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Effect of pre-accession physical fitness on training injuries among US Army recruits

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Abstract.
OBJECTIVE: To evaluate the association of pre-accession physical fitness, as measured by a five-minute step test, with incidence of overuse injuries and outpatient healthcare utilization among male United States (US) Army recruits.
PARTICIPANTS: US Army male trainees who met weight standards and took a pre-accession fitness test.
METHODS: In this prospective cohort study, incidence and outpatient healthcare visits for overuse injuries during the first 90 days of military service were compared between recruits who failed the pre-accession step test with those who passed.
RESULTS: The hazard rate ratio for injury among recruits who failed the fitness test compared to those who passed the test was 1.31 (95% C.I = 1.20–1.44). Among the subset of recruits with at least one medical encounter for an overuse injury, the utilization rate ratio for subjects who failed the fitness test versus those who passed was 1.15 (95% C.I = 1.09–1.22). Other factors associated with increased risk of injury or healthcare utilization include age, body mass index, and smoking history.
CONCLUSIONS: Risk of injury and utilization were associated with fitness test results. These findings may have implications for military accession and training policy as well as for other physically demanding training programs such as police, fire fighters and athletes.

Keywords: Musculoskeletal injury, military, healthcare utilization, step test

1. Introduction

Musculoskeletal injuries are a leading cause of morbidity and lost duty time among US Army trainees. In 2006, there were approximately 750,000 injury-related musculoskeletal conditions in 2006 among non-deployed active duty service members, and 82% of these were overuse injuries [9]. Lower extremity overuse injuries, the most common injuries in Army basic training, accounted for nearly four million days of limited duty for active duty service members in 2004 [26].

It has been shown that a low level of physical fitness is an independent predictor of musculoskeletal injury among military trainees [2,7,12–14,16–18,25,31, 33]. Most studies of fitness in the military have been conducted after accession, and included tests for run time for distances of 1.0 or more miles, a test that requires substantial logistical support. Measuring fitness level prior to accession into the military is limited by facility, equipment, cost and time constraints [27,28]. A commonly test used to estimate cardiorespiratory fitness is the step test [34]. When administered correctly, a submaximal step test, which evaluates an individual's capacity for oxygen consumption while exercising below maximal intensity, has been shown to be a reliable and valid measure of aerobic fitness [34]. Fur-

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thermore, using a step test to assess physical fitness has the advantage of being easily and safely administered to most healthy individuals [27,28,34]. The utility of pre-accession fitness testing and tailored training for Army recruits has not been adequately ascertained [4].

Knapik et al. [16] conducted a randomized trial among Army recruits, based on a fitness test (sit-ups, pushups, and 1 mile run) administered at the training installation after accession. The referent group included those recruits who passed the fitness test and entered regular training. Among those who failed the fitness test, one group was assigned to a Fitness Assessment Program where they participated in a specific physical training program until they could pass the fitness test (pre-conditioning, or PC). The other group among those who failed was allowed to directly enter regular training with those who passed the fitness test without undergoing remedial fitness training (no pre-conditioning, or NPC). Using any injury, not just overuse injuries, as an endpoint, the authors reported that risk ratio among NPC was 1.62 among both men and women, although it was statistically significant only among women. The risk ratio for the PC was 1.38 among men and 1.26 among women, and neither was statistically significant. In addition, significantly more ($p = 0.01$) of the PC group successfully completed their training than the NPC. Although this study was hampered by small study sizes and no data reported regarding overuse injuries, it does support the concept that early identification and remedial training has the potential to reduce injuries among those who enter the military with low fitness.

The purpose of this study was to determine if fitness as assessed by a simple test (the Assessment of Recruit Motivation and Strength (ARMS) step test) administered prior to military entry is useful in identifying those weight-qualified male recruits with increased incidence of and outpatient healthcare utilization for training-related musculoskeletal injury in the first 90 days of military service. At the time of military entrance we measured and assessed as control variables body mass index (BMI), age, history of smoking, and race.

