Body Composition is Strongly Associated With Cardiorespiratory Fitness in a Large Brazilian Military Firefighter Cohort: The Brazilian Firefighters Study

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Abstract

Nogueira, EC, Porto, LGG, Nogueira, RM, Martins, WR, Fonseca, RMC, Lunardi, CC, and de Oliveira, RJ. Body composition is strongly associated with cardiorespiratory fitness in a large Brazilian military firefighter cohort: The Brazilian Firefighters Study. *J Strength Cond Res* 30(1): 33–38, 2016—Firefighting is associated with high-level physical demands and requires appropriate physical fitness. Considering that obesity has been correlated with decreased cardiorespiratory fitness (CRF) and that the prevalence of obesity may also be elevated within firefighters (FF), we analyzed the association between CRF and body composition (BC) in Brazilian military FF. We assessed 4,237 male FF (18–49 years) who performed a physical fitness test that included BC and CRF. Body composition was assessed by body mass index (BMI), body adiposity index (BAI), body fat percentage (BF%), and waist circumference (WC). CRF was assessed by the 12-minute Cooper test. Comparisons of $\dot{V}O_2max$ between the BC categories were analyzed using the Mann-Whitney test, and the analysis was adjusted for age using the General Linear Model. The Spearman test was used for correlation analysis and the odds ratio (OR) was calculated to assess the odds of the unfit group (≤12 metabolic equivalents [METs]) for poor BC. Statistically significant differences were considered when $p \leq 0.05$. Considering the BMI categories, 8 volunteers (0.2%) were underweight, 1,306 (30.8%) were normal weight, 2,301 (54.3%) were overweight, and 622 (14.7%) were obese. The $\dot{V}O_2max$ was negatively correlated with age ($r_s = -0.21$), BMI ($r_s = -0.45$), WC ($r_s = -0.50$), and BAI ($r_s = -0.35$) ($p < 0.001$). Cardiorespiratory fitness was lower in the obese compared with the non-obese for all age categories ($-3.8\ ml \cdot kg^{-1} \cdot min^{-1}$; $p < 0.001$) and for all BC indices ($-4.5\ ml \cdot kg^{-1} \cdot min^{-1}$; $p < 0.001$). The OR of the unfit group having poor BC in all indices varied from 2.9 to 8.1 ($p < 0.001$). Despite the metabolically healthy obesity phenomenon, we found a strong association between CRF and BC irrespective of age and the BC method (BMI, BAI, WC, or BF %). These findings may aid in improving FF training programs with a focus on health and performance.

Key Words body fat, aerobic capacity, body adiposity index, BMI, MET, obesity

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Introduction

Firefighting is well recognized as a profession associated with high levels of physical and psychological demands (3,21,32). Although firefighter (FF) departments around the world may differ in their organization (whether civil or military), work routines, procedures, and job tasks, FF usually engage in several hazardous tasks such as fire suppression, rescues, and medical emergencies, exposing them to different health risk factors (9,32). Considering the complexity of their job demands, FF should possess good physical fitness, which includes good cardiorespiratory capacity, muscle strength/resistance, and body composition (BC) (31).

Several studies have presented data that raise concerns regarding FFs' physical fitness, and BC (4,13,30). Despite the inherent job characteristics, Poston et al. (30) have found a very high prevalence of overweight (79.5%) and obesity (33.5%) among American career FF. This high proportion of obese FF is similar to the general population (28), suggesting that the hypothesis that FF have a better BC then the general population appears to be, at least in some cases, a false assumption. Moreover, cardiorespiratory fitness (CRF) has been shown to be inversely associated with the prevalence of the metabolic syndrome (MS) in FF. The prevalence of MS was nearly 10-fold higher among the FF in the lowest CRF category (≤10 metabolic equivalents [METs]) compared with those in the highest fitness category (>14 METs) (3).

Another important topic to consider is that heart disease is responsible for 45% of U.S. FF deaths while on duty with most of the cases associated with emergency situations (21). Firefighters are at an increased risk of cardiovascular disease (CVD) because they reportedly have a higher BMI, which is associated with increased CVD risk (35). In that scenario, overweight and obesity have become major problems that are also faced by FF. Furthermore, high body mass index (BMI $\geq$30 $kg \cdot m^{-2}$) is also associated with a higher risk of musculoskeletal injuries in FF (23).

