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Physiological Factors of Expanded Roles for Military Women

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Perspective

Commander's Introduction

MG Steve Jones

Women in Combat

The contributions and sacrifices made by women have challenged many long-standing assumptions about their roles in battle as well as the efficacy of the rules meant to keep them from serving in combat units.

GEN Robert W. Cone[1]

Women have been part of the Army since 1775, serving with skill, determination, and valor. In Army Medicine they have played a critical role maintaining the health readiness of the force and caring for the injured and ill. The Army began expanding the role of women 40 years ago, allowing them to train and fight alongside men as members of the profession of arms. During the campaigns in Afghanistan and Iraq they have done their share of fighting and dying. On June 23, 2005, three women Marines were killed when their convoy was attacked by a suicide bomber outside Fallujah. Of the 13 Marines wounded in that attack, 11 were women.[2] This incident represented the largest loss of women in uniform since World War II. On June 16, 2005, SGT Leigh Ann Hester of Nashville, Tennessee was awarded the Silver Star in a ceremony at Camp Liberty, Iraq. An MP in the 617th MP Company of the Kentucky National Guard, she fought back fiercely when her convoy was ambushed. During the fight, Hester's squad moved to the side of the road, flanking the insurgents and cutting off their escape. She led her team through the kill zone and into their position where she assaulted a trench line with grenades and an M203 grenade-launcher. She and her squad leader cleared 2 trenches and when the fight was over, 27 insurgents were dead, 6 were wounded, and one was captured.[3] PFC Monica Brown, a combat medic from the 82nd Airborne Division's 782nd Brigade Support Battalion, 4th Brigade Combat Team, was on a routine security patrol along in Afghanistan's Paktika province when insurgents attacked her convoy in April 2007. Brown and her platoon sergeant exited their vehicle and ran several hundred meters under heavy fire to a burning Humvee. She provided aid to her fellow Soldiers under heavy fire, protecting them with her body while rounds were missing her by inches. Brown was the second woman awarded the Silver Star since World War II.[4] CPT Jennifer Moreno, an Army nurse, volunteered to serve on the Cultural Support Team of a Joint Special Operations Task Force in Afghanistan. During combat operations in Kandahar Province on October 5, 2013, she joined a team from the 3rd Battalion, 75th Ranger Regiment as they assaulted a remote compound occupied by enemy insurgents. During the assault, the enemy triggered multiple suicide and improvised explosive devices, wounding several Rangers. Fully understanding the risk, CPT Moreno ran through an area seeded with explosive devices to render aid to the casualties and assist with evacuation. While moving toward a wounded soldier, she triggered a device and was killed in action. CPT Moreno was awarded the Bronze Star Medal posthumously for her valor.[5]

Throughout our history, women have proven there are few limits to the contributions they are capable of making on the battlefield. It is time to allow them to serve in any unit or position for which they qualified, and the Army is working to remove as many barriers as possible. In 2012, the Army initiated Soldier 2020, a deliberate, service-wide effort to staff its units with the best qualified soldiers. The initiative is based on 3 principals: maintain the dominance of our nation's warfighting forces by preserving unit readiness, cohesion, and morale; validate both physical and mental occupational performance standards for all military occupational specialties; and set the conditions so all Soldiers, men or women, have an opportunity to succeed as their talents allow. The US Army Training and Doctrine Command began the process by studying attitudes of women in combat units. They found that most men who had worked and fought beside women expected them to perform well in combat roles; it is those with little or no experience serving beside women who require more convincing that women will perform well. There was agreement across the force that we not lower the standards for service in combat roles, and that women, based on their wartime performance, have earned the opportunity to stand in any of our formations for which they qualify, if they wish to do so. In just over 2 years, Soldier 2020 has opened 6 previously closed military occupational specialties and over 55,000 positions across all

Army components. Among the newly opened positions are 1,562 in the US Army Special Operations Command, including the 160th Special Operations Aviation Regiment. The Army is proceeding in an incremental, scientifically based approach, validating gender neutral physical standards and conducting a gender integration study to inform decisions on opening the remaining 14 military occupational specialties currently closed to women. The AMEDD is playing a major role in the process. Upon completion of the study, the Army will recommend to the Secretary of Defense the opening of as many as 166,000 positions in the Active and Reserve Components to women while preserving readiness, unit cohesion, discipline, and morale.[1,6]

Having served shoulder to shoulder with women during operations in Afghanistan and Iraq, I have seen firsthand their ability to perform on the battlefield. Soldier 2020 is setting the conditions for them to succeed in their new roles while strengthening the force.

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The Role of Strength and Power During Performance of High Intensity Military Tasks Under Heavy Load Carriage

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Abstract

Objective: Previous research has investigated the physiological determinants of heavy load carriage while performing medium to long distance road marching, yet research examining the physiological underpinnings of high-intensity battlefield tasks is limited. This study sought to examine the role of strength and power during high-intensity combat tasks under heavy load carriage.

Methods: Eighteen recreationally trained men (mean±SD: age, 21±2 years; height, 172±6 cm; weight, 80±13 kg) participated in this study and performed an anaerobic combat course under 2 randomized experimental conditions; unloaded and loaded. Subjects performed 3 trials under each condition on separate days, with a 5-minute rest between each trial. In the unloaded trial, subjects wore a uniform with boots weighing approximately 3.2 kg. During the loaded trial, in addition to the uniform and boots, subjects wore Interceptor body armor (6.94 kg-9.10 kg) and a MOLLE rucksack weighing 30 kg. The course consisted of 3 consecutive tasks, which began from the prone position, led into a 30 m sprint, followed by a 27 m zigzag run, and ended with a 10 m casualty drag weighing approximately 79.4 kg.

Results: Pearson correlations showed significant ($P \leq .05$) strong correlations between lower body strength (r=-0.63, -0.62), lower body power (r=-0.67, -0.67) and upper body strength (r=-0.60, -0.62) and overall performance times in the unloaded and loaded condition, respectively.

Conclusion: Strength and power are strongly related to high-intensity military tasks with and without heavy load carriage.

Throughout history, load carriage has been shown to be an essential aspect of soldiering during military operations. During training and on the battlefield, Warfighters are required to carry various loads on their person or in a pack while engaging in demanding activities, ranging from long distance marching to short explosive sprints. The speed with which the soldier is able to maneuver on an objective carrying these loads, while performing strenuous activities, is critical to the completion of missions and survivability of personnel.

Knapik et al[1] characterized the various loads that were carried by different Soldiers throughout history, from the Greek Hoplites to the US infantryman in Afghanistan during Operation Enduring Freedom, showing an increase in loads carried into battle. Load carriage has been shown to increase physiological strain, leading to excessive fatigue and attenuating combat effectiveness.[2-4] Much of the increase in load can be attributed to technological advances in weaponry and armor, which aim to improve the combat effectiveness and survivability of the Soldier, but have negative implications on mobility and endurance due to the increase in weight.[3,4] With the increase in weight resulting in a greater performance decrement, several studies have investigated approaches to optimal training programs designed to improve the load carriage capabilities of the Warfighter.[5-7]

The majority of the current research on military load carriage has examined the physiological determinants, the effects of various loads, and the training required to improve the speed of load carriage over medium to long distances, ranging from 2.5 km to 25 km.[8-10] While medium to long distance marching with various loads may be required on the battlefield and during training, it is merely a single component of the multifaceted occupational demands Warfighters face today. The emphasis on medium to long distance load carriage reflects the tactics of past wars where Soldiers would march long distances, over several days, carrying their supplies into battle. However, combat operations have evolved from marching into battle to primarily conducting direct action raids. During raids, troops are transported near or directly onto an objective and must quickly traverse the objective, performing anaerobic tasks such as sprinting, lifting, pulling, crawling, and climbing, while still carrying significant loads.

With the landscape of the modern battlefield becoming primarily anaerobic, more studies examining the demands of this "anaerobic battlefield"[11] are necessary, so that Soldiers can train optimally to meet these demands. There is limited research investigating the physiological underpinnings and effects of heavy load carriage during the performance of short duration, high-intensity anaerobic tasks, which more closely reflect the demands of the current battlefield. Treloar et al[4] examined the overall effect of a combat load (21.8 kg) during five 30 m rushes, and identified lower body power as having a strong relationship with unloaded and loaded sprint time ($r=-0.80$, $P \leq .01$), however no strength measures were examined in this investigation. Pandorf et al[12] examined the correlates of load carriage during the performance of a military obstacle course, yet no upper or lower body strength and power variables were assessed. Therefore the purpose of this investigation was to clarify the relationship between upper and lower body strength and lower body power and short duration, high-intensity military relevant tasks, while carrying heavy loads.

Table 1. Overall Subject Characteristics.

Subject Number	Height (cm)	Weight (kg)	Age (yr)
1	178	86.1	22
2	168	81.1	21
3	173.5	58.9	21
4	162	61.4	22
5	173	78	19
6	165	66.6	21
7	179.5	80	22
8	169.5	98.8	21
9	176.2	104.9	30
10	173.5	84.7	24
11	162	69.7	20
12	187	103.6	23
13	173.5	88.6	22
14	177	72.1	21
15	177	74.9	20
16	175	78.3	20
17	167	77.9	21
18	176	86.4	22
Mean±SD	172.9±6.4	80.7±13	21.8±2.4

Methods

Experimental Approach to the Problem

To examine the role of strength and power in high-intensity military tasks under heavy load carriage, lower body and upper body strength were measured using a one repetition maximum (1RM) squat and bench press protocol, and lower body power was assessed using countermovement jumps as measured by a force plate, using previously described methods.[13] Three military relevant tasks (30 m sprint, 27 m zigzag run, 10 m casualty drag) were used to simulate explosive offensive and defensive maneuvers routinely encountered on the battlefield.[4,12] During the performance of the tasks, subjects wore an Army combat uniform, boots, Interceptor body armor (IBA), and a Modular Lightweight Load-carrying Equipment (MOLLE) rucksack, resulting in a total weight of approximately 42 kg (body size dependent), which is representative of the typical load carried by US Army Soldiers during recent combat operations.[14]

Subjects

Eighteen recreationally active men (age: 21.8±2.4 years, height: 172.9±6.4 cm, weight: 80.7±13 kg) participated in this study. The physical characteristics of the subjects are presented in Table 1. To reduce variance caused by differences in age, and to be able to generalize our findings to an average military population, subjects recruited for this study were men between the ages of 18 and 35. Also, since most active combat units physically train at least 3 times a week to maintain a level of fitness and combat readiness,[15] subjects in this study were recreationally trained men who exercised at least 3 times a week for 60 minutes each day. Twelve subjects were from the Army Reserve Officer Training Corps (ROTC) unit from the university population, and 6 subjects were civilian students from the university population. Subjects were required to complete a medical questionnaire and were screened by a physician for any orthopedic, cardiovascular, or other medical problems that may have prevented a subject from safely completing the study or may have confounded the results of this investigation. Participants were briefed on the risks and benefits of the investigation and afterwards completed a written informed consent form to participate in the study. This investigation was approved by the local university Institutional Review Board for use of human subjects.

Procedures

To minimize learning effects related to the unfamiliarity of the different protocols in the study, participants underwent a familiarization session prior to any data collection, which exposed the subjects to the experimental conditions of the performance testing protocol, the Army Physical Fitness Test (APFT) protocol, and the military course protocol. In addition, anthropometric measurements were collected, and subjects were familiarized with a standardized dynamic warmup protocol that would be used before all experimental visits. The standardized warmup consisted of 5 minutes on a cycle ergometer at a resistance level of 5, with a speed maintained under 60 rpm, followed by dynamic stretches, including forward and lateral lunges, knee hugs, quadriceps stretches, straight leg marches, and body weight

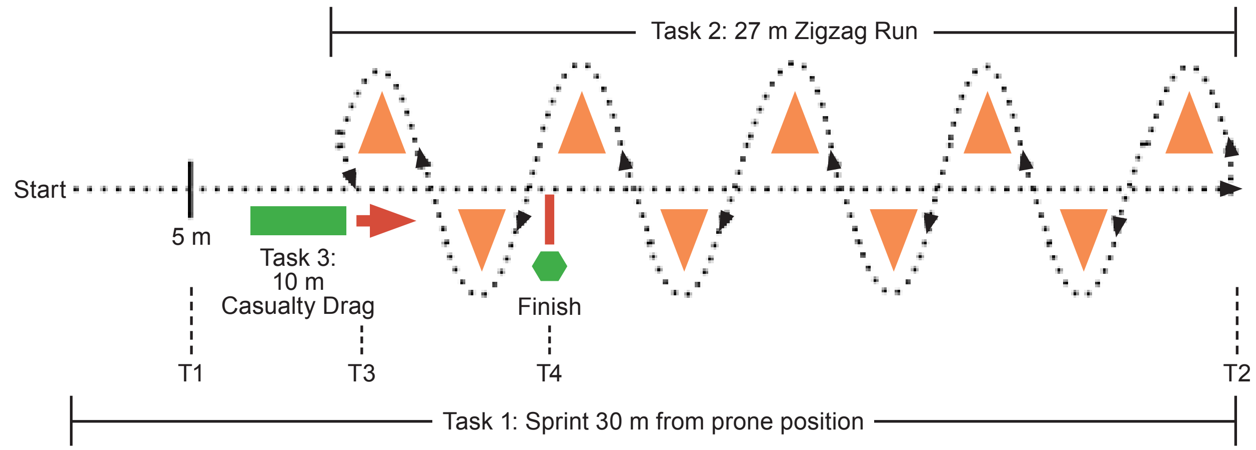

Figure 1. Military course design. Time check points are represented by T1, T2, T3, and T4.

squats.[16] Furthermore, to reduce any discomfort related to the military load, subjects were fitted for the IBA and MOLLE rucksack and also were instructed on proper wear technique.

Performance Testing Protocol

Following the familiarization session, participants completed a countermovement jump protocol, a 1 repetition maximum (1RM) squat protocol and a 1RM bench press protocol in the same visit. After performing the standardized warmup, countermovement vertical jump power was assessed using a force plate (Fitness Technology, Skye, South Australia) and Ballistic Measurement System software (http://ballistic-measurement-system.software.informer.com/2.0/). Lower body power and 1RM strength were assessed using previously described methods.[13] For the countermovement jump, subjects were asked to perform 3 consecutive maximal jumps with their hands on their hips. Participants performed 2 sets of the countermovement jumps, with at least 2 minutes of rest between sets. Peak power for each set was recorded. Subsequently, after the countermovement jump testing and a 5 minute rest, lower body strength was assessed by a 1RM squat protocol using a Smith machine, and upper body strength was assessed with the use of a 1RM free-weight (barbell) bench press protocol. For each 1RM test, subjects performed 8-10 repetitions at approximately 50% of estimated 1RM, followed by another set of 3-5 repetitions at 85% of 1RM. Up to 4 maximal trials separated by 2-3 minutes of rest were used to determine individual 1RMs for the squat and bench press exercise.[13]

Army Physical Fitness Testing

Following the performance testing protocol, civilian subjects were given at least 24 hours of rest before performing the APFT. After completing the standardized warmup, subjects performed the APFT, which consists of 2 minutes of maximal push-ups, 2 minutes of maximal sit-ups, and a timed 2-mile run, following guidelines outlined in *Army Field Manual 7-22*.[15] A rest of 5-10 minutes was allotted between each test. The ROTC cadets in this study performed the APFT with the ROTC cadre one week prior to participation in this study, following the same testing guidelines. The APFT scores were used from this testing session and were deemed reliable, since the test was administered by qualified and experienced Army personnel familiar with the testing procedures outlined in *Field Manual 7-22*.[15]

Military Course Protocol

To control for any extraneous variables in the participant's diet and activity, subjects were asked to record their diet and activity for 48 hours prior to their first performance of the military course. Participants were encouraged to continue their normal exercise routines, but were asked to refrain from strenuous exercise during the 48 hours prior to the first visit. Following a minimum of 48 hours of rest, subjects completed their first visit in random order, which was performed in either the unloaded (combat uniform and boots [approximately 3.2 kg]) or loaded condition (combat uniform, boots, IBA [6.9 kg, 8.1 kg, or 9.1 kg depending on body size], and MOLLE rucksack [30 kg]; total weight of approximately 42 kg). The final visit was completed after another 48 hours of rest, with subjects replicating their diet and activity logs during the 48 hours prior to their final performance of the military course, ensuring that subjects would be in a similar physiological state during both visits.

For each visit, after performing a standardized warmup, subjects were reminded of the test protocols for the military course. The military course, illustrated in Figure 1, consisted of 3 consecutive military relevant tasks and began from the prone position, leading into a 30 m sprint, followed by a 27 m zigzag run, and concluding with a 10 m, 79.5 kg casualty drag, which is the approximate weight of a US infantryman with a combat load.[14] Timing for the course began with the first upward movement from the prone position, and finished when the end of the casualty drag apparatus passed the 10 m mark. Times were hand-recorded by the same timer using a stopwatch (Thermo Fisher Scientific, Waltham, MA). Three trials were performed to increase the reliability of recorded performance times,[12] and a 5-minute rest between each trial ensured adequate recovery. Subjects also performed both of the military course visits during the same time of day, reducing the influence of diurnal hormone variations. All of the military task visits were conducted in the evening, since the majority of direct action raids and combat operations take place during this time. Lastly, to reduce tester induced variability, the same tester recorded the timing of the military course for each subject for both visits.

Statistical Analysis

It was determined that a sample size of 18 would be sufficient to defend the 0.05 alpha level of significance with a Cohen probability of 0.80 or more for each dependent variable (nQuery Advisor software, Statistical Solutions, Saugus, MA). Subjects were separated into 2 different groups, shown in Table 2, based on their primary modality of training for the past year (resistance-trained [RT] and traditional Army-trained [AT]). A 2 (traditional Army-trained vs strength-trained) by 2 (loaded trial vs unloaded trial) by 5 (total time, 5m time, 30 m time, agility time, casualty drag time) mixed methods analysis of variance (ANOVA) was used to detect significant mean differences (SPSS Version 21, IBM Corp, Armonk, NY). When significant differences were observed, a Fisher's least significant difference post-hoc analysis was used to make pairwise comparisons. A Pearson product moment correlation was used to determine the relationship between potential anthropometric and performance predictors and military task performance. We also used independent *t*-tests to compare mean values for these potential predictors in the 2 groups. All values are presented as means and standard deviations, and significance was set at $P \leq .05$.

Table 2. Subject Characteristics for RT and AT Groups.

RT			AT		
Age (yr)	Height (cm)	Weight (kg)	Age (yr)	Height (cm)	Weight (kg)
22	178	86.1	21	168	81.1
22	179.5	80	21	173.5	58.9
21	169.5	98.8	22	162	61.4
30	176.25	104.9	21	165	66.6
24	173.5	84.7	20	162	69.7
23	187	103.6	20	177	74.9
22	173.5	88.6	20	175	78.3
21	167	77.9	21	177	72.1
22	176	86.4			
19	173	78			
22.6±2.9	175.3±5.6	*88.9±10.1	20.8±0.7	169.9±6.5	*70.4±7.8

NOTE: Bottom row presents mean±SD (*Indicates significant difference).
RT indicates resistance-trained.
AT indicates Army-trained.

Results

Differences Between Unloaded and Loaded Times

The means and standard deviations of the unloaded military course time and the loaded military course time for the RT and AT groups are depicted in Figure 2.

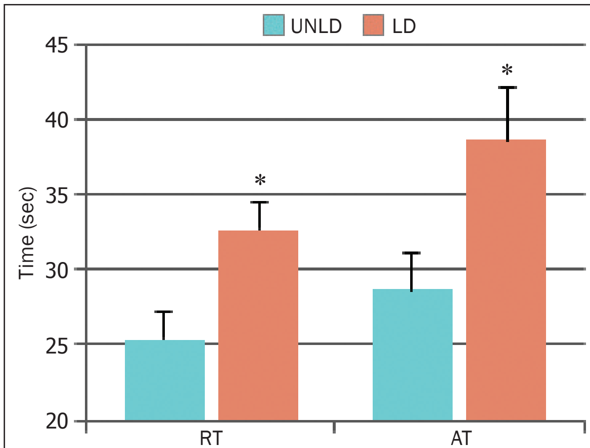

Figure 2. Means and standard deviations of unloaded (UNLD) and loaded (LD) total course time for RT (resistance-trained) and AT (Army-trained) groups.
RT: UNLD 25.4±1.8 sec; LD 32.7±3.6 sec.
AT: UNLD 28.75±2.5 sec; LD 38.7±4.8 sec.
*indicates significant difference.

In the AT group, significant differences were found between the unloaded (28.7±2.5 sec) and loaded (38.7±4.8 sec) conditions, with the loaded condition eliciting a significant 35% increase in overall course time when compared to the unloaded time (10.0±3.4 sec, $P \leq .05$). Significant differences were also found within the RT group between the unloaded (25.4±1.8 sec) and loaded (32.7±3.6 sec) conditions, with the loaded condition eliciting a significant 29% increase in overall course time when compared to the unloaded time (7.3±2.1 sec, $P \leq .05$). The AT group took significantly longer to complete the military course under load when compared to the RT group (RT: 7.3±2.1 sec, 29% increase vs AT: 10.0±3.4 sec, 35% increase, $P \leq .05$).

Overall Loaded Course Time and Times for Each Course Component

Average time to complete the total course and each component within the course in the loaded condition are depicted in Figure 3.

In the loaded condition, the RT group performed the entire military course significantly faster ($P \leq .05$) than the AT group. Within the course, the RT group performed significantly faster when rising from the prone position to the first 5 meters, and performing the casualty drag ($P \leq .05$).

Group-specific Differences in Strength and Power Variables

The means and standard deviations of peak power for the RT and AT groups are shown in Figure 4. The 2 groups differed significantly, with the RT group averaging 44% greater peak power (watts) than the AT group (RT=4806.7±936.3 W; AT=3333.6±449.5 W). Squat 1RM means and standard deviations for the RT and AT groups are shown in Figure 5. Significant differences were found between the RT (155.5±54 kg) and AT groups (84.7±16.9 kg), with the RT group averaging 83% greater lower body strength.

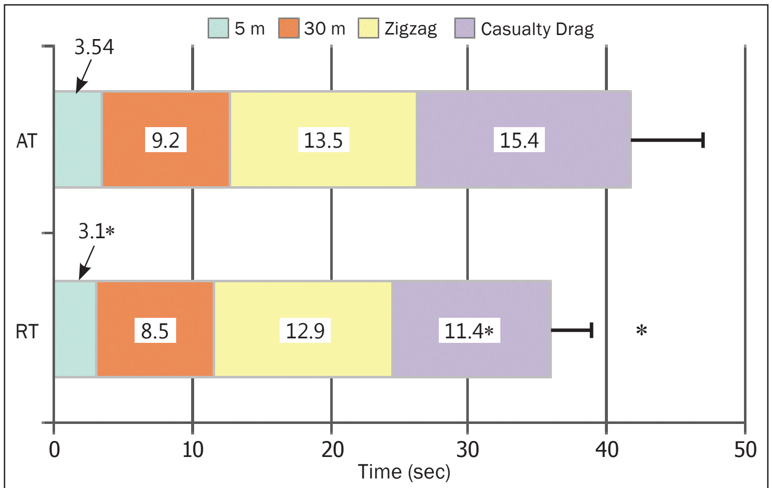

Figure 3. Mean times for each component of the military course for RT (resistance-trained) and AT (Army-trained) groups.
* indicates significant difference.