2. Methods

2.1. Study design and study population

These analyses are based on data from the ARMS study [3,21,22] and include weight-qualified men enlisting in the US Army for the first time between February 2005 and September 2006 at six Military Entrance Processing Stations (MEPS). Women were excluded from this analysis and will be reported separately as their risks and risk factors for training-related injuries differ substantially from men [8,17]. Findings related to those exceeding body fat standards have been presented elsewhere [6]. Subjects were followed for 90 days after entry. This study was approved by the Walter Reed Army Institute of Research Institutional Review Board. Subjects were 18 or more years of age and provided written informed consent for completing a questionnaire and allowing for medical and administrative follow-up.

Everyone entering the Army through one of the study sites was required to take a pre-accession physical fitness test (ARMS test), although performance on the fitness test did not impact the eligibility of study subjects to enter the Army. The fitness test of interest in this report was a modified Harvard step test with a step height of 16 inches. The test lasted five minutes with a 120 steps per minute pace set by a metronome [19,29, 30]. Passing criterion was determined *a priori* by consensus of the ARMS study investigators at that time [21, 22], and was defined as completing the full five minute step test. Additional information on the ARMS fitness test is presented elsewhere [21].

Enlistment and discharge data were provided by the Center for Accession Research, US Army Accession Command. Outpatient medical encounter data were supplied by the US Army Medical Command Patient Administration Systems and Biostatistics Activity. All diagnoses from each outpatient encounter were captured.

2.1.1. Independent variables

The primary predictor of interest was performance on the step test (pass-fail). Other covariates of interest included BMI categories (underweight ($\leqslant$ 18.5), normal (18.5 $<$ to $\leqslant$ 25), overweight (25 $<$ to $<$ 30) and obese ($\geqslant$ 30) and age (18–19, 20–24, and $\geqslant$ 25 years) at the time of testing, race (black, white, or other), and smoking history (ever/never).

2.1.2. Definition of musculoskeletal injury

The outcome of interest was musculoskeletal overuse injuries diagnosed during outpatient medical visits. These injuries have been studied in other military populations and occur frequently among military trainees, runners, and other physically active populations [1,10, 15,24]. Overuse injury incident cases were identified as the first outpatient medical encounter resulting in any overuse injury diagnosis. International Classifi-

Table 1
Demographic characteristics of study participants by ARMS step test status

	Failed ARMS		Passed ARMS		P value
Total	N	%	N	%	
	1945	100.0	6511	100.0	
Age (Years)					
18–19	784	40.3	2982	45.8	< 0.0001
20–24	869	44.7	2727	41.9	
$\geqslant 25$	292	15.0	802	12.3	
Race					
White	1335	68.6	4769	73.3	0.0004
Black	266	13.7	749	11.5	
Other	344	17.7	993	15.3	
Current or former smoker					
No	1443	74.2	4706	72.3	< 0.0001
Yes	500	25.7	1723	26.5	
Missing	2	0.1	82	1.3	
BMI categories (kg/m^2)					
Underweight	56	2.9	236	3.6	< 0.0001
Normal	791	40.7	3667	56.3	
Overweight	722	37.1	1840	28.3	
Obese	376	19.3	768	11.8	

ARMS = Assessment of Recruit Motivation and Strength; BMI = body mass index.

cation of Diseases, 9th Revision (ICD-9) codes 715–733 and 843–847 were used to define overuse injuries and sprains/strains, respectively. Overuse injuries have been defined as long-term energy exchanges resulting in cumulative microtrauma [15]. Additional detail on specific ICD-9 codes used is available [6].

For analysis of health care utilization, all visits on separate days with an overuse injury diagnosis were captured for those subjects with at least one medical encounter for an overuse injury. Because it often was not possible to determine if the visit was for a new injury or a follow-up for a previous injury no attempt was made to classify these visits as anything other than injury-related healthcare utilization.

