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Fitness, obesity and risk of heat illness among army trainees

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Background Exertional heat illness (EHI) affects military personnel, athletes and occupational groups such as agricultural workers, despite knowledge of preventive measures.

Aims To evaluate EHI diagnoses during US Army basic training and its associations with fitness and body fat on entering military service.

Methods From February 2005 to September 2006, US Army recruits at six different military entrance stations took a pre-accession fitness test, including a 5-min step test scored as pass or fail. Subsequent EHI incidence and incidence rate ratios were analysed with reference to subjects' fitness (step test performance) and whether they met (weight qualified [WQ]) or exceeded body fat (EBF) standards.

Results Among the 8621 WQ and 834 EBF male subjects, there were 67 incidents of EHI within 180 days of entering military service. Among WQ subjects, step test failure was significantly associated with EHI (odds ratio [OR] 2.00, 95% confidence interval [CI] 1.13, 3.53). For those passing the step test, the risk of EHI was significantly higher in EBF than in WQ subjects (OR 3.98, 95% CI 2.17, 7.29). Expected ORs for the joint effects of step test failure and EBF classification under additive and multiplicative models were 4.98 and 7.96, respectively. There were too few women to evaluate their data in detail.

Conclusions This study demonstrated that fitness and body fat are independently associated with incident EHI, and the effect of both was substantially higher. Those with low fitness levels and/or obesity should be evaluated further before engaging in intense physical activity, especially in warmer months.

Key words Body fat; fitness test; heat illness; military; obesity.

Introduction

Despite the widespread knowledge of preventive measures (at least among athletic and military trainers), exertional heat illness (EHI) continues to affect athletes, military personnel and certain groups of workers, such as agricultural workers. EHI in military populations can impair operational readiness, especially in training and combat in hot weather. Among active duty US military personnel, the incidence rate of heat stroke was higher in 2012 than in 2011, although the incidence of other heat illness was lower [1]. In a study of US high school athletes from 2005 to 2009, there were 118 cases of heat illness that resulted in more than 1 day of time lost from athletic activity, a rate of 1.6 per 100 000 athlete exposures [2]. According to Nelson *et al.*, EHI is a risk to all physically active individuals, with the majority of instances occurring in those performing sports or exercising [3].

Several risk factors for EHI have been identified. Obese individuals and those who are less physically fit have been found to be at greater risk [4,5]. Given the rising prevalence of obesity in the US population, several studies have demonstrated an increase in EHI among military personnel [6–8]. There have been few published studies where obesity has been described as a risk factor in heat illness among athletes, although in one study of high school athlete obesity was found to be a factor in the onset of EHI [9]. In a study of Marine recruits, the greatest risk of EHI was found among men with the highest body mass index (BMI) [6].

In 2010, we published a prospective study of EHI among male US Army trainees in the first 90 days of military service [10]. Since then, we have followed the subjects for a further 90 days, acquiring new data not previously considered, and have included some information on women. The additional data include newly identified cases and measured fitness (based on a 5-min step test) prior to military entry. We have conducted a number of additional analyses, including comparisons between 'fit' and 'unfit' weight-qualified individuals and comparisons between fit weight-qualified recruits and fit recruits with excess body fat [11–16]. These analyses provide substantial new insight regarding rates of and risk factors for heat illness.

Methods

These analyses were based on data from the Assessment of Recruit Motivation and Strength (ARMS) study. Study subjects included all men and women enlisting in the US Army for the first time between February 2005 and September 2006 at six Military Entrance Processing Stations (MEPS). Additional details on the study methods have been published elsewhere [10–17]. Subjects were followed for 180 days after entry. This study was approved by the Walter Reed Army Institute of Research Institutional Review Board. Subjects were aged 18 or more and provided written informed consent for completing a questionnaire and for medical and administrative follow-up. Individuals with no valid weight, height or date of birth recorded were excluded from analysis (n = 7). Individuals with a missing ambulatory health care record or no matching accession date within 30 days of the ARMS study entry date (n = 62) and one with a separation date preceding accession were also excluded. Because few cases of EHI occurred among women only summary data are provided. Everyone entering the US Army through any of the study sites was required to take a pre-accession physical fitness test (ARMS test). The fitness test of interest in this study involved a 5-min step test set by a metronome at a pace of 120 steps per minute, with a step height of 12 inches. The ARMS test is fully described elsewhere [10–16]. Those who exceeded body fat (EBF) percent standards were required to pass the physical fitness test in order to enter the Army under an ARMS waiver, whereas weight-qualified (WQ) study subjects were permitted to enter irrespective of their step test performance. Therefore, the study included three groups of subjects: 'fit WQ', 'unfit WQ' and 'fit EBF'. The referent group for all comparisons was those who were both fit and WQ. Due to ethical concerns about risks to those who were both unfit and EBF, those who failed the step test and did not meet body fat requirement were not provided with an ARMS waiver.

