Differences in Injuries during Road Marching among Male and Female U.S. Army Soldiers

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ABSTRACT

Introduction Road marching is an essential element of military physical training that prepares military personnel for common occupational duties. Understanding differences in road marching injury risks between sexes is imperative, with women comprising 15% of the U.S. Army population. This analysis compares road marching injuries for men and women in a large population of soldiers.

Methods Injuries occurring during the previous 12 months were collected by survey for 5,198 soldiers. Injury-related factors were compared using two-sample t-tests. Injury types and injured body regions from road marching were summarized for both men and women. The relative risk of injuries during road marching among women compared to men was calculated.

Results Among surveyed soldiers, women were shorter, had higher body fat, lower aerobic endurance, and carried a greater proportion of their body weight during road marching than men ($p<0.05$). Men reported greater physical training time, marching loads, and more tobacco use ($p<0.05$). Overall, 111 injuries occurred during road marching (n=91 men, n=20 women). Lower extremity injuries were common for both sexes, but hip injuries during road marching were significantly more prevalent among women (12 per 1,000 soldiers vs 2 per 1,000). Road marching injuries resulted in more limited duty days for women (44 ± 46 vs 36 ± 43 days).

*Conclusion*s Observed differences in injury-related factors among male and female soldiers (e.g., body fat, tobacco use, fitness, physical training, and weight carried during road marching) suggest that these factors contributed to differing distributions of injuries during road marching. Recommendations to carry less than 30% of one's body weight during road marching should be followed, especially for soldiers of smaller stature, as they are more likely to experience gait adaptations and physiologic effects that increase injury risk. Load carriage weight relative to lean body weight should be considered in future studies.

INTRODUCTION

Road marching (also referred to as foot marching, ruck marching, and load carriage) involves marching for an extended distance while carrying weight in a rucksack or military backpack. This is a common training activity in the United States (U.S.) Army and other militaries, conducted to physically condition soldiers and enhance readiness for overseas operations.[1] Carrying heavy loads up to 60 kg (132 pounds) that include equipment, weapons, ammunition, and other supplies is often required in combat situations.[2,3] Carrying loads can impair physical and cognitive task performance and leave soldiers in a fatigued state.[4-6] Therefore, road march training is important for soldiers, particularly those in combat occupations, to prepare for these situations. While this topic is especially relevant for military populations, other occupations such as firefighters and police officers also require load carriage and can benefit from the lessons learned in military studies.[5]

Road marching is one of the top three causes of injury in surveys of U.S. Army infantry soldiers,[7,8] and this activity often leads to musculoskeletal injuries among other military members as well.[1,7,9] Lower extremity stress fractures, ankle sprains, joint pain, lower back strains, brachial plexus palsy (also known as rucksack palsy), and foot blisters are all often reported to be associated with road marching, predominantly resulting from overuse.[5,7] In one population of U.S. Army infantry soldiers, road marching led to more injuries per mile of exposure than running.[7] Health behaviors have also been shown to impact injury risk among U.S. Army Soldiers, including tobacco use and regularly getting fewer hours of sleep per night.[10,11]

In addition to being a leading cause of injury, systematic reviews have reported that marching with a load significantly alters physiologic responses, such as increased flexion angles in the trunk, hip, and knee; increased hip and ankle range of motion; increased hip and knee extension moments; increased muscle activation of lower limbs and trunk;

increased forward inclination of trunk; increased ground reaction forces; and decreased stride length.[12-14] Additional effects include increased heart rate, increased cardiorespiratory demands and respiratory fatigue, reduced maximal oxygen consumption (VO_2 max), fatigue of knee extensors, increased vertical center of mass displacement, and decreased marching speed.[15-17] While some of these physiologic responses may be desired in moderation to increase physical fitness, they may also contribute to increased injury risk during road marching.

Women represented 15% of Active Duty U.S. Army soldiers in 2019.[9] Combat Arms occupations were first opened to women in 2016,[18] which introduced new injury risks for women who chose to enter these military occupational specialties. Female soldiers have historically experienced higher injury rates than men.[9,19,20] Especially when these injuries are severe, they can lead to attrition[21] and significant strategic and economic costs.[22] Therefore, understanding the differences in injuries between male and female soldiers is increasingly important,[23,24] especially for activities such as road marching that are frequently associated with injuries. Previous studies of road marching injuries among military members have primarily reported on men and have not focused on women.[25]

The purpose of this analysis was to compare road marching injury details and factors that impact road marching injury risk by sex in a large population of U.S. Army soldiers.