The means and standard deviations of bench press 1RM are listed in Figure 6 for the RT and AT groups. Significant differences ($P \leq .05$) were found between the RT (121.6±29.9 kg) and AT groups (75.6±10.9 kg), with the RT group averaging 61% greater bench press 1RM than the AT group.

No significant differences were found for any of the APFT components between the RT and AT groups. The means and standard deviations of performance outcomes for each APFT component for the two groups are provided in Table 3.

Relating Performance Test Variables to Loaded Military Course Performance

The correlation of all the performance testing variables with the loaded military course time and its 3 components is shown in Table 4. There was a strong negative correlation between total loaded time and peak power (watts) (r=-0.67, $P \leq .05$), total loaded time and squat 1RM (kg) (r=-0.62, $P \leq .05$), and total loaded time and bench press 1RM (kg) (r=-0.62, $P \leq .05$). Strong correlations were also observed between the strength and power measures and the majority of the components within the overall course. There was only one significant correlation between a component of the APFT (number of push-ups) and performance on the loaded military course (total time).

Comment

The purpose of this study was to determine the role of strength and power in short duration, high-intensity military tasks incorporating heavy load carriage. Most studies that have examined strength and power in military tasks have not employed significant loads, nor have assessed strength and power in conjunction with performance outcomes on high-intensity tasks with significant loads. This investigation used only 3 military relevant tasks (prone position into 30 m sprint, 27 m zigzag run, 10 m casualty drag) vs the multistation (8-19) obstacle courses frequently used in other investigations, since direct action raids mostly involve short distance sprinting around obstacles and to points of cover. The first 5 meters of the 30 m sprint began from the prone position, because it was here that Treloar et al[4] observed the greatest decrement in 30 m loaded sprint times. This is also the starting position for basic offensive and defensive maneuvers. A short distance casualty drag was

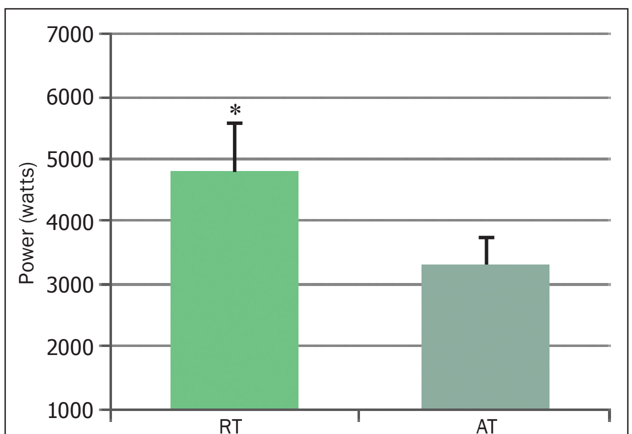

Figure 4. Mean differences between RT (resistance-trained) and AT (Army-trained) groups in peak power.
RT: 4806.7±963.3 W
AT: 3333.6±449.5 W
* indicates significant difference.

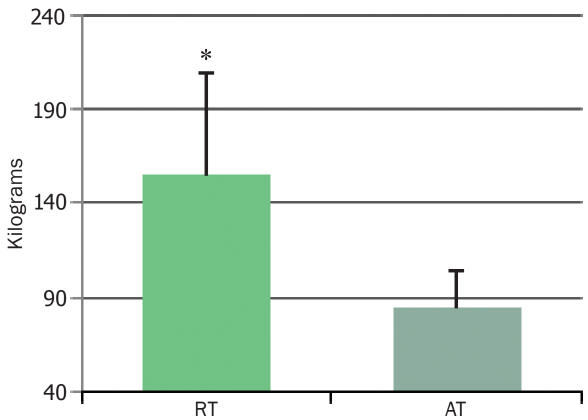

Figure 5. Mean differences between RT (resistance-trained) and AT (Army-trained) groups in 1 repetition maximum squat test.
RT: 155.5±54 kg
AT: 84.7±16.9 kg
* indicates significant difference.

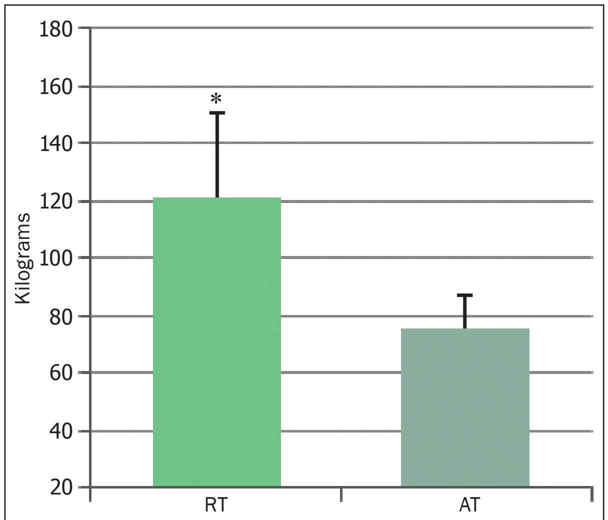

Figure 6. Mean differences between RT (resistance trained) and AT (Army trained) groups in bench press.
RT: 121.6±29.9 kg
AT: 75.6±10.9 kg
* indicates significant difference.

included to simulate a battlefield scenario where the Soldier would quickly transfer the casualty behind a point of cover to administer first aid. Also, the overall load used in this investigation (approximately 42 kg) is typical of loads carried by US infantrymen during modern combat operations.[14]

There were strong negative correlations between upper body strength, lower body strength, lower body power, and overall loaded military course time, highlighting the role of strength and power during high-intensity, combat-relevant tasks. It is important to mention that the negative correlations indicate that greater strength and power were associated with shorter course completion times. These findings coincide with those of Jette et al,[17] Bishop et al,[18] and Treloar et al,[4] who found significant correlations between strength and power and military obstacle course performance. Strength and power being highly correlated to high-intensity military tasks is also congruent with the findings of Harman et al[19] who found that lower body power could predict simulated battlefield performance on a course that included a 30 m run and a 27 m zigzag run with an 18 kg combat load. In the present study, lower body strength was the only variable that had a consistently strong correlation with overall loaded course time, as well as with every individual component of the course (prone position to 5 m, 30 m sprint, 27 m zigzag run, 10 m casualty drag).

Another important observation is the lack of a significant relationship between push-ups, sit-ups, and 2-mile run time with respect to overall time on the loaded military course. This coincides with previous findings by Pandorf et al[20] who observed that APFT scores did not correlate with performance on a loaded military obstacle course. The only significant correlation between any APFT component and military course time was the association between the number of push-ups performed and time to rise from the prone position and begin the first 5 m sprint of the course. This coincides with previous findings, which suggested that push up ability is related to the performance of fire and movement techniques.[4,19] The lack of correlation between push-ups, sit-ups, and 2-mile run time with respect to high-intensity combat tasks is highly relevant; as the majority of the military continues to use calisthenics and aerobic training as the primary methods of preparation for combat deployment. Yet, the physical demands of deployment more closely mirror the conditions of the loaded military course used in the present investigation. Given the observed strength of correlations between strength/power and performance on the high-intensity combat task, it is likely that a strength and conditioning program that focuses on the development of strength and power will better prepare Warfighters to meet the modern-day demands of the battlefield.[5,7,11]

To further illustrate differences between resistance training and traditional Army training in terms of the performance on high-intensity combat tasks, groups were dichotomized based on training history over the previous year, resulting in placement into a RT or traditional AT group. Significant differences between the groups were found for lower body power, squat 1RM, bench press 1RM, and most importantly, performance on the loaded military course. It is important to note that while the RT group outperformed the AT group on the overall loaded military course by on average 5.99

seconds ($P \leq .05$), 4.95 seconds (82%) of that time difference was attributed to performance of the casualty drag component. This is not surprising, as the casualty drag was the most heavily loaded component of the course, and was therefore likely to be most sensitive to differences in upper and lower body strength. As measured by the squat 1RM, the RT group had substantially greater lower body strength when compared to the AT group (RT: 155.5±54 kg. AT: 84.6±16.9 kg, $P \leq .05$). Significant differences were also found for bench press 1RM (RT: 121.6±29.9 kg. AT: 75.5±10.9 kg, $P \leq .05$). In view of these differences, it is no surprise that the RT group performed significantly better in the casualty drag, since this task involves the same muscle groups in the upper and lower body as the squat and bench press exercises.

Table 3. Raw scores for each component (max push-ups in 2 minutes, max sit-ups in 2 minutes, and 2 mile run) of the Army Physical Fitness Test (APFT) for the RT and AT groups.

APFT Components	RT (mean±SD)	AT (mean±SD)
Push-ups (repetitions)	72±17	66±10
Sit-ups (repetitions)	64±17	71±5
2 Mile run (seconds)	954±133	891±51

RT indicates resistance-trained.
AT indicates Army-trained.

The 2 groups also differed on the time to complete the first 5 m of the course, where subjects rose from the prone position to sprint 30 m. On average, this segment accounted for 10% of the difference in total course time (0.5 seconds), with RT outperforming AT. The action of rising from the prone position with a load into a sprint requires significant upper and lower body strength, which is also reinforced by the strong correlations of the bench press 1RM and the squat 1RM with the prone to 5 m task (r=-0.65, r=-0.70, respectively, $P \leq .05$). There were no significant differences between the RT group and the AT group for the loaded 30 m sprint time, and the loaded 27 m zigzag run time, which coincides with Harman et al,[21] who observed no significant differences between 8 weeks of Army training and weight training in terms of timed 30 m rushes with fighting loads.

The observed effect of loading on military course performance was expected and corresponds with previous research. Overall, performance on the military course decreased 31% when loaded (26.8±2.7 seconds vs 35.3±5.0 seconds, $P \leq .05$). This is similar to the findings of Treloar et al[4] who observed a 29% increase in time when a 21.6 kg load was added to 30 m sprints. The larger performance decrements observed in this study may be explained by the use of a heavier loading scheme. The increase of the weight of body armor has also been shown to significantly impair repeated high-intensity military tasks, with time to completion being 10% slower during armored trials.[3] An examination of overall performance decrements during loaded trials in the RT and AT groups showed that the AT group had a 35% increase in course time versus the RT group, for which a 29% increase in course time was observed. The significant difference in performance between the RT and AT groups can be attributed to the significant difference ($P \leq .05$) in group average body mass (RT 88.9±10.1 kg; AT 70.4±7.8 kg). This finding is in line with previous investigations, which have shown that larger, more muscular individuals perform better and are less affected by heavier loads than smaller, less muscular individuals.[20,22]

The lack of a significant difference between the RT and the AT group in the loaded 30 m sprint time and the 27 m zigzag run time may be due to the familiarity of the AT group with military loads and equipment. Even though each subject was familiarized with the course and the load, the AT group may have had an advantage due to prior training exposure. The AT group consisted of ROTC cadets, while the RT group was mainly comprised of civilians who had no prior experience carrying military loads. Thus even larger differences might have been evident if both groups had similar overall exposure to military load carriage.

Table 4. Correlation of Performance Testing Variables with the Military Course and Individual Components.

	Total Loaded	Loaded 5 m	Loaded 30 m	Loaded Zigzag	Loaded Casualty Drag
Peak power	-0.67*	-0.66*	-0.60*	-0.39	-0.64*
Squat 1RM	-0.62*	-0.70*	-0.58†	-0.48†	-0.57†
Bench press 1RM	-0.62*	-0.65*	-0.54†	-0.44	-0.59*
Push-ups	-0.38†	-0.507	-0.428	-0.254	-0.34
Sit-ups	0.113	0.104	-0.069	0.095	0.138
2 Mile run time	-0.374	-0.112	-0.285	0.043	0.036

*Indicates significant difference ($P \leq .01$).
†Indicates significant difference ($P \leq .05$).
1 RM indicates one repition maximum.

Furthermore, a significant difference in body mass was observed between the RT and the AT groups (88.9±10 kg vs 70.4±7.8 kg, $P \leq .05$), which may help explain the lack of difference in the 30 m and 27 m zigzag run time. Individuals with more body weight carry their own weight, in addition to the external load, with the heavier subjects carrying a greater overall load, which may place the heavier subject at a disadvantage in the 30 m sprint and 27 m zigzag run. Despite the significant differences in weight, 30 m sprint time (RT 8.5±0.9 seconds vs AT 9.3±1.1 sec) and 27 m zigzag run times (RT 12.8±1.1 seconds vs AT 13.7±0.9 seconds) were not statistically different between the RT and AT groups. This may be explained by the RT group possessing a significantly greater amount of lower body power, offsetting the detrimental effects of extra weight, reinforcing the importance of lower body power.

Subjects were also placed in the RT and AT groups on the basis of their training history (exercise at least 3 times per week for the past year in one modality) with no information on the specific variables of their training programs (power, hypertrophy, strength, intensity, etc). Greater differences may be observed if strictly power- or strength-trained subjects are compared with traditional Army-trained subjects. There is a need for further investigation concerning the effects of different training programs (strength, power, hypertrophy, calisthenics, etc) on the performance of short duration, high-intensity military load carriage tasks.

Relevance to the Performance Triad

This investigation examined the role of upper and lower body strength and power in the performance of short duration, high-intensity, combat relevant tasks, under conditions of heavy load carriage. While the combat task length examined in the current investigation was distinctly different from previous work (3 tasks vs 8-19 tasks in other studies), the current findings support the observations of previous studies. The physiological underpinnings of the modern battlefield remain to be fully clarified; nevertheless, this investigation has underscored the overriding importance of strength and power in today's "anaerobic battlefield."[11] The findings from this investigation can be used by military leadership and strength coaches working with the military population in providing a basis to develop optimal training regimens that include strength, power, and hypertrophy training. For modern combat occupations, training approaches which emphasize strength, power, and hypertrophy would likely improve combat effectiveness by helping Warfighters train for specific anaerobic demands of the battlefield, and thus enable them complete the mission with decreased injury risk, contributing to the overall resilience of the Soldier.

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Performance Differences Between Male and Female Marines on Standardized Physical Fitness Tests and Combat Proxy Tasks: Identifying the Gap

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Abstract

Objectives: For decades women have been restricted from direct assignment to certain military occupational specialties such as infantry. These restrictions can limit the advancement of women through the ranks of military leadership. Thus, the purpose of this effort was to identify those physical requirements most likely to serve as barriers for women wanting to enter closed combat arms positions, and to evaluate the quality of existing physical fitness tests as potential measures of assessment of combat readiness.

Methods: Data we[illegible]ing and Education Command. All par[illegible]ntly completed the Physical Fitness Te[illegible]ical tasks: 120-mm tank loading drill, [illegible] wearing a fighting load (≈30 lb), pull-[illegible]

Results: Overall, the[illegible]en, ≈80% to 100%; women, ≈70% to 1[illegible]; women, 9%) and pull-ups (men, 16±4; women, 4±2). The PFT and CFT components tasks were also related, strongly in some cases, with performance on combat-related proxy tasks (Spearman's ρ typically ranged from 0.60 to 0.80). Estimates of fat-free mass and $VO_{2}max$ were also strongly related to an overall measure of combat readiness (Spearman's $\rho=0.77$ and $\rho=0.56$, respectively).

Conclusions: The primary physical obstacle for women is upper body strength. However, some women could successfully complete all of the proxy tasks and thus are physically capable of meeting the demands of closed combat occupations. The fact that some female Marines could complete the most challenging upper body strength tasks suggests that these barriers are not inherent but might be due to a lack of training specificity.

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For decades women have been restricted from direct assignment to certain military occupational specialties (MOSs), such as infantry. These restrictions can limit the advancement of women through the ranks of military leadership, and could also potentially deprive the military of a rich pool of talented applicants. Since World War II, there has been a gradual push to open closed occupations (primarily combat roles) to women. Eventually this trend became policy when Section 535 of the National Defense Authorization Act for Fiscal Year 2011 (Pub L No. 111-383, 124 Stat 4137) specifically directed that:

> The Secretary of Defense, in coordination with the Secretaries of the military departments, shall conduct a review of laws, policies, and regulations, including the collocation policy, that may restrict the service of female members of the Armed Forces to determine whether changes in such laws, policies, and regulations are needed to ensure that female members have an equitable opportunity to compete and excel in the Armed Forces.

To ensure that this integration satisfies the goal of fairness without sacrificing military readiness, 2 important questions must be answered, each pointing to a potential barrier women might face: (1) What are the physical requirements of combat that could potentially prevent women from assignment to closed positions? (2) Can readiness for combat be assessed in a fair way, one that captures the actual physical requirements of those combat situations, and would not unfairly exclude women? This initial effort, as part of a larger physical standards validation effort, was aimed at answering these questions.

The general approaches in addressing the 2 questions have been:

Question 1

(*a*) Identify or develop tasks that could reasonably serve as proxies for important combat-related tasks.

(*b*) Identify and describe the physical capabilities required to meet the corresponding occupational demand.

(*c*) Compare the performance of women to the performance of men. The performance of active duty male Marines can serve as standard against which to evaluate the readiness of women for combat assignment.

Question 2

(*a*) Identify existing physical fitness tests currently in use to assess ... extent to which ... tify combat-rea...

(*b*) Evaluate candi... mated fat-free ... of physical fitn...

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Currently, all Marine... to pass 2 standard physical fitness tests semiannually: the Physical Fitness Test (PFT) and the Combat Fitness Test (CFT). The PFT assesses the "collective level of physical fitness Marine Corps wide and is a measurement of general fitness vice combat readiness and unit/MOS capability."[1] The CFT extends the PFT by incorporating physical activities that directly mirror (ie, exhibit greater fidelity to) actual combat tasks. The Commandant of the Marine Corps initiated the development of the CFT as a training and assessment tool in response to increased casualties that were related to common combat maneuvers. The CFT was developed in 2008, guided by the goal of incorporating high fidelity, functional movements that a Marine may face on a daily basis during training and/or combat.[2]

Thus the purpose of this effort was two-fold: (1) determine whether the existing physical fitness tests are good predictors of performance on ground combat element tasks; (2) identify physical obstacles that women may face during integration into previously closed combat arms positions. Second to these primary aims, the relationship between estimated aerobic capacity, body composition, and performance was also investigated.

Methods

Subjects

Active-duty male and female Marines were recruited from 3 different sites within the US Marine Corps: Marine Corps Recruit Depot, Parris Island, South Carolina; School of Infantry East, Marine Corps Base Camp Lejeune, North Carolina; and The Basic School, Quantico, Virginia. A briefing on the events was conducted for all participants, and informed consent was provided by those who volunteered. The combat-related tasks were designated as the physical training for the day, which is a mandatory requirement for active duty Marines. The volunteer rate for study participation was high at 98%. The testing protocol was reviewed and approved by the Marine Corps Combat Development Command Institutional Review Board.

Data Collection

All participants in the study were required to have completed a PFT and CFT within the last 6 months. The official PFT and CFT composite scores, as well as individu... d for each participant ... as not to rely on in... asks were performed ... n-day variability, and ... rom physical training

Following observations of increased casualties related to common combat maneuvers, the Commandant of the Marine Corps initiated the development of a training and assessment tool that goes beyond those factors measured by the existing PFT. The CFT consists of basic aerobic (880 yd run), strength testing (ammunition can lift of 97 repetitions or to exhaustion in 2 minutes), and the maneuver under fire (MANUF), which incorporates multiple combat-related tasks and emphasizes both fitness and technical skill in carrying out the maneuvers effectively.

The events within the MANUF are representative of the types of movements that Marines routinely make in training and in combat. A sprint-to-J-hook turn is a proxy for a quick momentum and directional change as may occur under sniper fire, while a low crawl to high crawl maneuver is reflective of a Marine covertly covering a distance and then transitioning to a faster high crawl to maneuver between 2 points for safety. A casualty evacuation is a lifesaving technique that requires dragging (and/or fireman carry) a fellow Marine out of danger to a safer location as quickly as possible. The MANUF also incorporates an ammunition can carry and run, as well as a grenade toss, all of which are common combat skills. These individual MANUF tasks are combined into a single timed event, which enables assessment of a Marine's combat capability and physical fitness, effectively measuring the simultaneous operation of multiple energy systems: strength, anaerobic, and aerobic.

The CFT score is a composite of scores from the 3 components. The maximum achievable score is 300 points.

Combat Proxy Tasks

All participants completed a dynamic warm-up prior to testing on the combat proxy tasks. The warm-up consisted of a 50-m jog, 50-m backward run, 25-m walking toe touch, 25 butt kickers, 25-m lateral shuffle, 10 body weight squats, 10 push-ups, and 10 burpees. Following the warm-up period, participants completed 6 combat proxy tasks in sequential order: maximum set of pull-ups, dead-lift, clean and press, 120-mm tank round lift and load, 155-mm artillery round lift and carry, and negotiating a 7-ft wall with a box lift. Specifically, participants were asked to execute as many full pull-ups (no kipping) as possible. … pants to complete one … increasing weights: 6 … 135 lb. Similarly, the … progression from 6 l … 80 lb, 95 lb, and 115 … weight with proper te … above their head, the … maximal lift. The 120-mm (replica) tank round lift and load involved lifting and loading five 120-mm projectiles (replica rounds weighing 55 lb) in 35 seconds. The 155-mm (replica) artillery round lift and carry consisted of picking up and carrying a 155-mm projectile (replica round weighing 95 lb) a distance of 50 m in 2 minutes. The final task required Marines to navigate a 7-ft obstacle course wall using a lower level entry (a 20-in assist box to standardize the 1-person or 2-person lift in a field environment), while wearing a fighting load (flak jacket with Small Arms Protective Insert plates).

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One important note is in order regarding the use of pull-ups as a combat proxy task, despite its prominent use in the PFT for testing with male Marines: while pull-ups have been included as part of the combat proxy test set, the task has been treated in this article as akin to a component of the PFT, to facilitate direct comparison between men and women.

Anthropometrics and Aerobic Capacity

Height and weight were measured and body mass index (BMI) calculated as a function of height and weight. From this information, percent body fat was calculated using the Gallagher equation.[3] Fat-free mass was then calculated for each individual. From these data, estimates of volume of oxygen consumption (VO_2max) were made for both men and women (AR, for "activity code" was set to 7, which is the code for estimated physical activity. On a coarse ordinal scale, "7" indicates "Run over 10 miles per week or spend over 3 hours per week in comparable physical activity")[3-5]:

For women, VO_2max (ml/kg/min)=

$$45.628-(0.265\times age)-(0.309\times \%fat)+(2.175\times AR)-(0.044\times \%fat\times AR)$$

For men, VO_2max (ml/kg/min)=

$$47.820-(0.259\times age)-(0.216\times \%fat)+(3.275\times AR)-(0.082\times \%fat\times AR)$$

Statistical Analysis

Descriptive statistics and results are presented as means and standard deviations. Performance scores (on the PFT and CFT) between Marines who passed the combat proxy tasks and those who failed were compared using *t* tests. In addition, the results in this study were also corroborated by the nonparametric equivalents of … when concerns were … d parametric assump- … ions of the study are … e used.

… liness, the proportion … re successfully com- … the pass/fail combat proxy tasks were included in this overall measure, not the pull-ups task, which was treated as a predictor, not outcome variable). Bivariate correlation analyses (nonparametric rank correlation coefficient, Spearman's ρ) were used to measure statistical dependence between variables. Spearman's ρ is useful for describing monotonic trends between 2 variables when it is not appropriate to assume that the relationship is linear, which was the case with the measured variables in this study (eg, cut-off scores producing restricted ranges; non-normal distributions; a key outcome measure being a proportion of tasks successfully completed). Interpretation of magnitudes is similar to that of the Pearson product-moment correlation.

