

# Fitness, obesity and risk of asthma among Army trainees

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|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Background</b>  | Epidemiological data suggest an association between overweight/obesity and asthma. However, less is known about the relationship between physical fitness and asthma.                                                                                                                                                                                                                                             |
| <b>Aims</b>        | To enumerate new-onset asthma diagnoses in Army recruits during the first 2 years of service and determine associations with fitness and excess body fat (EBF) at military entrance.                                                                                                                                                                                                                              |
| <b>Methods</b>     | New asthma diagnoses over 2 years in Army recruits at six entrance stations were obtained from military health and personnel records. Poisson regression models were used to determine associations of asthma diagnosis with pre-accession fitness testing, EBF and other potential factors.                                                                                                                      |
| <b>Results</b>     | In 9979 weight-qualified and 1117 EBF entrants with no prior history of asthma, 256 new cases of asthma were diagnosed within 2 years of military entry. Low level of fitness, defined by a step test and EBF, was significantly associated with new asthma diagnosis [adjusted incidence rate ratio (IRR), 1.47; 95% confidence interval (CI) 1.11–1.96 and adjusted IRR, 1.53; 95% CI 1.06–2.20, respectively]. |
| <b>Conclusions</b> | Individuals with low fitness levels, EBF or both are at higher risk of asthma diagnosis in the first 2 years of military service.                                                                                                                                                                                                                                                                                 |
| <b>Key words</b>   | Asthma; body fat; fitness test; military; obesity.                                                                                                                                                                                                                                                                                                                                                                |

## Introduction

Asthma is a common and serious chronic disease that often has an adverse effect on health and functioning, increases healthcare utilization and is associated with increased mortality. A recent survey of the general US adult population estimated that 5–11% of adults currently have asthma [1]. While research on incident asthma is sparse, a retrospective study of nearly 16 000 Swedish adults between the ages of 20 and 50 reported an incidence rate of adult-onset asthma as 1.1/1000 person-years [2]. A prospective study of ~10 000 US adults revealed a 5% incidence of asthma in a follow-up period of 11.5 years [3]. Groups at increased risk of asthma include women [2,4,5], non-Hispanic blacks [5–7], smokers [2,4,8], the overweight and obese [3,4,9–12] and persons with family income below the poverty level [4,5]. In the US military, from 1999 to 2008, the crude incidence rate of asthma was 53.2 per 10 000 person-years [13]. Service members who are in the Army, female, black, younger than 20 years old or in medical

occupations have been found to have a higher risk of developing asthma [13]. Black and female service members were also found to have higher risk of incident hospitalization for asthma [14].

Asthma diagnosis during military training has a significant impact on the preservation of a healthy, fit and effective fighting force. Health histories are reviewed prior to entrance into the military and those who have asthma or a history of asthma after age 13 are barred from enlisting. Individuals disqualified from enlistment may receive an accession medical waiver granted by a service-specific waiver authority based on the needs of that service if the condition is deemed not to prevent the applicant from performing military duties. Analyses of accession, medical encounter and attrition data indicate that soldiers with an encounter for asthma are ~15 times more likely to be discharged from the Army in the first year of service than soldiers without an asthma diagnosis [15].

The association between obesity and asthma risk has been investigated in a number of studies, meta-analyses

and reviews [3,4,9–12]. In a meta-analysis of epidemiological studies evaluating the association of obesity and asthma, Beuther and Sutherland [11] showed a dose-response relationship between elevated body mass index (BMI) and increased odds of developing asthma. Most studies evaluating the relationship between obesity and asthma have used BMI as a measurement to assess obesity [4,9–12]. However, Fenger *et al.* [10] showed that six different measures of obesity, including BMI, waist circumference, waist-to-hip ratio, visceral adipose tissue, subcutaneous adipose tissue and fat percentage, were all associated with asthma, with similar magnitude of risk.

While the role of physical fitness in the prevention of asthma is not well established, epidemiological studies indicate that physical activity may protect against the development of asthma [16]. Considerable heterogeneity in populations, exposures and outcomes found in existing studies indicate that the possible effects of physical activity on incident asthma are still poorly understood [16]. Smoking has been associated with both existing and new-onset asthma in some [2,4,8], but not all studies [17,18]. Some studies suggest that while smoking does appear to aggravate asthmatic symptoms, it is not an independent risk factor for the development of asthma [17,18].

