The Prevalence of Exercise-Induced Bronchospasm Among US Army Recruits and Its Effects on Physical Performance*

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Study objectives: **To measure the prevalence of exercise-induced bronchospasm (EIB) and to determine its effect on the physical performance response to training in otherwise healthy young adults.**
Design: **Observational, retrospective study.**
Setting: **Fort Jackson, SC, May to July 1998.**
Participants: **One hundred thirty-seven ethnically diverse US Army recruits undergoing an 8-week Army basic training course.**
Measurements and results: **Subjects underwent exercise challenge testing at the end of basic training to evaluate for EIB (defined as a decrease in FEV_1 of ≥ 15%, 1 or 10 min after running to peak oxygen uptake on a treadmill). Those subjects who were unable to run to peak oxygen uptake, or who were unable to perform two baseline FEV_1 maneuvers the results of which were within 5% of each other, were excluded from analysis. We measured peak oxygen uptake on a treadmill and the scores achieved on the components of the US Army physical fitness test (APFT). Of 137 subjects, 121 (58 men and 63 women) met our inclusion criteria. Eight subjects (7%) had EIB. Subjects who experienced EIB and unaffected control subjects both showed statistically significant gains in performance on the APFT events during basic training. At the end of basic training, peak oxygen uptake levels and APFT event scores were not significantly different between subjects with EIB and unaffected control subjects.**
Conclusions: **Seven percent of the US Army recruits who were tested had EIB, but this did not hinder their physical performance gains during basic training. EIB *per se* should not be an absolute reason to exclude individuals from employment in jobs with heavy physical demands.** ***(CHEST 2001; 119:1676–1684)***

Key words: asthma; athletic performance; epidemiology; exercise-induced asthma; military medicine; oxygen uptake; physical fitness; physical training

Abbreviations: ANOVA = analysis of variance; APFT = US Army physical fitness test; EIB = exercise-induced bronchospasm; mph = miles per hour; $\dot{V}O_2max$ = maximal oxygen uptake

Exercise-induced bronchospasm (EIB) is defined as reversible airways obstruction that is triggered by physical exertion or by the forcible inhalation of cool, dry air.[1,2] It occurs in 40 to 90% of patients with asthma but can also be the sole manifestation of reversible airways obstruction.[1,2] In cross-sectional studies, the prevalence of EIB among young athletes typically has been reported to be between 3% and 13%,[3–7] but it may be much higher in certain groups such as figure skaters.[8–10] There is some evidence to suggest that individuals with EIB or asthma have impaired physical performance. Children with asthma tend to have lower maximal oxygen uptake ($\dot{V}O_2max$) levels than healthy control subjects,[11] although this may be attributable to a less active lifestyle.[12] In one report, [5] high school athletes with EIB recorded slower times in a free run test than did their unaffected peers. Adults with asthma have been reported to have lower $\dot{V}O_2max$ levels, anaerobic thresholds, and oxygen pulses than unaffected

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control subjects with comparable habitual levels of activity,[13] although they can achieve statistically significant improvements in aerobic fitness in response to training.[14,15] However, it is not known whether there are systematic differences between adults with EIB and unaffected peers in the physical performance gains that can be realized during a training program.

US Army recruits represent an especially interesting population in which to study EIB and its effect on physical performance. In contrast to some groups in which the prevalence of EIB has been measured, US Army recruits are drawn from an otherwise healthy, ethnically diverse, and geographically dispersed population. Additionally, recruits undergoing basic training represent a large cohort of individuals who by virtue of their enlistment will undergo a closely monitored and strictly enforced training regimen, the outcome of which can be objectively measured using the US Army physical fitness test (APFT), a standardized instrument that has been used extensively since 1984.[16–19] Accordingly, US Army recruits afford a unique opportunity to study the effect of EIB on the physical performance response to training.

