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Body mass index predicts selected physical fitness attributes but is not associated with performance on military relevant tasks in U.S. Army Soldiers

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ABSTRACT

Objectives: Army body composition standards are based upon validated criteria; however, certain field-expedient methodologies (e.g., weight-for-height, body mass index [BMI]) may disqualify individuals from service who may otherwise excel on physical performance and military-relevant tasks. The purpose was to assess soldier physical performance and military-specific task/fitness performance stratified by BMI.
Design: Cross-sectional observational study.
Methods: Male (n = 275) and female (n = 46) soldiers performed a wide-array of physical fitness tests and military-specific tasks, including the Army physical fitness test (APFT). Within-sex performance data were analyzed by BMI tertile stratification or by Army Body Composition Program (ABCP) weight-for-height (calculated BMI) screening standards using ANOVA/Tukey post-hoc or independent t-tests, respectively.
Results: BMI stratification (higher vs. lower BMI) was associated with significant improvements in muscular strength and power, but also with decrements in speed/agility in male and female soldiers. Within the military specific tasks, a higher BMI was associated with an increased APFT 2-Mile Run time; however, performance on a 1600-m Loaded March or a Warrior Task and Battle Drill obstacle course was not related to BMI in either sex. Male and Female soldiers who did not meet ABCP screening standards demonstrated a slower 2-Mile Run time; however, not meeting the ABCP BMI standard only affected a minimal number (~6%) of soldiers' ability to pass the APFT.
Conclusions: Military body composition standards require a careful balance between physical performance, health, and military readiness. Allowances should be considered where tradeoffs exist between body composition classifications and performance on physical tasks with high military relevance.
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1. Introduction

Military members are held to high standards of physical fitness and body composition (BC)[1,2] in accordance with perceived physical demands and combat readiness requirements.[3,4] The original intentions of using height and weight thresholds were to prevent the inclusion of chronically malnourished and underweight individuals, but subsequent nutritional guideline changes shifted focus to preventing overweight and obese soldiers.[5] Current strict BC standards aim to ensure a physically capable and readily deployable force through proper nutrition and regular physical fitness.[2,5,6] Although military obesity[7] classifications are below U.S. average rates, unfavorable BC continues to negatively impact military health care costs[8] and validates the need for policies and programs which aim to reduce such prevalence.

The Army Body Composition Program (ABCP; AR 600-9)[6] implements BC requirements based on sex and age, in accordance with DoD Instruction 1308.3.[1] For soldiers who do not meet ABCP maximum allowable weight-for-height screening criteria, percent body fat (BF) is estimated using sex-specific circumference measurements. If the Soldier fails the BF standard, they are enrolled in the ABCP, which provides remediation. Despite emphasizing healthy BC levels, age-adjusted Army weight-for-height guidelines correspond to BMIs of 25–26 (female) and 25.9–27.5 (male) $kg \cdot m^{-2}$,

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allowing 'overweight' (BMI = 25.0–29.9 kg·m^{-2}) individuals to meet DoD and Army standards.[6] In fact, some of these same individuals could be physically fit and otherwise healthy potentially due to increased muscle mass vs. excess BF.[9]

We previously demonstrated that BMI and BF are strongly correlated (r = 0.86) in male infantry soldiers.[10] Interestingly, soldiers were correctly identified as subsequently meeting or exceeding the Army BF guidelines with an 83% accuracy using BMI alone,[10] indicating that BMI provides a relative measure of BC. Previous studies have reported a high BMI is negatively associated with aerobic capacity,[10,11] and routine military fitness tests[12]; however, much less is known about BC relationships with muscular strength/power and military-relevant task performance. A survey of military and civilian subject matter experts in strength and conditioning ranked muscular strength and power as the most important physical attributes required for military task completion, while they rated aerobic fitness with much lower importance.[4] Without fully appreciating BC and physical performance relationships, it is possible that individuals who do not meet military BC standards could also excel on military-relevant tasks, and therefore be inappropriately excluded or released from military service. A more complete understanding of the above interrelationships is needed to develop better anthropometry criteria and to minimize potential screening/testing bias.

As previously mentioned, BC standards are in place to help ensure physical readiness (e.g., maintaining a deployable force); however, those standards potentially exclude otherwise physically capable individuals from military service. This can be problematic given the perceived importance of certain physical capabilities in operational conditions. To address this, the purpose of this study was to examine how BMI relates to performance on a broad array of physical fitness attributes and simulated military tasks. We hypothesized that soldiers grouped into higher BC tiers (higher BMI) would outperform soldiers of lower tiers on certain tasks (e.g. muscular strength and power), highlighting flaws/limitations in currently employed anthropometric screening methods.

2. Methods

We enrolled 321 active duty Soldier volunteers (men, n = 275; women, n = 46), where the proportion of males (86%) and females (14%) approximated current active duty Army personnel demographics. The Soldier volunteers were from an infantry brigade combat team, and represented a wide variety of military occupational specialty (MOS) assignments. All procedures were approved by the U.S. Army Medical Research and Material Command (MRMC) Institutional Review Board. The investigators adhered to the policies for protection of human subjects prescribed in AR 70-25, and the research was conducted in adherence with 32 CFR Part 219.

Height and weight were measured using a stadiometer and electronic scale to the nearest whole unit, with BMI calculated as kg·m^{-2} using metric height and weight. Men and women did not differ in age (men: 24 ± 5 vs. women: 23 ± 3 years; P = 0.29), but men were taller and heavier than women (p < 0.01): height (men: 70.4 ± 2.6 vs. women: 65.1 ± 3.1 in.), weight (men: 179.6 ± 25.4 vs. women: 143.1 ± 22.4 lb.), and had a higher calculated BMI (men: 25.4 ± 3.1 vs. women: 23.7 ± 2.8 kg·m^{-2}, p < 0.01).