Subjects were matched to accession data 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 Military Occupational Specialty (MOS) codes. The Patient Administration Systems and Biostatistics Activity provided ambulatory health care encounter data from the Standard Ambulatory Data Record (SADR) and inpatient data from the Standard Inpatient Data Record (SIDR). EHI incident cases were defined as at least one ambulatory encounter resulting in a diagnosis of heat stroke (992.0), heat exhaustion (992.3–5), heat syncope (992.1), heat cramps (992.2), heat fatigue, transient (992.6), heat oedema (992.7), other specified heat effects (992.8) and unspecified effects of heat and light (992.9) entered in any diagnosis position. Inpatient medical records were also searched with the same diagnostic criteria. Rhabdomyolysis was excluded from the case definition because, while it can be heat-related, other causes not associated with heat exposure also occur [10]. The independent variables of interest were performance on the step test portion of the screening fitness test (pass/fail, described as fit/unfit hereafter), ARMS waiver status (WQ/EBF), age (18–19, 20–24 and ≧25 years), smoking history (ever/never), BMI (underweight [≤18.5 kg/m^2], normal weight [18.5–25.0 kg/m^2], overweight [25.0–29.9 kg/m^2], obese [≥30.0 kg/m^2]), race (black, white or other), and MOS category (combat support/combat support services, combat arms, and other/missing). Because BMI is highly correlated with receiving an ARMS waiver, BMI was not considered in models comparing fit EBF to fit WQ. The primary predictors of interest were performance on the step test, scored as pass/fail and ARMS waiver status (yes/no). For analyses evaluating step test performance as a predictor of heat illness diagnosis, only those meeting weight for height or body fat standards were included. For analyses comparing the incidence of heat illness diagnosis between EBF and WQ subjects, only those individuals passing the step test were considered in the analyses. To explore the potential joint effects of EBF and being unfit, we examined additive (independent effect) and multiplicative (effect modification) models to estimate the expected effects of failing the step test and being EBF, using the formulae ($RR_{\text{step test}} + RR_{\text{EBF}} - 1$) for an additive model, and ($RR_{\text{step test}} \times RR_{\text{EBF}}$) for a multiplicative model[18].

Chi-square and Fishers exact tests were used to analyze categorical data. Logistic regression was used to calculate the crude and adjusted odds ratios (cOR and aOR) of heat illness in the first 6 months of service. We also conducted Poisson regression to estimate the incidence (using person-time at risk) and the incidence rate ratios. Because the results were the same to the second decimal point as the OR, for convenience, we only report the OR. ORs are reported with their 95% confidence interval (CI). Variables evaluated included step test status, ARMS status, age, smoking history, BMI, race and MOS category. For multivariate models, parsimonious models were developed using backwards stepwise elimination in which all variables were entered into the model and then sequentially removed until only the primary predictor of interest and covariates with a *P* value of ≤0.05 remained in the model. Because the physical requirements for combat occupations are generally higher than for non-combat occupations, MOS was retained in all models regardless of statistical significance. Additionally, each covariate was entered into a separate regression to assess its impact on the primary predictor. However, including each covariate in the model failed to produce at least a 5% change in the OR of the main exposure–outcome association. All statistical analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC).