To facilitate comparison between sexes, overlapping density plots (ie, estimates of the underlying probability density function, using a Gaussian kernel) were constructed separately for men and women.[6] Density plots represent the distribution of a variable and can be interpreted in way similar to histograms, however, the smoothed patterns of density plots better reveal the differences in performance between males and females. All analyses were performed with SPSS 19.0 (IBM Corp, Armonk, NY) and R (http://www.r-project.org/). The packages dplyr (http://cran.r-project.org/web/packages/dplyr/index.html), ggplot2,[7] and scales (http://CRAN.R-project.org/package=scales) were employed for data preprocessing, visualization, and variable rescaling, respectively. The code used to generate the results is available upon request. Statistical significance was accepted when $P<.05$.

Table 1. Demographic Characteristics of Study Participants.*

	Mean	SD	Min	Max
Age (years)				
Men	22	4.3	17	42
Women	22	4.6	17	39
All	22	4.4	17	42
Height (cm)				
Men	175	6.8	147	196
Women	163	6.9	152	183
All	170	9.4	147	196
Weight (kg)				
Men	76	12	51	108
Women	60	7.0	43	81
All	68	12	43	108
BMI (kg/cm²)				
Men	24	3.0	17	33
Women	23	1.9	17	32
Body Fat (%)				
Men	16	4.5	5.6	30

Results

Subjects

The sample comprised 788 Marines (409 male, 379 female). Summaries of key demographic variables (eg, age, height, weight) as well as body composition estimates (eg, BMI, percentage fat, and VO_2max) are presented in Table 1. Note that overall means for the body composition variables were not included, as the calculation of percentage fat and VO_2max values were s

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Fitness Tests

Descriptive statistic … down of the PFT an … score and by compo … 2A and 2B. Overall, … component tasks; de … represented in Figures 1 and 2. Note that the pull-ups from the combat proxy testing were used as the basis of comparison, since both males and females completed the task. The component tasks of the PFT that do not admit direct comparison between males and females (ie, flexed-arm hang) have been excluded from the analysis.

Collectively, these data illustrate 2 key patterns: female scores tend to vary more than male scores, and men generally outperform women on the physical tasks. To illustrate this pattern more clearly, the measures associated with each physical fitness test (crunches, run, pull-ups, and the component CFT tasks) were rescaled into a range from 0 to 100; the mean of the rescaled test scores was then adopted as the measure of "overall performance" (scores for the timed events were reversed, before range rescaling, so that shorter duration times were translated into higher performance scores). The derived scale represents relative performance, anchored by the worst performer in the sample as a whole (a score of 0) and the best performer (a score of 100), with greater magnitudes reflecting better performance. The resulting density is provided in Figure 3.

Combat Proxy Tasks

Performance differences between men and women across all combat proxy tasks are shown in Figure 4A. Overall, there was a high rate of successful completion on the combat proxy tasks (men, ≈80% to 100%; women, ≈70% to 100%), with the notable exception being the clean and press (men, 80%, women, 9%). Given the low rate of completion, a breakdown of the clean and press task was conducted separately (Figure 4B).

Correlations

As expected, there were strong relationships between components of the PFT and CFT and the overall measure of combat readiness (Table 3A). The CFT tasks, in general, exhibited stronger … ombat readiness, as … ships between physi… (eg, BMI, VO_2max, … d the other physical … e composite measure … e also relatively high, … icularly well as a pre… … were statistically significant at $P<.01$.

Comment

In general, men outperformed women on physical ability tasks and combat proxy tasks. However, this difference was most pronounced for those tasks requiring a significant upper body strength component (ie, clean and press,

Table 2A. Physical Fitness Test Component Tasks.*

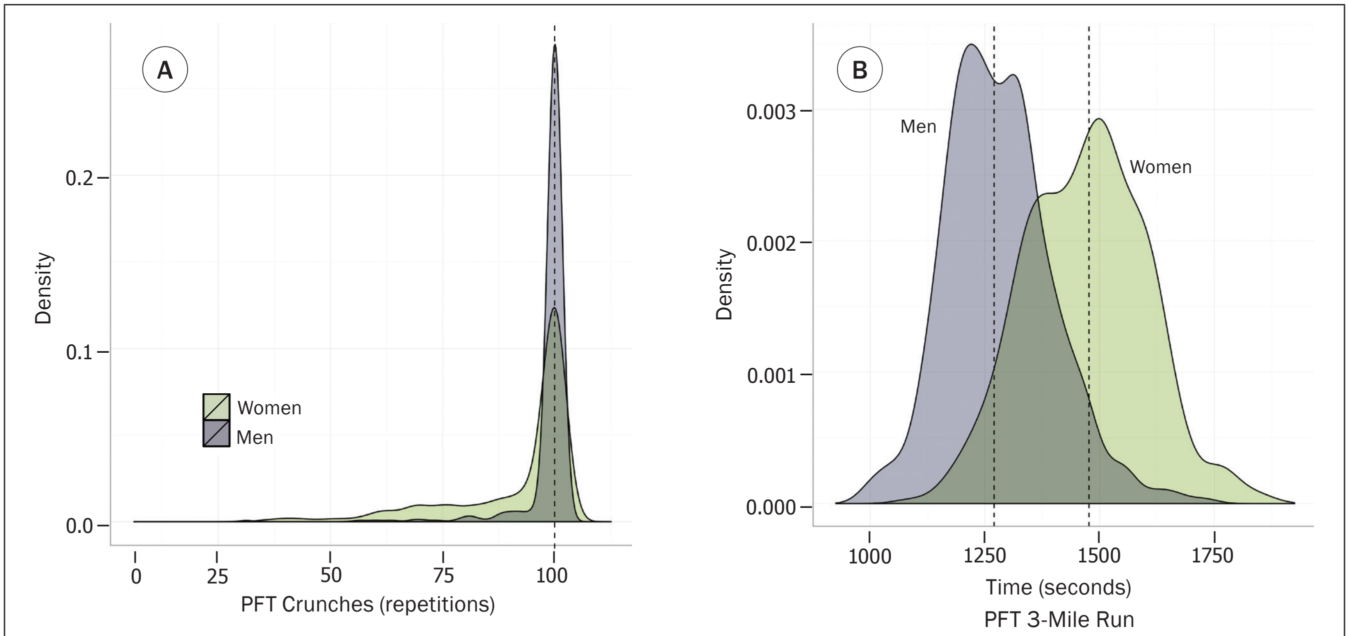
	Mean	SD	Min	Max
Crunches (repetitions)				
Men	99	5	45	100
Women	94	11	48	100
All	96	8.85	45	100
3-Mile Run (seconds)				
Men	1,282	115	994	1,729
Women	1,470	131	1,088	1,857
All	1,372	155	994	1,857
Pull-Ups (repetitions)				
Men	16	6	2	33
Women	4	4	0	23
All	10	8	0	33

*N=788 (men, n=409; women, n=379)

Table 2B. Combat Fitness Test Component Tasks.*

	Mean	SD	Min	Max
Movement to Contact (seconds)				
Men	173	15	132	233
Women	211	22	126	292
All	192	27	126	292
Maneuver Under Fire (seconds)				
Men	145	18	108	235
Women	200	26	138	308
All	172	36	108	308
Ammo Can Lift (repetitions)				
Men	97	10	55	125
Women	57	15	16	117
All	78	23	16	125

*N=788 (men, n=409; women, n=379)



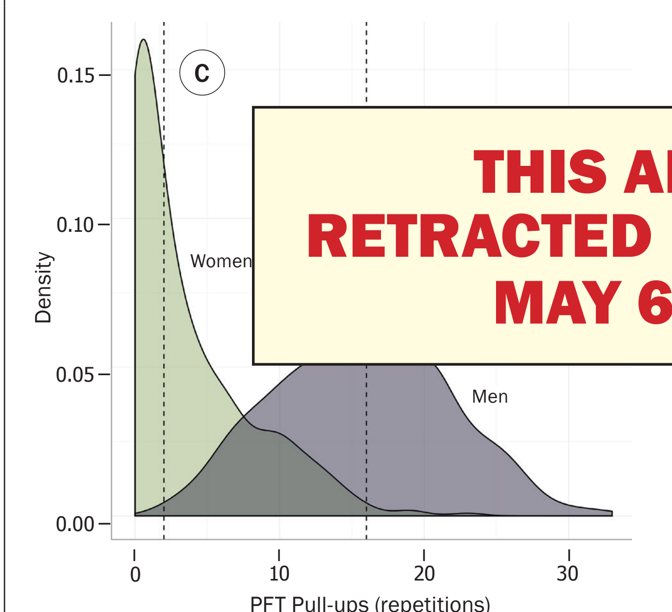


Figure 1. Comparison between men and women on the Physical Fitness Test (PFT) events: Crunches (A), 3-Mile Run (B), and Pull-ups (C). Data are presented as density plots, which are normalized representations of each distribution that facilitate comparison between samples differing in size. The dashed line in each plot represents the median performance of that group. Note that the Pull-ups event was tested along with the other combat proxy tasks and was not taken from the PFT proper, as it is the only version of pull-ups that enables direct comparison of men and women.

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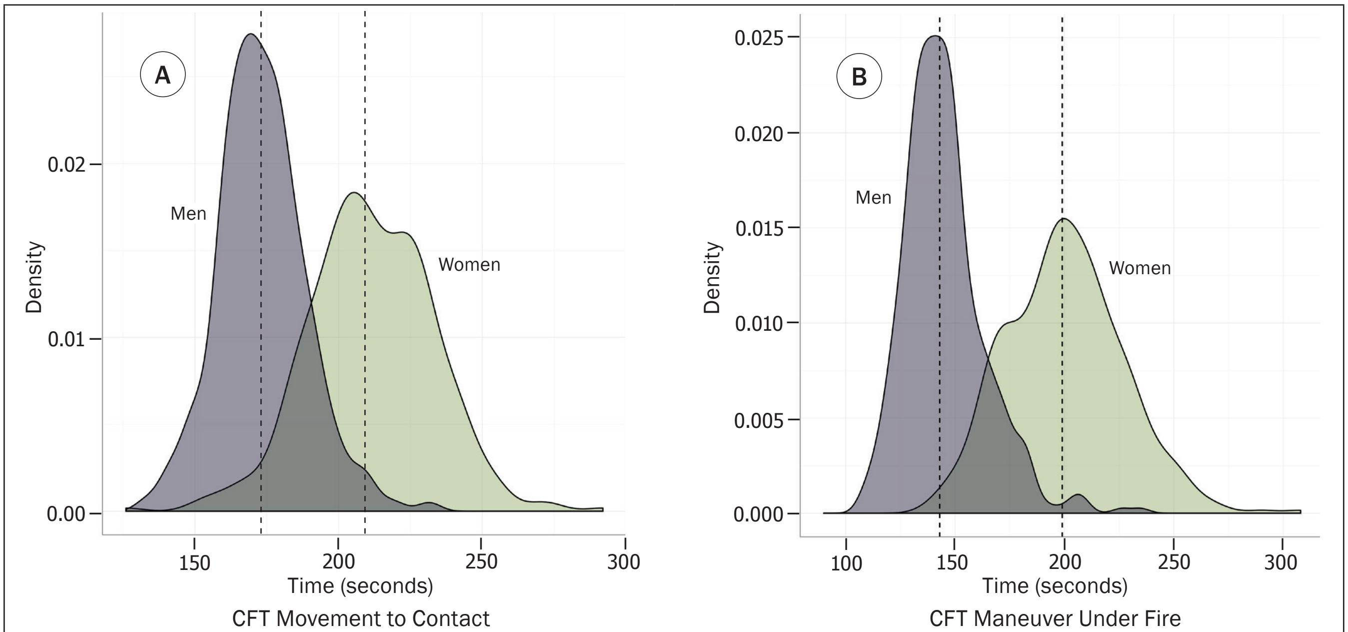
pull-ups). Thus, the most compelling finding is that upper body strength is a potential barrier to full integration of women into previously closed combat arms positions. How significant is this barrier? Can it be overcome? If it were an insurmountable barrier, we would expect few if any women to be capable of surpassing men in upper body strength. On the contrary, some women were able to perform well, or at least better, than many men. For example, 66 women outperformed the worst perform- ... ers (subsample of 44 ... Marine completed 23 ... eded 87% of all men

... e strong relationships ... ody tasks as well as ... ntage and estimated VO_2max, and various performance metrics. Indeed, the relative strength of the relationships between the derived measures of fat-free mass, VO_2max, and the physical tasks is striking and in line with previous research in the military which suggests that aerobic performance is related to body fat.[8,9]

Additionally, increased body fat has been associated with poor performance in female Army Soldiers. Therefore, based on this current and past efforts, it can be suggested that body composition standards should be established in parallel with physical standards for individuals seeking a direct combat MOS. The fact that this study used previously established regression equations and gleaned such valuable information with so little effort suggests that they may serve as useful replacements when laboratory measures such as DEXA scan or VO_2max testing are not available or practical.

These findings suggest that women who might be considered trained for overall fitness, as determined by existing, standardized fitness tests, are limited by upper body strength when it comes to lifting heavy objects.



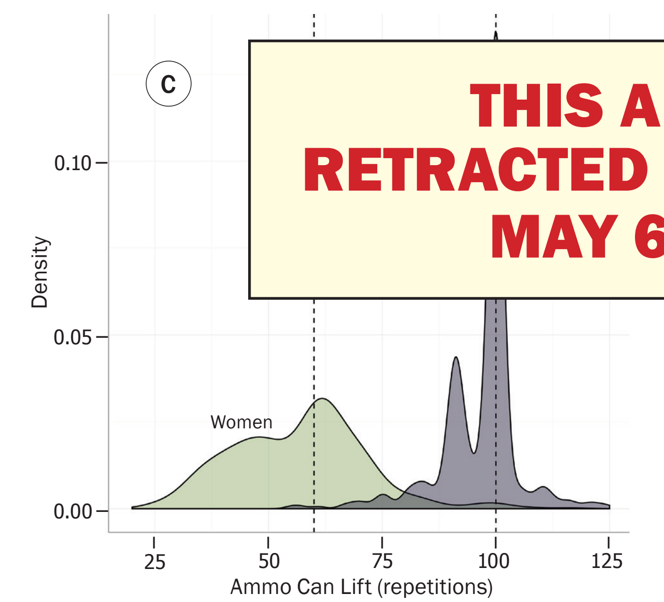


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Figure 2. Comparison between men and women on the Combat Fitness Test (CFT) events: Movement to Contact (A), Maneuver Under Fire (B), and Ammo Can Lift (C). Data are presented as density plots, which are normalized representations of each distribution that facilitate comparison between samples differing in size. The dashed line in each plot represents the median performance of that group.

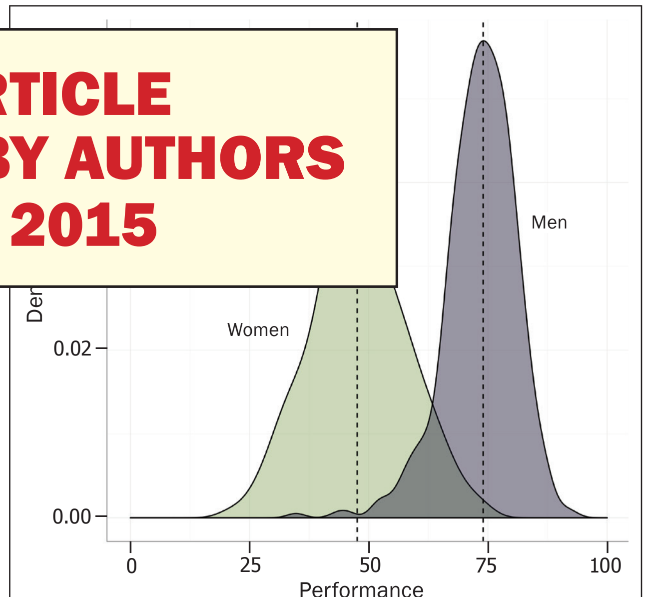

Figure 3. Comparison between men and women on a derived measure of overall performance. The raw scores for crunches, run, pull-ups, and the component CFT tasks, were rescaled into a range from 0 to 100; the mean of the rescaled test scores was then adopted as the measure of "overall performance" (scores for the timed events were reversed, before range rescaling, so that shorter duration times were translated into higher performance scores). The derived scale represents relative performance, anchored by the worst performer in the sample as a whole (a score of 0) and the best performer (a score of 100), with greater magnitudes reflecting better performance. The dashed line in each plot represents the median performance of that group.

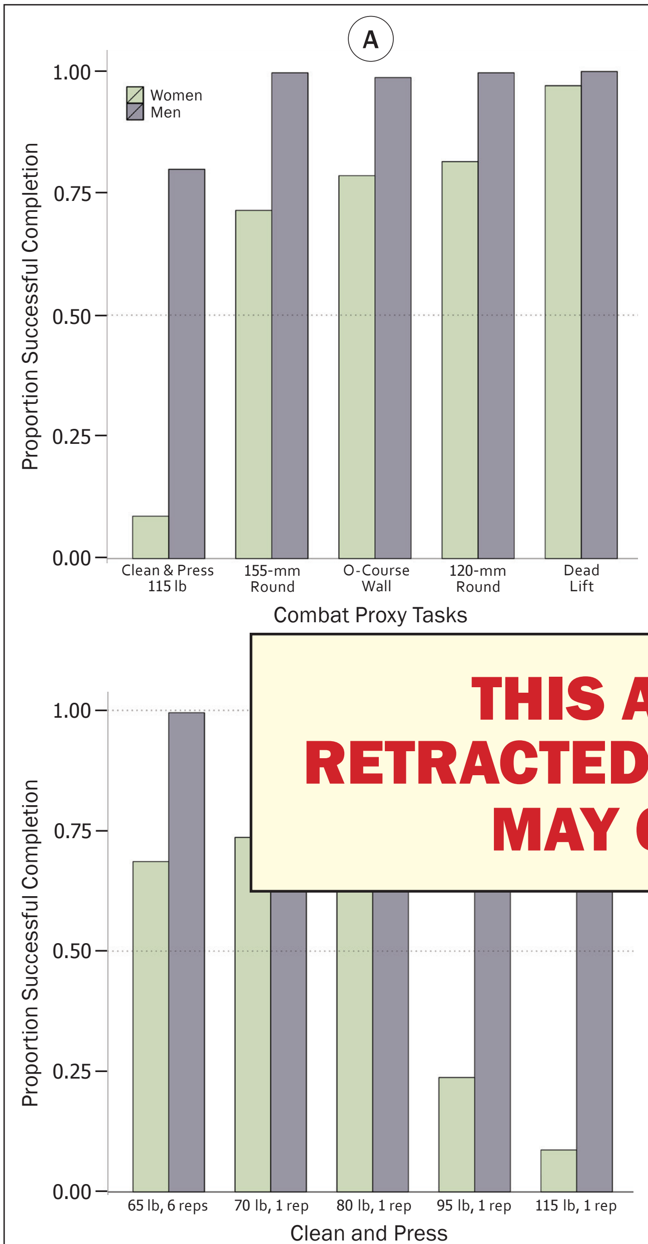

Figure 4. Comparison between men and women on Combat Proxy Tasks (A) and Clean and Press (B).

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It is important to note, however, that female Marines were not trained for these specific movements, and were likely not properly conditioned to perform these types of physical tasks. Thus, while the majority of women could be considered successful on most of the combat proxy tasks, the discrepancy in upper body strength may point to lack of conditioning, which could potentially be overcome with training.[10,11] Previous studies have shown that women who are strength trained and/or endurance trained can increase their performance on combat-related tasks.[10-12] Specifically, pull-ups training has been shown to be effective at increasing the number of pull-ups completed by women, as well as improving overall upper body muscle endurance. This may translate to other upper body exercises, such as push-ups. In a separate Marine Corps study, a 12-week training program increased the number of women who could perform more than 3 pull-ups by 30%.[15] In addition, the authors of the study concluded that pull-ups were a good indicator of upper body strength and that pull-up training may be the best way to increase upper body strength for female Marines. While women in this study were less successful than men in upper body strength tasks, existing literature suggests that, with proper training, women could increase their upper body strength and reduce the size of this gap.

In addition, an important question to address is whether PFT and CFT performances translate to performance on combat-related tasks. Specifically, Marines are currently required to complete both the PFT and CFT semiannually, and the results from those tests serve as markers
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A thorough investigation of test validity is a challenging and (potentially) indefinite endeavor, which is beyond the scope of the present study and is currently being addressed in a separate physical standards validation effort. Performance on the physical tasks in this study was limited to plausible occupational constraints (eg, particular weights, limited repetitions) and did not account for measuring maximum physical capacity. Thus, the resulting restricted range may underestimate the true validity of the PFT and CFT for predicting performance during combat. With this caveat in mind, one of the aims of this effort was to determine whether the PFT and CFT could be used as predictors of performance on combat proxy tasks. To what extent does the performance on one test indicate more successful performance on the other? In relation to the existing dataset, does better performance on the PFT and CFT translate to a more successful performance on the combat proxy tasks? Statistically, this question was addressed by separating women who were successful on the combat proxy tasks from those who were unsuccessful, and then examining their respective PFT and CFT scores as shown in Table 4. As expected, women who performed well on their semiannual physical fitness tests were more successful on combat proxy tasks. Also, a difference of 2 pull-ups separated successful from unsuccessful performers, with the exception of

Table 3A. Spearman Correlations Among the PFT and CFT Tasks, and Overall Mission Readiness.

Spearman's ρ	Crunches	3-Mile Run	MTC	AL	MANUF	Overall Mission Readiness
Pull-ups	0.46	-0.66	-0.76	0.74	-0.76	0.75
Crunches		-0.37	-0.43	0.43	-0.41	0.38
3-mile run			0.80	-0.63	0.74	-0.61
CFT MTC				-0.75	0.83	-0.71
CFT AL					-0.78	0.76
CFT MANUF						-0.77

PFT indicates physical fitness test. CFT indicates combat fitness test. MTC indicates movement to contact. AL indicates ammunition can lift. MANUF indicates maneuver under fire.

Table 3B. Spearman Correlations Among Physical Characteristics and Physical Tasks.

Spearman's ρ	Pull-ups	Crunches	3-Mile Run	MTC	AL	MANUF	Overall Mission Readiness
Height	0.53	0.29	-0.53	-0.62	0.68	-0.67	0.67
Weight	0.46	0.26	-0.44	-0.53	0.64	-0.61	0.68
BMI	0.20	0.10	-0.16	-0.20	0.34	-0.29	0.39
Body Fat %	-0.63	-0.28	0.52	0.61	-0.59	0.61	-0.50
FFM	0.62	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
VO_2max	0.64	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

MTC indicates movement t[illegible] fire. FFM indicates fat-free [illegible]

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the clean and press i[illegible] cessful from unsucce[illegible] ond difference on th[illegible] aerobic activity, sep[illegible] ful performers. Not surprisingly, 3-mile run time was strongly related to performance on the MANUF. Additionally, those women were more aerobically fit (as indicated by a nearly 30 second difference in MANUF times) and were more successful on the most challenging clean and press weight. This finding is consistent with other studies demonstrating a strong relationship between fat-free mass, aerobic capacity, and overhead lifting.[14,15] The results also provide evidence for a strong relationship between the PFT and CFT components tasks and overall mission readiness (Table 3A). In all, these results suggest that the PFT and CFT could serve as reliable indicators of performance on ground combat elements.