2.1.3. Statistical methods and data analysis

Chi-square tests were used to analyze categorical data for the study population. Incidence rates were calculated as the number of initial overuse injury events per 1,000 person-days of military service, and the rate ratio with 95% confidence interval (CI) was used to compare the risks between groups. Cox proportional hazards regression was used to examine the relationship of ARMS test status with time to incident musculoskeletal overuse injury, adjusting for BMI, age and smoking. Relative risks were approximated with the relative hazard.

Utilization rate (UR) was defined as the number of medical encounters for overuse injuries per 1,000 person-days follow-up, and the utilization rate ratio (URR), was the rate for a group compared to the reference group. Among those who had a qualifying injury, Poisson regression models were used to assess the relationship between the fitness test and other risk factors, and number of injury-related healthcare visits. All analyses were performed using SAS version 9.2 (Cary, North Carolina). A p value of < 0.05 was considered statistically significant.

Attributable risk percent [5] (AR%) was calculated using the formula (substituting hazard ratio for risk) (1-HR)/HR*100 to estimate the proportion of overuse injuries that are due to failing the ARMS test.

3. Results

There were 8456 study participants (Table 1); less than one percent of eligible recruits declined to participate. There were significant differences in all participant characteristics between those who failed and passed the fitness test.

The incidence of types (Fig. 1A) and locations of injuries (Fig. 1B) are presented for ARMS fitness test results. The risk of pain (hazard ratio (HR): 1.30, confidence interval (CI) 95% 1.17–1.45), sprain/strain (HR = 1.32, CI 95% 1.15–1.52), arthropathy (HR = 1.62, CI 95% 1.22–2.15), and bone stress injuries (HR = 1.60, CI 95% 1.14–2.24), was significantly higher among those who failed the fitness test; tendonitis was not associated with fitness (HR = 1.09, CI 95% 0.76–1.57).

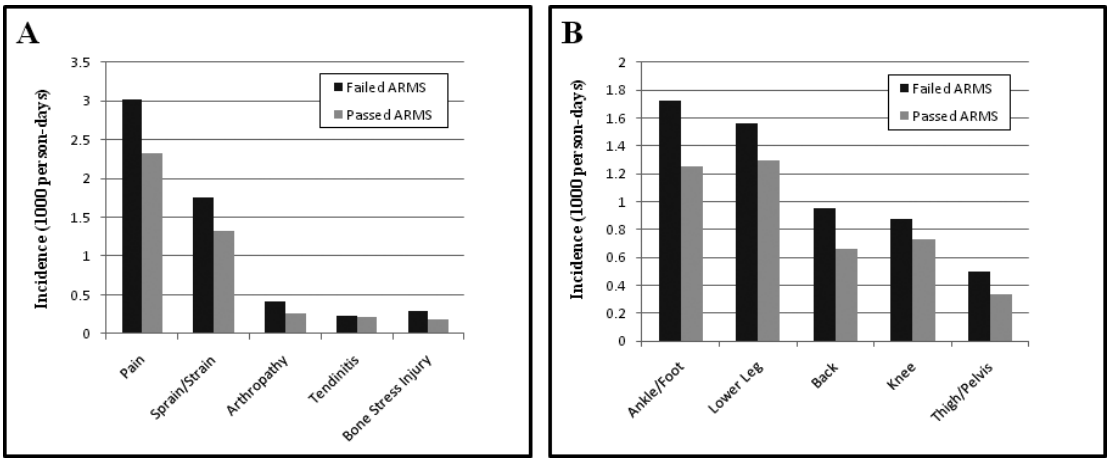

Fig. 1. Incidence Rates for (A) Types and (B) Locations of Overuse Injury by ARMS test status.

The incidence of injuries to the foot/ankle (HR = 1.37, CI 95% 1.19–1.57), lower leg (HR = 1.20, CI 95% 1.04–1.39), back (HR = 1.43, CI 95% 1.19–1.72), knee (HR = 1.22, CI 95% 1.01–1.47), and thigh/pelvis (HR = 1.46, CI 95% 1.13–1.89) were all significantly higher among those who failed the fitness test.