METHODS

This paper presents a secondary analysis of a larger retrospective cohort study investigating physical training programs, fitness, and injuries. An electronic survey was administered to 28,482 U.S. Army soldiers using the Verint Enterprise Feedback Management© system from October 2018-April 2019. The following data were collected for the previous 12 months: demographics, performance on the most recent Army Physical Fitness Test (APFT), activities related to unit and personal physical training (PT), road marching participation, health behaviors like tobacco use and sleep hygiene, injuries, and injury details including resulting days of limited duty (impaired ability to participate in training and job tasks due to injury). The project was reviewed and approved as public health practice by the Public Health Review Board of the authors' institution.

Injury was defined on the survey as "a physical injury caused either by a single incident or accident or by overuse of a body area that resulted in physical damage to the body and limited physical abilities." Respondents were asked to provide details about their two most physically limiting injuries in the 12 months prior to survey administration, including injured body area, type of injury, and activity associated with each injury. An injury was considered a road marching injury if the Soldier identified the activity associated with the injury as road marching. Details about injuries resulting from other activities were also collected, but road marching injuries were specifically of interest for this analysis due to the unprecedented capture of female-reported road marching injuries. Unfortunately medical records do not always reliably capture details about injury activities and mechanisms,[26] so self-reported details are necessary to explore specific injury causes. Previous investigations have relied on self-reported injury causes to investigate weight training injuries,[27] fall related injuries,[28] and road marching injuries of high, moderate, and low road marching mileage.[7]

SAS© v.9.4 was used for all statistical analyses. Descriptive statistics, including frequencies, means, and standard deviations were calculated for demographics and activities associated with injuries. Two-sample t-tests and chi-square tests were used to compare demographic, physical characteristics, road marching exposure, and health behavior variables for men and women. Injury rates and relative risks (RRs) of injury were calculated for men and women. Statistical significance was identified by $p<0.05$. Body fat and lean body mass were calculated using self-reported height, weight, sex, and age.[29] Incidence rates were calculated based on self-reported injuries and road marching participation, which were then used to calculate relative risks by sex with 95% CIs. Responses to survey questions about road marching participation during unit and personal physical training (average monthly frequency, average distance per session, and average weight carried per session) were used to calculate additional road marching exposure variables (average percent body weight carried, lean body mass carried, and average pound-miles per month). For consistency, all road marching load weights are reported in pounds. Duplicate survey responses were excluded.

RESULTS

A total of 5,198 respondents completed surveys, accounting for 18% of the surveyed population. Eighty two percent of respondents were men, with an average age of 29 (±8) years. Respondent demographics were similar to the overall Army population.[30] A diverse population of military occupational specialties were represented with the most common specialties being medical (17%), repair and maintenance (14%), and military intelligence (10%).

More than one-third of respondents (42%) reported a total of 3,129 injuries during the previous 12 months, for a reported injury rate of 600 injuries per 1,000 soldiers. Closely following the distribution of respondents, 79% of reported injuries were among men. Over half of survey respondents (59%, n=3,069) reported participating in road marching for unit and/or personal physical training (n=2,641 men,

62%; n=429 women, 45%). Overall, 4% of the first- and second-most physically limiting injuries were reported to be associated with road marching (n=111), representing 4% of all injuries among men (n=91) and 3% of all injuries among women (n=20).

Table 1 compares demographics, physical characteristics, health behaviors, and road marching characteristics among survey respondents by sex. Statistically significant differences between sexes ($p<0.05$) were observed for all characteristics except age, hours slept per night, and distance marched per road marching session. On average, women were shorter, had higher body fat, had lower aerobic performance, and carried a greater proportion of their weight during road marching (total body weight and lean body mass). Men reported higher overall physical training (minutes of unit and personal physical training per week), higher road marching loads (pound-miles per month), and a higher proportion of tobacco use.