Results

There were 8621 WQ and 834 EBF male study participants (Table 1). Among WQ participants, all reported and measured characteristics differed significantly between fit and unfit subjects. Among the fit, participants' smoking history, BMI, race and MOS category differed significantly between groups. EHI episodes were identified in 67 men and 13 women (from a total of 1913 women). All incident heat illness episodes occurred between April and October including nearly two-thirds in July and August. Table 2 summarizes numbers and percentages for specific heat illness diagnostic categories among men. There were 32 cases of EHI among the 'fit WQ' group (0.5%), 19 among the 'unfit WQ' group (1.0%) and 16 among the 'fit EBF' group (1.9%). Among women, there were too few to categorize into meaningful groups (results not shown). As Table 3 shows, among male WQ subjects, being unfit was significantly associated with EHI diagnosis in the first 6 months of service (aOR 2.00 [1.13, 3.53]). No other variables were predictive when entered in the multivariable model ($P > 0.05$). The cOR for unfit women was 1.69 (0.52, 5.58) (data not shown). Table 4 shows that among fit subjects, the risk of EHI in EBF was significantly higher than in WQ individuals (cOR 4.04, [2.21–7.40]). None of the measured demographic factors captured were significantly associated with heat illness. Compared with subjects assigned a combat support service MOS, those with a combat arms MOS had higher risk of EHI in the first 6 months of service (cOR 1.90 [1.06, 3.39]). Adjusting for MOS category had no appreciable effect on the OR for EHI comparing EBF with WQ (aOR 3.98 [2.17, 7.29]). There were no significant associations between EHI and age, smoking history or race. The cOR for EBF women was 1.12 (0.22, 5.56) (data not shown). The expected ORs for the joint effects of being unfit and EBF under the additive and multiplicative models were 4.98 and 7.96, respectively (Table 5).

Although the data were sparse, we were able to compare EHI among women to men. Overall, the cOR for

Table 1. Characteristics of male study participants ($N = 9455$)

Total	WQ: passed step test $N = 6645$ n (%)	WQ: failed step test $N = 1976$ n (%)	P^a	EBF: passed step test $N = 834$ n (%)	P^b
Age (years)					
18–19	3080 (46)	804 (41)	<0.001	365 (44)	NS
20–24	2754 (41)	875 (44)		379 (45)	
≥25	811 (12)	297 (15)		90 (11)	
Smoker[c]					
No	4804 (73)	1468 (74)	NS	635 (77)	<0.05
Yes	1745 (27)	506 (26)		193 (23)	
BMI					
Underweight ($x \le 18.5$)	234 (4)	55 (3)	<0.001	0 (0)	<0.001
Normal weight ($18.5 < x \le 25$)	3766 (57)	808 (41)		6 (1)	
Overweight ($25 < x < 30$)	1861 (28)	733 (37)		111 (13)	
Obese ($x \ge 30$)	784 (12)	380 (19)		717 (86)	
Race					
White	4863 (73)	1352 (68)	<0.001	618 (74)	<0.001
Black	774 (12)	274 (14)		62 (7)	
Other	1008 (15)	350 (18)		154 (18)	
MOS					
CS/CSS	3559 (54)	1168 (59)	<0.001	467 (56)	<0.001
Combat arms	2888 (43)	768 (39)		362 (43)	
Other/missing	198 (3)	40 (2)		5 (1)	

CS, Combat Support; CSS; Combat Service Support; NS, non-significant.
[a]Comparisons made between WQ step test passers and WQ step test failures.
[b]Comparisons made between WQ step test passers and EBF step test passers.
[c]*n* = 104 missing smoking values not included in calculation.

Table 2. Frequency of heat illness by step test status and ARMS waiver status among male ARMS subjects

Total	WQ: passed step test N = 6645	WQ: failed step test N = 1976	P[a]	EBF: passed step test N = 834	P[b]
	n (%)	n (%)		n (%)	
Heat illness category[c]					
Heat stroke	2 (0)	0 (0)	1.00	4 (0)	<0.01
Heat exhaustion	17 (0)	10 (1)	<0.01	7 (1)	<0.01
Other heat illness	20 (0)	12 (1)	<0.05	12 (1)	<0.001
All heat illness	32 (0)	19 (1)	<0.05	16 (2)	<0.001

[a]Comparisons made between WQ step test passers and WQ step test failures.
[b]Comparisons made between WQ step test passers and EBF step test passers.
[c]Categories not mutually exclusive.

