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Cardiovascular Demand Differences Between Male and Female US Marine Recruits During Progressive Loaded Hikes

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Abstract

Schram, B, Orr, R, Niederberger, B, Givens, A, Bernards, J, and Kelly, KR. Cardiovascular demand differences between male and female US Marine recruits during progressive loaded hikes. *J Strength Cond Res* XX(X): 000–000, 2024—Despite having to carry the same occupational load, female soldiers tend to be lighter than male soldiers. The aim of this study was to determine the differences in cardiovascular load between female and male US Marine recruits during progressive load carriage hikes. United States Marine Corps recruits (565 male recruits; 364 female recruits) completed 6 loaded hikes over 6 weeks (1: 10 kg, 30 minutes; 2: 10 kg, 45 minutes; 3: 15 kg, 30 minutes, 4: 15 kg, 45 minutes; 5: 20 kg, 30 minutes; 6: 20 kg, 45 minutes) during which cardiovascular response was measured. Average heart rate (HRavg), HR maximum (HRmax), and pace were measured via a wrist-worn physiological monitor. Independent sample *t*-tests were conducted to compare between sexes, with significance set at 0.008 after adjusting for multiple comparisons. The average female recruit had significantly lower body mass (BM) compared with the average male recruit ($p < 0.001$) and thus carried a significantly heavier relative load. (10 kg ~17%, 15 kg ~25%, 20 kg ~33%, $p < 0.001$). There were no significant differences in pace in any hike, and no significant differences were found in HRavg or HRmax when comparing female and male Marines during Hike 1. For female Marines, HRavg was significantly higher compared with male Marines during Hike 2 (+6.5 b·min^{-1}, $p < 0.001$) and Hike 3 (+7.4 b·min^{-1}, $p < 0.001$), and both HRavg and HRmax were significantly higher in Hike 4 (+11.9 b·min^{-1}, +8.4 b·min^{-1}, $p < 0.001$), Hike 5 (+7.7 b·min^{-1}, +7.9 b·min^{-1}, $p < 0.001$), and Hike 6 (+6.9 b·min^{-1}, +7.1 b·min^{-1}, $p < 0.001$), respectively. Female Marines endured greater cardiovascular demand compared with male Marines during load carriage events when carrying loads greater than 15 kg (~25% BM).

Key Words: soldier, load, heart rate

Introduction

Initial, or ab initio, military training is physically demanding. This military training consists of physical training, load carriage marching, military parade drills, field exercises, and a range of weapon and equipment handling activities (24), all typically conducted over an 8- to 14-week period (32). Designed to transition a civilian to a service member (35), new military recruits may experience an exponential increase from previous levels of physical activity due to the nature of this training (5). Given this transition, ab initio training is often associated with an increased injury risk (32), thought to be explained to a large degree by the aforementioned exponential increase in physical activity (5) combined with inadequate fitness (17). Individuals with less physical fitness work at a higher physiological level when compared with those who are more fit, leading to an earlier onset of fatigue and potential injury risk (21,36).

In the United States Marine Corps (USMC), and in line with global data, injuries are greatest in young Marines during periods of high volumes of intense exercise, such as in initial training (16). This training period in the USMC is a 13-week program inclusive of 3 weeks of administrative processing and 10 weeks of tactical training (10). It is an entry-level training that male and female recruits complete to gender-neutral standards before progressing to additional occupational-specific training. Load carriage is progressively trained throughout this period with a series of paved road and dirt road hikes, with the Marines gradually carrying heavier loads in accordance with previous research showing the importance of recent and progressive load carriage (28). Despite load carriage being occupationally relevant to the USMC and tactical personnel more broadly, it is known to contribute to injury risk (16), to change neuromuscular function, decrease performance across a variety of tasks (15,25), and increase physiological costs of a given activity (11).