The links between sex, race, smoking and BMI with asthma risk have been evaluated in numerous epidemiological studies. Fewer studies have evaluated the association between asthma risk and body fat per cent as a measure of obesity [3,10]. Data are more limited for fitness and incident asthma [3]. The primary goal of these analyses was to evaluate the relationship between measured fitness and excess body fat (EBF) per cent standards and new-onset asthma in a cohort of US Army trainees within 2 years of entering the military.

## Methods

These analyses are based on data from the Assessment of Recruit Motivation and Strength (ARMS) study. Details on the study methods have been published elsewhere [19–23]. Study subjects included active duty members without prior service enlisting in the US Army between February 2005 and September 2006 at six Military Entrance Processing Stations (MEPS). Subjects were aged 18 or older and provided written informed consent that included medical and administrative follow-up.

All recruits entering the Army through one of the study sites were required to take a pre-accession physical fitness test (ARMS test), a 5-min step test at a pace of 120 steps/min. Details of the ARMS test are described elsewhere [19–23]. Those who passed (subjects who completed the full 5 min at the correct pace) were considered fit, while those who failed were considered unfit. Performance on the ARMS test did not preclude the eligibility of weight-qualified (WQ) study subjects to enter service. However,

subjects with elevated weight-for-height and EBF per cent standards beyond 30% body fat for men and 36% body fat for women (the maximum allowable per cent body fat standards for age 40 and older) were required to pass the physical fitness test to enter the Army. If they passed, they were given an ARMS accession waiver.

ARMS participants were matched to accession dates provided by the Center for Accession Research, US Army Accession Command. The US Military Entrance Processing Command (US MEPCOM) and the Defense Manpower Data Center (DMDC) provided education, military occupational speciality (MOS or military job category) and separation codes. The US MEPCOM also provides details of conditions existing prior to service (EPTS) discharge data and disqualifying medical status. The US Army Recruiting Command provided waiver medical data and the Patient Administration Systems and Biostatistics Activity provided ambulatory health-care encounter data from the Standard Ambulatory Data Record (SADR) and hospitalization data from the Standard Inpatient Data Record (SIDR).

New-onset asthma cases were defined as an asthma diagnosis (ICD-9: 493) given by a health service provider on at least two ambulatory encounters or one inpatient encounter in the first 2 years (761 days) of service [13].

The explanatory variables of interest were fitness and body fat per cent standards, as defined above. Control variables included age as a continuous variable, smoking status (yes/no), BMI [underweight ( $\leq 18.5 \text{ kg/m}^2$ ), normal weight ( $18.5\text{--}24.9 \text{ kg/m}^2$ ), overweight ( $25\text{--}29.9 \text{ kg/m}^2$ ), obese ( $\geq 30 \text{ kg/m}^2$ )], race [black, white or other (Asian, Indian, Pacific, Unknown)], MOS category [combat support/combat support services, combat arms (infantry, artillery, armour, combat engineers) and other/missing] and education category (high school diploma or equivalent, bachelor's degree and above and unsure/missing).

The primary predictors of interest were fitness, defined as step test performance, in WQ individuals, and EBF per cent standards compared with WQ among fit individuals. For analyses evaluating fitness, only WQ were included. For analyses comparing the incidence of asthma diagnosis between EBF and WQ subjects, only fit individuals were considered in the analyses. Sex-stratified and combined analyses were conducted. Individuals who were both unfit and EBF were precluded from entering the Army and consequently not included in the study; it is not possible to measure the combined effect of these two factors.

Chi-squared and Fisher's exact tests were used to analyse categorical data. Poisson regression was used to estimate the incidence rate ratio (IRR) and 95% confidence intervals (95% CIs) of asthma diagnosis within the first 2 years of service. Variables included fitness, weight status, sex, age, smoking history, BMI, race, MOS category and level of education. For multivariate models, analyses were adjusted for sex, age, smoking history,

race, MOS category and fitness or weight status. Missing smoking history and education data were excluded from categorical statistical analysis. Missing data were included in all other models, as including or excluding missing values had no significant impact on estimates. Additive (independent effect) and multiplicative (effect modification) models were used to estimate the expected effects of EBF and of failing the step test, using the formulae  $(OR_{\text{step test}} + OR_{\text{EBF}} - 1)$  for an additive model and  $(OR_{\text{step test}} * OR_{\text{EBF}})$  for a multiplicative model [24].

All statistical analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC, USA). This study was approved by the Walter Reed Army Institute of Research Institutional Review Board.