The results of multivariate modeling are presented in Table 2. Those who failed the fitness test were 31% more likely to experience an injury. Both extremes of BMI were at increased risk, as underweight individuals had a statistically significant 32% higher risk while obese were at marginally significant 12% higher risk of injury. Age was significantly associated with injury, with those ages 20–24 and $\geqslant$ 25 years at 25% and 63% increased risk, respectively. Current and former smokers were at 27% increased risk. Race was not significantly associated with risk of injury. The attributable risk percent for those failing the ARMS test was 24%.

Table 3 presents the crude healthcare utilization rates and rate ratios. The URR for failing the ARMS test was 1.45 (CI 95% 1.37–1.54). It was significantly higher for extremes of BMI (Underweight URR = 1.17, CI 95% 1.02–1.34; Obese URR = 1.40, CI 95% 1.31–1.51), increased for each age group over 19 (Ages 20–24 URR = 1.31, CI 95% 1.23–1.38; Ages $\geqslant$ 25 URR = 1.78, CI 95% 1.64–1.90), and was higher for smokers (URR = 1.25, CI 95% 1.19–1.33). Crude utilization was significantly lower among those of "other" race (URR = 0.92, CI 95% 0.86–0.99).

Among those trainees with an overuse injury diagnosis (n = 2418), health care utilization was elevated 16% among those who failed the fitness test, 14% among the obese, and 16% among the oldest age category (Table 4). Increased utilization was not associated with smoking or race.

4. Discussion

This study evaluated the association between fitness as assessed by a simple pre-entry test and the incidence of injury and health care utilization, and four control variables (BMI, age, smoking history, and race) in a population that included only men who met military body fat standards. Our study showed that men who failed a fitness screening step test have significantly higher injury rates than men who passed. We have also demonstrated that both extremes of BMI, not just those overweight or obese, but the underweight also are at increased risk of musculoskeletal injury, as are those over age 19, and, current and former smokers.

Crude healthcare utilization was higher among those groups at increased risk of injury; however, because the definition of injury was based on healthcare utilization, this is not surprising and should not be over-interpreted. Although crude utilization was lower among those of "other" race, this category includes several minority groups, those reporting mixed race, and, those who declined to report a race group. Therefore, this association is not interpretable.

A potentially more important consideration is healthcare utilization among those who have experienced an injury, as this may reflect more serious injuries requiring additional follow-up, or it may reflect an increased risk of re-injury or additional injuries. Among those who experienced an injury, those who failed the fitness test and those age $\geqslant$ 25 years both had 16% more injury-related healthcare visits than the referent groups; utilization was 14% higher among the obese, and 7% higher among those age 20–24. Additional research is necessary to further elucidate the types and severity

Table 2
Adjusted* hazard ratios for first musculoskeletal Injury by ARMS test results, BMI category, age, and smoking history

		Adjusted hazard ratio	95% CI
ARMS test status	Pass (Ref)	1.00	–
	Fail	1.31	1.20, 1.43
BMI (kg/m^2)	Underweight	1.31	1.07, 1.61
	Normal (Ref)	1.00	–
	Overweight	0.98	0.89, 1.07
	Obese	1.12	0.99, 1.26
Age (years)	18–19 (Ref)	1.00	–
	20–24	1.25	1.14, 1.36
	$\geqslant$ 25	1.63	1.44, 1.83
Current or former smoker	No (Ref)	1.00	–
	Yes	1.27	1.16, 1.38

*Adjusted for all other variables in the model; race was not significant;
ARMS = Assessment of Recruit Motivation and Strength.