Table 2 summarizes the road marching injury types and injured body regions. Many injury types and body region categories consisted of low injury counts, therefore reporting is limited to categories containing three or more injuries with associated limited duty days. Lower extremity injuries were frequently associated with limited duty among both

Table 1. Demographics, physical characteristics, health behaviors, and road marching characteristics among surveyed soldiers by sex

Variables		Male n=4,238 survey respondents	Female n=960 survey respondents	Statistical differences, males vs. females (Independent t-test and chi-square)
Demographics and physical characteristics	Age (years)	28.8 ± 7.9	28.3 ± 7.3	p=0.06
	Height (inches)	70.1 ± 3.2	64.9 ± 3.3	p<0.0001
	Weight (pounds)	184.1 ± 27.6	146.8 ± 21.3	p<0.0001
	BMI[a] (kg/m2)	26.4 ± 3.5	24.5 ± 3.1	p<0.0001
	Body Fat[b] (%)	20.8 ± 4.4	31.9 ± 4.2	p<0.0001
	Lean body mass[b] (pounds)	144.8 ± 16.0	99.2 ± 10.0	p<0.0001
	Aerobic fitness (U.S. Army Physical Fitness Test two-mile run time, minutes)	15.1 ± 1.5 n=3,750	17.4 ± 1.7 n=811	p<0.0001
Health behaviors	Physical training load (total unit and personal PT minutes per week)	640.4 ± 500.9 n=4,110	537.4 ± 442.1 n=899	p<0.0001
	Ever used tobacco[α] (%)	42.2	21.6	p<0.0001
	Current tobacco users[c] (%)	8.1	3.9	p<0.0001
	Average sleep (hours per night)	6.1 ± 1.3	6.1 ± 1.4	p=0.19
Road marching characteristics[d], (only respondents who reported road marching participation; n=2,641 men, n=428 women)	Road march frequency (sessions per month)	3.0 ± 2.5	2.7 ± 2.4	p=0.02
	Average distance marched (miles per session)	6.7 ± 4.3	6.5 ± 4.2	p=0.37
	Average weight carried (pounds per session)	39.3 ± 9.4	34.2 ± 8.6	p<0.0001
	Proportion body weight carried (%)	21.9 ± 6.2	24.1 ± 6.4	p<0.0001
	Proportion lean body mass carried (%)	27.5 ± 7.1	35.2 ± 8.9	p<0.0001
	Monthly road marching load[e] (pound-miles)	886.5 ± 1351.9	693.0 ± 1128.7	p=0.003

[a]BMI calculated from self-reported height and weight

[b]Body fat percentage (and subsequently lean body mass) calculated using self-reported height, weight, age, and sex[29]

[c]Current and lifetime tobacco use includes cigarettes, smokeless tobacco, and e-cigarettes

[d]Reported road marching participation variables combine responses for unit physical training and personal physical training

[e]Road marching load calculated by multiplying self-reported marching frequency per month, average marching distance per session, and average weight carried.

Table 2. Leading injury types and injured body regions associated with road marching by sex (n= 111 injuries)