The prevalence of EIB among US Army recruits is unknown. The US Army screens all prospective applicants medically prior to enlistment by means of a standardized history and physical examination. Asthma disqualifies a prospective volunteer from enlistment in the US Army,[20] although a waiver can be obtained in some circumstances for individuals with a history of childhood asthma who have been asymptomatic since age 12 years.[20,21] However, historical information alone can lack both sensitivity and specificity for detecting EIB,[6,7] and a subject whose only manifestation of reversible airways obstruction is EIB may not be wheezing at the time of the physical examination at induction. Thus, it is not necessarily surprising that the Air Force, which has a screening policy similar to that of the Army, found a 6% point prevalence of EIB in a study of 100 consecutive hospital personnel.[22]

The above considerations suggest that, despite initial medical screening, a substantial number of US Army recruits nevertheless might have unrecognized EIB. Therefore, we measured the prevalence of EIB in a cohort of recruits undergoing basic training. Furthermore, we evaluated whether or not unrecognized (and hence untreated) EIB might adversely affect adaptations to physical training by measuring peak oxygen uptake levels and exercise performance (by aerobic endurance and muscular strength and endurance) before and after basic training.

Materials and Methods

Research Volunteers

This study was one of several conducted from May through July 1998 on a cohort of Army recruits undergoing the 8-week basic training course at Fort Jackson, SC. The other studies included an assessment of the fitness of these soldiers compared to historical standards,[23] an evaluation of the effect of angiotensin-converting enzyme genotype on the physical performance gains realized during basic training, and a study of the relationship between training injuries and physical fitness (to be reported elsewhere). Three hundred fifty soldiers (182 men and 168 women) from two basic training battalions at Fort Jackson, SC, agreed to participate in the physical fitness study. Of those 350 participants, 66 men and 71 women also enrolled in the present study. All subjects gave voluntary and informed consent to participate in this study in accordance with the standards of Army Regulation 70–25.[24]

Army recruits undergo a standard history and physical examination prior to enlistment to screen for a variety of medical conditions. The screening questionnaire specifically asks the applicant about a history of asthma, wheezing, or chronic cough. Auscultation of the chest is performed as part of this physical examination. Pulmonary function tests and specialist consultation can be requested at the discretion of the screening medical officer to determine whether a subject has asthma or other exclusionary conditions. Since 1995, the standards of medical fitness for the Army have required that applicants with obstructive airways disease (including asthma, EIB, and asthmatic bronchitis) that has been reliably diagnosed at any age be excluded from enlistment.[20] In exceptional circumstances, waivers to this policy may be granted to individuals who have a history of childhood asthma but who have been asymptomatic since age 12 years.[21] Individuals with active symptoms of asthma or those who require medication to remain asymptomatic are not permitted to enlist.

Subjects who enrolled in this study underwent measurement of their peak oxygen uptake levels at the beginning and the end of basic training. Screening for EIB was performed at the end of basic training, concurrent with the measurement of peak oxygen uptake levels. The scoring of the spirometry data was performed by an investigator who was not present at the testing site, after all testing had been completed. As a result, the subjects, the personnel who supervised the administration of the APFT (see below), and the study investigators who conducted the on-site data collection were blinded to the EIB status of the subjects (as defined by spirometry) during the data-collection phase of this study.

Subjects were excluded from further data analysis if they failed to achieve peak oxygen uptake levels at the second assessment (which was performed at the end of basic training) or if they were unable to perform two FEV_1 maneuvers with results that were within 5% of each other before exercising.

Army Basic Training

Subjects participated in physical training four to six mornings per week for 1 to 1.5 h, beginning at 5:30 AM. Training sessions alternated between aerobic and muscle strength sessions. On aerobic training days, soldiers ran between 0.5 and 3 miles, sometimes performing sprints. To ensure that a training effect would be achieved in all individuals, soldiers ran in one of four ability groups, which were established based on quartiles from a 2-mile timed run that was performed during the first week of basic training. On muscle strength training days, training consisted of push-ups, sit-ups, and calisthenic-type exercises. In addition to morning physical training, trainees participated in many other physical activities, such as road marches (with and without additional loads, such as backpacks, weapons, and combat equipment), fitness obstacle courses, climbing, rappelling, bayonet training, and tactical movement exercises (under fire and not under fire), culminating in a 3-day field training exercise.