Given the gender-neutral training standards, which correspond to the gender-neutral occupational requirements within the military, female recruits complete the same progressive loaded hikes as male recruits in USMC basic training. Because female recruits are generally smaller in stature and lighter in mass than male recruits (10,27), this additional load is typically a greater relative load than those carried by their male counterparts. In addition,

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female recruits, in general, have a lower aerobic capacity than male recruits (2), which leads to a generally greater cardiovascular workload for the same task (13). With most reports from recruit training globally reporting higher injury rates among female service members when compared with male service members (32), and load carriage being a primary source of injury in USMC recruit training in particular (16), understanding the differences in physiological costs between male and female personnel during progressive hikes is an important consideration to injury reduction programs. The aim of this study was to investigate the differences in cardiovascular demand between female and male recruits during progressive load carriage hikes in USMC recruit training.

Methods

Experimental Approach to the Problem

A prospective cohort study was employed where 3 companies of USMC recruits undergoing recruit training from January 2021 to January 2022 were monitored for their cardiovascular response to 6 progressive load carriage hikes via a physiological monitor.http://links.lww.com/JSCR/A492

Subjects

An a priori power analysis conducted using G*Power software to determine the minimum sample size to achieve 95% power for detecting a large effect ($d = 0.8$) was determined to be $n = 126$. Both female and male recruits (age 18–22) were provided information regarding the risks and benefits of the study before data collection and signed an institutionally approved informed consent document to participate. Data for 929 individuals were provided (364 female recruits, 565 male recruits) across the 6 hikes, with data for a varying number of subjects provided per hike.

The study protocol was approved by the Naval Health Research Center Institutional Review Board in compliance with all applicable Federal regulations governing the protection of human subjects. Research data were derived from an approved Naval Health Research Center Institutional Review Board protocol number NHRC.2020.0008.

Procedures

Subjects were issued a Polar Grit X wrist-wearable physiological monitor (Polar Electro, Kempele, Finland) for the duration of their training. The devices were programmed for the individual based on their demographic information (age, height, weight, etc.) and were worn continuously, except for removal for charging and data downloads by directing staff, which was approximately 4 hours total per week. These devices have used and validated previously within this population (10,20). Anthropometric data were collected by sports medicine and athletic trainer staff at medical intake with height measured with a stadiometer and weight on a scale. During the 6 load carriage hikes, recruits "started" and "stopped" an activity recording on the Polar Grit X to continuously measure physiologic metrics during the hike. Variables of interest were average heart rate (HRavg), maximum heart rate (HRmax), and average pace ($km \cdot h^{-1}$).

The loaded hikes of interest within the training program were the first 6, which were hikes for time on paved roads, as opposed to the subsequent hikes for distance on dirt roads that occur later in the training program. Given the differences in completion times for the distance-based hikes, these were excluded from the analysis. Load was carried in standard issue Marine Corps backpacks with Marine Corps gear to mimic hikes that occur once in the fleet with all weight being carried in the backpack. All hikes were conducted in standard military-issued boots. Backpacks were weighed the night before to guarantee the weight accuracy. Because the program of instruction was the same for each company, the results from each of the 3 companies were pooled. The details of these hikes are seen in Table 1.

Statistical Analyses

Descriptive statistics and analysis were conducted on the Statistical Package for the Social Sciences (SPSS version 28, IBM Corporation, Armonk, NY) after being imported from an Excel document. Comparisons between female and male recruits were conducted with independent samples *t*-tests after ensuring normal data distribution, with mean differences and 95% confidence intervals determined. Significance was set at 0.008 after adjusting for the 6 comparisons.