The association between regular physical activity and health has been well established, particularly in the prevention of cardiovascular diseases (7,19). Adequate levels of health-related physical fitness (HRPF) are associated with reduced risk of several cardiometabolic conditions, whereas impaired CRF is an important risk factor for overall mortality, obesity, and the MS (3,16,19,24–26).

Cardiorespiratory fitness improvement may have a positive impact on cardiovascular health and overall mortality (4,26) and small changes in BMI may be associated with the reduction of cardiometabolic risk factors (22). Thus, it is important to assess the association between BC and physical fitness in FF, particularly within military FF in whom less scientific evidence is available. This assessment is further justified in the context of the high prevalence of obesity, high job demands, and the physical activity levels, as previously reported in different FF departments (4,13).

Therefore, the aim of our study was to analyze the association between CRF and BC in a large Brazilian military firefighter cohort.

Methods

Experimental Approach to the Problem

We conducted a cross-sectional study in a large Brazilian military firefighter cohort. The recruited participants were male military career FF older than 18 years and younger than 50 years who work for the Military Firefighters Department of the Brazil Federal District (Corpo de Bombeiros Militar do Distrito Federal [CBMDF]). The data were collected during the 2011 Brasília Military Firefighters' annual physical fitness examination. In the year 2011, 4,609 male FF underwent the mandatory CBMDF physical examination. Because the data for 372 (8.1%) were incomplete, all analyses were performed on a cohort of 4,237 men from the CBMDF. The CBMDF includes all fire departments of the Brazilian Federal District, where Brasília (Brazil capital) is located. The Brasília Military FF annual physical fitness examination is a mandatory battery of physical tests for all CBMDF FF younger than 50 years and was designed for occupational purposes.

Subjects

The use of the recorded physical evaluation data for research purposes was approved by the University of Brasília Faculty of Health Sciences Ethics Committee on Human Research, and an authorization from the CBMDF was also properly obtained for this study. All data were extracted from the Brasilia Firefighter Department database and were analyzed in a de-identified (anonymous) fashion. Based on using de-identified data the study was approved by the UnB-FHS-IRB with exemption from requiring individual informed consent.

Physical Activity Assessment. Body composition was assessed by 4 different indices: (a) BMI with the cutoff points proposed by the World Health Organization (34). For BMI categorization, 2 cutoff points were considered. We used the 25.0 $kg \cdot m^{-2}$ cutoff point in some of the analyses to group all FF with BMIs higher than the upper limit of normal. Nevertheless, we also used the conventional 30.0 $kg \cdot m^{-2}$ cutoff point to separate only those considered obese by BMI; (b) body adiposity index (BAI), proposed by Bergman et al. (6) to estimate the body fat percentage (BF%); (c) BF%, calculated by the Guedes' 3-skinfold protocol that is based on Brazilian population data (17), and (d) waist circumference (WC). Guedes' 3-skinfold protocol is a validated body density (BD) estimation obtained from a Brazilian population that uses the tricipital (TR), suprailiac (SI), and abdominal (AB) skinfolds to estimate BD by the formula: $D = 117{,}136 - 006{,}706 \log (TR + SI + AB)$, where "$D$" is the BD. To convert BD into BF%, we used the Siri equation as follows: $BF\% = ([4.95/D] - 4.50) \times 100$ (17).

Cardiorespiratory fitness was assessed by the 12-minute Cooper test, which is an indirect estimate of the maximum oxygen consumption ($\dot{V}O_2max$ in $mL \cdot kg^{-1} \cdot min^{-1}$). The objective of the Cooper test is to run as far as possible within 12 minutes on a running track. The distance run is converted into oxygen consumption ($\dot{V}O_2$) using a validated formula (24). All tests were performed on the same running track to improve the test's precision and standardization among the participants. CRF was converted to METs in some analyses, dividing the $\dot{V}O_2max$ values by 3.5 (14).

All physical assessments, which included measures of weight, height, and skinfolds, were conducted in the morning by FF instructors who had prior training in the CBMDF physical fitness examination protocol and experience in the skinfold measurement technique.

Statistical Analyses

Data are presented as the median, minimum and maximum values because some variables showed a nonparametric distribution after the Shapiro-Wilk test. The Spearman test was used for correlation analysis. Unadjusted comparisons of $\dot{V}O_2max$ between groups were analyzed using the Mann-Whitney *U*-test. We calculated the absolute and the relative prevalence of BC categories, according to the standardized categories for different BC indices. CRF of FF was also

Table 1. Comparison of $\dot{V}O_2max$ values of 4,237 Brazilian FF according to BMI category in different age range as defined by the CBMDF.