Peak Oxygen Uptake

Aerobic power was measured by an open-circuit method, using a continuous uphill treadmill running protocol that was similar to that used by Patton et al[25] and was based on standard methods.[26,27] The initial 5-min warm-up was run at a 0% grade and at 2.68 m/s (6 miles per hour [mph]) for men and at 2.24 m/s (5 mph) for women. If the heart rate was < 150 beats/min by minute 5 of the warm-up, the treadmill speed was increased by 0.45 m/s (0.5 mph) for the remainder of the test. Following the warm-up, the treadmill grade was increased by 2% every 3 min until volitional fatigue. The level of oxygen uptake at volitional fatigue was considered to be the peak oxygen uptake level of the subject. $\dot{V}O_2$max was considered to have been achieved if there was an increase in oxygen uptake of < 2 mL/kg/min (or 0.15 L/min) with an increase in treadmill grade prior to volitional fatigue. Subjects wore a nose clip and were connected to the oxygen uptake-measuring device via a low-resistance nonrebreathing valve (Hans Rudolf, Inc; Kansas City, MO) by a mouthpiece. The on-line oxygen uptake system consisted of an oxygen analyzer (Applied Electrochemistry S-3A; AEI Technologies; Pittsburgh, PA), a carbon dioxide analyzer (Beckman LB-2; SensorMedics, Inc; Yorba Linda, CA), and a flowmeter turbine (KL Engineering Turbine Company; Northridge, CA) interfaced with a computer (model 9122; Hewlett-Packard; Palo Alto, CA). A single-lead ECG (model 1511B; Hewlett-Packard) was monitored by trained personnel during the test to determine heart rates and to ensure the safety of the subject.

Spirometry

Subjects underwent the measurement of FEV_1 just before running on a treadmill, then 1 and 10 min after running on a treadmill to peak oxygen uptake, using a hand-held anemometric spirometer (Micro Spirometer; MicroMedical Ltd; Kent, UK). Subjects were asked to perform up to eight forced expiratory maneuvers before exercise, and at least two at each time interval after exercise. The best-effort (highest) FEV_1 obtained before exercise and at 1 and 10 min after exercise was taken to be the FEV_1 for the subject at that time point. The smaller of the two best-effort postexercise FEV_1 values was used to calculate the exercise-induced change in FEV_1 for the subject. The subject was considered to have EIB when the exercise-induced decrease in FEV_1 was $\geq 15\%$, which is in accordance with existing guidelines.[28]

The time points chosen to measure FEV_1 after exercise (1 and 10 min) were a compromise between the known biology of EIB (in which, for most subjects, FEV_1 begins to fall shortly after the cessation of exercise and reaches a nadir between 5 and 10 min after exercise[2,28]), the time points used by other investigators (which among others, typically include both 1-min and 10-min time points[7–9]), and the need to screen a large number of subjects at each testing session. Although some individuals may experience a delayed onset of bronchoconstriction after exercise (with the diagnostic fall in FEV_1 not occurring until up to 30 min after exercise), these individuals represent a small minority of those persons with EIB.[28] Furthermore, because others[8] have shown convincingly that the mean FEV_1 of individuals with EIB is fairly constant between 5 and 15 min postexercise, we believed that the error of underestimation that would be introduced by taking measurements at 1 and 10 min postexercise would be small.

Exercise challenge testing was carried out on 6 separate days in early summer at Fort Jackson in a building that had no air conditioning. Testing sessions typically ran from either 5 AM to noon or from noon to 4 PM (and occasionally, both). On testing days, the mean ($\pm$ SD) ambient temperatures at Fort Jackson ranged from 22.3 ± 1.0°C to 36.7 ± 1.0°C. The mean relative humidity at Columbia, SC (the nearest weather station that records these data) ranged from $32 \pm 4\%$ to $86 \pm 8\%$.

APFT

The APFT is a standard assessment of physical fitness that is administered to all active-duty personnel at least twice per year, to recruits at the beginning and the end of basic training, and to all members of the reserve components at least once per year. It consists of the following three events: (1) a push-up event, in which the soldier performs as many Army-standard push-ups in 2 min as possible; (2) a sit-up event, in which the soldier performs as many Army-standard sit-ups in 2 min as possible; and (3) a timed 2-mile run. The accepted techniques for performing Army-standard push-ups and sit-ups are explained and demonstrated to the soldiers just before each event. The precise wording of the explanations given before each event is standard throughout the US Army.[16] A soldier who does not perform push-ups or sit-ups to standard during the first 10 repetitions is stopped, given an explanation of why the performance technique is incorrect, and, after a rest period, is retested. Any push-up or sit-up repetition not performed to Army standards is not counted. The 2-mile run is unassisted and is performed at a pace determined by the subject; soldiers are not disqualified if they alternate running and walking on this performance test.