Table 3. Crude and adjusted ORs for heat illness diagnosis among male weight-qualified subjects (N = 8621)

Total	No heat illness N = 8570	One or more heat illness episode N = 51	Crude OR	P value	95% CI	Adjusted[a] OR	P value	95% CI
	n (%)	n (%)						
Step test status								
Pass	6613 (99.5)	32 (0.5)	Ref.			Ref.		
Fail	1957 (99.0)	19 (1.0)	2.01	<0.05	1.14, 3.55	2.00	<0.05	1.13, 3.53
Age (years)								
18–19	3863 (99.5)	21 (0.5)	Ref.					
20–24	3604 (99.3)	25 (0.7)	1.28		0.71, 2.28			
≥25	1103 (99.5)	5 (0.5)	0.83		0.31 2.22			
Smoker								
No	6232 (99.4)	40 (0.6)	Ref.					
Yes	2240 (99.5)	11 (0.5)	0.77		0.39, 1.49			
BMI								
Underweight (x < 18.5)	286 (99.0)	3 (1.0)	1.91		0.57, 6.36			
Normal weight (18.5 < x ≤ 25)	4549 (99.5)	25 (0.5)	Ref.					
Overweight (25 < x <30)	2583 (99.6)	11 (0.4)	0.78		0.38, 1.58			
Obese (x ≥ 30)	1152 (99.0)	12 (1.0)	1.90		0.95, 3.78			
Race								
White	6182 (99.5)	33 (0.5)	Ref.					
Black	1042 (99.4)	6 (0.6)	1.08		0.45, 2.58			
Other	1346 (99.1)	12 (0.9)	1.67		0.86, 3.24			
MOS								
CS/CSS	4699 (99.4)	28 (0.6)	Ref.			Ref.		
Combat arms	3633 (99.4)	23 (0.6)	1.06		0.61, 1.85	1.10		0.63, 1.91
Other/missing	238 (100.0)	0 (0.0)	—		—	—		—

[a]Adjusted for MOS

women was 1.04 (0.57, 1.89); among WQ fit women, it was 0.86 (0.36, 2.05); among WQ unfit, it was 1.01 (0.38, 2.73), and among EBF fit, it was 3.10 (0.71, 13.56).

Few cases of hospitalization resulting in an EHI diagnosis were identified (N = 10). All subjects with inpatient diagnoses for EHI were also identified as outpatient EHI cases included in this study.

Discussion

This study found that being unfit, as measured by the step test, was an important risk factor for heat illness in male US Army recruits with an aOR of 2.00. Other factors, including age at accession, race, smoking history, BMI and military occupation, were not significantly associated with heat illness. The aOR for the obese BMI category was not statistically significantly raised. It should be noted that none of the WQ individuals EBF percent limits, and BMI can be an inaccurate indicator of body fat, especially among fit young men [19]. Although we have found that older age at accession is associated with risk of musculoskeletal injury [12–15], we found no significant associations between age and heat illness.

Table 4. Crude and adjusted ORs for heat illness diagnosis among male subjects who passed the ARMS test (*N* = 7479)

Total	No heat illness *N* = 7431 *n* (%)	One or more heat illness episode *N* = 48 *n* (%)	Crude OR	*P* value	95% CI	Adjusted[a] OR	*P* value	95% CI
ARMS waiver status								
WQ	6613 (99.5)	32 (0.5)	Ref.			Ref.		
EBF	818 (98.1)	16 (1.9)	4.04	<0.001	2.21, 7.40	3.98	<0.001	2.17, 7.29
Age (years)								
18–19	3421 (99.3)	24 (0.7)	Ref.					
20–24	3112 (99.3)	21 (0.7)	0.96		0.53, 1.73			
≥25	898 (99.7)	3 (0.3)	0.48		0.14, 1.59			
Smoker								
No	5402 (99.3)	37 (0.7)	Ref.					
Yes	1927 (99.4)	11 (0.6)	0.83		0.42, 1.64			
Race								
White	5448 (99.4)	33 (0.6)	Ref.					
Black	833 (99.6)	3 (0.4)	0.60		0.18, 1.94			
Other	1150 (99.0)	12 (1.0)	1.72		0.89, 3.35			
MOS								
CS/CSS	4007 (99.5)	19 (0.5)	Ref.			Ref.		
Combat arms	3221 (99.1)	29 (0.9)	1.90	<0.05	1.06, 3.39	1.92	<0.05	1.08, 3.44
Other/missing	203 (100.0)	0 (0.0)	—		—	—		—

[a]Adjusted for MOS.

