G Model
JSAMS-1625; No. of Pages 6
ARTICLE IN PRESS
Journal of Science and Medicine in Sport xxx (2017) xxx–xxx
Contents lists available at ScienceDirect
Journal of Science and Medicine in Sport
journal homepage: www.elsevier.com/locate/jsams

Original research

Impact of physical fitness and body composition on injury risk among active young adults: A study of Army trainees

Bruce H. Jones[a,*], Keith G. Hauret[a], Shamola K. Dye[a], Veronique D. Hauschild[a], Stephen P. Rossi[a], Melissa D. Richardson[a], Karl E. Friedl[b]

[a] Army Public Health Center, Clinical Public Health and Epidemiology Directorate, Injury Prevention Division, United States
[b] U.S. Army Research Institute of Environmental Medicine, United States

ARTICLE INFO

Article history:
Received 31 March 2017
Received in revised form 19 August 2017
Accepted 20 September 2017
Available online xxx

Keywords:
Physical fitness
Running
Body composition
Musculoskeletal
Overuse
Gender

ABSTRACT

Objectives: To determine the combined effects of physical fitness and body composition on risk of training-related musculoskeletal injuries among Army trainees.
Design: Retrospective cohort study.
Methods: Rosters of soldiers entering Army basic combat training (BCT) from 2010 to 2012 were linked with data from multiple sources for age, sex, physical fitness (heights, weights (mass), body mass index (BMI), 2 mile run times, push-ups), and medical injury diagnoses. Analyses included descriptive means and standard deviations, comparative t-tests, risks of injury, and relative risks (RR) and 95% confidence intervals (CI). Fitness and BMI were divided into quintiles (groups of 20%) and stratified for chi-square (χ^2) comparisons and to determine trends.
Results: Data were obtained for 143,398 men and 41,727 women. As run times became slower, injury risks increased steadily (men = 9.8–24.3%, women = 26.5–56.0%; χ^2 trends ($p < 0.00001$)). For both genders, the relationship of BMI to injury risk was bimodal, with the lowest risk in the average BMI group (middle quintile). Injury risks were highest in the slowest groups with lowest BMIs (male trainees = 26.5%; female trainees = 63.1%). Compared to lowest risk group (average BMI with fastest run-times), RRs were significant (male trainees = 8.5%; RR 3.1, CI: 2.8–3.4; female trainees = 24.6%; RR 2.6, CI: 2.3–2.8). Trainees with the lowest BMIs exhibited highest injury risks for both genders and across all fitness levels.
Conclusions: While the most aerobically fit Army trainees experience lower risk of training-related injury, at any given aerobic fitness level those with the lowest BMIs are at highest risk. This has implications for recruitment and retention fitness standards.

1. Introduction

Musculoskeletal (MSK) injuries among active duty soldiers result in over 1.3 million medical visits and over 10 million limited duty days each year.[1,2] These injuries have been estimated to account for over 70% of those who are medically non-deployable.[2] As with civilian athletes and exercise participants, MSK injuries commonly result from vigorous physical training and overuse.[3] Among soldiers in the U.S. Army, over 50% of the injuries are training-related overuse injuries.[4,5] These injuries occur primarily in the lower extremities and the low back.[4,5] Such MSK overuse injuries have been called "the single most significant medical impediment to military readiness."[6,7]

Recruits entering the Army are at particular risk of injury.[3,6] A number of studies have shown that having poor physical fitness on entry to the Army is a leading risk factor for injuries among trainees.[1,8] Although the ten week Army basic combat training (BCT) programs accommodate some gradual acclimation to the extremely physically-demanding routines, the short time period to develop fitness may contribute to injury risk.[5,9] To advance, Army recruits must demonstrate basic measures of physical fitness upon entry, achieve Army fitness standards by completion of BCT, and then maintain standards when in operational units.[10,11]

The primary health-related components of physical fitness include cardiorespiratory endurance (i.e., aerobic fitness), muscle endurance, muscle strength, flexibility, and body composition.[7,12] Of these fitness components, aerobic fitness has been shown to most strongly correlate with the performance of physical-demanding tasks required of Army soldiers.[13] Additionally, among these components low levels of aerobic fitness (typically measured

* Corresponding author.
E-mail address: bruce.h.jones.civ@mail.mil (B.H. Jones).

http://dx.doi.org/10.1016/j.jsams.2017.09.015
1440-2440/© 2017 Published by Elsevier Ltd on behalf of Sports Medicine Australia.

as timed-runs) are most consistently and most strongly associated with higher risk of injuries among both male and female military trainees.[1,8,14–18] Other components of physical fitness (i.e., muscle endurance, muscle strength, flexibility and body composition) have not been as strongly or consistently associated with injury risk.[8,14,16,17,19]

The U.S. Department of Defense and Army also place great emphasis on maintaining acceptable body composition (measured as body fat percentage or body mass index (BMI) determined from height and weight standards).[10,11,20] In the past, military height and weight and body fat standards have focused on appearance as well as physical fitness.[21] Only in the last few decades have studies began to look at the association of body composition with injuries. Several military studies have shown bimodal or J-shaped patterns of risk for injury, where the highest and lowest extremes of BMI are at greatest risk.[18,22–24] Other studies suggest highest risk occurs among those running average run times or slower and who exhibit the lowest BMIs.[1,7] These data suggest a need to further evaluate the extremes of current U.S. Army BMI standards. Specifically, injury risk associated with low BMI, and how it relates to lean body mass, may need to be factored into the well-established relationship between higher body fat and lower aerobic fitness.[21]

Because training-related MSK injuries represent the leading threat to military readiness, a means to reduce injury risk will enhance force strength.[1,4] Current military policies may place too much emphasis on and encourage lower BMIs, and not adequately recognize that soldiers with higher BMIs may be less likely to experience MSK injuries, or in other terms, they may be more "musculoskeletally-resilient." To provide a scientific basis for future military physical fitness and body composition policy, the interrelationships between the fitness components and associations with injury risk must be better understood. Therefore, the purpose of this study was to examine the association between physical fitness as measured by the Army Physical Fitness Test (APFT), which includes a 2 mile run, push-ups, and sit-ups, and BMI with MSK injury risk.