Performance on each event is given an age-adjusted and gender-adjusted score on a scale of 1 to 100, based on the number of repetitions performed or the time taken to run 2 miles. A minimum score of 50 in each event is required to graduate from basic training, but soldiers are encouraged to achieve a score of ≥ 60, which is the standard they will subsequently be required to meet. In healthy, trained individuals, the 2-mile run event is known to correlate well with the $\dot{V}O_2$max of a subject[18]; the sit-up and push-up events are generally considered to be measures of muscular endurance.[18] One significant advantage of the APFT scoring system is that it accounts for individuals who are unable to complete a 2-mile run by assigning them a score of zero for the run event. Additionally, extraordinary athletes can achieve only a maximum score of 100. These features reduce the statistical impact of outliers on the overall population without excluding them from the analysis. The APFT scoring system is based on a normative scale[19] and has been in use since 1984, although a refinement of the scoring system was introduced shortly after this study was completed in 1998.[17]

The APFT was administered by the soldiers' basic training units according to Army standards by individuals not otherwise directly involved with this study. The age-adjusted and gender-adjusted APFT scores for each subject were calculated in accordance with the standards in effect at the time.[16]

Statistical Analysis

Statistical analysis was performed using computer software (SigmaStat for Windows 2.0[29] and SPSS for Windows 10.0[30]; SPSS; Chicago, IL). As a general data analysis strategy, groups of interest were examined for normality and equal variance prior to applying any statistical tests. For normally distributed data, we have reported the mean and SE; otherwise, we have reported medians and interquartile ranges. Parametric statistics (paired t tests for paired comparisons, unpaired t tests for across-group comparisons and one-way analysis of variance [ANOVA] for multiple group comparisons) were reported to be used when assumptions of normality (Kolmogorov-Smirnov test) and equal variance were met; otherwise, we used nonparametric statistics (*ie*, Wilcoxon test for paired comparisons, Mann-Whitney rank sum test for unpaired comparisons, and ANOVA on ranks for multiple comparisons). Differences in categoric variables were compared by the Pearson χ^2 test.

Percentage changes in FEV_1 from baseline were analyzed using Friedman repeated-measures ANOVA on ranks, followed by the Tukey test. In addition to paired *t* tests, peak oxygen uptake data were analyzed by repeated-measures ANOVA using oxygen uptake levels at the beginning and the end of basic training as the within-subjects factor, the presence or absence of EIB as the between-subjects factor, and gender as a covariate.

The APFT performance data were analyzed after subjects had been stratified into categories based on the greatest percentage drop in best-effort, postexercise FEV_1. Differences between the strata were evaluated by ANOVA on ranks. Because the number of subjects in each subgroup was not equal, *post hoc* analysis of the ANOVA on ranks was performed by Dunn's test.

Results

Characteristics of the Volunteers

Table 1 summarizes the baseline demographic characteristics, baseline body mass indexes, and baseline peak oxygen uptake levels of the subjects who participated in this study and of those who did not. There were no significant differences in age, race, gender, baseline body mass index, or baseline peak oxygen uptake level between subjects who underwent exercise challenge testing at the end of basic training and those who did not.

Of the 137 subjects who participated in this study, 7 (3 men and 4 women) did not perform a technically adequate peak oxygen uptake test at the time of the post-basic training exercise challenge and were excluded from the analysis. Only one of these seven excluded subjects (a male subject) would have otherwise met our criteria for EIB. Additionally, nine subjects (five men and four women) were unable to perform at least two FEV_1 maneuvers with results that were within 5% of each other at baseline, and they also were excluded from further analysis. Of the subjects included in the analysis, 52 of the 58 men and 54 of the 63 women performed at least three FEV_1 maneuvers with results that were within 5% of each other before exercise.

Excluding those individuals who failed to perform a technically adequate peak oxygen uptake at the time of exercise challenge and those who could not perform two FEV_1 maneuvers within 5% of each other at baseline, the median age of the 121 participants (58 men and 63 women) included in the analysis was 21 years (range, 18 to 35 years). Their self-reported ethnic backgrounds were the following: whites, 67; African Americans, 32; Hispanics, 16; Asians, 5; and Native Americans, 1. Their self-reported homes of origin included 36 different states in the United States, the US Virgin Islands, and Puerto Rico.