RESULTS

Table 2 displays the results of the hikes with respect to body mass (BM), relative load, average pace, and cardiovascular response. The female recruits who completed the hikes (61.6 ± 7.4 kg, range 46.3–93.4 kg) had, on average, significantly lower BM than the male recruits (72.9 ± 12.2 kg, range 47.6–107.0 kg) with a mean difference of −11.4 kg (95% CI [10.0, 12.79], $p < 0.001$). As companies hiked together, there were no differences in average pace between female and male recruits during any of the hikes, with Hike 1 being the slowest at 3.9 $km \cdot h^{-1}$ (2.4 mph), Hike 5 at 4.3 $km \cdot h^{-1}$ (2.7mph), Hikes 2 and 3 at 4.2 $km \cdot h^{-1}$ (2.6mph), and Hikes 4 and 6 the quickest at 4.5 $km \cdot h^{-1}$ (2.8mph). The female recruits carried a significantly heavier relative load in all hikes (circa 17% body mass [BM] in the 10 kg hike, 25% BM in the 15 kg hike, and 33% BM in the 20 kg hike) when compared with male recruits (circa 14% BM in the 10 kg hike, 20% BM in the 15 kg hike, and 28% BM in the 20 kg hike). Mean HRmax did not differ significantly in any of the 10 kg hikes, while mean HRavg was significantly higher in female compared with male recruits completing Hike 2 (45 minutes, 10 kg) and Hike 3 (30 minutes, 15 kg), and both HRavg and HRmax were significantly higher in female recruits completing Hike 4 (45 minutes, 15 kg). Both Hikes 5 and 6 elicited significantly higher HRavg and HRmax in female recruits when compared with male recruits with HRavg being 7.7 $b \cdot min^{-1}$ (95% CI [3.9, 11.4]) and 6.9 $b \cdot min^{-1}$ (95% CI [2.9, 10.9]) higher in Hikes 5 and 6, respectively, and HRmax being 7.9 $b \cdot min^{-1}$ (95% CI [4.0, 11.4]) higher and 7.1bpm (95% CI [3.1, 11.0]) higher in Hikes 5 and 6, respectively.

Table 1
Details of the 6 hikes.

Hike	Duration	Load
1	30 min	10 kg
2	45 min	10 kg
3	30 min	15 kg
4	45 min	15 kg
5	30 min	20 kg
6	45 min	20 kg

Table 2
Loaded hike results of male and female recruits with respect to body mass, relative load, and cardiovascular response.

	Hike 1: 30 min, 10 kg		Hike 2: 45 min, 10 kg		Hike 3: 30 min, 15 kg		Hike 4: 45 min, 15 kg		Hike 5: 30 min, 20 kg		Hike 6: 45 min, 20 kg	
	M (n = 94)	F (n = 56)	M (n = 83)	F (n = 67)	M (n = 91)	F (n = 50)	M (n = 110)	F (n = 69)	M (n = 105)	F (n = 73)	M (n = 82)	F (n = 49)
Body mass (kg)	73.6 ± 13.0	61.1 ± 7.8*	72.8 ± 13.2	61.2 ± 7.6*	73.5 ± 12.0	61.4 ± 7.8*	72.7 ± 12.2	62.4 ± 7.5*	71.8 ± 11.4	61.7 ± 6.8*	73.6 ± 11.45	61.3 ± 7.0*
Relative load (%)	14.0 ± 2.5	16.7 ± 7.8*	14.2 ± 2.5	16.6 ± 2.0*	20.9 ± 3.4	24.8 ± 3.1*	21.2 ± 3.5	24.4 ± 2.7*	28.5 ± 4.5	32.8 ± 3.7*	27.8 ± 4.4	33.0 ± 3.7*
Average HR (b·min^{-1})	116.7 ± 12.6	121.5 ± 12.0	119.0 ± 12.9	125.5 ± 10.6*	113.0 ± 12.1	120.4 ± 10.4*	120.6 ± 14.8	132.5 ± 10.9*	118.0 ± 12.8	125.7 ± 11.9*	114.4 ± 11.9	121.2 ± 10.1*
Max HR (b·min^{-1})	138.8 ± 13.8	142.0 ± 11.9	138.8 ± 13.1	142.6 ± 12.5	134.8 ± 15.0	136.5 ± 12.1	144.8 ± 14.1	153.2 ± 11.5*	136.7 ± 13.4	144.6 ± 11.6*	133.9 ± 11.9	140.9 ± 9.7*

*Significantly different between male and female recruits.