2. Methods

This study employed a retrospective cohort design. The study was approved by the Army Public Health Center's Public Health Review Board as a public health surveillance project. Rosters of all male and female trainees entering the 10 week U.S. Army BCT program between October 2009 and September 2012 were provided by the Training and Doctrine Command (TRADOC). Data were analyzed for all trainees (over 180,000) with complete data for age, gender, heights, weights, and APFT results (2 mile run times, and the number of push-ups and sit ups in two minutes). These variables were linked to any injury the trainee experienced and received a diagnosis recorded in their medical record during the 10 week BCT period.

Age and gender data were received from the Defense Manpower Data Center and Defense Medical Surveillance System (DMSS), maintained by the Armed Forces Health Surveillance Branch of the Defense Health Agency. Heights and weights were acquired from the TRADOC Military Entrance Processing Stations (MEPS) records. Body mass index (BMI) was calculated from weights or mass (kg) and heights (m) [BMI = weight (kg)/height $(m)^2$]. BMI was used as an estimate of % body fat because in was not possible to directly measure % body fat in a study of this size. Trainees' APFT results were obtained from the TRADOC Resident Individual Training Management System (RITMS).

The medically-documented injury data were extracted from the DMSS. Injuries in this study were operationally defined by the specific International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) diagnosis codes for the most frequently identified training-related MSK injuries to the low back and lower extremities. Examples include acute mechanical trauma (e.g., fractures, ankle sprains, and muscle strains) or cumulative mechanical micro-trauma (e.g., overuse injuries such as stress fractures, Achilles tendonitis, and plantar fasciitis). The diagnosis codes used for this study are referred to as the Training Related Injury Index, originally described in a 2004 report by Knapik et al.[25]

Descriptive statistics included means and standard deviations for height, weight (mass), BMI, and APFT results. Risk of injury (% injured) was calculated as the number of trainees with one or more training-related MSK injury during the 10 week BCT period divided by the number of trainees in a particular group of men or women. Relative risk (RR) of injury was calculated for women compared to men and by categories of risk factor, equal size quintile groups (~20%) for BMI and 2 mile run times [RR = % injured in risk group/% risk of referent group, with 95% confidence interval (95% CI)]. Chi-square (χ^2) tests were used to determine the significance of compared risks. When appropriate, Mantel–Haenszel (MH) χ^2 tests for trend were performed.

3. Results

Descriptive statistics for the 184,670 trainees (143,398 men and 41,272 women) are shown in Table 1. Compared to men, women were shorter, weighed less, had lower BMIs, and had lower levels of fitness by APFT scores. The injury risk (%) of women was 2.6 times higher than for men (40.3%/15.7%, 95% CI: 2.5–2.6).

The second table (Table 2) displays the injury risks (%) of the men grouped into quintiles (20% groups) of 2-mile run times (fastest to slowest group) stratified by quintiles of BMI (lowest to highest BMIs). As run times become slower, risk of injury increases steadily from 9.8% to 24.3% ($RR_{slowest/fastest}$ = 2.5 (95% CI: 2.45–2.51; MH χ^2 trend $p < 0.0001$)). The relationship of BMI to injury risk is a slightly bi-modal curve, with the lowest risk (14.4%) in the middle quintile (BMIQ3) and highest risk at the extremes (BMIQ1 and BMIQ5). The lowest injury risk (8.5%) occurred in the referent group (Fastest RUNQ1–Middle BMIQ3). The highest risk (26.6%) is the group of male trainees with the slowest run times and lowest BMI (Slowest RUNQ5–Lowest BMIQ1), a risk 3.1 times higher than the referent (95% CI: 2.8–3.4). Across all run-time quintiles, the highest risk was among the male trainees with the lowest BMIs, while those with the highest BMIs exhibit some of the lowest injury risk.

Table 3 displays similar results for the female trainees. As run times become slower, risks of injury increase steadily from 26.5% to 56.0% (MH χ^2 trend, $p < 0.00001$). The relationship of BMI to injury risk for women is also a bimodal curve (lowest risk in the middle quintiles, BMIQ2 and BMIQ3). As with men, the extremes of BMI (BMIQ1 and BMIQ5) exhibit the highest risk. The lowest injury risk (24.6%) occurs in the referent group (Fastest RUNQ1–Middle BMIQ3). The group with the slowest run times and the lowest BMI (RUNQ5–BMIQ1) had the highest risk (63.1%), a 2.6 times higher risk than the referent (95% CI: 2.3–2.8, $p < 0.00001$). As had been shown among male trainees, the highest risk among female trainees across all run time groups were to those with the lowest BMIs. The women with the highest BMIs exhibited some of the lowest injury risk.

Associations of injury risk with muscle endurance fitness (measured by push-ups and sit ups) (data not included) yielded some similarities as shown between injury risk and aerobic fitness (run times). For example, as the number of push-ups performed increased (indicating increased fitness), injury risk decreased sequentially for each quintile [male trainees = 20.9–12.4% ($RR = 1.7_{lowest\ number\ of\ push\text{-}ups/highest}$, 95% CI: 1.6–1.7; MH χ^2 trend, p-value < 0.0001); female trainees = 48.8%