Male (91 injuries)				Female (20 injuries)			
Injury Types							
Injury Type	**n (% of all injuries)**	**n (% of injury type with Limited Duty)***	**Average Limited Duty Days**	**Body region**	**n (% of all injuries)**	**n (% of injury type with Limited Duty)***	**Average Limited Duty Days**
Pain	18 (19%)	4 (18%)	26 days	Strained muscle	4 (20%)	3 (75%)	70 days
Sprained joint	14 (17%)	8 (60%)	26 days				
Strained muscle	14 (15%)	8 (54%)	23 days				
Tendonitis	5 (6%)	4 (80%)	51 days				
Total	91 (100%)	52 (57%)	36 days (±43)	Total	20	10 (50%)	44 days (±46)
Injured Body Regions							
Body Region	**n (% of all injuries)**	**n (% of injuries to body region with Limited Duty)***	**Average Limited Duty Days**	**Body region**	**n (% of all injuries)**	**n (% of injuries to body region with Limited Duty)***	**Average Limited Duty Days**
Knee	20 (22%)	10 (50%)	49 days	Hip	5 (25%)	4 (80%)	64 days
Lower back	18 (20%)	9 (50%)	19 days	Knee	3 (15%)	3 (100%)	42 days
Ankle	17 (19%)	12 (71%)	41 days				
Lower leg	7 (8%)	5 (71%)	33 days				
Hip	5 (5%)	3 (60%)	20 days				
Upper back	5 (5%)	3 (60%)	24 days				
Total	91	52 (57%)	36 days (±43)	Total	20	10 (50%)	44 days (±46)
Combined Injury Type and Injured Body Regions							
Injury Type and Body Region	**n (%)**	**n (% with Limited Duty)***	**Average Limited Duty Days**	**Injury type and body region**	**n (%)**	**n (% with Limited Duty)[a]**	**Average Limited Duty Days**
Sprained ankle	8 (9%)	4 (50%)	22 days	[b]			
Strained lower back	5 (5%)	4 (80%)	13 days				
Runners' knee	5 (5%)	3 (60%)	23 days				
Total	91	52 (57%)	36 days (±43)	Total	20	10 (50%)	44 days (±46)

[a]Data reported if ≥3 injuries with Limited Duty were reported

[b]All injury type/injured body region combinations had <3 injuries with Limited Duty

Table 3. Rates of injury types and injured body regions associated with road marching by sex (n= 111 injuries)

	Male			Female			Relative risk of road marching injury Female : Male (95% CI)
	Number of Injuries	Number of Road marching participants	Rate of Injuries per 1,000 soldiers	Number of Injuries	Number of Road marching participants	Rate of Injuries per 1,000 soldiers	
Any road marching injury	91	2,677	34	20	441	45	1.33 (0.82-2.17)
Any road marching injury with limited duty	52	2,677	19	10	441	23	1.17 (0.59-2.30)
By Injury Type[a]							
Strained muscle	14	2,677	5	4	441	9	1.73 (0.57-5.27)
By Injured Body Region[a]							
Hip	5	2,677	2	5	441	11	6.07 (1.76-20.97)[b]
Knee	20	2,677	7	3	441	7	0.91 (0.27-3.06)

[a]Only injury types and body regions shown for women in Table 2 were included

[b]Statistically significant difference (p<0.05)

sexes, and back injuries were also associated with limited duty for men. Overall, when road marching injuries resulted in limited duty, the average number of limited duty days were 36 days for men and 44 days for women. Hip injuries were more prevalent among women (25% of reported road marching injuries) than men (5%), and hip injuries among women also resulted in more days of limited duty on average (64 days) than those among men (20 days). When injury types and injured body regions were combined, there were no categories with ≥3 injuries with limited duty for women, but sprains and strains of the lower extremities were most frequently associated with limited-duty road marching injuries for men. The leading reported mechanism of road marching injuries was "overuse or repetitive activity" for both sexes (65% of injuries among men, 70% for women; data not shown).

Table 3 compares rates of road marching injuries by sex, among respondents who reported participating in road marching. The rate of hip injuries during road marching among women was six times higher than the rate of hip injuries among men. Rates of all road marching injuries, road marching injuries resulting in limited duty, and strained muscles were also higher among women, though observed differences between sexes did not reach statistical significance due to low counts among women. Rates of other injury types and injured body regions did not occur frequently enough among both sexes in this population to be compared.

DISCUSSION

Road marching injuries among female U.S. Army Soldiers have not previously been explored in depth in non-deployment settings, as causes of injury are often difficult to capture and there are fewer females in infantry units that are exposed to greater miles of road march training. The purpose of this study was to provide a novel exploration of U.S. Army road marching injuries among females, and compare road marching injuries experienced by females to those experienced by men.