## Results

There were 11 468 individuals available for analysis in the original study group. A total of 161 were excluded for the following reasons: no valid weight, height or date of birth recorded ( $n = 8$ ); EBF per cent standards but entered the Army at a later date ( $n = 9$ ); missing ambulatory health-care record or without a matching accession date within

30 days of the ARMS study entry date ( $n = 82$ ); separation date preceding accession ( $n = 1$ ); and asthma diagnosis EPTS ( $n = 61$ ). Additionally, 211 individuals with one ambulatory asthma diagnosis within the first 2 years of service, which were considered equivocal asthma, were excluded from the analysis.

After exclusions, a total of 11 096 subjects were included in the final analysis of which 9979 were WQ and 1117 were EBF (Table 1). Among WQ subjects, all reported and measured characteristics differed significantly between fit and unfit, with the exception of smoking status. Among the fit, subject's sex, smoking status, BMI, MOS category and education category differed significantly between WQ and EBF.

There were 256 cases of new-onset asthma diagnosed in ~7 000 000 person-days; 160 (1.7%) and 96 (5.3%) cases in men and women, respectively. The relationship between the two primary predictors, fitness and EBF, and asthma was evaluated for men and women in separate analyses (data not shown). The direction of the observed associations was consistent between sexes, although not statistically significant in women, so the sexes were combined for subsequent analyses.

**Table 1.** Characteristics of ARMS study participants ( $n = 11\,096$ )

|                                               | WQ: passed step test<br>( $n = 7549$ ) | WQ: failed step test<br>( $n = 2430$ ) | $P^a$  | EBF: passed step test<br>( $n = 1117$ ) | $P^b$  |
|-----------------------------------------------|----------------------------------------|----------------------------------------|--------|-----------------------------------------|--------|
| Age (years)                                   |                                        |                                        |        |                                         |        |
| Mean (SD)                                     | 20.8 (3.3)                             | 21.3 (3.7)                             | <0.001 | 20.7 (2.9)                              | NS     |
|                                               | $n$ (%)                                | $n$ (%)                                |        | $n$ (%)                                 |        |
| Sex                                           |                                        |                                        |        |                                         |        |
| Male                                          | 6534 (87)                              | 1923 (79)                              | <0.001 | 816 (73)                                | <0.001 |
| Female                                        | 1015 (13)                              | 507 (21)                               |        | 301 (27)                                |        |
| Smoker <sup>c</sup>                           |                                        |                                        |        |                                         |        |
| No                                            | 5545 (75)                              | 1841 (76)                              | NS     | 868 (79)                                | <0.01  |
| Yes                                           | 1896 (25)                              | 587 (24)                               |        | 236 (21)                                |        |
| BMI                                           |                                        |                                        |        |                                         |        |
| Underweight ( $\leq 18.5$ kg/m <sup>2</sup> ) | 274 (4)                                | 80 (3)                                 | <0.001 | 0 (0)                                   | <0.001 |
| Normal weight (18.5–24.9 kg/m <sup>2</sup> )  | 4385 (58)                              | 1128 (46)                              |        | 23 (2)                                  |        |
| Overweight (25–29.9 kg/m <sup>2</sup> )       | 2100 (28)                              | 842 (35)                               |        | 347 (31)                                |        |
| Obese ( $\geq 30$ kg/m <sup>2</sup> )         | 790 (10)                               | 380 (16)                               |        | 747 (67)                                |        |
| Race                                          |                                        |                                        |        |                                         |        |
| White                                         | 5421 (72)                              | 1602 (66)                              | <0.001 | 797 (71)                                | NS     |
| Black                                         | 978 (13)                               | 405 (17)                               |        | 132 (12)                                |        |
| Other                                         | 1150 (15)                              | 423 (17)                               |        | 188 (17)                                |        |
| MOS                                           |                                        |                                        |        |                                         |        |
| CS/CSS                                        | 4469 (59)                              | 1632 (67)                              | <0.001 | 749 (67)                                | <0.001 |
| Combat arms                                   | 2858 (38)                              | 754 (31)                               |        | 360 (32)                                |        |
| Unsure/missing                                | 222 (3)                                | 44 (2)                                 |        | 8 (1)                                   |        |
| Education <sup>c</sup>                        |                                        |                                        |        |                                         |        |
| HS diploma or equivalent                      | 7186 (95)                              | 2352 (97)                              | <0.001 | 1082 (97)                               | <0.05  |
| Bachelor and above                            | 362 (5)                                | 78 (3)                                 |        | 35 (3)                                  |        |

CS/CSS, combat support/combat support services; HS, high school; NS, non-significant; SD, standard deviation.