While the results provided in the study support reasonably strong conclusions, there are limitations that must be addressed. The primary limitation derived from necessary restrictions on allowable performance, constraints that were required due to the large population being sampled in a field environment. The resulting range restriction on performance scores likely underestimated the true population correlation coefficients. However, the goal of the study was simply to establish that the physical tests were good predictors of performance on combat-related tasks, which was amply demonstrated by the uncorrected correlations.

Another limitation concerned the high success rates of performance on most of the combat proxy tasks. Once a participant successfully completed a task, the test was terminated rather than allowing someone to reach their true maximum, as in the deadlift. In that task, there were no weights available above 135 lb, nor were the participants asked to complete as many repetitions as possible. Those weights were chosen to be reflective of actual occupational demands, and not to be unnecessarily taxing. If a more accurate picture of the maximum capabilities of Marines is required, additional, nonrestricted testing would be required. Similarly, at the time of this study, women did not perform pull-ups in the PFT (except for infrequent [illegible]) and thus the pull-ups [illegible] during the combat [illegible] was used as a replace[illegible] to enable compari[illegible] [illegible]owever, this decision [illegible]ted in the study were [illegible]ncurrent validity than [illegible] these nuances are unlikely to matter as far as the practical decision to include pull-ups as an assessment instrument is concerned.

In conclusion, the key limiting factor for females is upper body strength and greater emphasis should be placed on developing this capability in female Marines if they intend to serve in closed combat arms positions. The results also suggest that the PFT and CFT serve as useful indicators of combat readiness. However, further study on unrestricted performance will likely shed light on the validity of the PFT and CFT as predictors of performance on combat-relevant tasks.

Acknowledgement

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Table 4. Successes and Failures of Female Marines on Combat Proxy Tasks in Relation to Physical Fitness Test (PFT) and Combat Fitness Test (CFT) Scores (continued on next page).

Combat Proxy Task			PFT/CFT Event Results			Combat Proxy Task			PFT/CFT Event Results		
	Outcome	n	Mean	SD	sig (*P*)		Outcome	n	Mean	SD	sig (*P*)
			PFT Crunches						PFT Crunches		
	Pass	33	96	9	.19		Pass	271	95	9	<.01
	Fail	346	93	11			Fail	108	89	13	
			PFT 3-mile Run (sec)						PFT 3-mile Run (sec)		
	Pass	33	1,400	137	<.01		Pass	271	1,446	133	<.01
	Fail	346	1,477	128			Fail	108	1,531	102	
			PFT Pull-ups						PFT Pull-ups		
	Pass	33	8	6	<.01		Pass	271	4	5	<.01
Clean & Press, 115 lb	Fail	346	3	4		155-mm Artillery Round Lift and Carry	Fail	108	2	2	
			CFT Movement to Contact (sec)						CFT Movement to Contact (sec)		
	Pass	33	194	19	<.01		Pass	270	206	21	<.01
	Fail	345	213	21			Fail	108	224	18	
			CFT Ammunition Can Lift						CFT Ammunition Can Lift		
	Pass	33	68	16	<.01		Pass	270	60	14	<.01
	Fail	345	56	14			Fail	108	48	13	
			CFT Maneuver Under Fire (sec)						CFT Maneuver Under Fire (sec)		
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	26	<.01
	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	22	
			[illegible]						[illegible] Crunches		
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	10	<.05
	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	13	
			[illegible]						[illegible] mile Run (sec)		
	[illegible]	[illegible]	[illegible]	[illegible]	<.01		[illegible]	[illegible]	[illegible]	129	<.01
	Fail	70	1,526	119			Fail	81	1,525	120	
			PFT Pull-ups						PFT Pull-ups		
	Pass	309	4	4	<.01		Pass	298	4	4	<.01
	Fail	70	2	3			Fail	81	2	2	
120-mm Tank Round Lift and Carry			CFT Movement to Contact (sec)			Obstacle Course Wall			CFT Movement to Contact (sec)		
	Pass	308	209	22	<.01		Pass	297	209	21	<.01
	Fail	70	222	18			Fail	81	221	20	
			CFT Ammunition Can Lift						CFT Ammunition Can Lift		
	Pass	308	58	15	<.01		Pass	297	58	15	<.01
	Fail	70	51	14			Fail	81	53	14	
			CFT Maneuver Under Fire (sec)						CFT Maneuver Under Fire (sec)		
	Pass	308	197	25	<.01		Pass	297	197	26	<.01
	Fail	70	215	25			Fail	81	214	24	

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Table 4 (continued). Successes and Failures of Female Marines on Combat Proxy Tasks in Relation to Physical Fitness Test (PFT) and Combat Fitness Test (CFT) Scores (continuation from previous page).

Combat Proxy Task			PFT/CFT Event Results		
	Outcome	n	Mean	SD	sig (*P*)
Deadlift 135 lb			PFT Crunches		
	Pass	368	94	11	.95
	Fail	11	93	13	
			PFT 3-mile Run (sec)		
	Pass	368	1,467	130	<.01
	Fail	11	1,586	103	
			PFT Pull-ups		
	Pass	368	4	4	<.01
	Fail	11	2	2	
			CFT Movement to Contact (sec)		
	Pass	367	211	21	<.01
	Fail	11	233	20	
			CFT Ammunition Can Lift		
	Pass	367	57	15	.20
	Fail	11	52	12	
			...Maneuver Under Fire (sec)		
	[illegible]	[illegible]	[illegible]	26	<.01
	[illegible]	[illegible]	[illegible]	21	

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Musculoskeletal, Biomechanical, and Physiological Gender Differences in the US Military

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Abstract

The repeal of the Direct Ground Combat Assignment Rule has renewed focus on examining performance capabilities of female military personnel and their ability to occupy previously restricted military occupational specialties. Previous research has revealed female Soldiers suffer a greater proportion of musculoskeletal injuries compared to males, including a significantly higher proportion of lower extremity, knee, and overuse injuries. Potential differences may also exist in musculoskeletal, biomechanical, and physiological characteristics between male and female Soldiers requiring implementation of gender-specific training in order to mitigate injury risk and enhance performance.

Purpose: To examine differences in musculoskeletal, biomechanical, and physiological characteristics in male and female Soldiers.

Methods: A total of 406 101st Airborne Division (Air Assault) Soldiers (348 male; 58 female) participated. Subjects underwent testing for flexibility, isokinetic and isometric strength (percent body weight), single-leg balance, lower body biomechanics during a stop jump and drop landing, body composition, anaerobic power/capacity, and aerobic capacity. Independent *t* tests assessed between-group comparisons.

Results: Women demonstrated significantly greater flexibility ($P<.01$-$P<.001$) and better balance ($P\leq.001$) than men. Men demonstrated significantly greater strength ($P\leq.001$), aerobic capacity (47.5±7.6 vs 40.3±5.4 ml/kg/min, $P<.001$), anaerobic power (13.3±2.1 vs 9.5±1.7 W/kg, $P<.001$), and anaerobic capacity (7.8±1.0 vs 6.1±0.8 W/kg, $P<.001$) and lower body fat (20.1±7.5 vs 26.7±5.7 (%BF), $P<.001$). Women demonstrated significantly greater hip flexion and knee valgus at initial contact during both the stop jump and drop landing tasks and greater knee flexion at initial contact during the drop landing task ($P<.05$-$P<.001$).

Conclusions: Gender differences exist in biomechanical, musculoskeletal, and physiological characteristics. Sex-specific interventions may aid in improving such characteristics to optimize physical readiness and decrease the injury risk during gender-neutral training, and decreasing between-sex variability in performance characteristics may result in enhanced overall unit readiness. Identification of sex-specific differences in injury patterns and characteristics should facilitate adjustments in training in order for both sexes to meet the gender-neutral occupational demands for physically demanding military occupational specialties.

Women have historically played an important role in the US military despite facing restrictions on unit assignment.[1] Since the repeal of the Direct Ground Combat and Assignment Rule, the US armed forces renewed focus on evaluation of women performing in previously-restricted military occupational specialties (MOSs) by assessing sex-neutral performance standards and training capabilities. Previous research demonstrated male and female athletes and military personnel possess different musculoskeletal, biomechanical, and physiological profiles[2-4] and suffer musculoskeletal injuries at differing rates and severity.[5] Physical, physiological, and musculoskeletal profiles of male and female military personnel are important to determine the potential for women to safely and successfully occupy newly-opened MOSs, and if modifiable risk factors for performance and injury can be addressed in sex-specific physical training programs.

Epidemiological research has explored injury rates, types, and causes in military personnel.[5-9] Studies investigating nonbattle injuries sustained during deployment revealed female Soldiers had a significantly higher incidence of injury than male Soldiers.[10,11] Other research indicated female Soldiers sustain a greater proportion of lower extremity and overuse injuries.[6-8] Researchers reporting 50% of female Soldiers will sustain one or more injury, including stress fractures, by the end of Basic Combat Training, postulated the increased rate of injury in female Soldiers may be because female and male Soldiers of differing fitness levels participate in the same training.[12] Although the reason(s) for sex differences in injury rates, types, and causes are unclear, they may result from sex differences in physical, physiological, and musculoskeletal characteristics and differences in training intensity during basic combat training, daily physical training, and deployment.

Previous research evaluating requirements for physically-demanding jobs, like lifting, carrying, pushing/pulling loads, and basic soldiering tasks, identified components of fitness necessary for safe and successful completion of these tasks, including strength, power, endurance, mobility, and flexibility.[13,14] It is well known that female Soldiers, on average, possess less absolute strength and force generating capacity, less endurance and higher fatigability during repetitive tasks, and less aerobic capacity than male Soldiers.[14] Studies investigating movement patterns of military personnel also demonstrated significant sex differences in parachute landing techniques that may contribute to ACL injury risk,[15,16] which is important in airborne units. Sex disparities in physical, physiological, and musculoskeletal characteristics should be examined further in contemporary military populations to determine the capability of women to safely and successfully perform strenuous occupational tasks and to reduce performance gaps between sexes.

The purpose of this study was to investigate potential sex differences across a comprehensive set of physical, physiological, musculoskeletal, and biomechanical characteristics within a modern military population. It was hypothesized that male and female Soldiers would display significantly different physical, physiological, musculoskeletal, and biomechanical profiles. If differences in characteristics are identified, targeted, gender-specific physical training may increase overall force readiness and resiliency, especially as women are integrated into previously restricted MOSs.

Materials and Methods

Subjects

A total of 406 Soldiers (348 male, 58 female) of the 101st Airborne Division (Air Assault) at Fort Campbell, Kentucky, participated in this study. Demographic information is presented in Table 1. Subjects are a subset of subjects enrolled in the Human Performance and Injury Prevention Initiative (Eagle Tactical Athlete Program) 6-step model derived from the public health model of injury prevention and control.[9,17] All subjects met the following criteria: 18 to 45 years of age and no current medical or musculoskeletal conditions that prevented full active duty. Human protection for the current study was approved by the appropriate civilian and military institutional review boards. Written informed consent was obtained from each subject prior to participation in this study.

Procedures

Testing occurred over 2 days (approximately one week apart) at the University of Pittsburgh Human Performance Research Center (Fort Campbell). Each session lasted 2 hours. Testing was performed bilaterally where applicable; only right-sided data is presented, as no between side differences were noted.

A standard goniometer or digital inclinometer was used to measure passive range of motion of the shoulder, hip, and knee (flexion) and active range of motion of the knee (extension) and ankle.[18] Reliability of these measurements has been previously established.[19,20] Hip flexion was assessed in the supine position with the knee flexed while hip extension and knee flexion were assessed in the prone position. Shoulder flexion, abduction, and internal and external rotation were assessed in the supine position. Shoulder extension was assessed in the prone position. Posterior shoulder tightness was also assessed passively in the supine position. Active range of motion was used to assess hamstring flexibility at the knee with the active knee extension test and to assess gastrocnemius-soleus flexibility at the ankle with active dorsiflexion with the knee straight. The Biodex Multi-Joint System 3 Pro (Biodex Medical Systems, Inc, Shirley, NY) measured active torso range of motion, with the subject seated and actively rotating in the right and left directions.

The Biodex Multi-Joint System 3 Pro measured shoulder internal/external rotation, shoulder abduction/adduction, hip abduction/adduction, knee flexion/extension, ankle plantarflexion/dorsiflexion, and torso rotation strength. The reliability of isokinetic strength testing has been previously established for peak torque/body weight (intraclass correlation coefficient [ICC]=0.73-0.97).[21] For shoulder, knee, and torso strength testing, subjects

Table 1. Subject Demographics

	Men			Women			*P* Value
	n	Mean	±SD	n	Mean	±SD	
Age (years)	348	28.06	6.63	58	26.72	5.48	.147
Height (m)[a]	348	1.77	0.07	58	1.65	0.06	<.001
Weight (kg)[a]	348	83.48	12.57	58	64.93	9.90	<.001

[a]Statistically significant difference between men and women (*P*<.05).

performed 3 practice trials at 50% maximum effort followed by 3 more at 100% effort. Following a rest period of 60 seconds, 5 repetitions of reciprocal concentric isokinetic testing were performed at 60° per second. Hip abduction/adduction was assessed isometrically in a sidelying, neutral hip position. Subjects performed 3 sets of 5-second isometric contractions, alternating between hip abduction and adduction. Ankle plantarflexion/dorsiflexion was assessed isometrically in a seated position with the knee and hip at 90°. Subjects performed 3 sets of 5-second isometric contractions, alternating between plantarflexion and dorsiflexion.

A hand held dynamometer (Lafayette Instrument Company, Lafayette, IN) assessed ankle inversion and eversion strength. Strength measured via hand held dynamometry has been demonstrated to be reliable for ankle inversion and eversion (ICC=0.84-0.86 and ICC=0.74-0.85, respectively)[22,23] and is a valid measurement of ankle strength.[22-24] Ankle inversion and eversion strength was tested with the subject long-sitting with the foot and ankle off the end of the table.

A single force plate (Kistler 9286A, Amherst, NY), with a sampling frequency of 100 Hz, measured balance. Three, 10 second trials of single-leg standing balance were performed with subjects barefooted with their hands on their hips, with eyes opened and eyes closed conditions based on Goldie et al.[25,26] This protocol was previously demonstrated valid and reliable.[20,25-27] Trials were discarded and recollected if the subject's non-stance leg hit the stance limb or the ground outside of the force plate. Subjects were permitted to briefly touch down on the force plate with their non-stance leg and immediately lift the leg back into test position.

A portable metabolic system (OxyCon Mobile, Viasys, Yorba Linda, CA) and lactate analyzer (Arkray, Inc, Kyoto, Japan) captured maximal oxygen consumption (VO_2max) and lactate threshold during an incremental ramp protocol. The OxyCon Mobile has been demonstrated as a valid metabolic system with less than 3% difference compared to simulated VO_2 during a maximal cardiopulmonary exercise test.[28] Following a 5-minute warm-up, the test was performed in 3-minute stages, with the initial at 0% grade and each subsequent stage increased by 2.5% grade until exhaustion (cardiovascular or peripheral inhibition). Speed was set at 70% of each subject's 2-mile run time during the Army Physical Fitness Test and remained constant throughout the test. Blood samples were obtained via a finger prick during the last minute of each stage prior to an increase in incline in order to assess blood lactate levels. Heart rate (Polar USA, Lake Success, NY) and VO_2 were collected and monitored continuously throughout the test. Relative VO_2max, maximum heart rate, VO_2 at lactate threshold, percent of VO_2max at lactate threshold, heart rate at lactate threshold, and percentage of maximum heart rate at lactate threshold were reported.

An electromagnetic cycle ergometer (RacerMate, Inc, Seattle, WA) measured anaerobic power and capacity during a Wingate protocol,[29] which has been previously demonstrated as a highly valid and reliable test of these variables.[30] Following a warm-up at a self-selected cadence at 125 watts, the 50-second protocol was performed: 15 seconds maintaining 100 RPM at 125 W with minimal resistance; 5 seconds sprinting to generate maximum speed prior to initiation of normalized resistance; and 30 seconds attempting to sprint and maintain maximal speed against the normalized resistance. Braking torque was standardized to 9% and 7.5% body weight for men and women, respectively.

The Bod Pod Body Composition System (Life Measurement Instruments, Concord, CA) assessed body composition, which has previously demonstrated reliability (ICC=0.98, SEM=0.47% BF)[21] and validity.[31] Men wore spandex shorts and a swim cap while women wore spandex shorts, a sports bra, and swim cap. Once 2 consistent body volume measurements were obtained, percent body fat was calculated using predicted lung volume and the appropriate body densitometry equation; body mass index (BMI) was also calculated.

Six high-speed cameras (Vicon, Centennial, CO) with 200 Hz sampling frequency captured biomechanical data during an athletic task (stop jump task) and functional landing task (drop landing task). Following Vicon's Plug-in-Gait model, 16 retro-reflective markers were affixed to the anterior superior iliac spine, posterior superior iliac spines lateral thigh, lateral femoral condyle, lateral lower leg, lateral malleous, posterior calcaneus, and head of the second metatarsal. Appropriate anthropometrics were measured with an anthropometer (Lafayette Instrument, Lafayette, IN). A static trial in an anatomical neutral position captured a baseline for joint angle calculations. The accuracy and validity of the Plug-in Gait model have been previously established.[32-34] The stop jump task was a standing broad jump, initiated from a normalized distance of 40% of the subject's height, followed immediately (after landing on the force plates) by a maximal effort vertical jump. The drop landing was initiated by subjects leaning forward while standing on a standardized, 0.51 meter high platform, allowing gravity to drive the drop movement, followed by landing with one foot on each of the force plates (1200 Hz).

Data Processing and Reduction

Flexibility/range of motion and handheld dynamometer strength measures were averaged across 3 trials. Strength obtained with The Biodex dynamometer was reported as the peak average torque across 5 trials normalized to each subject's individual body mass.

For VO_2max data, a 15-second moving window was used to filter metabolic data in order to reduce the overall breath-by-breath data points. Maximal oxygen uptake was calculated as the highest consecutive oxygen uptake levels over one minute of data collection relative to body mass. Lactate threshold was identified by the inflection point when blood lactate levels increased by one mmol/L or more between stages. Anaerobic power output was identified as the peak power within the first 5 seconds of the test following resistance initiation, while anaerobic capacity was calculated as the mean power output over the 30 seconds of the test following resistance initiation normalized to body mass.

For both balance and biomechanical data, force plate data were passed through an amplifier and analog to a digital board (DT3010, Digital Translation, Marlboro, MA) and stored on a personal computer. A custom MATLAB Version 7.0.4 (MathWorks, Inc, Natick, MA) script processed ground reaction force data. For eyes opened and eyes closed balance conditions, the standard deviation for the ground reaction forces for each direction (anterior-posterior, medial-lateral, vertical) was calculated and then averaged across all 3 trials. Prior to calculation of joint kinematics, the Vicon Nexus software reconstructed 3-dimensional trajectories of the reflective markers, and smoothed with a general cross-validation Woltring filter. Trajectories of hip, knee, and ankle joint centers were estimated based on marker locations and anthropometric parameters according to Vicon's Plug-in Gait model. Joint kinematics including the following variables were calculated for the stop jump and drop landing tasks: hip flexion and abduction angles at initial contact, knee flexion and valgus/varus angles at initial contact, and maximum knee flexion angle. The maximum vertical ground reaction force was identified for each trial. Data were averaged across the 3 trials prior to analysis.

Statistical Analysis

All variables were assessed for normality and frequency distribution. The mean and standard deviation were calculated for each of the variables included in the study. All variables were analyzed with independent *t* tests to examine potential sex differences. An alpha level of 0.05 was chosen a priori to denote statistical significance for comparisons. Statistical analyses were performed with IBM SPSS Statistics Version 19.0 (IBM Corp, Armonk, NY).

Results

Range of motion and flexibility data are presented in Table 2. Female Soldiers demonstrated significantly greater shoulder extension, abduction, and external rotation range of motion and hip extension and knee flexion. Female Soldiers had significantly lower values for active knee extension, indicating significantly better hamstring flexibility than male Soldiers. Female Soldiers also had significantly more range of motion for the posterior shoulder tightness test, indicating less posterior shoulder tightness than male Soldiers.

Table 2. Range of Motion and Flexibility (in degrees)

	Men			Women			*P* Value
	n	Mean	±SD	n	Mean	±SD	
Shoulder Flexion	160	187.2	7.3	35	188.0	14.7	.636
Shoulder Extension[a]	338	70.8	13.3	56	83.6	9.8	<.001
Shoulder Abduction[a]	159	206.1	9.5	34	211.8	8.8	.002
Shoulder External Rotation[a]	340	109.9	13.2	57	120.3	16.8	<.001
Shoulder Internal Rotation	340	58.5	10.6	57	59.9	11.6	.399
Posterior Shoulder Tightness[a]	299	102.4	9.7	52	108.7	7.5	<.001
Knee Flexion[a]	156	143.1	6.6	33	148.5	5.9	<.001
Active Knee Extension[a]	340	18.8	9.4	57	11.4	7.9	<.001
Hip Flexion	170	133.1	7.1	35	135.8	16.9	.126
Hip Extension[a]	340	29.3	8.0	56	33.9	7.3	<.001
Calf Flexibility	340	15.9	6.8	57	15.1	5.4	.399
Torso Rotation	341	70.4	11.0	57	72.7	11.5	.147

[a]Statistically significant difference between men and women ($P<.05$).

Strength data are presented in Table 3. Female Soldiers demonstrated significantly weaker shoulder internal and external rotation and shoulder abduction and adduction. Shoulder internal/external rotation strength ratio was significantly higher in female Soldiers. Knee flexion and extension, ankle inversion, eversion, and dorsiflexion and torso rotation were significantly lower in female Soldiers.

Balance data are presented in Table 4. Male Soldiers demonstrated significantly higher anterior/posterior, medial/lateral, and vertical scores bilaterally, under both eyes open and eyes closed conditions. Higher scores represent poor balance.

Physiology data are presented in Table 5. Female Soldiers demonstrated significantly higher BMI and body fat percentage. Male Soldiers had significantly higher anaerobic power, anaerobic capacity, VO_2max, and VO_2 at lactate threshold.

Biomechanical data are presented in Table 6 for the stop-jump task and vertical drop landing. Female Soldiers demonstrated significantly greater hip flexion at initial contact and greater knee valgus at initial contact during both the stop jump and drop landing tasks. Female Soldiers demonstrated significantly greater knee flexion at initial contact during the drop landing task.

