriene-receptor antagonist for the treatment of mild asthma and exercise-induced bronchoconstriction. *N. Engl. J. Med.* 339: 147–152, 1998.
12. Mahler, D. A. Exercise-induced asthma. *Med. Sci. Sports Exerc.* 25:554–561, 1993.
13. Mannix, E. T., F. Manfredi, and M. O. Farber. A comparison of two challenge tests for identifying [illegible]
N. Engl. J. Med. 330:1362–1367, 1994.
16. Meza, C. E., A. A. Martin, S. Jensen, and S. S. Teuber. Prevalence of exercise-induced asthma in a division I athletic program (Abstract 38). *J. Allergy Clin. Immunol.* 103:S10, 1999.
17. National Heart, Lung, and Blood Institute, National Asthma Education, and Prevention Program. *Expert Panel Report 2: Guidelines for the Diagnosis and Management of Asthma.* Bethesda, MD: National Institutes of Health, 1997. Publication No. 97–4151 4053.
18. Nelson J., L. Strauss, M. Skowronski, R. Ciufo, R. Novak, and E. R. McFadden. Effect of long-term salmeterol treatment on exercise-induced asthma. *N. Engl. J. Med.* 339:141–146, 1998.
19. Noviski, N., E. Bar-Yishay, I. Gur, and S. Godfrey. Exercise intensity determines, and climatic conditions modify the severity of exercise-induced asthma. *Am. Rev. Respir. Dis.* 136:592–594, 1987.
20. Pierson, W. E., D. S. Covert, and J. Q. Koenig. Air pollutants, bronchial hyperreactivity, and exercise. *J. Allergy Clin. Immunol.* 73(5 pt 2):717–721, 1984.
21. Rice, S. G., C. W. Biernman, G. G. Shapiro, C. T. Furukawa, and W. E. Pierson. Identification OF exercise-induced asthma among intercollegiate athletes. *Ann. Allergy* 55:790–793, 1985.
22. Rundell, K. W., R. L. Wilber, L. Szmedra, D. M. Jenkinson, L. B. Mayers, and J. Im. Exercise-induced asthma screening of elite athletes: field versus laboratory exercise challenge. *Med. Sci. Sports Exerc.* 32:309–316, 2000.
23. Rupp, N. T., D. S. Brundo, and M. F. Guill. The value of screening for risk of exercise-induced asthma in high school athletes. *Ann. Allergy* 70:339–342, 1993.
24. Shoene, R. B., K. Giboney, C. Schimmel, et al. Spirometry and airway reactivity in elite track and field athletes. *Clin. J. Sport Med.* 7:257–261, 1997.
25. Smith, B. W., and M. Labotz. Pharmacologic treatment of exercise-induced asthma. *Clin. Sports Med.* 17:343–363, 1998.
26. Strauss, R. H., E. R. McFadden, Jr., R. H. Ingram, Jr., and J. J. Jaeger. Enhancement of exercise-induced asthma by cold air. *N. Engl. J. Med.* 297:743–747, 1977.
27. Weiler, J. M., T. Layton, and M. Hunt. Asthma in United States olympic athletes who participated in the summer games. *J. Allergy Clin. Immunol.* 102:722–726, 1998.
28. Weiler, J. M., W. J. Metzger, A. L. Donnelly, E. T. Crowley [illegible]
30. Wilber, R. L., K. W. Rundell, L. Szmedra, D. M. Jenkinson, J. Im, and S. D. Drake. Incidence of exercise-induced bronchospasm in Olympic winter sport athletes. *Med. Sci. Sports Exerc.* 32:732–737, 2000.