Table 3
Crude Overuse Injury Utilization Rates (UR) and Rate Ratios (URR)

	Qualified Visits[a] ($n = 5931$)	Total person-days at risk (1000s)	Utilization rate per 1000 person days at risk	Utilization rate ratio	95% CI
ARMS test results					
Pass (Ref)	4134	579.12	7.14	1.00	–
Fail	1797	172.47	10.42	1.45	1.37, 1.54
BMI categories					
Underweight	222	25.49	8.71	1.17	1.02, 1.34
Normal (Ref)	2960	397.09	7.45	1.00	–
Overweight	1718	227.70	7.55	1.03	0.97, 1.09
Obese	1031	101.31	10.18	1.40	1.31, 1.51
Age group					
18–19 (Ref)	2146	335.32	6.40	1.00	–
20–24	2672	318.83	8.38	1.31	1.23, 1.38
$\geqslant$ 25	1113	97.43	11.42	1.78	1.64, 1.90
Current or former smoker[b]					
No (Ref)	4061	546.98	7.42	1.00	–
Yes	1830	197.21	9.28	1.25	1.19, 1.33
Race					
White (Ref)	4357	542.30	8.03	1.00	–
Black	696	90.43	7.70	0.96	0.88, 1.04
Other	878	118.85	7.39	0.92	0.86, 0.99

[a]Total overuse injury visits during the first 90 days of service;
[b]Due to missing responses ($n = 40$), total is not the same for this category.

of injuries that are associated with increased utilization once an individual has experienced an initial injury.

The findings of this study support the concept that an easy and economical method of screening military applicants for fitness prior to accession is available, and should be considered when evaluating and developing recommendations for preventing training-related injuries in the military [4]. There are a number of actual or potential advantages of using a step test prior to accession compared to a run test after accession. These include but are not limited to the potentially lower injury risk relative to run tests of 1.0 miles or more, avoidance of costs directly associated with accession (such as pay, travel, lodging for new recruits, and other direct and indirect administrative costs). The use of a step test reduces logistic support needs, including the requirement of securing a satisfactory running area and administrative personnel to monitor and maintain order among trainees.

The test we used is low risk, compared to a run test, and has the potential of providing organizations a quick and simple method identifying those at increased risk of injury, who may be amenable to intervention. While the basic validity of the test has been demonstrated in this study, additional research may identify optimal combinations of duration, step height, and tempo parameters that will identify with high sensitivity and specificity individuals who can successfully per-

Table 4
Adjusted[a] among subjects with overuse injury visits ($N = 2418$)

	URR	95% CI
ARMS TEST status		
Pass (Ref)	1.00	–
Fail	1.16	1.09, 1.22
BMI categories		
Underweight	0.94	0.83, 1.08
Normal (Ref)	1.00	–
Overweight	0.95	0.90, 1.01
Obese	1.14	1.06, 1.23
Age group		
18–19 (Ref)	1.00	–
20–24	1.07	1.01, 1.13
$\geqslant 25$	1.16	1.08, 1.25

[a]Adjusted for all other variables in the model; race and smoking were not significant;
URR = Utilization Rate Ratios.

form and survive in the physically demanding military environment, or to whom remedial training should be recommended. Study strengths include the prospective design, pre-accession assessment, and complete capture of endpoints.

Limitations include that we used only one assessment of fitness and BMI, measured at a single time prior to basic military training, and therefore do not know the extent to which these factors may have changed between testing and military accession, or by the time injuries were occurred. Injury data presented were limited to the first 90 days of military including basic training, but this period likely captures the majority of injuries that occur in the training environment. Although certain groups, including those who failed the ARMS test, had more health care visits once an injury had occurred, we were not able to determine if this was the result of a need for more follow-up for the original injury, or if those individuals were at increased risk of subsequent injuries.

In summary, our prospective cohort study indicates that performance on a step test, extremes of BMI, age, and smoking are associated with an increased risk of overuse injury and additional health care utilization once an injury had occurred. The use of a pre-accession step test offers potentially substantial advantages to fitness tests, particularly run tests, conducted after accession. These findings have important implications beyond the military, as other occupations, such as police and firefighters, are also facing the challenges of poor fitness and obesity in a similar context of high physical demands [20,32]. These occupations recruit from the same pool of young adult civilian applicants who are increasingly overweight and less fit [2,11,23].

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Disclaimer

The views expressed are those of the authors and should not be construed to represent the positions of the Department of the Army or Department of Defense.

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