Soldiers were asked to complete several common and easy-to-administer physical fitness assessments (Table 1). The tests chosen represented a broad array of physical attributes, including muscular strength [Hex bar deadlift (HB DL) Strength, Bench Press (BP) Strength],[13] muscular power [Sled Drag, Sled Push, Medicine ball power throw (MB PT)[14]], muscular endurance [BP Endurance, Goblet kettlebell (KB) Squat Endurance], and speed/agility [400-m run, 300-yd shuttle run, Illinois Agility Test[15]]. Participants performed these tests in standard Army physical fitness uniform (APFU; t-shirt, shorts, and sneakers). Additional testing details are provided in Table 1. To assess military task performance (Table 2), participants completed a series of obstacles which represented key, physically demanding Common Soldiering Tasks (CSTs) and Warrior Tasks and Battle Drills (WTBDs). The four components of the WTBD course were: (1) establish a fighting position, (2) move over, under, around, and through obstacles, (3) combatives simulation, and (4) casualty extraction and evacuation. Participants were first familiarized to this course in their APFU, next in Army Combat Uniform (ACU; jacket, undershirt, pants, boots), and finally in the ACU with a modified fighting load (FL; helmet, weighted improved outer tactical vest (IOTV), non-functional weapon, etc.). The final FL condition simulated operational conditions, and was the trial used for performance analysis (WTBD (FL)). In the second military task assessment, Soldiers completed a 1600-m Ruck March with an added 20-lb. load, with time to task completion recorded. Finally, we captured soldiers' most recent Army Physical Fitness Test scores (APFT; 2-minute maximum Push-ups, 2-minute maximum Sit-ups, 2-Mile Run time) via survey, considered a valid method for collecting this data.[16]

Table 1
BMI tertile descriptives and physical performance by BMI tertiles.

	Low BMI tertile (T1); <33%	Mid BMI tertile (T2); 33–66%	High BMI tertile (T3); >66%	ANOVA p-value
BMI tertile descriptives				
Men				
BMI, kg·m^{-2}	22.2 ± 1.3	25.2 ± 0.8	28.8 ± 1.9	
Range, kg·m^{-2}	(18.6–23.8)	(23.9–26.5)	(26.6–34.9)	
n = 275	n = 91	n = 90	n = 94	
Women				
BMI, kg·m^{-2}	20.4 ± 1.4	23.8 ± 1.0	26.7 ± 1.0	
Range, kg·m^{-2}	(16.9–22.1)	(22.1–25.4)	(25.6–28.6)	
n = 46	n = 15	n = 16	n = 15	
Physical performance test				
HB DL strength (lb.)				
Men	242.7 ± 28.9	255.9 ± 28.1*	271.9 ± 32.5*	<0.01
Women	144.8 ± 29.0	170.4 ± 29.7*	176.4 ± 28.6*	0.011
BP strength (lb.)				
Men	175.7 ± 34.2	198.6 ± 36.0*	229.3 ± 35.1*	<0.01
Women	83.4 ± 16.8	97.4 ± 23.0	100.7 ± 15.1*	0.035
25-m Sled Drag time (s)				
Men	17.0 ± 3.5	15.8 ± 3.0*	14.9 ± 4.2*	<0.01
Women	35.9 ± 11.9	34.2 ± 12.4	29.0 ± 9.4	0.223
25-m Sled Push time (s)				
Men	8.7 ± 2.1	8.3 ± 1.2	7.7 ± 1.1*	<0.01
Women	13.6 ± 1.8	13.0 ± 2.8	11.3 ± 1.6*	0.014
MB PT distance (ft.)				
Men	18.5 ± 3.4	19.0 ± 3.7	21.5 ± 4.0*	<0.01
Women	10.0 ± 2.6	10.5 ± 2.9	10.7 ± 3.0	0.767
BP Endurance (RTF)				
Men	43.1 ± 12.9	51.6 ± 14.4*	66.2 ± 20.7*	<0.01
Women	18.0 ± 9.8	16.3 ± 10.9	19.1 ± 7.3	0.708
Goblet KB Squat Endurance (RTF)				
Men	30.8 ± 11.4	31.4 ± 12.0	34.4 ± 12.1	0.083
Women	13.8 ± 5.6	20.1 ± 8.3*	19.5 ± 6.3	0.027
400-m run time (min:s)				
Men	1:13 ± 0:13	1:15 ± 0:13	1:16 ± 0:10	0.171
Women	1:29 ± 0:14	1:36 ± 0:18	1:34 ± 0:14	0.387
300-yd shuttle run time (min:s)				
Men	1:06 ± 0:03	1:07 ± 0:03*	1:09 ± 0:04*	<0.01
Women	1:14 ± 0:04	1:19 ± 0:06	1:20 ± 0:05*	0.019
Illinois Agility Test time (s)				
Men	19.0 ± 1.1	19.4 ± 1.4	19.6 ± 1.3*	<0.01
Women	21.0 ± 1.3	21.8 ± 0.7	21.7 ± 1.7	0.180

* P ≤ 0.05 vs. T1 within sex via Tukey post-hoc; HB DL = hex bar dead lift; BP = bench press; Sled Drag = 10-lb. sled plus 150-lb. pulled by 40-lb sandbag; Sled Push = 56-lb sled plus 120-lb.; MB PT = medicine ball power throw; BP Endurance = 44-lb. barbell plus 20-lb.; KB = 40-lb. kettlebell; RTF = repetitions to fatigue; min: minutes; s = seconds; values are mean ± SD (range where provided) within BMI tertile.

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