Prevalence of EIB

The distribution of exercise-induced changes in FEV_1 is shown in Figure 1. EIB was defined as a decrease of ≥ 15% in best-effort FEV_1 at either of the time intervals after exercise when measurements

Table 1—*Demographic Characteristics of Subjects Who Participated in the Present Study and Those Who Did Not**

Characteristics	Participants (n = 137)	Nonparticipants (n = 213)	p Value
Age, yr	21 (19–24)	20 (19–23)	0.3†
Gender			0.3‡
Male	66 (48)	116 (54)	
Female	71 (52)	97 (46)	
Race			0.6‡
African American	36 (26)	61 (29)	
White	75 (55)	121 (57)	
Hispanic	19 (14)	25 (12)	
Other	7 (5)	6 (3)	
Body mass index, kg/m^2			
Men	24.9 (22.9–26.9)	24.5 (22.3–28.2)	0.7†
Women	23.4 (21.3–25.5)	23.8 (21.4–25.7)	0.8†
Peak oxygen uptake, ml/min/kg			
Men	51.1 ± 0.8	50.2 ± 0.6§	0.4‖
Women	39.6 ± 0.6	38.9 ± 0.6	0.4‖

*Values given as median (interquartile range), No. (%), or mean ± SEM, unless otherwise indicated.
†Rank sum test.
‡χ^2 test.
§Peak oxygen uptake data were obtained on 105 of the 116 men and 84 of the 97 women in this group.
‖*t* test.

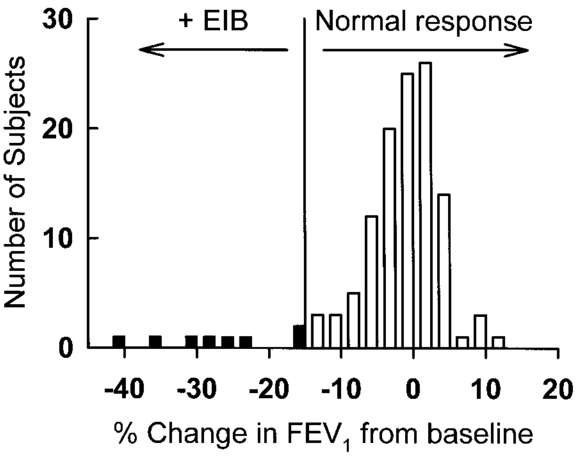

FIGURE 1. Distribution of the exercise-induced change in FEV_1. EIB was defined as a fall in FEV_1 of ≥ 15% at any time after exercise. By this criterion, 7% of the subjects had EIB.

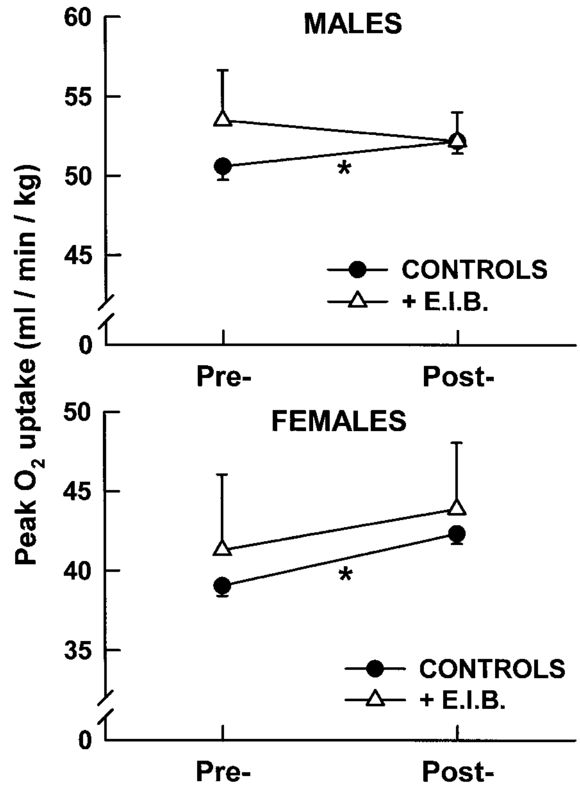

FIGURE 2. The effect of EIB on treadmill peak oxygen uptake at the beginning of basic training (Pre-) and at the end (Post-). Data are presented as mean ± SEM. Subjects unaffected by EIB showed statistically significant gains in peak oxygen uptake (* = $p < 0.05$ for the difference between Pre- and Post-). There were no clinically or statistically significant differences between subjects with EIB and unaffected control subjects.