	$\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)			
Age (yr)	BMI $\geq$25 $kg \cdot m^{-2}$	BMI $<$25 $kg \cdot m^{-2}$	p*	Dif ($ml \cdot min^{-1} \cdot kg^{-1}$)
18–25	47.2 (44.8–51.5)	52.8 (52–53.6)	<0.001	5.6
26–33	43.5 (27.4–58)	44.8 (34.8–60.3)	<0.001	1.3
34–39	41.5 (33.4–60.3)	44.8 (32.5–64.7)	<0.001	3.3
40–45	40.1 (18.2–60.3)	44.4 (24.5–63.8)	<0.001	4.3
46–49	38.1 (24.5–54.5)	42.4 (30.5–60.7)	<0.001	4.3

Dif = mean difference between groups.
*Mann-Whitney test.

categorized as sufficient (or fit) when $\dot{V}O_2max$ >12 METs and insufficient (or unfit) when $\dot{V}O_2max \leq$12 METs, as proposed by the American National Fire Protection Association as the minimum threshold for safe firefighting performance (27). The U.S. standard for CRF was used because there is no CRF standard value proposed for Brazilian FF and because the 12 METs threshold already has been used in the literature (2,5,13).

Adjusted analysis was performed using the univariate General Linear Model with age as the only covariate, because it was the only variable of interest with a difference between volunteers in the different BC groups. To analyze the association between categorical variables we used the chi-square test and odds ratio (OR) with 95% confidence interval to verify the strength of association. The OR was calculated using a 2-by-2 contingency table analysis to calculate the odds of the unfit group (<12 METs) presenting a poor BC according to the different BC indices.

The differences were considered statistically significant when a 2-tailed p value was less than 5% ($p \leq 0.05$). Data processing and analysis were performed using the SPSS Statistics v20 (IBM Corporation) software package.

Results

The Brazilian FF cohort had a median age of 39 (22–49) years and a BMI of 26.6 (16.9–43.8) $kg \cdot m^{-2}$. We observed that 8 (0.2%) of the volunteers were underweight, 1,306 (30.8%) were normal weight, 2,301 (54.3%) were classified as overweight, and 622 (14.7%) were obese, according to the BMI classification (34). The median CRF was 42.4 (18.2–64.7) $mL \cdot kg^{-1} \cdot min^{-1}$ and 2,240 (52.9%) of the participants had $\dot{V}O_2max$ values >12 METs. The median values for the other BC indices were as follows: WC = 90.0 (55.0–136.0) cm; BAI = 24.9 (10.5–38.3), and BF% = 21.7 (14.0–34.3%).

$\dot{V}O_2max$ was negatively correlated with age ($r_s = -0.21$, $p < 0.001$), WC ($r_s = -0.50$, $p < 0.001$), BMI ($r_s = -0.45$,

Table 2. Comparison of $\dot{V}O_2max$ values of 4,237 Brazilian FF according to BMI, BAI, and BF% standardized cutoff points overweight (BMI $\geq$25.0 $kg \cdot m^{-2}$) or obesity (BAI and BF% $\geq$25.0).

	High	Normal	p*	p†	Dif ($ml \cdot min^{-1} \cdot kg^{-1}$)
$\dot{V}O_2max$ ($ml \cdot min^{-1} \cdot kg^{-1}$)	BMI $\geq$25.0 $kg \cdot m^{-2}$ 41.0 (18.2–60.3)	BMI $<$25.0 $kg \cdot m^{-2}$ 44.6 (24.5–64.7)	<0.001	<0.001	3.6
	BMI $\geq$30.0 $kg \cdot m^{-2}$ 36.8 (23.4–53.4)	BMI $<$30.0 $kg \cdot m^{-2}$ 42.8 (18.2–63.8)	<0.001	<0.001	6.0
	BAI $\geq$25.0 40.1 (18.2–60.2)	BAI $<$25.0 43.5 (24.4–64.7)	<0.001	<0.001	3.4
	BF% $\geq$25.0 37.7 (23.4–55.1)	BF% $<$25.0 42.8 (18.2–64.7)	<0.001	<0.001	5.1

Dif = mean difference between groups.
*Mann-Whitney test.
†Adjusted analysis for age using General Linear Model.

Table 3. Absolute frequency (relative) and bivariate analysis of the risk of being unfit ($\dot{V}O_2max$ <12 METs) associated with a poor BC classification in different indexes ($n = 4,237$).