<sup>a</sup>Chi-squared and Fisher's exact tests were used to analyse categorical variables and the Student's *t*-test was used to compare age between WQ step test passers and WQ step test failers.

<sup>b</sup>Chi-squared and Fisher's exact tests were used to analyse categorical variables and the Student's *t*-test was used to compare age between WQ step test passers and EBF step test passers.

<sup>c</sup> $n = 123$  missing smoking values and  $n = 1$  missing education value not included in calculations.

A total of 218 cases of asthma were diagnosed among 9979 WQ subjects (fit and unfit) across ~6 300 000 person-days (Table 2). Being unfit, female sex, black race and combat arms speciality were associated with increased risk of asthma diagnosis in the crude model. Bivariate analyses revealed no significant association of asthma diagnosis with age, education, smoking history or BMI category. After adjusting for covariates, significant associations with asthma included being unfit (IRR, 1.47; 95% CI 1.11–1.96), female sex (IRR, 3.29; 95% CI 2.40–4.51), smoker (IRR, 1.52; 95% CI 1.12–2.06) and black race (IRR, 2.07; 95% CI 1.50–2.87).

Among 8666 fit (WQ and EBF) subjects, there were 184 cases of asthma diagnosed across ~5 500 000 person-days (Table 3). EBF, female sex, black race and combat arms speciality were associated with asthma diagnosis in the crude model. Adjusted point estimates were (IRR, 1.53; 95% CI 1.06–2.20) for EBF, female sex (IRR, 3.13; 95% CI 2.23–4.41) and black race (IRR, 2.20; 95% CI 1.55–3.11). Among fit subjects, smoking was not associated with asthma in the adjusted model (IRR, 1.40; 95% CI 0.99–1.96).

The joint effects of being unfit and EBF on the risk of asthma were estimated; results are shown in Table 4. The estimated odds ratios (ORs) for both factors together

under the additive and multiplicative models were 2.34 and 2.77, respectively.

Discussion

Our results showed that unfit individuals were at increased risk of asthma in the first 2 years of service and this was independent of sex, smoking status and race. In addition, we found those with EBF were at increased risk of asthma. Being unfit and having positive EBF have both been identified as increasing risk for musculoskeletal injury and stress fracture [19,21,22], attrition from the military [20], new-onset mental disorder [23] and heat illness [25]. Although data were unavailable on the risk among those who were both EBF and unfit, the estimated ORs of asthma for both an additive (independent) and multiplicative (single or joint effect modification) relationship between EBF and lack of fitness were 2.3- to 2.7-fold greater than fit and WQ. The findings of the current study regarding being unfit and EBF on risk of asthma are supported by Ortega *et al.* [3] who reported a decreased risk of adult-onset asthma (OR, 0.68) in subjects with high cardiorespiratory fitness, as defined by performance from a maximal treadmill exercise test, over a mean follow-up period of 11.5 years and

Table 2. Crude and adjusted IRRs for asthma diagnosis in the first 2 years of service among WQ ARMS subjects (n = 9979)

|                          | Number of asthma cases | 1000 person-days | Crude IRR (95% CI)            | Adjusted <sup>a</sup> IRR (95% CI) |
|--------------------------|------------------------|------------------|-------------------------------|------------------------------------|
| Step test status         |                        |                  |                               |                                    |
| Pass                     | 146                    | 4839             | REF                           | REF                                |
| Fail                     | 72                     | 1462             | <b>1.63 (1.23–2.16)</b>       | <b>1.47 (1.11–1.96)</b>            |
| Sex                      |                        |                  |                               |                                    |
| Male                     | 141                    | 5428             | REF                           | REF                                |
| Female                   | 77                     | 872              | <b>3.40 (2.57–4.49)</b>       | <b>3.29 (2.40–4.51)</b>            |
| Age                      |                        |                  | 0.98 <sup>b</sup> (0.94–1.02) | 0.97 <sup>b</sup> (0.93–1.01)      |
| Smoker                   |                        |                  |                               |                                    |
| No                       | 153                    | 4712             | REF                           | REF                                |
| Yes                      | 61                     | 1518             | 1.24 (0.92–1.67)              | <b>1.52 (1.12–2.06)</b>            |
| BMI                      |                        |                  |                               |                                    |
| Underweight              | 8                      | 214              | 1.12 (0.55–2.29)              |                                    |
| Normal                   | 116                    | 3480             | REF                           |                                    |
| Overweight               | 72                     | 1874             | 1.15 (0.86–1.55)              |                                    |
| Obese                    | 22                     | 214              | 0.90 (0.57–1.42)              |                                    |
| Race                     |                        |                  |                               |                                    |
| White                    | 129                    | 4428             | REF                           | REF                                |
| Black                    | 60                     | 870              | <b>2.37 (1.74–3.22)</b>       | <b>2.07 (1.50–2.87)</b>            |
| Other                    | 29                     | 1003             | 0.99 (0.66–1.49)              | 0.97 (0.65–1.46)                   |
| MOS                      |                        |                  |                               |                                    |
| CS/CSS                   | 150                    | 3864             | REF                           | REF                                |
| Combat arms              | 64                     | 2299             | <b>0.72 (0.54–0.96)</b>       | 1.21 (0.87–1.70)                   |
| Other/unsure             | 4                      | 138              | 0.75 (0.28–2.02)              | 0.99 (0.37–2.69)                   |
| Education                |                        |                  |                               |                                    |
| HS diploma or equivalent | 214                    | 6048             | REF                           |                                    |
| Bachelor and above       | 4                      | 251              | 0.45 (0.17–1.21)              |                                    |