were taken (*ie*, 1 and 10 min after the cessation of exercise). Eight subjects (five men and three women) had evidence of EIB, a point prevalence of 7%. Of these subjects, three were white, four were African-American, and one was Hispanic. Five subjects met the criterion for EIB only at the 10-min time interval, two subjects met the criterion at both the 1-min and 10-min time intervals, and one subject met the criterion only at the 1-min time interval. In the subjects with EIB, the median percentage postexercise changes at 1 and 10 min were −10.6% (interquartile range, −15.8 to +1.5%) and −23.7% (interquartile range, −29.9 to −15.8%), respectively. These decreases in FEV_1 were statistically significant overall by repeated-measures ANOVA on ranks ($p = 0.002$), but *post hoc* analysis (by Tukey test) showed that only the decrement at 10 min was significantly different from the preexercise FEV_1 level. By contrast, in unaffected subjects, the median percentage postexercise changes in FEV_1 were +0.3% (interquartile range, −2.4 to +2.8%) and +0.3% (interquartile range, −2.2 to +2.5%) and were not statistically significant ($p = 0.2$).

Although we defined EIB as a decrease of ≥ 15% in FEV_1 after exercise, in accordance with existing guidelines, some investigators consider a decrease in FEV_1 of ≥ 10% to be sufficient to diagnose the condition.[28] By this less restrictive criterion, 6 women (9.5%) and 8 men (14%) had EIB, which represents an overall prevalence of 12%.

Effect of EIB on Aerobic Performance

Changes in peak oxygen uptake that occurred during basic training are illustrated in Figure 2. The 53 male subjects unaffected by EIB showed an increase in mean (± SEM) peak oxygen uptake from 50.6 ± 0.9 to 52.2 ± 0.8 mL/kg/min ($p = 0.01$ by paired *t* test). The 60 female subjects who were unaffected by EIB showed an increase from 39.1 ± 0.6 to 42.3 ± 0.6 mL/kg/min ($p < 0.001$). In subjects with EIB, the mean peak oxygen uptake changed from 53.5 ± 3.2 to 52.2 ± 1.8 mL/kg/min in the five men ($p = 0.4$) and from 41.3 ± 4.8 to 43.9 ± 4.2 mL/kg/min in the three women ($p = 0.1$). Differences in mean peak oxygen uptake between unaffected subjects and subjects with EIB were not statistically significant, either at the beginning of basic training (men, $p = 0.3$ [*t* test]; women, $p = 0.5$ [*t* test]) or at the end (men, $p = 1.0$; women, $p = 0.6$). To confirm these findings, the changes in peak oxygen uptake that occurred in the cohort were analyzed by repeated-measures ANOVA, using the presence or absence of EIB as the between-subjects factor and gender as a covariate. This analysis revealed a significant increase in peak oxygen uptake for the cohort ($p = 0.01$), with a statistically significant interaction between gender and increase in peak oxygen uptake ($p = 0.02$), but not between the presence or absence of EIB and increase in peak oxygen uptake

($p = 0.2$). Gender ($p < 0.001$), but not EIB ($p = 0.4$), had a statistically significant effect on the increase in peak oxygen uptake levels.

The continuous treadmill protocol was intended to measure peak oxygen uptake rather than a true $\dot{V}O_2$max. Of the 121 subjects included in our study, 88 (73%) achieved either a heart rate that was $\geq$ 90% predicted for age, a respiratory exchange ratio $\geq$ 1.1, or a plateau in $\dot{V}O_2$ (as defined in "Materials and Methods") both before and after basic training. Another 25 subjects (21%) met one or more of these criteria before basic training but not after basic training, whereas only 5 subjects (4%) met at least one of these criteria after basic training but not before. Using a plateau in $\dot{V}O_2$ as the criterion for $\dot{V}O_{2max}$, only 5 subjects (4%) achieved $\dot{V}O_{2max}$ both before and after basic training. Twenty-one subjects (17%) achieved in $\dot{V}O_{2max}$ before basic training but not after basic training, whereas 14 subjects (12%) failed to achieve $\dot{V}O_{2max}$ before basic training but did so after basic training. The remaining 81 subjects (67%) did not achieve a plateau in $\dot{V}O_2$ either before or after basic training. Of the eight subjects with EIB, only two (one man and one woman) achieved a plateau in $\dot{V}O_2$ before basic training, and none achieved it after basic training.