Table 3. Strength

	Men			Women			P Value
	n	Mean	±SD	n	Mean	±SD	
Shoulder Strength							
Internal Rotation (%BW)[a]	334	59.6	15.5	57	36.3	8.5	<.001
External Rotation (%BW)[a]	334	42.1	8.8	57	29.9	5.1	<.001
Internal/External Strength Ratio[a]	334	0.73	0.14	57	0.85	0.20	<.001
Abduction (%BW)[a]	169	78.1	15.2	24	55.3	6.7	<.001
Adduction (%BW)[a]	169	83.1	25.5	24	55.7	16.2	<.001
Abduction/Addubction Strength Ratio	169	1.00	0.30	24	1.16	0.87	.077
Knee Strength							
Flexion (%BW)[a]	334	114.8	27.1	57	93.0	21.1	<.001
Extension (%BW)[a]	334	236.1	48.0	57	191.3	37.2	<.001
Flexion/Extension Strength Ratio	334	0.49	0.09	57	0.49	0.06	1.000
Hip Strength							
Abduction (%BW)	169	167.3	34.2	24	158.8	32.9	.254
Adduction (%BW)	169	148.1	35.8	24	139.5	30.4	.264
Abduction/Adduction Strength Ratio	169	0.89	0.18	24	0.89	0.19	1.000
Ankle Strength							
Plantar Flexion (%BW)	150	133.6	45.9	22	120.9	44.9	.226
Dorsiflexion (%BW)[a]	150	45.4	10.2	22	37.40	8.1	.001
Plantar Flexion/Dorsiflexion Strength Ratio	150	3.06	1.20	22	3.44	1.59	.186
Inversion Strength (kg)[a]	335	34.4	7.2	57	24.9	6.7	<.001
Eversion Strength (kg)[a]	335	30.5	6.7	57	22.2	5.9	<.001
Inversion/Eversion Strength Ratio	335	1.15	0.19	57	1.13	0.21	.470
Torso Strength							
Rotation (%BW)[a]	340	145.1	33.1	57	110.5	32.9	<.001

[a]Statistically significant difference between men and women ($P<.05$).
BW indicates body weight.

Table 4. Single-leg Balance: Variability (SD) in Ground Reaction Forces (N)

	Men			Women			P Value
	n	Mean	±SD	n	Mean	±SD	
Eyes Open							
Anterior/Posterior[a]	267	2.78	0.86	51	2.02	0.55	<.001
Medial/Lateral[a]	266	3.44	1.16	51	2.43	0.96	<.001
Vertical[a]	267	4.65	2.19	51	3.18	1.34	<.001
Eyes Closed							
Anterior/Posterior[a]	267	6.44	2.66	51	4.43	1.77	<.001
Medial/Lateral[a]	266	10.11	4.57	51	6.15	2.39	<.001
Vertical[a]	267	14.53	12.22	51	8.61	5.52	.001

[a]Statistically significant difference between men and women ($P<.05$).

Comment

The elimination of the Direct Ground Combat and Assignment Rule and the potential for an increased number of female service members in combat arms warrants examination of potential sex differences that may result in decreased performance and increased injury risk depending on occupational task requirements. The purpose of this study was to assess musculoskeletal, biomechanical, and physiological differences between sexes in a modern military population. Significant between-sex differences were found in Soldiers of the 101st Airborne Division (Air Assault) in range of motion and flexibility, strength, static balance, physiology, and biomechanics. However, within-sex variability of characteristics and specific occupational task requirements should be considered when determining individual job-specific performance capabilities and injury risk.

Male Soldiers demonstrated significantly less range of motion and flexibility in both lower and upper extremities compared to female Soldiers. Previous research demonstrated deficits in range of motion or flexibility increase risk of acute and overuse musculoskeletal injuries,[35-39] while high or excessive flexibility has also been demonstrated to increase the risk of musculoskeletal injury.[7] A previous study identified Australian footballers with greater than 27° of knee flexion during active knee extension were almost 3 times more likely to sustain a hamstring strain (RR=2.8; 95% CI, 0.9-8.5). However, both men and women in the current study were, on average, well below this threshold.[40] Men with first and third tertiles for hamstring flexibility assessed with the sit-and-reach test were at more than 2 times the risk to sustain a time-loss injury during basic combat training than those in the middle tertile.[7] No such relationship was seen in women in basic combat training. Other researchers demonstrated decreased knee flexion and quadriceps flexibility increase the risk of quadriceps muscle injury, patellofemoral pain syndrome, and patellar tendinitis.[37-39] Similarly, subjects with shoulder instability and impingement demonstrated deficits in shoulder range of motion.[41] However, due to methodological differences in testing positions and the use of

Table 5. Physiology

	Men			Women			P Value
	n	Mean	±SD	n	Mean	±SD	
Body Mass Index (kg/m²)[a]	347	23.0	2.9	58	24.0	3.1	.017
Body Fat (%)[a]	338	20.1	7.5	57	26.7	5.7	<.001
Anaerobic Power (watts/kg)[a]	326	13.3	2.1	56	9.5	1.7	<.001
Anaerobic Capacity (watts/kg)[a]	326	7.8	1.0	55	6.1	0.8	<.001
VO_2 Max (mL/kg/min)[a]	322	47.5	7.6	54	40.3	5.4	<.001
VO_2 at Lactate Threshold (mL/kg/min)[a]	320	39.0	7.0	54	33.5	5.5	<.001
VO_2% at Lactate Threshold	320	81.8	10.3	54	82.2	14.0	.803
HR Max (bpm)	322	188.6	14.2	53	188.9	9.6	.882
HR at Lactate Threshold (bpm)	319	169.4	15.3	53	171.4	12.1	.366
HR% at Lactate Threshold	319	89.6	7.2	53	91.0	5.2	.176

[a]Statistically significant difference between men and women (*P*<.05).

pathological populations in these studies, comparisons cannot be made between the results from these studies and those in the current study. Further, no threshold for increased injury risk was reported in any of these studies. Based on this previous research and current findings, it may be beneficial for Soldiers, regardless of sex, with less flexibility/range of motion to incorporate flexibility exercises into training to decrease injury risk. Future research should investigate if such thresholds exist (and if they are gender-specific) using the methods in the current study, which are representative of typical goniometric measures obtained in clinical settings.

Female Soldiers demonstrated strength deficits compared to men even after normalization to body mass. Yet, in the US Army, male and female Soldiers may be called upon to perform the same occupational tasks. Strength differences may put female Soldiers at increased risk of unintentional musculoskeletal injury while performing the duties required of their positions. Additionally, since women generally use a greater percentage of their absolute strength than males during high intensity repetitive tasks, they are more likely to fatigue earlier,[14] and may be at higher injury risk due to compensated technique. Previous research revealed targeted resistance training programs result in increased performance on military specific tasks and reduce gender disparity in strength and occupational lifting/carrying tasks,[42,43] indicating these programs and subsequent adaptations are beneficial in increasing the proportion of women able to successfully perform physically demanding jobs.

Lower extremity strength deficits may contribute to increased injury risk. Weak hamstrings have been demonstrated to increase the risk of hamstring strain.[44] Lower hamstring to quadriceps ratios, falling below the optimal range of 0.60 to 0.90, increases the risk of hamstring strain and injury to the lower leg.[44,45] Although there was no significant difference between men and women in hamstring to quadriceps ratio, both demonstrated ratios (0.49 to 0.50) well below the ratios recommended for decreased injury risk. This may indicate training for both men and women should be adjusted to increase hamstring strength while maintaining quadriceps strength in order to achieve more favorable ratios. Female Soldiers possess less ankle dorsiflexion, inversion, and eversion strength than male Soldiers. Individuals with less ankle strength may be at increased risk for ankle sprains, chronic ankle instability, and other lower leg injuries,[46-49] so targeted programs may be beneficial for any Soldier with less ankle strength in order to reduce injury risk.

Female Soldiers demonstrated significantly weaker shoulder and torso musculature than male Soldiers. Tasks identified in Soldiers with physically-demanding MOSs (lifting/lowering, carrying/load bearing, pulling) each rely heavily on upper body and core strength. Individuals with shoulder instability and shoulder impingement have demonstrated deficits in shoulder strength.[41] Studies

Table 6. Biomechanical Analysis

	Men			Women			P Value
	n	Mean	±SD	n	Mean	±SD	
Stop-Jump Task							
Hip Flexion at Initial Contact (°)[a]	259	42.37	11.26	49	45.87	11.74	.048
Hip Abduction at Initial Contact (°)	259	-3.70	4.07	49	-2.58	3.48	.072
Knee Flexion at Initial Contact (°)	259	25.79	8.02	49	26.82	7.73	.408
Knee Varus/Valgus at Initial Contact (°)[a,b]	259	4.58	6.25	49	-1.36	5.58	<.001
Maximum Knee Flexion (°)	259	91.98	13.97	49	89.41	13.40	.236
Maximal Vertical GRF (%BW)	258	205.28	56.32	49	201.64	63.88	.685
Vertical Drop Landing							
Hip Flexion at Initial Contact (°)[a]	237	19.4	7.3	50	23.6	6.7	<.001
Hip Abduction at Initial Contact (°)	237	-3.7	3.4	50	-2.7	4.0	.068
Knee Flexion at Initial Contact (°)[a]	237	17.9	6.1	50	20.1	6.4	.022
Knee Varus/Valgus at Initial Contact (°)[a,b]	237	2.8	5.0	50	-0.5	4.4	<.001
Maximum Knee Flexion (°)	237	86.7	18.9	50	90.5	14.0	.264
Maximal Vertical GRF (%BW)	236	365.3	98.4	50	359.2	92.3	.688

[a]Statistically significant difference between men and women (*P*<.05).
[b]Negative value indicates valgus.

in civilians and in the workplace have associated low torso rotation strength with low back pain.[50,51] Soldiers with lower levels of strength may benefit from increasing upper body and torso strength in an attempt to decrease injury risk and increase performance capabilities.

Previous research demonstrated female Soldiers possess less absolute strength than males. However, data revealed some women are stronger than some men, and strength overlap is increased when strength is normalized for body mass and fat-free body mass.[14] This evidence suggests the ability to produce a muscle force is similar between sexes, but differences in quantity of muscle mass between males and females limits the absolute amount of force able to be generated.[14] In the current study, while female Soldiers, on average, possess less strength than male Soldiers, examination of individual variability among strength characteristics revealed the top performing women possess similar or better strength characteristics than the bottom performing men, indicating a potential strength capability overlap. Specifically, when assessed by percentiles, the top 25th percentile of women demonstrated greater shoulder strength than the bottom 10th percentile of men and better knee and torso strength than the bottom 25th percentile of men. The top 25th percentile of women demonstrated greater ankle plantar- and dorsiflexion than the bottom 50% of men, and the top 10th percentile of women demonstrated greater ankle inversion and eversion strength than the bottom 50% of men. Therefore, individual variability should be considered when assessing capabilities of male and female Soldiers to safely and successfully perform tactical activities. Strength overlaps should be interpreted with caution, as strength in the current study is normalized to body weight, and absolute strength sex overlaps are likely more conservative.

Male Soldiers demonstrated worse static balance than female Soldiers. Balance plays an important role in athletic and tactical tasks by providing a stable base of support and enhancing overall joint stability, especially with unstable surfaces or unexpected perturbations. Prospective studies demonstrated athletes with increased postural sway in the anterior/posterior and medial/lateral directions have increased risk of sustaining an ankle injury.[52-54] Female Soldiers may possess better balance, because, on average, the center of gravity/center of mass is lower than in male Soldiers. However, previous research revealed men tend to have better balance as the difficulty of the balance task increases, like during tasks involving dynamic postural stability.[55] Further research is warranted to investigate sex differences in postural control during more challenging tactical tasks and maneuvers.

Male Soldiers demonstrated significantly higher anaerobic power and capacity. These characteristics are reflective of the ability to perform quick burst activity and to sustain that performance for a period of time. By participating in training targeting anaerobic components of fitness, female Soldiers will be able to sprint faster and maintain a higher intensity longer. A limitation of the current study is the braking torque applied during the Wingate test differed for male and female Soldiers, so results must be interpreted with caution, and may differ compared to what would have been demonstrated with uniform braking torque.

Male Soldiers also had higher VO_{2max} and VO_2 at lactate threshold in the current study. Previous research postulated women may have reduced aerobic capacity because they carry less fat-free mass and a greater percentage of nonmetabolic (fat) tissue, have a lower oxygen carrying capacity, and possess a decreased cardiac output compared to males.[14,56] While VO_{2max} is largely based these factors, in addition to genetics and age, it can be positively affected by training. Perhaps more importantly, the point at which lactate threshold occurs is more readily influenced by training. If lactate threshold occurs at a higher percentage of maximal oxygen consumption, then an individual will be able to train at a higher intensity for a longer period of time. Individuals who train to enhance lactate threshold may be able to perform physical activity longer and at a higher intensity, thereby potentially improving performance and maximizing operational readiness. Overall, increasing cardiovascular fitness and anaerobic threshold may play a role in mitigating onset of fatigue and reducing risk of unintentional, musculoskeletal injuries.

When anaerobic and aerobic data was assessed by percentiles to investigate variance within sex, an overlap of capabilities was revealed. While considering the limitation of different braking torques, the top 25th percentile of women demonstrated better anaerobic power and capacity than the bottom 10th percentile of men. The top 25th percentile of women demonstrated better aerobic capacity than the bottom 25th percentile of men. The top 50% of women demonstrated a higher lactate threshold (%VO_{2max}) than the bottom 25th percentile of men. Therefore, physiological capabilities must be assessed on an individual level when determining job-specific injury risk and performance capabilities.

Female Soldiers demonstrated significantly higher BMI and body fat percentage than male Soldiers, similar to previous findings that female Soldiers possess 20% less overall body mass, 10% greater body fat, and 30% less muscle mass than their male counterparts.[57] Since fat-free mass is positively correlated with maximum muscular strength, and body fat is negatively correlated with aerobic capacity,[57,58] body composition plays an important role in force generating capacity and performance capability. Previous retrospective research found higher BMI is associated with increased injury risk, including plantar fasciitis and ankle sprain.[59,60] Higher body mass and BMI are prospectively demonstrated risk factors of injury to the low back and lower extremity in a military population.[61] Soldiers with lower (BMI<18 kg/m^2) and higher BMI (BMI>33 kg/m^2) had higher rates of medical and all-cause discharges compared to those classified into the median category (BMI=24.0-24.9 kg/m^2) during the first year of enlistment, suggesting Soldiers with a normal/average body composition are least likely to sustain an injury.[62] Soldiers with body fat percentages considered to be too high or too low may benefit from nutritional and physical training programs designed to optimize body composition to reduce injury risk, enhance performance, and augment health/longevity, but an appropriate range of body fat for male and female Soldiers should be assessed separately.

Biomechanical differences were found between male and female Soldiers during both the stop-jump and the vertical drop landing. Women tended to land with greater hip flexion and knee valgus at initial contact during both tasks. During the drop landing, women landed with increased knee flexion at initial contact, similar to previous research in the athletic population revealing sex differences in cutting, stopping, and jumping maneuvers.[2,27,63-65] Prospective research found individuals who land with greater knee valgus are at increased risk of anterior cruciate ligament injury.[66] Subjects with injury to the anterior cruciate ligament land with increased hip flexion compared to controls; similar increases have been noted in fatigued subjects.[67-69] Insufficient muscular strength and endurance may play a role in the increased hip flexion and knee valgus demonstrated by female Soldiers. Poor landing mechanics may be a function of these deficits coupled with a lack of training in proper landing mechanics. Previous research demonstrated training programs that address both strength and landing mechanics are able to improve landing biomechanics and reduce the injury risk.[70]

A limitation of the current study is the uneven distribution of male and female Soldiers available for analysis. However, the percentage of female Soldiers in the current study (≈14.3%) mirrors the approximate distribution of female Soldiers in the US Army (≈13.6%).[13] Another limitation is that job-specific tasks were not assessed in the current study. Future research should assess the performance of specific occupational tasks, especially those unique to ground combat units.

Conclusion

The current study demonstrated female Soldiers are significantly different from male Soldiers across a majority of physical, physiological, and musculoskeletal characteristics. Targeted training may be beneficial in order to address the sex-specific differences and to induce adaptions specific to job task requirements. While both male and female Soldiers possess the capability to perform physically-demanding job requirements, on average, female Soldiers possessed lower strength, power, endurance, and worse body composition and biomechanics than male Soldiers. Therefore, progressive, periodized programs designed to enhance these characteristics in female Soldiers may increase the proportion of women capable of safely and successfully performing job tasks and reduce the sex disparity evidenced in the current study. At the same time, within-sex variability of characteristics demonstrating the highest performing women possess comparable or better strength, anaerobic, and aerobic characteristics than the lowest performing men suggests military personnel should be evaluated on an individual (gender neutral) basis to determine performance capabilities, injury risk, and targeted program implementation. Overall, targeted, sex-specific training adaptations may be critical to improving overall force-wide safety, efficiency, and tactical preparedness, especially as female Soldiers are integrated into ground combat positions.

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The Effects of Cross-Training on Fitness and Injury in Women

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Abstract

Background: As combat arms occupations become available to women, adequate muscular strength and aerobic endurance will be essential for the completion of physically demanding job-related tasks. Therefore, in addition to US Army Physical Readiness Training, Soldiers will often engage in their own personal physical fitness training programs.

Purpose: To evaluate fitness and injury outcomes for women participating in personal cross-training programs compared to women performing one mode of training or having no personal fitness program.

Methods: Demographics, physical training activities, physical fitness, and injuries were obtained from surveys administered to female Soldiers in an infantry division. Women were categorized into the following 4 groups based on their personal physical fitness program: cross-training (CT), running only (R), weight training only (WT), and no personal fitness program (NPF). An ANOVA was used to compare physical training, health behaviors, and physical fitness across groups. A χ^2 test was used to compare injury rates between fitness programs. Risk (%), risk ratios (RR) and 95% confidence intervals (95% CI) were used to determine injury risk.

Results: A total of 620 women completed the survey and indicated whether or not they had a personal fitness program (cross-training, n=260; running only, n=93; weight training only, n=86; no personal fitness program, n=181). Average age and body mass index was 26.2±5.8 years and 24.5±3.3 kg/m^2 respectively with no differences between the 4 fitness groups. The cross-training group had higher physical performance on the muscular endurance (push-ups and sit-ups) portion of the Army physical fitness test (APFT) when compared to the 3 other groups (CT 42 push-ups vs (R 38, WT 35, NPF 36)); (CT 68 sit-ups vs (R 63, WT 62, NPF 62)). For the aerobic endurance (2-mile run) portion of the APFT, the cross-training group had higher performance when compared to those with no personal fitness program (CT 17.4 minutes vs NPF 18.5 minutes). Overall, 53% of female Soldiers sustained an injury over a 12-month period. All injury rates and lower extremity injury rates among women with a cross-training personal fitness program were not different from the other personal fitness programs. Those performing cross-training were 2.6 and 2.1 times more likely to experience a running related injury when compared to those in the weight training and no personal fitness group, respectively. On the other hand, women performing cross-training were 65% less likely to experience a lifting/moving heavy objects related injury when compared to the weight training only group.

Conclusions: Women who participated in a cross-training program for personal physical fitness training had higher muscular endurance compared to the other fitness groups and higher aerobic endurance when compared to the no personal fitness group. There were no differences for all injuries and lower body injuries between cross-training and other fitness programs. Cross-training may be the best option for improving physical fitness when compared to just one mode of fitness training.

As combat arms occupations become available to women, adequate muscular strength and aerobic endurance will be essential for the completion of physically demanding, job-related tasks. *The Army Physical Readiness Training Manual* (*Field Manual 7-22*)[1] provides guidance on developing strength, endurance, and mobility among Soldiers. However, the Physical Readiness Training system is performed in groups and may not always meet the needs of an individual Soldier's personal fitness goals or objectives. Therefore, in addition to Army Physical Readiness Training, Soldiers will often engage in their own personal physical fitness training programs.

The ultimate goal of physical training is to improve occupational or physical performance. In an attempt to optimize training goals, the frequency, intensity, and duration of workouts can be manipulated over time. However, performing too much of one activity, exercising too long, and improper technique can result in both overuse and traumatic injury. Therefore in an attempt to minimize injuries and improve or maintain performance, some athletes have tried cross-training.[2-6] Cross-training is defined as training for more than one sport simultaneously, or training for several different components of fitness such as endurance, strength, and flexibility.[7]

Previous studies investigating cross-training type programs have found that performance remains similar or improves with the addition of a different training component.[2-5] As part of a study investigating female distance runners, 50% of running training volume was substituted with cycling. They found no change in VO_2max and concluded that aerobic performance was adequately maintained in the running/cycling group when compared to the running only group.[3] In an investigation of competitive swimmers, the intervention group (performing both strength and endurance training) improved their land strength, tethered swimming force and 400 meter freestyle performance when compared to the control group (endurance training only).[2] It has also been shown that 60 minutes of cross-training (combined aerobic and resistance training) results in improved state anxiety or mental health 10 minutes after exercising,[8] whereas acute bouts of resistance training have resulted in no reductions[9] or delayed reductions occurring at 180 minutes.[10]

Single mode training such as aerobic or resistance training has also been shown to improve occupational and fitness performance.[11-16] The purpose of this investigation was to evaluate fitness and injury outcomes for women participating in personal cross-training programs (more than one mode of training) compared to women performing one mode of training or having no personal fitness program.

Methods

Population

The population consisted of 620 female Soldiers within 3 light infantry brigades. Each brigade consisted of 6 battalions/regiments including a special troops battalion, a cavalry regiment, an armor regiment, an infantry regiment (1 brigade had 2 infantry regiments and no armor regiment), a field artillery regiment and a brigade support battalion. Rosters of unit members were requested and obtained through the S-1 offices. Roster information included name, sex, rank and battalion.

Survey

Surveys were administered between 2010 and 2011. The surveys were used to collect information from the Soldiers about personal characteristics, physical training, performance on their most recent Army physical fitness test (APFT), and injuries occurring within the last 12 months. Women who indicated that they performed strength training, distance running or sprinting/interval training once or more a week as part of their personal physical fitness program were considered as having participated in these personal fitness programs. Women who indicated that they performed personal strength training, distance running or sprinting/interval training less than once a week or not at all were considered as not participating in these fitness programs. Based on their personal fitness programs, the women were then categorized into a cross-training group, running only group, weight training only group, and no personal fitness program group (Table 1).

Army Physical Fitness Test

Performance on the APFT was used as a measure of physical fitness. Soldiers' most recent APFT scores were obtained from the survey. High correlations have been shown between unit records and self-reported APFT scores.[17] The APFT consisted of 3 events: a 2 minute maximal effort push-up event, a 2 minute maximal effort sit-up event, and a 2-mile run for time. Events were performed in accordance with instructions contained in *Field Manual 7-22*.[1] Predicted VO_2max was estimated from 2-mile run times using the following equation: predicted $VO_2max = 72.9 - (1.77 \times (\text{2-mile run time}))$.[18]

Data Analysis

The application SPSS 19.0 (IBM Corp, Armonk, New York) was used for statistical analysis. Frequencies and percent distribution were calculated for categorical variables such as age groups, military occupational specialty, body mass index (BMI) level, etc, as shown in Table 2. Means and SD were calculated for continuous variables such as age in years, weight, height, miles run per week, 2-mile run times in minutes, number of push-ups, etc, shown in Table 3. The BMI (weight in kilograms divided by height in meters squared (kg/m^2)) was categorized according to the Centers for Disease Control and Prevention classifications for underweight, normal, overweight, and obese.[19]

Table 1. Fitness Group Categories Defined by Physical Training Activities.

Personal Fitness Training Program	WT, RUN, ST	WT, RUN	WT, ST	RUN, ST	RUN	WT	NPF
Cross-Training	✓	✓	✓				
Running Only				✓	✓		
Weight Training Only						✓	
No Personal Fitness Program							✓

WT: Performed weight training as part of a personal physical training program one or more times a week.
RUN: Performed distance running (1 mile or more) as part of a personal physical training program one or more times a week.
ST: Performed sprinting/interval training as part of a personal physical training program one or more times a week.
NPF: Reported no personal fitness program.

Table 2. Personal Characteristics, Physical Fitness Activities, and Fitness Training Group Categories Among Women in 3 Light Infantry Brigades (N=620).