Table 5. Expected OR of joint effects for being unfit and having excess body fat for multiplicative and additive models

Fitness status	Arms waiver status	Multiplicative model OR	Additive model OR
Fit	WQ	1 (ref.)	1 (ref.)
Fit	EBF	3.98	3.98
Unfit	WQ	2	2
Unfit	EBF	7.96	4.98

Among fit men, obesity was strongly associated with heat illness, with an aOR = 3.98. This finding is supported by the literature, indicating that overweight people are at increased risk of EHI [6,7]. Apparently, this increase in risk exists even among fit young men. Although data were lacking regarding the risk among those who were both EBF and unfit, the expected relative risks assuming both an additive (independent) and multiplicative (single or joint effect modification) relationship between EBF and lack of fitness were substantial. Given the 5- to 8-fold increased expected OR for the joint effects of low fitness and EBF, it was appropriate to not include those applicants in the study. Occupation was also significantly associated with heat illness, as those with a combat MOS (which includes particularly physically demanding jobs such as infantry, armour, combat engineers and field artillery) had an aOR = 1.92. This is biologically plausible as the training requirements for these jobs are particularly strenuous and their period of intense training is often longer than for those entering support military occupations. Although no association with sex was observed, the sparse data and subsequent low statistical power prevents us reaching any conclusions about EHI risks in women.

The strengths of this study include its prospective design and the large population studied. In addition, information not usually gathered on US Army recruits was captured, including an objective measure of fitness and history of smoking. Because this study was of an operational test programme, individuals who normally would have been disqualified from Army service due to excess body fat were included if they passed the fitness test. This EBF study group is of special value as it allowed the identification of an important risk factor.

The weaknesses of this study include the relatively few numbers of EHI cases identified, especially among demographic subgroups and particularly among women. This results in low power to detect potentially important risk factors and allows for deviations from expected associations to be explained by random fluctuations in events. This low power is reflected in many of the wide CIs reported. In addition, no morbidly obese individuals were included, nor any who EBF limits and who could not pass the fitness test. These exclusions preclude studying the effects among two groups probably at higher risk of heat illness. It is likely that not all EHI episodes, particularly mild events, resulted in medical encounters or lost duty time. The magnitude of this probable under-reporting, and any resulting biases in our findings, cannot be quantified. However, since it is likely that all serious cases of EHI are captured, these findings are likely to be valid for those events of most concern.

The ARMS Program was terminated in 2009 and therefore individuals who exceed body fat standards and presumably would be at increased risk of EHI are no longer allowed to join the Army. At present, there are no formal physical fitness standards or pre-accession tests of fitness for US Army applicants. After further evaluation of the fitness test and its relationship to various adverse endpoints [10–16,20], including cost-effectiveness analyses, consideration may be given to requiring a demonstration of fitness prior to enlistment to reduce the risk of EHI as well as musculoskeletal injuries, stress fractures [13,14] and psychiatric disorders [16].

Our findings are relevant to the general US population, especially males. Those who are unfit or have a sedentary lifestyle should exercise caution when beginning any strenuous activity programme, particularly during warmer weather. The same advice also holds for those who are obese, regardless of degree of fitness. Those who are both unfit and obese may be at even greater risk than either of the two risk groups we evaluated.

Key points

- Among fit male US Army trainees, the risk of exertional heat illness was significantly higher in those who exceeded body fat standards compared with those who were weight qualified.
- Among those who were weight qualified, failing a step test of fitness was associated with an increased risk of exertional heat illness.
- There was a 5- to 8-fold increase in expected odds of exertional heat illness for the joint effects of low fitness and exceeding body fat standards.

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Conflicts of interest

None declared.

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