				χ^2	p	OR (95% CI)
$\dot{V}O_2max$		BMI ≥25.0 kg·m^{-2} ($n = 2,923$)	BMI <25.0 kg·m^{-2} ($n = 1,314$)			
	<12 METs	1,632 (81.7%)	365 (18.3%)	286.3	<0.001	3.3 (2.9–3.8)
	≥12 METs	1,291 (57.6%)	949 (42.4%)			
		BMI ≥30.0 kg·m^{-2} ($n = 622$)	BMI <30.0 kg·m^{-2} ($n = 3,615$)			
	<12 METs	516 (25.8%)	1,481 (74.2)	375.5	<0.001	7.0 (5.6–8.7)
	≥12 METs	106 (4.7%)	2,134 (95.3%)			
		BAI ≥25.0% ($n = 2,063$)	BAI <25.0% ($n = 2,174$)			
	<12 METs	1,248 (62.5%)	749 (37.5%)	288.1	<0.001	2.9 (2.6–3.3)
	≥12 METs	815 (36.4%)	1,425 (63.6%)			
		BF% ≥25.0 ($n = 710$)	BF% <25.0 ($n = 3,527$)			
	<12 METs	556 (27.8%)	1,441 (72.2%)	332.7	<0.001	5.2 (4.3–6.3)
	≥12 METs	154 (6.9%)	2,086 (93.1%)			
		High WC ($n = 570$)	Low WC ($n = 3,667$)			
	<12 METs	485 (24.3%)	1,512 (75.7%)	380.8	<0.001	8.1 (6.4–10.3)
	≥12 METs	85 (3.8%)	2,155 (96.2%)			

χ^2 = Chi-square test value; p = χ^2 test level of significance; OR (95% CI) = odds ratio (95% confidence interval).

$p < 0.001$), and BAI ($r_s = -0.35$, $p < 0.001$). The comparison of $\dot{V}O_2max$ values between the normal and high BMI categories, by age range, is shown in Table 1. The age range categories used for analysis are the same as those used by the CBMDF in their physical fitness classification. The comparison of the CRF between the groups, stratified by the standardized cutoff points irrespective of age, is presented in Table 2.

The proportion of obese FF among the less fit participants was 5.5-fold higher than among the fittest group. Table 3 presents the frequency and bivariate analysis of the risk factor analysis (being unfit) associated with poor BC classification in 4 different indices.

Discussion

The aim of this study was to assess the association of CRF and BC in a large military FF cohort. The data collected from a sample of 4,237 male FF showed a strong association between CRF and BC irrespective of age and the BC method used. This may be considered an important outcome because it was observed in all the statistical analyses (with respect to the correlation, comparison between groups, and risk estimation), in different BC indices and for different BMI cutoff points (25.0 or 30.0 kg·m^{-2}). Although some studies have shown an independent effect of BC and CRF on health outcomes (18), it should be emphasized that the consistency of our results indicates that both components of HRPF (BC and CRF) may be simultaneously considered for job performance, as well as for occupational health purposes regarding military FF. To the best of our knowledge, this is the first study that has addressed the association between CRF and BC in a military population–based FF cohort. Considering the sample size and the approach employed, with different BC indices and statistical analyses, our findings may represent a singular contribution to the field, with practical implications for the strength and conditioning professional involved in FF health promotion and training.

One of the main issues that should be considered in BC assessment is the use of BMI to identify the BC of FF. Concerns may exist due to the possibility of BMI overestimating overweight and obesity among some working groups that are allegedly more active than the general population, such as FF. In a previous study, BMI did not overestimate obesity in FF when compared with the BF% obesity estimate, even when the analyses were performed by age and CRF subgroups (29,30). In addition, the obesity prevalence estimated by BMI, BF%, and WC were similar (14.7, 16.8, 13.2%, respectively) in this FF cohort. Therefore, BMI appears to be an adequate method to assess BC in FF.

As to the proportion of FF considered obese or overweight, we found that the prevalence of obesity and overweight in the Brazilian FF cohort were less than those of U.S. FF samples (10,30). Additionally, the obesity prevalence in FF was very similar to that of the average adult male population (14.8%) in Brasília in 2011 (8). This is an important finding because Brazilian FF and U.S. FF are exposed to similar risk factors for increasing obesity. These risk factors are unhealthy eating habits at the fire departments, sleep interruption, high-level job demands, and/or increased sedentary work due to the historical changes of FF work toward increased medical emergency demands with a reduction in the incidence of fire suppression-related activities (11,12). Moreover, obesity in Brazilian FF is similar to that of regular population. This difference between Brazilian and U.S. FF may be explained by the fact that Brazilian FF are military workers, whereas their U.S. counterparts are of civilian career FF and voluntary workers. Although most U.S. fire departments do not mandate exercise training and do not require any minimum physical performance (13), Brazilian FF from the CBMDF must undergo an annual physical examination, which has a minimum physical fitness threshold. If this minimum is not achieved, this may have negative implications on FF career promotion. Thus, the annual mandatory physical fitness examination may be an important way to improve physical fitness and BC in FF. Additionally, it may positively affect the work performance and health status of FF.