Four percent of injuries in this population were attributed to road marching, which is comparable to the proportion of road marching injuries in other U.S. Army populations,[31,32] though more road marching injuries have been observed in infantry Soldiers.[7,8] The results indicate differing distributions of injuries resulting from road marching among men and women (Table 2). Numerous factors can contribute to military injury risk, including demographics, physical characteristics, health behaviors, and physical training.[33] These factors have also been shown to specifically impact risks for road marching injuries, along with road marching training factors such as frequency of road marching training, average distance marched, weight carried during marching, monthly pound-miles (combined frequency, distance, and weight carried), and the proportion of body weight worn while marching.[7,34] When comparing factors associated with road marching injuries in this population, statistically significant differences between sexes were observed for most factors (Table 1; e.g., height, body fat, tobacco use, physical training, marching load, proportion of body weight and lean body mass carried). Differences between men and women were expected for demographic and characteristic variables

due to physiological differences, and previous studies have reported sex differences in physical training time[35] and road marching mileage.[36]

For both sexes, road marching injuries predominantly affected the lower extremities and back in this population (Table 2). These results are consistent with the injured body regions found in a previous investigation of marching injuries among Australian military members of both sexes.[37] The current analysis also showed that road marching injuries were more severe for women, resulting in more limited duty days on average than men. There was a significantly higher rate of hip injuries among women in this population, compared to men (Table 3); higher rates of hip injuries among female U.S. Army soldiers have previously been observed,[38] though not specifically for road marching injuries. Anatomical factors may partially explain differences in the distribution of injuries between sexes, especially the greater incidence of hip injuries among women observed in the current investigation. Women often have a wider pelvic breadth than men, which results in a greater quadriceps angle ("Q-angle") and angular tilt on the hips and knees, leading to subsequent additional stress on the bones of the lower extremities.[39] In one study, females also showed greater peak hip abduction angles than men in both unloaded and loaded marching conditions.[40] Especially when movements are repeated while bearing a load, these additional stresses can lead to greater risks for lower extremity injuries.

Physiological factors, metabolism, body composition, bone density, and cardiorespiratory fitness can all contribute to differences in injury risk between male and female soldiers.[41] Female soldiers often exhibit greater flexibility and balance compared to men, whereas men have greater strength, power, and aerobic capacity.[42] Since greater strength and power have been significantly associated with better performance on high intensity tasks like load carriage,[43] men may be at a greater physiologic advantage for road marching tasks than women, on average. These trends may lead to lower road marching injury incidence among men compared to women, as was observed in the current study (Tables 2 and 3). However, it has repeatedly been demonstrated that there is minimal increase to overall injury risk based on sex alone.[23,44] Rather, lower fitness is a more significant risk factor for injury; in fact, when male and female soldiers have the same fitness level, their injury risk is approximately the same.[23,45] Similar effects have been observed for military road marching performance, with aerobic fitness and body composition having a more significant impact on load carriage tasks than sex.[46]

Physical stature also affects injury risk, especially for lower extremity injuries during road marching.[25] Soldiers of smaller stature and lower muscle strength may bear a greater relative load during road marching than larger soldiers, which could lead to increased joint loading and decreased ability to adapt gait biomechanics.[19,25] As height and leg length are correlated with stride length and cadence, shorter soldiers may need to increase stride length and marching speed beyond a comfortable pace in order to remain "in step" with taller soldiers. This "over-striding" may increase mechanical stress on the lower extremities and subsequently lead to injury.[19,25,39] Given that women are often shorter and smaller in stature than men,[19] increased lower extremity injury risks for people with smaller stature impact female soldiers more than male soldiers.

Several studies have shown that mechanical and kinematic sex differences are negligible during load carriage.[15,47] Women who are taller, heavier, stronger and have greater aerobic fitness have better load carriage performance than smaller and less fit women.[19] A 22.7 kg load only increased strain and stress fracture risk in women under 163.5 cm (5 feet, 4 inches)[48] and higher load increased hip joint reaction forces most among women shorter than 159 cm (4 feet, 11 inches).[49] This evidence suggests that individual injury risks are associated with attributes like height, body size, and fitness, rather than with sex.

Road Marching Injury Prevention

Recommendations to prevent injuries during road marching often focus on balancing marching frequency, distance, speed, and load weight to improve fitness and endurance and minimize injury risk.[1,5,7] Progressive loading is recommended in road marching training, to gradually increase endurance while minimizing injury risk.[1] Specific guidance for soldiers to alternate incremental increases in load weight, marching distance, and marching speed is provided by Army regulation.[50] Likewise, balancing road marching activities with other physical training can help reduce overuse and overexertion, as well as program-induced cumulative overload.[1,4] Gradually progressing road marching training has been shown to improve soldiers' road marching performance and overall fitness. A recent literature review reported mixed effectiveness of physical training programs, but concluded that a combination of strength and aerobic training had the greatest impact on improving load carriage performance while minimizing injury risk.[51] These training recommendations do not differ by sex.