Discussion

The aim of this study was to investigate the differences in cardiovascular demands, as measured by heart rate, between female and male recruits during progressive hikes in USMC recruit training. Female recruits had significantly lower BM compared with male recruits and thus carried significantly heavier relative loads than male recruits. Previously, Orr et al. (26) found no significant differences in relative loads between female (43% BM) and male (47% BM) service members carrying 26 and 39 kg packs, respectively. Military combat loads are based upon required equipment, and there is no standard besides what is presented in the MIL-STD-1472G (8). These absolute loads do not consider individual's BM and thus increase the relative load (absolute load as a function of BM). As such, smaller stature Marines, to include male recruits and female recruits, are often required to carry higher relative loads than their larger counterparts. Orr et al. (26) postulated that if female service members were required to carry the same absolute loads as male service members, the relative loads would be greater, as demonstrated by this study. While this study focussed on the US Marine Corps, these findings are relevant across the tactical spectrum, given the occupational requirement for load carriage and the increasing numbers of female personnel (33).

The results suggest that female recruits have a greater cardiovascular demand than male recruits during load carriage events when carrying loads above 15 kg or approximately 25% BM. The same could be said for the male recruits of smaller stature, given the large range of BM in this study. For example, the lightest male recruits (~47 kg) would be carrying 42% BM in the 20 kg hike, similar to the 43.2% of the smallest female recruits (~46 kg). This additional demand occurs despite carrying the same absolute load and moving at the same speed. When attempting a maximal speed, the relative impacts of load become more apparent. Carlton et al. (6), for example, found that highly trained Australian specialist police officers, who wore loads more than 25% BM while performing a sprint and drag task, performed worse than officers who wore loads of <25% BM. Thus, while maximum loads of more than 40–50% BM are common in the literature (9,14), Kinoshita (19) recommends loads of no more than 20% BM for subjects not accustomed to load-carriage tasks due to a higher risk of stress-related injuries.

If loads of >25% BM reduce speed of movement (6), the only way to maintain a given pace or speed would therefore be to increase work output and overall effort. Thus, the lighter mass, on average, of female recruits would see them working at a higher percentage of their cardiovascular fitness, risking earlier fatigue than male recruits. This supposition is supported by the findings of Holewijn et al. (13), who reported that female personnel worked at a 22% higher intensity level (determined by $\dot{V}O_{2max}$) than their male cohorts ($p \leq 0.05$) while performing a load carriage task at various given speeds in boots and wearing a load of 12 kg in a waist pack. Further support is provided whereby, when both sexes were required to work at the same relative aerobic intensity, female personnel walked at a slower pace (−0.7 to 0.8 km·h^{-1}) (13) or were 21% slower to complete a given distance than their male counterparts (12). Moreover, it has been shown that larger female recruits generally outperform smaller stature male and female counterparts on combat tasks (18). The volume of evidence, as supported by this study, therefore suggests that when required to maintain a given task intensity, the average female recruit, in general, works harder than their male counterparts.

Apart from differences in relative load weights, female recruits generally possess a lower aerobic capacity (34) and strength (upper body > lower body) than male recruits (22). These differences are of importance in this context as load carriage performance has been shown to be highly correlated to aerobic fitness ($r = 0.709$ to 0.712) (31) and strength ($r = 0.265$ to 0.742) (29). Furthermore, research suggests that relative, as opposed to absolute, strength is of greater importance to load carriage performance with upper body relative strength in particular the most highly correlated ($r = 0.742$) (29). As such, female recruits in generally, may be carrying a heavier relative load, with a lower aerobic capacity and strength, and thus be required to work harder to complete the given load carriage task.

While loaded hikes are a leading cause of injuries in this population (16), this study, which found a significant difference in cardiovascular demand, only considered a single activity (loaded hikes). Including the rest of the training day in the analysis may wash out these differences, with administrative movements and lower-intensity activities equalising the cardiovascular demands between the sexes. Thus, in context, the additional loads sustained by female recruits during these hikes may be washed out over the entire training day. Findings from previous studies in military personnel support this hypothesis finding no differences in daily HRavg between male and female recruits completing basic training (4,30). More recently a study in the British Army (24) identified that while male recruits experienced greater external training loads as measured by distance covered, female recruits experienced greater internal training loads as measured by training impulse and spent more time in higher heart rate zones, reported more muscle soreness, and reported more fatigue. Therefore, over an entire working day, the differences imparted from the single event may be washed out. However, this is not assured and requires further study.