Variable	Subcategory of Variable	n	% N
Age (years)	18-22	178	29%
	23-27	255	41%
	≥28	184	30%
Body Mass Index	<18.5 kg/m² (underweight)	15	3%
	18.5-24.9 kg/m² (normal)	332	54%
	25-29 kg/m² (overweight)	237	39%
	30+ kg/m² (obese)	28	5%
Rank	E1-E3	138	23%
	E4-E5	357	58%
	E6-E9	55	9%
	Officer/Warrant Officer	64	10%
Military Occupational Specialty	Combat Support	176	30%
	Combat Services Support	429	70%
Brigade	Infantry brigade A	196	32%
	Infantry brigade B	253	41%
	Infantry brigade C	171	28%
Unit Distance Running	None	178	30%
	≥1 time per week	423	70%
Unit Strength Training	None/<1 time per week	417	69%
	≥1 time per week	186	31%
Unit Sprinting/Interval Training	None/<1 time per week	198	33%
	≥1 time per week	407	67%
Unit Agility Training	None/<1 time per week	392	65%
	≥1 time per week	208	35%
Personal Distance Running	None/<1 time per week	298	48%
	≥1 time per week	322	52%
Personal Strength Training	None/<1 time per week	274	44%
	≥1 time per week	346	56%
Personal Sprinting/Interval Training	None/<1 time per week	390	63%
	≥1 time per week	174	37%
Fitness Training Group	Cross-Training	260	42%
	Running Only	93	15%
	Weight Training Only	86	14%
	No Personal Fitness Training	181	29%

A χ^2 test was used to compare injury rates between fitness programs. Injury rates were calculated for all (overall) injuries, lower extremity injuries, and upper extremity injuries. An ANOVA was used to compare descriptive statistics, physical training, and physical fitness. A post hoc Tukey test was used to look for specific interactions. An independent *t* test was used to determine any differences in miles run per week. For injury cause, risks (%) of injury and risk ratios with 95% confidence intervals (95% CI) were calculated for different risk factors.

Results

The average age of the female Soldiers was 26.2±5.8 years with an average BMI of 24.5±3.3 kg/m². A majority of the Soldiers were of ranks E4 and E5, in a combat services support role, and had a normal BMI. A majority of the Soldiers reported participating in personal and unit distance running, personal strength training, and unit sprint/interval training one or more times per week. Less than half of the Soldiers reported participating in unit resistance training, agility training, and personal sprint/interval training one or more times per week. As shown in Table 2, 42% of the women were classified as performing cross-training for personal fitness, with 15% having a running only program, 14% having a weight training only program, and 29% with no personal fitness program.

Age, height, weight, and BMI were similar among participants of the various personal fitness programs. The cross-training group was different from the running group in that they ran more miles per week during personal fitness training. The cross-training group also performed more push-ups and sit-ups on their APFT compared to the other 3 groups. The cross-training group had better performance and higher estimated VO_2max times for the APFT 2-mile run compared to the no personal fitness program group (Table 3).

Overall, 53% of female Soldiers sustained an injury over a 12-month period. Table 4 displays injury rates by personal fitness training program. All injury rates and lower extremity injury rates among women with a cross-training personal fitness program were not different from the other personal fitness programs. Women with a cross-training personal fitness program had a lower risk of upper extremity injury when compared to the weight training only program. The running only and no personal fitness program groups also had lower injury rates than the weight training only group for both all injuries and upper extremity injuries.

Table 5 displays the activities associated with injuries for women participating in the cross-training and running only programs. There were no statistically significant differences in injury risk by activity between the 2 groups.

Table 6 displays the activities associated with injuries for women participating in a cross-training and weight training only programs. The comparison of injury incidence by fitness program showed women performing cross-training were more likely to experience a running related injury when compared to women performing weight training only. However, women performing weight training only were more likely to experience a lifting/moving heavy objects related injury in comparison to women performing cross-training.

Table 3. Personal Characteristics, Physical Training, and Physical Fitness Performance Averages by Personal Fitness Training Program.

Variables	Cross-Training	Running Only	Weight Training Only	No Personal Fitness Program	ANOVA	ANOVA With Tukey (Specific Interactions)
Age (years)	25.8±5.5 (n=259)	26.6±6.4 (n=93)	27.3±6.1 (n=85)	26.2±5.9 (n=180)	0.20	–
Height (cm)	164.3±8.1 (n=256)	163.0±7.6 (n=92)	165.0±7.1 (n=86)	163.6±7.0 (n=181)	0.24	–
Weight (kg)	65.7±9.6 (n=255)	66.2±9.2 (n=90)	68.3±9.2 (n=86)	65.7±10.2 (n=181)	0.09	–
BMI (kg/m^2)	24.3±3.3 (n=234)	24.9±3.3 (n=90)	25.0±3.1 (n=86)	24.3±3.2 (n=181)	0.10	–
Miles Run Per Week	7.7±6.5 (n=234)	6.1±5.2 (n=78)	–	–	0.03*	–
APFT Push-Up	41.8±12.2 (n=243)	37.7±13.8 (n=85)	35.4±10.9 (n=80)	36.3±11.3 (n=160)	<0.01	Cross-Training – Running Program *P*=.04 Cross-Training – Weight Training *P*<.01 Cross-Training – No Program *P*<.01
APFT Sit-up	67.8±13.5 (n=244)	63.4±15.1 (n=86)	61.7±10.9 (n=76)	61.8±11.3 (n=156)	<0.01	Cross-Training – Running Program *P*=.04 Cross-Training – Weight Training *P*<.01 Cross-Training – No Program *P*<.01
APFT 2-mile Run	17.4±2.1 (n=230)	18.0±2.1 (n=76)	17.8±1.6 (n=49)	18.5±2.3 (n=136)	<0.01	Cross-Training – No Program *P*<.01
Estimated VO_2max (ml/kg/min)	42.1±3.7	41.0±3.8	41.5±2.9	40.2±4.1	<0.01	Cross-Training – No Program *P*<.01

*Independent *t* test

Table 4. Comparison of Injury Incidence by Personal Fitness Training Program.

Injury Type*	Cross-Training	Running Only	Weight Training Only	No Personal Fitness Program	*P* Value
All Injuries	55% (n=260)	40%† (n=93)	65% (n=86)	49%† (n=181)	<.01
Lower Extremity Injuries	24% (n=235)	20% (n=91)	23% (n=78)	24% (n=174)	.47
Upper Extremity Injuries	23%† (n=235)	19%† (n=91)	39% (n=78)	24%† (n=174)	.02

*Approximately 7% (n=42) of the injuries could not be classified as either upper or lower extremity injuries due to incomplete survey data or injuries containing both upper and lower body areas.
†Significantly different from Weight Training Only.

Table 7 displays the activities associated with injuries for women participating in a cross-training program and women with no personal fitness training program. The comparison of injury incidence by fitness program showed women performing cross-training were more likely to experience a running related injury when compared to women with no fitness training program. However, women with no fitness program were more likely to experience a walking, hiking, or marching with no load injury in comparison to the cross-training group.

Comment

This analysis assessed fitness and injury outcomes for women with personal cross-training programs compared to women performing only one mode of personal fitness training (running only or weight training only) or having no personal fitness program. Women with a cross-training program had greater muscular endurance as measured by performance on APFT push-up and sit-up tests compared to women with other types of personal fitness programs. Women who participated in cross-training also had a higher estimated VO_2max as measured by APFT run time performance compared to women with no personal fitness program. There were no differences for all injuries and lower body injuries between cross-training and the other programs. However, the cross-training group had a lower risk of upper body injury when compared to the weight training only group.

An examination of activities associated with injury showed women with a cross-training program were more than twice as likely to experience a running related injury when compared to women with a personal fitness program focused on weight training only and women with no personal fitness program. However, women with no fitness program or just a weight training program were twice as likely to experience a walking, hiking, or marching with no load injury, and were almost 3 times as likely to experience a lifting/moving heavy objects related injury when compared to the cross-training group.

Higher muscular and aerobic endurance have been demonstrated in other studies of cross-training programs.

Studies examining the addition of a resistance training program to an already established endurance training program found improvement in both strength and aerobic performance.[20-24] These findings are also supported by a recent meta-analysis of concurrent resistance and endurance training, where investigators found larger effects on strength (1.76 (95% CI, 1.34-2.18)) and endurance (1.44 (95% CI, 1.03-1.84)), when compared to endurance training alone (0.78 (95% CI, 0.36-1.19)).[25] Previous studies investigating resistance training and running performance found increased running economy[24,26,27] and improved running performance when resistance training was incorporated into their training program.[27,28] In another study investigating moderately trained runners participating in a running, sprinting, and weight training program (RSW) compared to a running only program (RO), the RSW program showed improvements in running performance and dynamic strength over the RO program.[29] As suggested by this analysis, these studies indicate that a fitness program with 2 or more fitness components is more effective than a fitness program with one mode of training.

Table 5. Activity Associated with Injury for Women Performing Cross-Training Compared to Women with a Running Only Personal Fitness Training Program.

Cause of Injury	Cross-Training % (n)	Running Only % (n)	Risk Ratio (Cross-Training/No Program)	Chi square *P* Value
Running	33% (44)	19% (7)	1.75 (0.86-3.56)	.10
Other Exercise	15% (20)	19% (7)	0.79 (0.36-1.73)	.57
Walking, Hiking, or Marching with no load	11% (15)	8% (3)	1.39 (0.43-4.55)	.84*
Lifting/Moving Heavy Objects	10% (13)	14% (5)	0.72 (0.28-1.90)	.51
Sports	9% (12)	5% (2)	1.67 (0.39-7.13)	.75*
Stepping, Climbing	5% (6)	11% (4)	0.42 (0.12-1.40)	.30*
Marching with a load	4% (5)	8% (3)	0.46 (0.12-1.85)	.48*
Riding/Driving in a Motorized Vehicle	3% (4)	8% (3)	0.37 (0.09-1.58)	.35*
Repairing/ Maintaining Equipment	0% (0)	0% (0)	----	----
Other	11% (14)	8% (3)	1.30 (0.39-4.28)	.94*

*Fisher exact test used due to at least one cell count <5.

Table 6. Activity Associated with Injury for Women Performing Cross-Training Compared to Women with a Weight Training Personal Fitness Training Program.

Cause of Injury	Cross-training	Weight Training Only	Risk Ratio (Cross-Training/No Program)	*P* Value
Running	33% (44)	13% (7)	2.55 (1.23-5.31)	<.01
Other Exercise	15% (20)	13% (7)	1.16 (0.52-2.58)	.71
Walking, Hiking, or Marching with no load	11% (15)	11% (6)	1.02 (0.42-2.48)	.97
Lifting/Moving Heavy Objects	10% (13)	28% (15)	0.35 (0.18-0.69)	<.01
Sports	9% (12)	4% (2)	2.44 (0.56-10.52)	.35*
Stepping, Climbing	5% (6)	0% (0)	–	–
Marching with a load	4% (5)	4% (2)	1.02 (0.20-5.07)	.99*
Riding/Driving in a Motorized Vehicle	3% (4)	4% (2)	0.81 (0.15-4.30)	.99*
Repairing / Maintaining Equipment	0 (0%)	4% (2)	–	–
Other	11% (14)	20% (11)	0.52 (0.25-1.07)	.07

*Fisher exact test used due to at least one cell count <5.

Overall (all) injury rates among women with a cross-training personal fitness program were not different from injury rates among women with other training programs. In previous military studies investigating the implementation of new exercise programs (incorporating additional cross-training components), injury rates neither increased nor decreased with implementation of a cross-training-like program.[6,30,31]

Women who performed weight training only were more likely to experience an upper body injury compared to the cross-training group as well as the other programs. Women performing weight training only as part of their personal fitness program also had a higher risk of overall injury when compared to women with a program based on running only or those with no personal fitness program. In a study comparing women who participated in a resistance training program to a control group, the resistance training group had higher injury rates (23% per year) compared to the control group (7% per year).[32] The investigators went on to say that strength training provided favorable changes in lean mass and strength, while injury rates were lower than previously reported population-based survey rates. Even though injury rates were higher for the weight only group when compared to the running only and no personal fitness program group, previous studies have shown that resistance training improves physical and occupational task performance.[12-16] However, it is more effective to use 2 modes of training rather than one, as shown by improved muscular endurance in the cross-training group when compared to the weight training only group

For men, resistance training has been shown to be protective against injury.[33] When looking at sex differences in resistance training, women were found to have a 69% greater risk of being accidentally injured when compared to men.[34] It may be that women have less experience with weight training, poor exercise technique, or lack of coaching education when compared to men, placing them at a greater risk of injury and possibly an even higher risk of upper body injury. It is likely that muscular strength would also have improved had it been measured. Other studies have shown an increase in muscular strength after the addition of a resistance training program.[15,35] In a 6-week study of untrained (regarding resistance training) college women, absolute one repetition maximum (1RM) leg press strength was improved by 62%, absolute 1RM squat strength by 46%, and absolute 1RM knee extension strength by 54% using a traditional strength training program. In another resistance and aerobic training study, women who participated in a 12 week aerobic and resistance training program improved their 1RM squat and shoulder press by 26% and 17% respectively, compared to a control group where no changes were found.[35] Strength training programs would likely show similar outcomes in Army populations.

In this investigation, women performing cross-training were more than twice as likely to experience a running related injury when compared to the weight training and no personnel fitness program groups, who reported very minimal (less that once a week) or no additional running per week beyond unit PT. The greater exposure to running in the cross-training group placed them at a higher risk of injury. Prior studies have shown increased risk of injury with miles run per week.[36-38] In another cross-training study consisting of running, sprinting, weight training, backpacking, and lift and carry drills, weight lifting accounted for about one third of the injuries and clinic visits, while running injuries accounted for about one fifth of the injuries and clinic visits.[5] These results are different from the current study in that those participating in cross-training were more likely to experience a running related injury. It may be that the participants in the current investigation ran more miles per week, whereas the other study had a more diverse training program with quite a few more strength training activities.

Women who performed weight training only were at almost 3 times the risk of injury for moving/lifting heavy objects when compared to the cross-training group. It may be that women in the weight training group spent more time per week weight training or had advanced to lifting heavier weights, possibly increasing their risk for strains and sprains when compared to the cross-training group. However additional data about the specifics of their weight training program would be required to determine why their risk of injury was higher.

Those with no personal fitness program were at a higher risk of injury for walking, hiking, and marching without a load when compared to the cross-training group. The women in the no personal fitness group also had lower estimated aerobic capacities when compared to the cross-training group. Soldiers with lower aerobic capacities will likely experience greater amounts of physiological stress and/or fatigue during tasks such as running, marching and hiking due to exercising at a higher percentage of their maximum aerobic capacity in comparison with Soldiers with greater fitness levels. The greater physiological stress and/or fatigue

Table 7. Activity Associated with Injury for Women Performing Cross-Training Compared to Women with a No Personal Fitness Training Program.

Cause of Injury	Cross-training	No Personal Fitness Program	Risk Ratio (Cross-Training/No Program)	*P* Value
Running	33% (44)	16% (13)	2.14 (1.23-3.72)	<.01
Other Exercise	15% (20)	13% (11)	1.15 (0.58-2.27)	.69
Walking, Hiking, or Marching With No Load	11% (15)	23% (19)	0.50 (0.27-0.93)	.03
Lifting/Moving Heavy Objects	10% (13)	14% (12)	0.68 (0.33-1.43)	.31
Sports	9% (12)	6% (5)	1.52 (0.55-4.15)	.41
Stepping, Climbing	5% (6)	6% (5)	0.76 (0.24-2.41)	.64
Marching with a Load	4% (5)	5% (4)	0.79 (0.22-2.86)	.97*
Riding/Driving in a Motorized Vehicle	3% (4)	1% (1)	2.53 (0.29-22.22)	.71*
Repairing/ Maintaining Equipment	0 (0%)	0 (0%)	–	–
Other	11% (14)	17% (14)	0.63 (0.32-1.26)	.19

*Fisher exact test used due to at least one cell count <5.

experienced may lead to a higher risk of injury. Studies on fatigue have demonstrated decrements in proprioceptive ability,[39] a decrease in joint stability,[40] alterations in muscle activity,[39] changes in gait,[41-45] balance,[46,47] low frequency fatigue,[48] neuromuscular function,[49] and ligament laxity.[50]

Conclusion

Women with a cross-training personal fitness program had higher muscular endurance compared to women with a personal fitness program based on single mode training or no personal fitness program. Women with a cross-training personal fitness program also had higher estimated VO_{2max} when compared to the no personal fitness group. There were no differences for all injuries and lower body injuries between cross-training and other fitness programs. Those performing cross-training were more than twice as likely to experience a running related injury when compared to weight training and no personal fitness group. Cross-training may be the best option for improving physical fitness when compared to just one mode of fitness training.

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Physical Training, Smoking, and Injury During Deployment: A Comparison of Men and Women in the US Army

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Abstract

Purpose: To investigate changes in physical training (PT), fitness, and injury during deployment and identify differences between men and women.

Methods: Data were collected on male and female US Army Soldiers through self-reported surveys completed before and after deployment to Afghanistan. Changes in physical training activities, physical fitness, injury incidence, BMI, and smoking status were analyzed. Descriptive statistics were used to compare before deployment and deployment results and differences between men and women.

Results: Surveys were completed by 727 men and 43 women. The percentage of Soldiers engaging in unit PT running of 5 miles or more per week decreased by almost half for men and women. The percentage of Soldiers doing personal PT running of 5 miles or more per week and engaged in resistance training 3 or more days per week more than doubled for men and women during deployment. Cardiorespiratory endurance for women improved by 50 seconds (P=.06) and for men declined by 29 seconds (P<.01), while muscular endurance increased by 0.6 repetitions (P<.01) during deployment. Injury rates for men decreased, on average, 36.2 to 19.0 injuries per 1,000 Soldiers per month (P=.01). Injury rates for women decreased on average from 42.6 to 14.0 injuries per 1,000 Soldiers per month (P=.02). During deployment, BMI did not change for men or women and smoking increased 19% for men (P<.01), but did not increase for women.

Conclusion: Comparisons of physical training activities and health behavior among men and women before and during deployment suggests that increased resistance training could be recommended for women and smoking cessation for men. Given the potentially important role of personal PT in maintaining physical fitness in the deployment environment, future work should support provision of the necessary environment and equipment for Soldiers to perform personal PT effectively and safely on their own. Further, the physical training gaps between men and women should be addressed, with suggestions regarding where improvements can be made, especially for women interested in seeking combat positions with high physical demands.

Military deployments can have a significant effect on Soldiers' physical and/or mental well-being due to altered schedules, environmental conditions, and available resources during deployments. Physical training (PT), fitness levels, injury incidence, and health behaviors can be affected by these changes. Understanding how these fitness and health components are affected can help improve the readiness and effectiveness of deployed Soldiers.

Both men and women perform occupational tasks with varying physical demands during deployments. It is important that all Soldiers have the aerobic endurance and strength necessary to successfully complete missions without injury. The ability for a deployed unit to maintain a physical training program requires appropriate space, equipment, and time, which varies by location. Low levels of physical fitness have been shown to increase injury risk, which can limit unit readiness.[1-3] It is essential to continue physical training, either with the unit, during personal time, or both.

In 2013, the US military announced that women would be eligible for combat roles previously only open to men.[4] This announcement raised questions about the physical training requirements necessary for women entering these positions, and highlighted a need to better understand current physical training practices, both before and during deployment.[5] There have been few studies examining the physical training and fitness levels of deployed Soldiers, and none that have included women. One study looking at 137 male combat arms Soldiers during a 13-month deployment showed upper and lower body strength improved, upper body power improved, aerobic performance declined, fat mass increased, and fewer Soldiers participated in aerobic exercise and sports during deployment.[6] Another investigation which looked at changes in fitness and body composition after a 9-month deployment to Afghanistan showed decreases in aerobic capacity, upper body power, and body composition, with no change in lifting strength and vertical jump performance.[7]

With the average deployment lasting 9 months, Soldiers and leadership should understand the effects of deployment on fitness, health, and physical training practices.[8] The focus of this investigation was to see how a 9-month deployment changed Soldiers' physical training, injury incidence, health behaviors, and fitness levels, and to compare physical training practices of men and women before and during deployment.

Methods

Data Collected

A volunteer-based survey was administered to Soldiers in a light infantry brigade prior to their deployment in 2011, and again when they returned from deployment in 2013. The surveys obtained self-reported data on unit and personal PT, physical fitness, injury, body mass index (BMI), and tobacco use during the 6 months prior to deployment, and again during the 9 months of deployment (asked postdeployment). Participation in a variety of physical training activities was measured with questions pertaining to the frequency of resistance, sprint, cross-training, and running. The project was reviewed and approved by the US Army Public Health Command Public Health Review Board.

Physical training weekly running distance was calculated from reported average running frequency per week multiplied by average miles per run. Physical fitness was assessed using self-reported performance on the Army Physical Fitness Test (APFT), with the APFT push-up event and sit-up event reflecting muscular endurance and the 2 mile run reflecting cardiovascular fitness.[9] APFT scores consisted of a timed (2 minutes) push-up event, a timed (2 minutes) sit-up event and timed 2 mile run. Injury questions asked were pertaining to Soldiers most recent injury during the time-frame specified. Body mass index (BMI (kg/m^2)) was calculated from self-reported height (meters) and weight (kg). Cigarette smokers were identified as those who had smoked at least 100 cigarettes in their lifetime and smoked at least one cigarette in the 30 days prior to the survey administration date.

Data Analysis

Data were analyzed using SPSS, Version 19.0 (IBM Corp, Armonk, New York). Descriptive statistics for demographics were calculated. Means and standard deviations were calculated for all continuous variables. OpenEpi (http://www.openepi.com) was used for ANOVA, chi-square, and person-time rates. Chi-square and ANOVA tests were used to compare significant changes among before-deployment and during-deployment variables. Person-time rates were calculated for injury incidence. *P* values of 0.05 or less were considered significant changes, while *P* values between 0.06 and 0.10 were considered marginally significant changes.

Results

Descriptive Statistics

Before- and during-deployment surveys were completed by 727 men and 43 women. The comparison of injury rates before and during deployment showed the average injury rate decreased from 36.2 to 19.0 injuries per 1,000 Soldiers per month for men ($P<.01$) and decreased from 42.6 to 14.0 injuries per 1,000 Soldiers per month for women ($P=.02$) (Table 1). Prior to deployment, average age and BMI was 24.7 years and 25.8 kg/m^2 for men, and 25.2 years and 24.4 kg/m^2 for women (Table 2). Age and BMI did not significantly change during deployment for men or women. Incidence of smoking increased by 19% during deployment for men ($P<.01$), but did not change for women.

Table 1. Injury Rates Differences Before and During Deployment for Men and Women.

	Before deployment injury rate (per 1,000 Soldiers per month)	Deployment injury rate (per 1,000 Soldiers per month)	*P* value, before deployment vs deployment*
Male Soldiers (n=727)	36.2*	19.0*	<.01
Female Soldiers (n=43)	42.6*	14.0*	.02
P value, male vs female*	<.01	<.01	

*P is calculated using 2 person-time rates z-score

Personal and Unit Physical Training

For personal PT, resistance training participation of 3 or more days per week more than doubled for men, from 33% before deployment to 77% during deployment, and increased 8 fold for women, from 5% before deployment to 40% during deployment. The percentage of personnel sprinting during personal PT increased slightly for men, from 50% to 67% reporting sprinting one or more days per week, but did not change for women during

Table 2. Demographic, Physical Fitness, and Physical Training Differences Before and During Deployment for Men and Women.