CS/CSS, combat support/combat support services; HS, high school; REF, reference. The bold values indicate statistical significance at the 0.05 level.

<sup>a</sup>Adjusted for step test status, sex, age, smoking, race and MOS.

<sup>b</sup>IRR for each year increase in age.

**Table 3.** Crude and adjusted IRRs for asthma diagnosis in the first 2 years of service among ARMS study participants who passed the ARMS test ( $n = 8666$ )

|                          | Number of asthma cases | 1000 person-days | Crude IRR (95% CI)            | Adjusted <sup>a</sup> IRR (95% CI) |
|--------------------------|------------------------|------------------|-------------------------------|------------------------------------|
| ARMS waiver status       |                        |                  |                               |                                    |
| WQ                       | 146                    | 4839             | REF                           | REF                                |
| EBF                      | 38                     | 686              | <b>1.84 (1.28–2.62)</b>       | <b>1.53 (1.06–2.20)</b>            |
| Sex                      |                        |                  |                               |                                    |
| Male                     | 116                    | 4750             | REF                           | REF                                |
| Female                   | 68                     | 775              | <b>3.59 (2.66–4.85)</b>       | <b>3.13 (2.23–4.41)</b>            |
| Age                      |                        |                  |                               |                                    |
| Smoker                   |                        |                  | 1.01 <sup>b</sup> (0.96–1.05) | 1.00 <sup>b</sup> (0.96–1.04)      |
| No                       | 133                    | 4127             | REF                           | REF                                |
| Yes                      | 48                     | 1321             | 1.13 (0.81–1.57)              | 1.40 (0.99–1.96)                   |
| Race                     |                        |                  |                               |                                    |
| White                    | 111                    | 3959             | REF                           | REF                                |
| Black                    | 50                     | 698              | <b>2.55 (1.83–3.57)</b>       | <b>2.20 (1.55–3.11)</b>            |
| Other                    | 23                     | 867              | 0.95 (0.60–1.48)              | 0.96 (0.61–1.50)                   |
| MOS                      |                        |                  |                               |                                    |
| CS/CSS                   | 132                    | 3340             | REF                           | REF                                |
| Combat arms              | 49                     | 2063             | <b>0.60 (0.43–0.83)</b>       | 1.00 (0.69–1.44)                   |
| Other/unsure             | 3                      | 123              | 0.62 (0.20–1.95)              | 0.77 (0.24–2.42)                   |
| Education                |                        |                  |                               |                                    |
| HS diploma or equivalent | 181                    | 5291             | REF                           |                                    |
| Bachelor and above       | 3                      | 233              | 0.38 (0.12–1.18)              |                                    |

CS/CSS, combat support/combat support services; HS, high school; REF, reference. The bold values indicate statistical significance at the 0.05 level.

<sup>a</sup>Adjusted for ARMS waiver status, sex, age, smoking, race and MOS.

<sup>b</sup>IRR for each year increase in age.

**Table 4.** Expected ORs for asthma associated with the joint effect of being unfit and having EBF: additive and multiplicative models

| Fitness status | Body fat status | Additive model OR | Multiplicative model OR |
|----------------|-----------------|-------------------|-------------------------|
| Fit            | WQ              | 1 (REF)           | 1 (REF)                 |
|                | EBF             | 1.79 <sup>a</sup> | 1.79 <sup>a</sup>       |
| Unfit          | WQ              | 1.55 <sup>b</sup> | 1.55 <sup>b</sup>       |
|                | EBF             | 2.34 <sup>c</sup> | 2.77 <sup>d</sup>       |

REF, reference.