In this study, the average Soldier carried between 22% (men) and 24% (women) of their body weight. Especially when higher proportions are carried, modifying marching loads based on body weight has been recommended to prevent injuries.[1,34] This practice encourages individuals, even those in the same unit, to carry personalized loads. Previous studies have found increased injury risk when the road marching load carried was heavier than a particular proportion of body weight. One study found increased injury risk when carrying >25% of body weight[7]; another observed increased injury risk at 21% of body weight[52]; and a third study reported increased instability at 30-40%

of body weight.[53] All of these results approximately correspond with U.S. Army regulations instructing that loads remain smaller than 30% of soldiers' body weight to minimize overexertion and reduce injuries.[50] These recommendations are for situations such as training when load reduction is possible, however, load reduction may not always be practical in operational scenarios; when weapons technology equipment and body armor are required, some military members may carry over 100 pounds.[54]

The current study also considered the proportion of estimated lean body mass carried during road marching, which highlighted even greater differences between sexes (Table 1; women carried 24% of their body weight and 35% of lean body mass on average, compared to 22% of body weight and 28% of lean body mass for men). While it has been established that greater lean body mass contributes to better road marching performance,[55] the proportion of lean body mass carried during road marching has only been assessed as a potential factor contributing to injury risk in one previous study,[56] and most previous studies and recommendations have focused on the proportion of overall bodyweight carried.

Finally, the way a load is carried can impact injury risk. Loads carried close to the center of gravity are recommended, using a double pack to distribute the weight between both front and back to lower energy expenditure and reduce biomechanical alterations.[12] To specifically improve load carriage functionality for women, and potentially address some of the increased injury risk observed among women in this population, modifications to equipment have been recommended to better fit the female body (e.g., adjustable ruck sack straps and body armor to accommodate a variety of breast sizes).[19]

Strengths and Limitations

This is the first known comparison of injuries during road marching in a large population of non-deployed U.S. Army soldiers that included both men and women, offering a unique look at differences in marching injuries and potential associated factors between sexes.

However, there are some limitations to note. Self-reported injury information is necessary to identify injuries occurring during road marching, as medical encounter records do not often document the precipitating activity associated with injury,[26] but this requires survey respondents to remember and report injury details. In spite of potential recall bias, a validation study of military injury survey reporting found that survey respondents accurately reported injury details 75% of the time, providing confidence in the use of surveys for investigations that require more detailed information than medical records can provide.[57]

Additional considerations like occupation, previous road marching exposure, previous injury, road marching experience, marching gradient and terrain, and weather conditions also impact energy expenditure and injury risk during road marching.[1,12,14] Though these factors were not assessed in this study, they can impact road marching injury risk and should be considered in future investigations if possible.

While this study reported sex differences in road marching injuries that have not often been quantifiable in past studies, unfortunately the number of female road marching participants was relatively small. This impacted statistical comparisons between sexes (e.g., large 95% CI ranges) and limited the ability to explore multivariable logistic regression risk factor analyses. Future work should include a greater number of female road marching participants, if possible, so more comprehensive risk factor analyses can be conducted for both sexes.

CONCLUSIONS

In this population of U.S. Army soldiers, men and women had a different distribution of injuries associated with road marching. Women experienced more limited duty related to road marching injuries than men and experienced a higher prevalence of hip injuries. Differences in injury-related factors among surveyed soldiers like height, body fat, tobacco use, fitness, physical training, and weight carried during road marching contributed to differences in road marching injuries, as also suggested by literature. Guidance to carry marching loads that are less than 30% of body weight should continue to be followed on an individual basis, especially for soldiers of smaller stature, as they are more likely to experience gait adaptations and physiologic effects that increase risk of lower extremity injuries. Future studies should investigate injury risk factors for each sex and explore recommendations for load weights based on lean body mass.

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