	Men (n=727)				Women (n=43)				% Difference Between Sexes: Predeployment	% Difference Between Sexes: Deployed
	Predeploy (mean±SD)	Deployed (mean±SD)	*P**	% Change	Predeploy (mean±SD)	Deployed (mean±SD)	*P**	% Change		
Age (years)	24.7±5.1	25.8±5.1	<.01†	+4%	25.2±4.7	26.3±4.7	.28†	+4%	4%	2%
BMI (kg/m²)	25.8±3.3	26.0±3.2	.24†	+<1%	24.4±2.8	24.5±2.5	.86†	+<1%	6%	6%
Smokers (%)	47%	56%	<.01†	+19%	40%	38%	.90‡	-5%	7%	18%
APFT										
2 mile run (minutes)	14.34±1.33	14.82 ±1.40	<.01†	+3%	17.83 ±2.14	16.99 ±1.78	.06†	-5%	24%	15%
Sit-ups (repetitions)	69.8±10.7	69.5±9.9	.37†	-<1%	66.8±13.4	69.1±14.2	.45†	+3%	4%	1%
Push-ups (repetitions)	65.9±12.6	66.5±12.3	<.01†	+1%	43.4±17.2	44.2±11.3	.80†	+2%	52%	50%
Personal PT										
Resistance Training (n)	723	720			43	43				
None	31%	8%		-74%	51%	21%		-59%	+20%	+13%
≤1-2 days per week	36%	20%	<.01‡	-44%	44%	40%	<.01‡	-11%	+8%	+20%
≥3 days per week	33%	72%		+119%	5%	40%		+750%	-28%	-32%
Sprinting (n)	722	723			43	43				
None	50%	33%		-34%	70%	35%		-50%	+20%	+2%
≤1-2 days per week	42%	57%	<.01‡	+37%	26%	61%	<.01‡	+136%	-16%	+4%
≥3 days per week	8%	10%		+20%	5%	5%		0%	-3%	-5%
Running Mileage (n)	697	700			41	43				
None	33%	12%		-64%	44%	14%		-67%	+10%	+2%
<5 miles per week	42%	29%	<.01‡	-30%	49%	28%	<.01‡	-40%	+7%	-1%
≥5 miles per week	25%	59%		+134%	7%	58%		+733%	-18%	-1%
Unit PT										
Resistance Training (n)	708	723			41	43				
None	11%	47%		+333%	20%	51%		+175%	+9%	+4%
≤1-2 days per week	53%	16%	<.01‡	-69%	56%	28%	.01‡	-48%	+3%	+12%
≥3 days per week	36%	37%		+7%	24%	21%		-10%	-12%	-16%
Sprinting (n)	709	725			42	43				
None	10%	59%		+484%	17%	56%		+243%	+7%	-3%
≤1-2 days per week	72%	36%	<.01‡	-49%	67%	44%	<.01‡	-32%	-5%	+8%
≥3 days per week	18%	6%		-68%	17%	0%		-100%	-1%	-6%
Cross-Training (n)	704	722			38	43				
None	21%	56%		+174%	37%	61%		+86%	+3%	-4%
≤1-2 days per week	42%	35%	<.01‡	-15%	45%	26%	.10‡	-35%	+1%	-4%
≥3 times per week	37%	7%		-80%	19%	14%		-14%	-5%	+8%
Running Mileage (n)	699	710			41	40				
None	4%	54%		+117%	7%	50%		+578%	+16%	+5%
<5 miles per week	28%	17%	<.01‡	-39%	29%	13%	<.01‡	-75%	+3%	-9%
≥5 miles per week	68%	30%		-56%	63%	38%		-42%	-18%	+7%

*$P<.10$ is considered significant †ANOVA ‡Chi-square

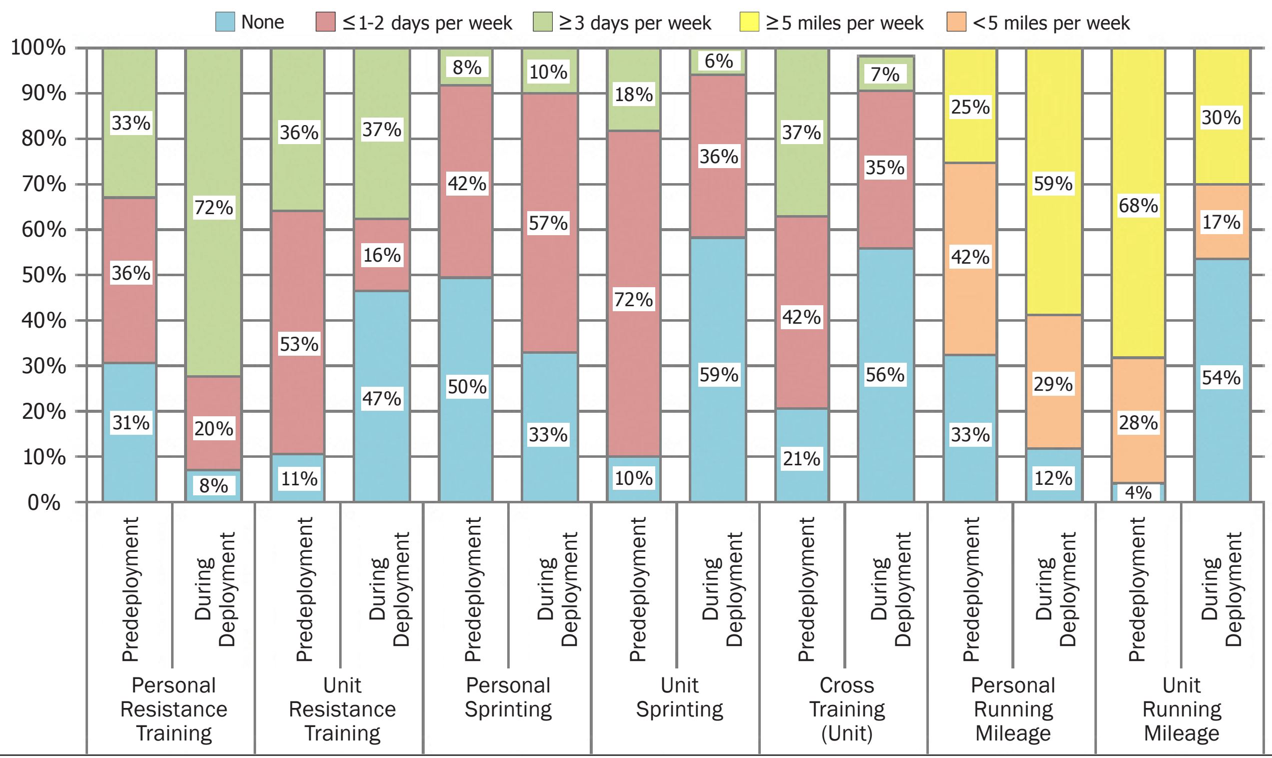

Figure 1. Men's physical training participation before and during deployment.

deployment. The percentage of Soldiers running 5 or more miles per week during personal PT doubled for men (25% to 59%), and increased more than 8 times for women (7% to 58%).

For unit PT, resistance training participation of 3 or more days per week remained about the same for men during deployment (36% and 37%) and slightly decreased for women (24% to 21%). Participation in unit sprinting drills 3 or more days per week decreased for men (18% to 6%) and women (17% to 0%) during deployment. Participation in unit cross-training drills 3 or more days per week decreased for men (37% to 7%) and women (19% to 14%) during deployment. Unit running mileage of 5 miles or more per week decreased for both men (68% to 30%) and women (63% to 38%) during deployment (Table 2; Figures 1 and 2).

When comparing PT for men and women before deployment (Table 2), personal resistance training showed the largest difference between the 2 groups with 33% of men and 5% of women participating 3 or more days per week. The smallest difference between men and women prior to deployment was seen in unit sprinting with 68% of men and 63% of women performing some sort of sprint training 3 or more days per week. In the comparison of men and women during deployment (Table 2), personal resistance training showed the largest difference between the 2 groups with 72% of men and 40% of women participating 3 or more days per week. The smallest difference between men and women during deployment was seen in personal running mileage with 59% of men and 58% of women participating 3 or more days per week.

Physical Fitness

During deployment, cardiorespiratory endurance improved for women by 0.84 minutes (50 seconds) (APFT 2-mile) (P=.06). Cardiorespiratory endurance decreased for men by 0.48 minutes (29 seconds) (APFT 2-mile) (P<.01) but their muscular strength improved by 0.6 repetitions (APFT push-ups) (P<.01) during deployment (Table 2).

Comment

The focus of this investigation was to assess how a nine 9-deployment affected Soldiers' physical training activities, physical fitness, injury incidence, and health behaviors. It also showed differences between men and women. Deployment resulted in increases in personal physical training, decreases in unit physical training, improvement in physical fitness, reductions in reported injury incidence, and increases in smoking among men.

While deployed women saw a 50 second improvement in 2-mile run time, a measure of cardiorespiratory

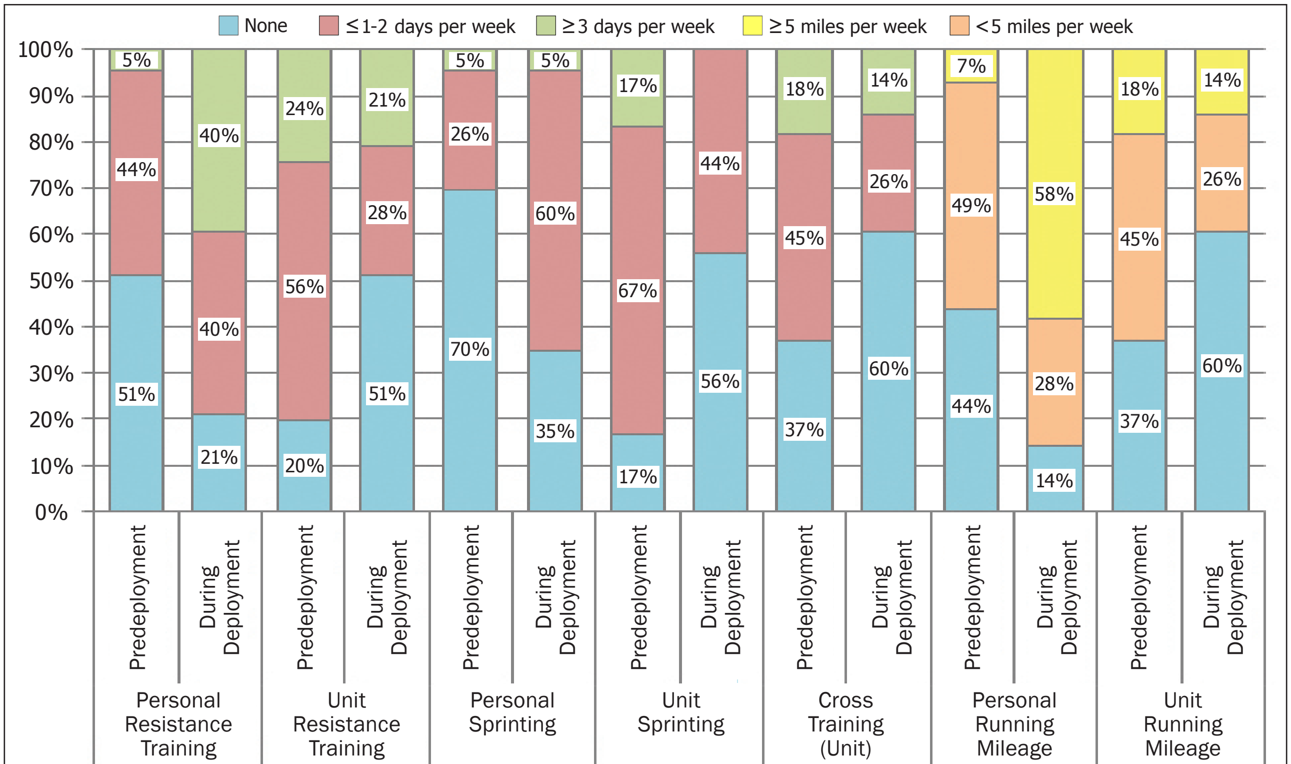

Figure 2. Women's physical training participation before and during deployment.

endurance on the APFT, men's run time performance declined by 29 seconds. Lester et al[6] and Sharpe et al[7] also showed cardiorespiratory endurance among men was negatively affected by deployments of 13 months and 9 months respectively. The reported increase in personal running mileage among both men and women during deployment appears to have had a positive effect for women. For men, personal running may not have been a sufficient replacement for the decrease in unit training. More men also initiated smoking while deployed which may have affected their aerobic fitness. Several studies have observed cigarette smoking to have a negative effect on aerobic and muscular fitness.[9-13] A study of male Navy personnel observed smokers were almost 30 seconds slower at the 1.5 mile run/walk, performed 6 fewer curl-ups and 5 fewer push-ups on average, when compared to nonsmokers.[11] The increase in cardiorespiratory endurance in women could be due to increased personal distance running and resistance training frequency during deployment. Past studies have reported a combination of strength and endurance training promotes increases in muscular and aerobic endurance.[14,15]

Muscular endurance, as measured by APFT push-up performance, improved for men during deployment. This improvement could be due to the increase in the rates of frequency in personal resistance training of 3 or more days per week from 33% to 72% during deployment. Although women also increased the rates of personal time resistance training participation during deployment from 5% to 40% (Table 2, Figure 2), their muscular endurance fitness levels did not change. This could indicate that women desire to improve their muscular endurance, but are unfamiliar with appropriate resistance training exercises. Resistance training instruction and equipment geared towards women might help overcome these issues. The benefits of PT during deployment include reduction in injury risk, maintaining a healthy weight and improved circulation, balance, coordination, and bone/ligament strength.[16,17] The American College of Sports Medicine recommends that men and women should perform 2 to 3 days of resistance training for each major muscle group, with 2 to 4 sets per muscle group to improve strength and power.[18]

When comparing physical training activities of men and women, similarities were seen in running mileage with their unit before deployment and during personal time during deployment. Physical training differences between men and women were seen in personal resistance training before deployment and during deployment. Both running and resistance training are crucial components to improving and maintaining Soldiers' cardiovascular and muscular endurance. Resistance training during personal time and with the unit should be highly encouraged for women by unit leaders as it has shown to improve occupational task performance.[19] Gender differences in physical performance decreased in the repetitive box lift and the 2-mile loaded run when women participated in endurance and strength/power training.[19] Another study looked at strength and cardiovascular training, and showed individuals who participated in both types of training had the largest percentage improvement in assigned occupational tasks (mannequin drag, lift and carry, and load carriage).[14] Women benefit from resistance training, but participation is low in garrison compared to men. Encouraging similar physical training regimen between men and women might be an effective method for preparing men and women for combat and other physically demanding military occupational tasks.

Injury rates decreased during deployment for both men and women. Even though unit level PT decreased and personal PT participation increased, the combined frequency of unit and personal physical training during deployment stayed similar to that seen before deployment. The ability for Soldiers to train on their own while deployed allowed them more flexibility to train at their own pace and intensity level, which may explain why injury rates decreased among deployed Soldiers. A study by Knapik et al[20] observed Soldiers that participated in similar ability groups for long-distance running had lower injury risk and equal or greater improvements in fitness as basic training progressed.

Cigarette use did not change during deployment for women, but increased by 19% for men. A study of 48,304 US male and female service members by Smith et al[21] showed smoking rates increased during deployment among those that had never smoked by 2%, and among those who had previously quit smoking by 53%. Smoking initiation was especially high during prolonged deployments, multiple deployments, and combat exposures. Another study showed that male and female Soldiers reported initiating smoking during deployment due to boredom (54%), social factors (24%), and stress (13%).[22]

Strengths and Limitations

Data were collected through self-reported surveys, which can be subject to recall bias as well as questions about honesty in answers and lack of comprehension of the questions. Prior analyses have found high correlations between actual and self-reported Army Physical Fitness Test data.[23]

Conclusion

During deployment, unit PT participation decreased, while personal PT participation increased for both men and women. Personal PT played a larger role in physical training compared to unit PT participation during deployment, which may have contributed to the decrease in injury rates, possibly due to more self-paced personal training. Body mass index remained similar for both men and women, while there was an increase in the number of men who began smoking. Comparisons of physical training activities and health behavior among men and women before and during deployment suggest that increased resistance training could be recommended for women and smoking cessation for men.

Information on personal PT activities described in this paper can be used to inform future unit PT and personal PT recommendations to improve fitness levels in garrison and during deployment. Given the potentially important role of personal PT in maintaining physical fitness in the deployment environment, future work should aim to provide the necessary tools for Soldiers to perform personal PT effectively and safely on their own. Addressing physical training gaps between men and women, such as the lack of resistance training among women in garrison, suggest where improvements can be made, especially for women looking to successfully fill combat positions with high physical demands.

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Physical Fitness and Injury Reporting Among Active Duty and National Guard/Reserve Women: Associations with Risk and Lifestyle Factors

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Abstract

Objective: As more women enter the military, it is important to understand how different risks and lifestyle factors influence physical fitness and injury among women in both active duty (AD) and National Guard/Reserve (NG/R). Women in military service are less fit and more likely to suffer musculoskeletal injuries during physical training than men. They also use more medical care during deployment than men. Using data from the Comprehensive Soldier and Family Fitness Global Assessment Tool 2.0 (GAT 2.0), self-reported health and lifestyle and behavioral risk factors were analyzed in nondeployed Army personnel, with the goals of examining (1) service-component differences across traditional risk and lifestyle factors, and (2) correlates of physical performance and physical activity-related injury.

Methods: Self-report GAT 2.0 data included health risk factors (overall perceived health, sleep, diet, tobacco and alcohol use), self-reported health metrics (height, weight, Army Physical Fitness Test (APFT) scores), and history of physical activity-related injury. The GAT 2.0 was completed by 1,322 AD and 1,033 NG/R women, and APFT data were available for a subsample of 605 AD and 582 NG/R women.

Results: Initial analyses of GAT 2.0 data indicated that AD had higher rates of fair/poor perceived health, poor sleep, and unhealthy diet compared to NG/R women. However, AD women had a lower APFT fail rate (8%) than NG (27%) and R (28%). Active duty women were more likely to experience a physical injury in the past 6 months (38%) than NG (19%) and R (22%) women, and more likely to seek medical care than NG/R women. Across all service components, predictive factors for APFT failure included high body mass index (BMI), fair/poor health, and unhealthy diet. Predictive factors for physical injury included high BMI, fair/poor health, and binge drinking.

Conclusion: Our analyses suggest that AD women Soldiers are more physically fit than NG/R women Soldiers, which is accompanied by a greater prevalence of physical activity-related injuries. As women's roles expand into combat military occupation specialties, a thorough understanding of service component differences will be critical to inform training programs, mitigate physical injury, and enhance force health protection and readiness.

As combat roles become open to women serving in the military, questions about their ability to maintain the physical demands and stay injury-free in these roles have been raised.[1,2] Musculoskeletal injuries (MSK-I) and other noncombat illnesses are a leading cause of lost-duty time and morbidity among training and deployed military populations, particularly among women.[3-8] Today, women comprise approximately 13% of the US armed forces[9]; however, they are more likely than men to suffer from MSK-I[3,5-7,10-12] and be medically discharged from service due to their training-related injuries.[13] Other risk factors for MSK-I and physical activity-related conditions (eg, heat stroke, exertional rhabdomyolysis) in women include older age, lower body mass/bone density, lower physical fitness levels, lower body mass index (BMI) and previous MSK-I history.[6,10,14,15] High-risk psychological and behavioral factors, which may be inflated in the military,[16] also differ by sex.[17,18] Women, for example, report higher rates of disordered sleep,[18] which may contribute to their increased risk for MSK-I.[19] In contrast, men report higher rates of alcohol and tobacco use,[16] which contributes to their MSK-I.[7]

Service component differences further complicate MSK-I concerns in military women. During Operation Iraqi Freedom and Operation Enduring Freedom, over 650,000 Army and Air National Guard (NG) Soldiers deployed, which represented over 30% of the fighting force.[20] Even though active duty (AD) and NG troops may have similar physical fitness immediately prior to deployment,[21] NG soldiers used greater medical care and suffered from more MSK-I during deployment than AD women.[11] And even though women serving in the Army as AD, NG, or reserve (R) are expected to maintain similar levels of physical fitness, their levels of activity are likely different. For example, AD Soldiers typically spend 1-1.5 hours, 4 days per week participating in physical fitness training with their unit, whereas NG and R Soldiers are expected to individually maintain physical fitness standards.[22] However, little is known about how these service components differ in terms of physical fitness, MSK-I, and other health factors outside of deployment.[11,23,24]

The Comprehensive Soldier and Family Fitness (CSF2) Global Assessment Tool 2.0 (GAT 2.0) is an annual online survey of physical, emotional, social, family, and spiritual fitness in nondeployed Army personnel.[25] The GAT 2.0 is part of a larger multifaceted program designed to build and improve psychological resilience and warfighter well-being.[26] The GAT 2.0 includes all Army service components, so it provides a unique opportunity to assess a variety of risk factors among Army AD, NG, and R. Therefore, the objectives of the present study were to examine how traditional risk and lifestyle factors related to physical performance and to physical injury among female Soldiers across service components. Identifying key risk factors related to physical injury and performance in female AD, NG, and R Soldiers would be critical for revising training programs and implementing injury mitigation strategies.

Methods

As a key component of the Army's CSF2 program, nondeployed Army soldiers are required to complete the GAT on an annual basis (while it is optional for their families and DoD civilians).[25] The GAT is a self-report online survey that assesses 5 components of strength: social, emotional, family, spiritual and physical fitness.[27] In 2012, 57 pilot questions were added to the original 105 questions in order to more accurately assess physical fitness, nutrition, and sleep quality. The present study consists of a subset of Army AD, NG and R female Soldiers (n=2,335) who completed the updated GAT over a 2-week period in July 2012. Fifty participants were excluded due to missing health behavior data, which allowed for a total sample size of 2,305 Army AD (n=1,014; 44%), NG (n=645; 28%), and R (n=646; 28%) women. Participants were on average 26.4±8.1 (17 to 58) years of age, and 15% were officers. Table 1 contains additional participant characteristics divided by service component (AD, NG, R).

Health and Behavioral Risk Factors

The GAT 2.0 assessment includes lifestyle health behaviors (sleep, diet, heavy alcohol use and tobacco use) and general health questions. Measures were dichotomized, as described below, based on available standards or previous research where available.

Body Mass Index. Self-reported height and weight were used to compute body mass index (BMI, weight (kg)·height (m)$^{-2}$), which was then dichotomized at the cut point 27.5 kg/m^2, based on *Army Regulation 600-9*.[28] Although low BMI has previously been reported to be a risk factor for MSK-I among women,[6] only 1% of participants in our sample were underweight (BMI<18.5), and these women were included in the normal weight category.

Nutrition Behavior. Nutrition behavior was assessed by using a 5-question Healthy Eating Score (HES-5).[29] This measure was derived from the more comprehensive US Department of Agriculture's Healthy Eating Index,[30] but with only 5 food category components: the frequency of fruit, vegetable, whole grain, dairy, and fish intake, answered by using a 6-point Likert-type scale (ranging from 0, "rarely or never", to 5, "3 or more times per day"). The HES-5 was extensively analyzed in the larger CSF2 GAT 2.0 sample,[29] and has adequate internal consistency (Cronbach α in present sample=0.74). Based on previous analyses,[29] the HES-5 was dichotomized, such that participants with a sum score in the lowest quartile were coded as unhealthy eaters.