<sup>a</sup>Observed OR for asthma diagnosis in first 2 years of service for those who were EBF, among fit subjects.

<sup>b</sup>Observed OR for asthma diagnosis in first 2 years of service for those who were unfit, among WQ subjects.

<sup>c</sup>Expected OR for joint effects of being unfit and EBF under additive model:

$OR_{\text{step test}} + OR_{\text{EBF}} - 1$ .

<sup>d</sup>Expected OR for joint effects of being unfit and EBF under multiplicative model:  $OR_{\text{step test}} * OR_{\text{EBF}}$ .

an increased risk of asthma with high body fat percentage, as established by hydrostatic weighing. Although a significant relationship between body fat percentage and asthma remained after adjusting for fitness, the association between fitness and asthma was lost after adjusting for body fat percentage. While not wholly comparable, Ortega *et al.* did observe that, among individuals who are overweight, high cardiorespiratory fitness lowers the risk of incident asthma by half. The inverse association would indicate an ~2-fold greater incidence of asthma for subjects with a low level of fitness.

Studies of the relationship between smoking and asthma have reported mixed results [2,4,8,17,18]. Our study did find an association between current smoking and the development of asthma in the first 2 years of service among WQ subjects, but not among fit subjects. The 'healthy smoker effect' [26], whereby current smokers may be resistant to developing asthma, is a possible reason why fit subjects who smoke did not appear to be at higher risk of an asthma diagnosis. In our study, ex-smokers are not considered separately, which may also explain the lack of association between current smoking and asthma risk. The higher incidence of asthma among service members who self-reported black race compared with white is consistent with other literature that has found a higher prevalence of asthma in the US black population [5–7]. Factors that may contribute to the higher risk of asthma in blacks include genetics [27,28], increased exposure to environmental allergens and tobacco smoke and higher rates of obesity [27].

Our study has important strengths, including its prospective cohort design. This study is based on a large population of generally healthy young adults with essentially 100% capture of medical encounters. We were able to exclude individuals who were diagnosed with asthma EPTS and those with either a medical waiver or disqualification for asthma, which allowed us to identify new-onset cases. Fitness, height, weight and body fat were objectively measured prior to entrance. The study population shares similarities to other young adults in

the general population, including police officers and firefighters who encounter similar demands where asthma could impair safe job performance.

This study has some limitations. A potentially important issue is the possibility of failure to disclose a history of asthma before entering the military. This misclassification could lead to overestimation of incident cases in the study population and cannot be ruled out. However, because we excluded subjects from the analyses who had evidence of pre-existing asthma, we feel that this potential bias has been minimized. Further, any consequence of misclassification would most likely be non-differential because there is no evidence to believe that fitness or obesity would affect asthma disclosure prior to enlistment. The current analyses used self-reported data for smoking status and race category. Current smoking habits were recorded, which may have led to underestimation or misclassification of light and ex-smokers. The findings of this study may not be applicable to populations that are older or who have underlying health conditions, or who self-defer from military service because they are unfit or obese, or for other health-related reasons. This healthy worker bias could lead to an underestimation of the adverse impact of fitness and obesity on asthma.

These findings may have value for personnel planning and policymakers in the military as well as other organizations where workers are required to be physically fit in demanding situations. Because the ARMS project has been halted, EBF individuals who exceed age- and gender-specific weight for height or body fat standards are no longer being enlisted into the Army. However, current policy requires no measure of physical fitness or history of fitness activity prior to enlistment. Depending on the recruiting or applicant environment, it may be possible to exclude from consideration those who are at higher risk of asthma. Because being unfit is a potentially modifiable risk factor, consideration could be given to requiring applicants to pass a fitness test or obtaining a valid history of physical activity. Cost-effectiveness analyses should be conducted to determine the appropriate level of fitness required for varying recruitment requirements under conditions of differing applicant pools.

### Key points

- This prospective epidemiological study found that, among US Army recruits, fitness was an important independent predictor of new-onset asthma.
- In fit Army recruits, those who exceeded body fat standards were at significantly increased risk of new-onset asthma.
- Requiring recruits to demonstrate fitness and meeting body fat standards prior to entering service may be considered as a means of reducing asthma incidence in the armed forces.

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### Conflicts of interest

None declared.

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