As to the strong association observed between CRF and BC, our results corroborate the previous findings showing that increased BMI was associated with a reduction of CRF in FF (13). However, other studies also indicate an independent effect of both components (18). A recent metaanalysis has shown that fit, overweight, and obese participants had similar mortality risks than the normal-weight fit group (2). In the setting of an obesity epidemic (33), a high number of overweight and obese FF (10,29,30), and the known association of an impaired CRF or BMI with different health outcomes, such as diabetes (1) and overall mortality (26), our results deserve special importance. Moreover, similar findings derived from FF populations were found between CRF and MS, in which obesity is one of its possible components (3).

Another perspective should also be considered to precisely assess the magnitude of the potential negative health-related risks that may occur when both poor BMI and insufficient CRF coexist. Some studies have found a strong association between each one of these 2 components of HRPF with different outcomes, mainly with mortality. Myers et al.(26) (2002) found that the exercise capacity measured during treadmill exercise testing (ET), performed for clinical reasons, was the more powerful predictor of mortality among men referred for ET. Using a similar approach, Goraya et al.(15) found that each MET increase in exercise capacity assessed in a treadmill exercise test was associated with a 14% reduction in cardiac events in participants younger than 65 years of age. Similarly, in an FF sample, Baur et al.(5) found an inverse relationship between CRF and the presence of stress test abnormalities, such as exaggerated blood pressure response and impaired heart rate recovery, which are well-known cardiovascular risk factors. Furthermore, some studies have shown that even small reductions in BMI were associated with the reduction of cardiometabolic risk (22,25). Although CRF and BC may exert independent roles on the health-related risk profile (10), one could assume that the sum of the risk factors may increase cardiometabolic or overall mortality risk (20). This appears to be a crucial key point to which FF departments should direct their attention, considering the inherent cardiovascular risk associated with firefighting (32).

Finally, some possible limitations related to this cross-sectional study design and the CBMDF annual physical examination protocol should be addressed. It is well known that cross-sectional studies cannot identify any cause-effect relationship. Considering that skinfold measurement validity is dependent on the measurement technique, all evaluations were performed by experienced and trained FF instructors. Despite this inherent limitation and independent of the statistical analysis method or the BC index applied, the consistency of the findings supports the strength of the observed relationship between CRF and BC in this large FF cohort. Thus, this strongly suggests that both issues should be addressed in programs focused on improving FF health and/or job performance. As to the fitness test protocol, we must acknowledge the possibility that some FF did not perform to their maximum capacity. According to the CBMDF annual physical test examination rules, when a participant reaches his age-specific established performance threshold he receives the maximum grade, irrespective of the final distance achieved. However, the possible influence of that test rule is mitigated by the sample size and by the fact that in a military environment, it is also expected that each of the participants would be expected to deliver their very best performance because this could lead to better job opportunities and/or prestige at work.

Practical Applications

In this large Brazilian male FF cohort, we found a strong association between CRF and BC irrespective of age, BC method (BMI, BAI, BF%, or WC) and statistical analysis (correlation, inferential, or risk estimation). Longitudinal studies should be conducted within this specific population to assess how changes in CRF affect BC and vice versa, and the analysis of their possible associations with several health and performance outcomes of FF. Our data strongly suggest that FF departments should consider the possibility of using CRF and BC to promote the health and improved job performance of FF. For that specific purpose, it should be highlighted that BMI appears to be the optimal BC evaluation method to be used given that it showed the same results as BAI, BF%, or WC, apart from its inherent advantages, such as practicality, applicability in large samples, and very low cost. Therefore, it is noteworthy to recall that in 2012, the CBMDF inaugurated a large and well-equipped military center for physical training (±35,000 m^2) in Brasília and began implementing fitness centers in each FF station. The possible beneficial effects of that occupational policy may merit follow-up and may produce important findings to better understand the relationship between CRF, BC, health, and the job performance of FF.

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