To further determine whether the postexercise change in FEV_1 had an effect on physical performance, we stratified our cohort according to their exercise-induced changes in FEV_1. We defined the following three strata: no bronchoconstrictor response (*ie*, no decrease in FEV_1 after exercise); indeterminate response (*ie*, a decrease in FEV_1 of less than 15% after exercise); and EIB (*ie*, a decrease in FEV_1 of 15% or more after exercise). Subjects in all three strata displayed statistically significant gains in median 2-mile run score over the course of basic training (Table 2). However, there were no statistically significant differences in 2-mile run scores between the subjects with EIB and the subjects who showed no bronchoconstriction after exercise (Table 2) at either the beginning or the end of basic training. The differences in median scores at the end of basic training correspond to a 12-s per mile difference in run time between subjects with EIB and unaffected subjects. The median and 25th percentile scores achieved by all groups of subjects were substantially higher than the minimum score of 50 required to graduate from basic training.

When stratified according to the exercise-induced change in FEV_1, no statistically significant differences in mean peak oxygen uptake were found among subjects with EIB, subjects with no bronchoconstrictor response, and subjects with an indeterminate response, either at the beginning of basic training (men, $p = 0.3$; women, $p = 0.8$) or at the end (men, $p = 0.3$; women, $p = 0.8$).

Effect of EIB on Measures of Muscular Endurance

Subjects with EIB and unaffected control subjects showed significant gains in push-up and sit-up scores

Table 2—*Effect of EIB on the APFT Score Gains Realized Over the Course of Basic Training**

FEV_1 Response to Exercise	No.	APFT Event Scores: Beginning of Basic Training	APFT Event Scores: End of Basic Training	p Value†
2-Mile run event				
No bronchoconstriction	51	52 (12–77)	76 (66–87)	< 0.001
Indeterminate	62‡	36 (0–60)	76 (65–86)	< 0.001
EIB	8	52 (43–61)	72 (63–86)	0.008
p Value§		0.08	0.9	
Push-ups				
No bronchoconstriction	51	55 (42–65)	71 (62–76)	< 0.001
Indeterminate	62‡	53 (43–62)	65 (58–75)	< 0.001
EIB	8	50 (44–63)	67 (58–72)	0.04
p Value		0.7	0.3	
Sit-ups				
No bronchoconstriction	51	54‖ (44–66)	66 (59–76)	< 0.001
Indeterminate	62‡	51 (44–58)	68 (62–75)	< 0.001
EIB	8	40‖ (37–49)	62 (60–70)	0.008
p Value§		0.04	0.6	

*Values given as median (interquartile range), unless otherwise indicated.
†Wilcoxon rank sum test.
‡One subject did not have APFT data collected at the beginning of basic training.
§Kruskal-Wallis ANOVA.
‖Post hoc $p < 0.05$ by Dunn test.

over the course of basic training (Table 2). There were no statistically significant differences in push-up scores between subjects with EIB and unaffected control subjects either at the beginning or at the end of basic training. Subjects with EIB performed significantly fewer sit-up repetitions at the beginning of basic training. However, their fitness gains were such that no statistically significant difference in sit-up score between subjects with EIB and unaffected control subjects was evident at the end of basic training.

In absolute terms, the differences in median APFT push-up and sit-up scores at the end of basic training represent a four-repetition difference in each event (over the course of 2 min) between subjects with EIB and subjects with no bronchoconstrictor response to exercise.

Discussion

We found a point prevalence for EIB of 7% in our ethnically diverse population of recruits drawn from geographically dispersed backgrounds in the United States. Under a less restrictive definition of the condition (*ie*, a 10% instead of a 15% drop in FEV_1 after exercise), 12% of Army recruits who were tested had EIB. The point prevalence reported herein is comparable to what has been found previously in other populations of healthy, young athletes[3–7] and in Air Force personnel.[22] The relatively high prevalence of EIB that we detected in recruits undergoing basic training is not necessarily surprising, as the medical examination performed during induction into the Army relies on history and physical examination alone to identify bronchospastic conditions. As noted by others,[6,7] historical information alone lacks both sensitivity and specificity to detect EIB in otherwise healthy subjects. Furthermore, in addition to those individuals who did not know that they had EIB, it is possible that there were others with asthma who successfully concealed it during their induction screening examination. Indeed, a 1998 internal Department of Defense survey[21] found that of 1,014 individuals discharged from the armed forces for asthma in 1995, 17% had been unaware of their diagnosis prior to entry into the service, and 73% had known of their condition at the time of enlistment but had concealed it during their initial screening.