While gender-neutral standards are essential in military contexts, the additional strain through increased workload these individual hikes place on female recruits is noteworthy. This additional cardiovascular strain on female recruits has been proposed to contribute to both fatigue and risk of overuse injury (4). Numerous strategies have been implemented in an attempt to decrease this injury risk in female personnel given the integral role they play in any modern military (1). These strategies include separating male and female personnel into separate platoons in initial training (4) and decreasing the initial intensity of military training (30). Through these approaches, female and male recruits would cover the same program of instruction; however, the physiological intensity would be lower for female recruits when compared with male recruits (30). While lowering the intensity of initial military training may be an appropriate step, unless the duration of a training program is extended, the end-state requirement of fitness level commensurate to the occupational requirement stays the same. However, caution should be used with extending the duration of training particularly if more activity is added to the longer time frame, as injury rates have been shown to be similar when basic course lengths are increased with a concomitant increase in content (7).

In addition, separating female and male platoons may erroneously place fitter female members into training programs with inadequate physical stimulus, leading to plateauing in physical fitness, and more significantly, an increased injury risk. Thus, the concept of either a longer training period of equivalent content or ability group-based training (stratified by fitness level) may be more beneficial regardless of sex. Numerous studies have shown that it is not sex, which is the primary injury risk factor, but aerobic fitness (1–3,18,23,33). Furthermore, aerobic fitness and muscular strength, which are generally lower in female members (2,23), are both strongly associated with load carriage performance (28,29,31). The importance of strength in this population is further supported by heavy occupational tasks being a risk factor for injury (33), meaning that those who possess greater strength would be working at a lower level of their absolute capacity, and will not fatigue as quickly as those with lesser strength. Equipment design and fit may also play a role if it were designed for the female form or smaller statured individuals. A greater variety in sizing options may lead to a decrease in the absolute load carried by smaller individuals.

Given this association between elements of fitness, which are generally lower in female service members, and loaded hike performance, a greater focus on conditioning female members before enlistment would be a logical recommendation (23,33). Supporting this approach, research suggests that female personnel tend to make greater improvements in fitness in military training than male recruits due to female recruits entering training at a lower level of their true potential (2,10). Apart from strength and aerobic fitness conditioning, a greater focus on load carriage conditioning should be encouraged for the USMC context before enlistment for female personnel (16). Important contributors to load carriage ability for female personnel would therefore include load carriage conditioning, both absolute and relative strength (for the upper body resistance in particular for females) and aerobic fitness (18,27). Education on optimal pelvic floor function may likewise be valuable (27). Moving forward, these recommendations are highlighted by upcoming challenges across the tactical spectrum through population increases in levels of inactivity, obesity, and other health-related problems (37).

While the use of wrist-worn monitors is a limitation of this study, it does provide some preliminary insight into the differences in cardiovascular demand between the sexes. As the individual's fitness level, load carriage experience and body composition were not captured in this study; future research should investigate the influence of these factors on load carriage performance. While only the first 6 hikes were examined in this study due to the same training load exposure of a timed hike, future longitudinal studies, over a longer period, accounting for the individuals lactate threshold or maximal aerobic capacity might also be useful.

Practical Applications

The average female recruit carries significantly greater relative load in military training compared with the average male and consequently have a considerably greater cardiovascular demand. This is particularly evident with loads above 15 kg or 25% of their body mass. Strength and conditioning coaches need to develop strategies for conditioning female recruits with both aerobic fitness and strength, as well as load carriage-specific conditioning before initial recruit training. The amount of load an individual carries could be adjusted for relative load to ensure equal cardiovascular demands are being elicited.

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