With the exception of one measure of physical performance (*ie*, sit-ups at the beginning of basic training), the subjects we identified as having EIB showed no evidence of a physical performance disadvantage when compared to unaffected peers. Both the subjects with EIB and their unaffected peers showed statistically significant gains in physical performance on the APFT over the course of basic training, and the scores achieved at the end of basic training were comparable across the groups.

The peak oxygen uptakes achieved by subjects with EIB at the beginning and at the end of basic training were not clinically or statistically different from those of unaffected subjects. These data must be interpreted cautiously, however, due to the low number of subjects with EIB. Although the unaffected subjects showed statistically significant gains in peak oxygen uptake over the course of basic training, subjects with EIB did not. This may have been due to the low number of subjects with EIB in each gender subgroup and, at least among men with EIB, the relatively high peak oxygen uptake already present at baseline. Consistent with this interpretation, the difference between the mean peak oxygen uptake of subjects with EIB and their unaffected peers was $< 6\%$ and was not statistically significant.

Our protocol was designed to measure peak oxygen uptake rather than $\dot{V}O_2$max. Because fewer subjects achieved a true plateau in oxygen uptake at the end of basic training than before, it is possible that, although statistically significant, the observed increases in peak oxygen uptake underestimate the true gains in $\dot{V}O_2$max that occurred. This underestimate could have contributed to the failure of the subjects with EIB to show a statistically significant gain in peak oxygen uptake as a result of basic training.

The physical performance findings of this study cannot yet be generalized to all subjects with EIB, because, despite ethnically diverse and geographically dispersed origins in the United States, our subjects represented a select population because of the following: (1) they were young and otherwise healthy enough to meet the Army's physical requirements for entry into the service; (2) they had been able to complete 8 weeks of Army basic training; (3) they were able to perform the physical tasks demanded of them without the need for medication; and (4) they underwent a mandatory and strictly enforced program of physical training. Nevertheless, our findings demonstrate that, even without medical intervention, some individuals with EIB can respond to physical training in a manner comparable to unaffected individuals. This suggests that a diagnosis of EIB, *per se*, should not be used as an absolute exclusionary criterion for employment in jobs with heavy physical demands. However, a larger, longitudinal study will be needed to establish whether or notindividuals with EIB are at a significant physical performance disadvantage over longer periods of observation and to determine how many subjects with EIB will subsequently manifest other clinical symptoms of asthma.

An important limitation of this study is that the exercise challenge testing was performed under hot and humid environmental conditions. Because EIB is best precipitated by cool, dry air,[31] it is likely that some subjects that we identified as "indeterminate" in fact would have been identified as having EIB under more sensitive testing conditions. A few others might have been misclassified as "indeterminate" as a result of the postexercise time points at which we chose to measure FEV_1 (*ie*, 1 and 10 min). Our study, therefore, may have underestimated the actual prevalence of EIB. Furthermore, if EIB does adversely affect performance, such misclassification would tend to lower the average performance scores of the unaffected peers. To investigate whether such a misclassification might have biased our conclusions, we stratified our population by their postexercise change in FEV_1 (Table 2). In this analysis, the physical performance of subjects with EIB at the end of basic training was not clinically or statistically different from that of subjects who showed no bronchoconstrictor response to exercise. Therefore, we believe that, although we may have underestimated the true prevalence of EIB in our population, this source of bias would not have been likely to have affected our conclusions about physical performance.

A substantial strength of our study was that the physical training regimen was carried out in a highly structured environment. The noncompliance of subjects with an exercise regimen and individual differences in motivation to perform can, in principle, be significant sources of variability in a physical performance study that are difficult to control for. These potentially confounding elements were minimized by the circumstances of our subjects, who trained in groups and who had to answer to their drill sergeants for any lapses in their apparent desire to exercise. We believe this "drill sergeant effect" was also apparent in the APFT scores achieved at the end of basic training, which were generally well above the minimum required to graduate (the lowest 25th percentile score recorded on any event in any subgroup was still 8 points above the minimum required).

In summary, we found a 7% prevalence of unrecognized EIB among US Army recruits. In the eight subjects who we identified as having EIB, we found no evidence that this condition impaired their ability to realize performance gains during basic training. Our findings, therefore, suggest that, at least among some young, otherwise healthy, motivated, and physically fit adults, EIB *per se* need not be an absolute exclusionary criterion for employment in positions that have heavy physical demands or, perhaps, even for entry into military service.

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