Sleep. Sleep was assessed with the 2-item[31] version of the Pittsburgh Insomnia Rating Scale (PIRS2),[32] which was also extensively analyzed in the larger CSF2 GAT 2.0 sample.[18] The 2 items ask about sleep over the past 7 days with a focus on how much a person was bothered by lack of energy due to poor sleep and perception of overall sleep satisfaction, each answered along separate 4-point Likert-type scales. The items were developed using item-response theory to efficiently screen for insomnia[31] with an overall cutoff score that was used to dichotomize participants. The PIRS2 demonstrated adequate internal consistency (Cronbach α=0.81) in the present analysis.

Additional Health Behaviors. Additional health behaviors included tobacco and alcohol use. Tobacco was assessed by asking participants about their "use of tobacco products (cigarettes, cigars, smokeless tobacco, chew, dipping, pinching) in the last year," with responses dichotomized based on regular (≥4 times per week) use versus minimal (<4 times per week, no use, or quit in past year) use of tobacco products. Since only 1.4% of females reported use of smokeless tobacco, it was not feasible to distinguish between types of tobacco use. Heavy alcohol use was assessed with the question "Have you exceeded 5 alcoholic drinks on any single occasion during the past 3 months?" This is a common definition of binge drinking[33] and has been used in previous military survey research.[16]

General Health. General health was measured with the single item, "How do you consider your general health?", which was answered along a 4-point Likert-type scale (excellent, good, fair, and poor), to include "don't know." Using a single question to measure overall health has been shown to provide an efficient and reliable composite of both physical and mental health, or measure of global health.[34] Although general health is broader than the other predictors above, and is often assessed as a health outcome, it has strong predictive power for injury risk[35-37] and is a practical screening measure in general.[34,38] As with previous research in this sample,[18,29] responses to this question were dichotomized, with participants reporting "fair" and "poor" health categorized as "at risk."

Outcome Variables

The primary health outcomes of interest from the GAT 2.0 were self-reported physical fitness, self-reported physical activity-related injury in the previous 6 months, and medical care seeking for any physical activity-related injury.

Physical Fitness. Participants reported raw data scores from their most recent Army Physical Fitness Test (APFT, number of push-ups, number of sit-ups, and run-time in minutes and seconds), which were converted to a pass/fail score based on age-specific Army standards.[22]

Physical Injury Reporting and Medical Care Seeking Behaviors**.** Participants indicated whether they had experienced a "physical activity-related injury" over the past 6 months. Examples of physical activity-related injuries included "joint sprains, muscle or tendon strains, concussion, broken bone, shin splints, heat stroke, and/or exertional rhyabdomyolysis." Participants reporting a physical activity-related injury were then asked whether or not they "sought medical care for the reported injury."

Statistical Analyses

Service component differences for all GAT 2.0 variables were compared using Pearson χ^2 analyses. Pearson χ^2 analyses were also used to test univariate relations between health/behavioral risk factor categories, including service component, and outcome measures. Among those participants who sustained a physical activity-related injury, χ^2 analyses were conducted to determine service-component differences in seeking medical care for that injury (eg, do injured AD seek medical care for their injuries more than injured NG?). For all univariate analyses, measures of effect size include Cramér's V (suitable for ordinal or dichotomous variable analyses,[39] such that a small effect=0.1, moderate=0.3, and large≥0.5) or Cohen's *d* (for continuous variables, notably age, such that small effect=0.2, moderate=0.5, and large≥0.8).[40]

Multivariate logistic regression analyses with backwards-stepwise methodology were used to determine predictive health and behavioral risk factors for the following outcomes: (1) APFT pass/fail, (2) physical injury, and (3) seeking medical care for a physical injury. First, demographic variables (age, service component, and rank) were force-entered. Next, health and behavioral risk factors were individually selected using backwards stepwise entry, with a *P* value for the likelihood ratio set at 0.1. Interactions between Army service component (AD, NG, R) and significant predictors from multiple regression analysis were tested. All analyses were conducted using SPSS Version 22.0 (IBM Corp, Armonk, NY).

Results

Table 1 presents descriptive statistics for all participants by service component. Pearson χ^2 analyses revealed several service component differences among all GAT variables. Active duty participants had higher rates of most health and behavioral risk factors. Active duty participants were 1.3 (95% CI, 1.05-1.55; $P<.05$) times more likely to report fair/poor general health than NG; 1.3 (95% CI, 1.04-1.72, $P<.05$) and 1.4 (95% CI, 1.09-1.83; $P<.05$) times more likely to report poor sleep than NG and R, respectively; and 1.2 (95% CI, 1.05-1.47; $P<.05$) times more likely to report an unhealthy diet than NG. In contrast, NG were 1.7 (95% CI, 1.25-2.23; $P<.001$) and 1.5 (95% CI, 1.13-1.99; $P<.01$) times more likely to report binge drinking than AD and R, respectively.

Other notable descriptive findings included AD women reporting fewer APFT failures (8%) than NG (27%) and R (28%) women (χ^2=87.7, V=0.25, $P<.001$); R participants being 4.3 (95% CI, 3.04, 6.14; $P<.001$) and NG participants 4.0 (95% CI, 2.81-5.71; $P<.001$) times more likely to fail APFT compared to AD women. Active duty women also reported higher physical injury rates (28%) than NG (19%) or R (22%) women (χ^2=84.0, V=0.19, $P<.001$), such that AD women were 2.6 (95% CI, 2.04-3.28; $P<.001$) times more likely than NG and

2.1 (95% CI, 1.70-2.69; $P<.001$) times more likely than R women to report a physical injury in the previous 6 months. Among those with reported physical activity-related injuries (n=624), 80% of AD sought medical care for the injury, compared to 76% of NG and 67% of R (χ^2=8.4, V=0.12, $P<.05$); the difference between AD and R was statistically significant.

Outcome Variables: Univariate and Multivariate Analyses

APFT Failure. Table 2 presents univariate and multivariate analyses with APFT pass/fail as the outcome variable. On the left of Table 2, participant characteristics are presented for those who passed versus those who failed their APFT; multivariate regression results are depicted on the right. Univariate analyses revealed several significant associations between predictor and outcome variables, the majority of which were retained in the multivariate model. Namely, female Soldiers who were younger, enlisted, NG or R, with high BMI, poor diet, and self-reported fair/poor overall health were more likely to fail the APFT.

Physical Injury. Table 3 presents univariate and multivariate analyses with physical injury as the outcome variable. On the left of Table 3, participant characteristics are presented for those who reported a physical injury versus those who did not report a physical injury. Women with high BMI and self-reported fair/poor overall health and binge drinking were more likely to report experiencing a physical injury in the previous 6 months.

Medical Care Seeking Behavior for Physical Injury. Table 4 presents univariate and multivariate analyses with seeking medical care for a physical injury as the outcome variable. On the left of Table 4, participant characteristics are presented for those who sought medical care for a physical injury versus those who did not seek medical care for a physical injury. Results similar to physical injury were noted, with the exception that BMI was not retained in the medical care model.

No significant interactions between any health and behavioral risk factors and multivariate outcomes were noted.

Table 1. Participant Characteristics and Service Group Differences.

	All Women (N=2,305)	Active Duty (n=1,014)	National Guard (n=645)	Reserve (n=646)	Effect Size*
Age (years)	26.4±8.13	26.7±7.64[a]	25.2±7.65[a,b]	27.3±9.16[b]	0.01[†]
Height (m)	1.63±0.08	1.63±0.08	1.63±0.08	1.62±0.09	
Weight (kg)	66.4±10.63	66.2±9.84	66.5±11.10	66.8±11.41	
BMI (kg/m²) (n=1,758)					
High (>27.5)	22%	20% (30.7±3.4)	24% (30.7±3.2)	23% (31.4±3.6)	0.05
Normal (18.5-27.5)	78%	80% (23.6±2.1)	76% (23.3±2.3)	77% (23.6±2.3)	
Value	25.2±3.9	25.0±3.7	25.0±4.1	25.3±4.3	
Military Status					
Officer	15%	19%[a]	9%[a]	13%[a]	0.12[‡]
Enlisted	85%	81%	91%	87%	
Health					
Fair/Poor	21%	24%[a]	19%[a]	20%	0.06[†]
Good/Excellent	79%	76%	81%	80%	
Sleep (n=2,058)					
Poor sleep	15%	18%[a,b]	13%[a]	13%[b]	0.07[†]
Good sleep	85%	82%	87%	87%	
Diet					
Unhealthy	27%	29%[a]	23%[a]	27%	0.05[†]
Healthy	73%	71%	77%	73%	
Tobacco Use					
Smoker	16%	16%	18%	15%	0.03
Nonsmoker	84%	84%	82%	85%	
Alcohol Use					
Binged	12%	10%[a]	16%[a,b]	11%[b]	0.08[‡]
Did not binge	88%	90%	84%	89%	
APFT (n=1,431)					
Fail	18%	8%[a,b]	27%[a]	28%[b]	0.25[‡]
Pass	82%	92%	73%	72%	
Physical Injury (n=2,219)					
Injured	28%	38%[a,b]	19%[a]	22%[b]	0.19[‡]
Not injured	72%	62%	81%	78%	
Care for Injury (n=2,076)					
Sought care	25%	34%[a,b]	17%[a]	18%[b]	0.19[‡]
Did not seek care	75%	66%	83%	82%	

NOTE: For pairwise comparisons, values within a row sharing a common superscript (a or b) are significantly different from each other at $P<.05$.

*Omnibus effect size with η^2 was used for continuous variables, while Cramer's V was used for all other ordinal variables.

†$P<.05$

‡$P<.001$

Table 2. Univariate and Multivariate Predictors of APFT Failure.

	Univariate (N=1,431)			Backwards Stepwise[a] (N=1,174)
	Failed APFT (n=259)	Passed APFT (n=1,172)	Effect Size[b]	Adjusted OR (95% CI)
Age (years)	22.9±5.50	26.8±7.86	0.20[c]	0.9 (0.89, 0.94)[c]
Army Status				
Active Duty	8%	92%	0.25[c]	
National Guard	27%	73%		3.7 (2.50, 5.57)[c]
Reserve	28%	72%		4.9 (3.27, 7.43)[c]
Military Status				
Officer	6%	94%	0.14[c]	1.8 (0.95, 3.29)
Enlisted	20%	80%		
BMI (kg/m^2) (n=1,174)				
High (>27.5)	26%	74%	0.12[c]	2.2 (1.53, 3.21)[c]
Normal (18.5-27.5)	15%	85%		
Health				
Fair/Poor	24%	76%	0.08[d]	1.6 (1.12, 2.40)[d]
Good/Excellent	17%	83%		
Sleep (n=1,267)				
Poor sleep	20%	80%	0.01	
Good sleep	18%	82%		
Diet				
Unhealthy	22%	78%	0.06[d]	1.6 (1.10, 2.25)[d]
Healthy	17%	83%		
Tobacco Use				
Smoker	23%	77%	0.06[d]	–
Nonsmoker	17%	83%		
Alcohol Use				
Binged	20%	80%	0.02	
Did not binge	18%	82%		
Physical Injury (n=1,387)				
Injured	15%	85%	0.04	
Not injured	19%	81%		
Care for Injury (n=1,296)				
Sought care	17%	83%	0.02	
Did not seek care	18%	82%		

[a]Multiple backwards stepwise regression conducted, with demographic variables (age, Army status, military status) force-entered and significant health risks then entered stepwise.

[b]For effect size, Cohen's *d* was used for continuous variables (age), while Cramer's V was used for all other ordinal variables.

[c]*P*<.001

[d]*P*<.05

Comment

Female service members comprise approximately 13% of the US Armed Forces,[9] but are much more likely than men to suffer from MSK-I, even when exercising under the same conditions.[3-7,10-12] Previous studies have identified numerous risk factors for poor health outcomes and physical injury in female service members,[3,6,12,41] but few have focused on differences between AD, NG and/or R female Soldiers. As combat roles across service components open to women, the state of their health and fitness is of prime concern.[1,2] One study comparing AD and NG female Soldiers preparing for deployment found that they had similar levels of fitness.[21] However, during deployment, NG Soldiers appeared to seek more medical care and suffer from MSK-I more than AD.[11] No studies had previously examined these differences outside of the deployment cycle. Our results demonstrate differences in physical fitness (APFT pass/fail) and physical injury across service components among women. Among NG and R women, age, enlisted status, high BMI, poor diet, and overall poor health were significantly associated with APFT failure. However, despite these lower levels of fitness, our findings show NG or R females were less likely to suffer from physical injury in the previous 6 months than AD females.

Physical fitness is one of the most influential factors related to self-reported perceived health and physical injury.[23] A study by Warr et al[23] demonstrated that cardiovascular fitness (VO_2max) had the largest influence on perceived health changes over the deployment of a NG unit, regardless of baseline fitness. It is important to note that our results indicate that female Soldiers with high BMI and poor health were more likely to fail their APFT. Women serving in Army AD, NG, or R are expected to maintain similar levels of physical fitness, but requirements and expectations about how that fitness is achieved and maintained vary greatly. NG/R females are required to train with their unit once a month, but outside of this, they are expected to maintain physical fitness standards on their own. Whereas Army guidelines related to physical fitness have been published as *Field Manual 7-22*, NG/R Soldiers who are not within a structured environment may find it difficult to use this manual when daily physical training is not commonplace.

For other health and behavioral risk factors, AD females were more likely to report fair/poor health, poor sleep, and consuming an unhealthy diet compared to NG/R females. Having healthy food patterns should improve overall health and wellness, and be one approach for physical injury prevention.[1] The finding of poorer eating in AD females is worrisome, as healthy dietary patterns can counteract glycogen depletion, restore energy balance, mitigate fatigue, and minimize muscle damage.[1] In the present study, AD females were more likely to report physical injury than NG/R over the past 6 months, and unhealthy diet, along with poor sleep and overall health, may be contributing factors.

In addition to AD status, predictive factors for physical injury in our study included high BMI, poor overall health, and binge drinking behaviors, which correspond to previously established risk factors in similar populations.[3,10,42] Previous research has linked low BMI to MSK-I risk among women.[6] In the present study, the number of women with low BMI was too small to determine its effect on any of study outcomes. Smoking behavior, which has previously been strongly linked to physical injury,[7,43] had a weak effect on fitness and injury in univariate analyses, and became nonsignificant in multiple regression analysis. However, female Soldiers tend to use tobacco products less than male Soldiers, which may account for this finding.[16]

Of the 624 females who reported a physical injury in the previous six months, AD were slightly more likely to seek medical care (80%) than NG (76%) or R (67%). It is unclear whether this reflects differences in injury severity, access to medical care, or both. The lower rate of seeking medical care among injured R may warrant further investigation. Changes in fitness status over deployment appear to be a particularly strong risk factor for noncombat physical injury. In particular, NG male and female Soldiers who experienced declines in fitness during deployment were twice as likely to use medical resources for noncombat physical injuries than those who experienced improvements in fitness.[23]

Table 3. Univariate and Multivariate Predictors of Reported Physical Injury.

	Univariate (N=2,219)			Backwards Stepwise[a] (N=1,174)
	Sought Care (n=624)	Did Not Seek Care (n=1,595)	Effect Size[b]	Adjusted OR (95% CI)
Age (years)	27.1±8.20	26.3±8.13	0.05[c]	1.0 (0.99, 1.02)
Army Status				
Active Duty (ref)	22%	78%	0.19[d]	
National Guard	18%	81%		0.3 (0.26, 0.46)[d]
Reserve	22%	78%		0.5 (0.35, 0.61)[d]
Military Status				
Officer	26%	74%	0.02	1.3 (0.95, 1.88)
Enlisted	29%	71%		
BMI (kg/m^2) (n=1,699)				
High (>27.5)	37%	63%	0.09[d]	1.4 (1.10, 1.90)[d]
Normal (18.5-27.5)	27%	73%		
Health				
Fair/Poor	43%	57%	0.18[d]	2.4 (1.83, 3.09)[d]
Good/Excellent	24%	76%		
Sleep (n=1,980)				
Poor sleep	44%	56%	0.13[d]	–
Good sleep	27%	73%		
Diet				
Unhealthy	32%	68%	0.05[c]	–
Healthy	27%	73%		
Tobacco Use				
Smoker	33%	67%	0.05[c]	–
Nonsmoker	27%	73%		
Alcohol Use				
Binged	39%	61%	0.09[d]	1.6 (1.14, 2.17)[d]
Did not binge	27%	73%		
APFT (n=1,387)				
Fail	26%	74%	0.04	
Pass	31%	69%		

[a]Multiple backwards stepwise regression conducted, with demographic variables (age, Army status, military status) force-entered and significant health risks then entered stepwise.

[b]For effect size, Cohen's *d* was used for continuous variables (age), while Cramer's V was used for all other ordinal variables.

[c]$P<.05$

[d]$P<.001$

Our study has several limitations. First, self-report data are not always consistent with measured values, although the data are mixed.[44,45] Importantly, the GAT 2.0 was rigorously developed, with simple measures of physical fitness, dietary patterns, health, and wellness, all of which have been previously validated. Second, the military occupational specialties (MOSs) of women in this cohort are not known. Particular MOSs may vary greatly in their physical and mental demands, and therefore exhibit diverse health and behavioral outcomes. Third, it is unclear as to whether these women had deployed in the previous 6 months, and thus we cannot ascertain how deployment may have affected the service component differences in fitness and injury history. Lastly, we have no prior injury history information or specific diagnosis codes for physical injuries, both of which could provide more granularity with regard to injury risk factors specific to each service component. Despite these limitations, the GAT 2.0 data have allowed for the simultaneous investigation into the broad range of previously identified potential risk factors in a large population of female Soldiers. This is important for targeting risk factors.

In conclusion, our study is the first to examine service component differences in health, fitness, and behavioral risk factors for fitness and MSK-I in female service members. In particular, we simultaneously examined multiple, previously validated measures of physical fitness, and health and behavioral risk factors using the

GAT 2.0, a mandatory online reporting mechanism to assess the overall health of service members. As women are officially integrated into frontline combat roles, their performance during combat training may be determined by various risk factors. Our results show that service component is a key factor to consider as women transition into these roles. Overall, NG and R female Soldiers are more likely to have lower physical fitness (APFT pass rates), while women with high BMI and self-reported poor health are at greater risk for physical injury. These data lend credence towards the development of component-specific human performance optimization strategies for women as their roles in the military expand.

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Table 4. Univariate and Multivariate Predictors of Seeking Medical Care.

	Univariate (N=2,076)			Backwards Stepwise[a] (N=1,174)
	Sought Care (n=509)	**Did Not Seek Care** (n=1,567)	**Effect Size**[b]	**Adjusted OR (95% CI)**
Age (years)	26.9±8.27	26.4±8.20	0.03	1.0 (1.00, 1.02)
Army Status				
Active Duty	34%	66%	0.19[c]	
National Guard	17%	87%		0.4 (0.26, 0.51)[c]
Reserve	18%	82%		0.4 (0.31, 0.54)[c]
Military Status				
Officer	20%	80%	0.04[d]	1.3 (0.95, 1.88)
Enlisted	25%	75%		
BMI (kg/m^2) (n=1,591)				
High (>27.5)	34%	66%	0.11[c]	–
Normal (18.5-27.5)	22%	78%		
Health				
Fair/Poor	36%	64%	0.14[c]	1.8 (1.41, 2.29)[c]
Good/Excellent	21%	79%		
Sleep (n=1,864)				
Poor sleep	35%	65%	0.10[c]	–
Good sleep	23%	77%		
Diet				
Unhealthy	27%	73%	0.03	
Healthy	24%	76%		
Tobacco Use				
Smoker	29%	71%	0.04[d]	–
Nonsmoker	24%	76%		
Alcohol Use				
Binged	32%	68%	0.07[c]	1.6 (1.18, 2.16)[c]
Did not binge	23%	77%		
APFT (n=1,296)				
Fail	24%	76%	0.02	
Pass	26%	74%		

[a] Multiple backwards stepwise regression conducted, with demographic variables (age, Army status, military status) force-entered and significant health risks then entered stepwise.
[b] For effect size, Cohen's *d* was used for continuous variables (age), while Cramer's V was used for all other ordinal variables.
[c] *P*<.001
[d] *P*<.05

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Women and Exertional Heat Illness: Identification of Gender Specific Risk Factors

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Abstract

Objective: With the expanding role of women into previously closed combat military occupational specialties, women will likely be exposed more to challenging and extreme conditions. Physical work or exercise in extreme environments could increase the risk for exertional heat illness (EHI) and exertional heat stroke (EHS), the most severe type of EHI. Although men have higher rates of EHS than women, women have slightly higher rates of other EHI. Women may respond differently to exertion in the heat than men, as they typically have higher percentage of body fat (BF%) and lower aerobic power. Further, published pilot-data using the Israeli heat tolerance test (HTT) indicate that women are more likely to be classified as heat intolerant than men. The objectives of the present study were to (1) compare male and female classification patterns of heat tolerance, and (2) identify EHI risk factors that might account for the relationship between heat tolerance classification and sex.

Methods: Fifty-five male and 20 female participants were recruited from military and university communities to participate in a standardized HTT. Subjects underwent measures to calculate anthropometric variables (BF%, body surface area, and waist circumference), a maximal oxygen uptake test to assess aerobic power (VO_2max), and a standardized HTT, which consisted of treadmill walking at 5 km/h at a 2% grade for 120 minutes at 40°C and 40% relative humidity. Heat intolerance was defined as attaining a maximum heart rate (HR) greater than 150 bpm or a core body temperature (T_c) more than 38.5°C. Separate hierarchical regressions were conducted using categorical (heat tolerant/intolerant) and continuous (physiological strain index, maximum HR, T_c) HTT outcomes. Risk factors were identified with and without controlling for sex.

Results: Women were 3.7 (95% CI, 1.21-11.24) times more likely to be heat intolerant than men (χ^2=6.85, P<.01). Compared to men, women had significantly higher BF% and lower body surface area, waist circumference, and VO_2max. All heat intolerant participants had lower VO_2max and higher BF% than those who were classified as heat tolerant. When VO_2max and BF% were entered into regression equations to predict HTT outcomes, sex became nonsignificant; VO_2max predicted maximum HR and physiological strain index after controlling for sex.

Conclusion: The present study found that differences between men and women in heat tolerance classification are largely explained by VO_2max. The higher rates of heat intolerance among women likely correlate with higher EHI risk, and underscore the need to understand the physiological and thermoregulatory differences between men and women. As lower aerobic power is a major risk factor for EHI, maximizing the aerobic power of women will be critical to force health protection and readiness as they integrate into combat military occupational specialties.

As women enter into previously closed military occupational specialties,[1] they are likely to be exposed more to challenging and extreme conditions. For example, exercise in extreme environments could increase their risk for exertional heat illness (EHI)[2] and exertional heat stroke (EHS), the most extreme type of EHI and a fatal threat to Warfighters,[3-6] athletes,[7-9] and others who engage in physically demanding jobs.[10] EHS occurs during physical exertion, typically in a hot and humid environment, and is characterized by a rise in core body temperature (usually 40°C or more), accompanied by central nervous system dysfunction (eg, delirium, convulsions, coma) and sometimes multiple organ system failure.[11] Although EHS continues to be a significant threat to Warfighters' health, force readiness, and operational resources,[3,5] in most cases it is preventable, given our understanding of predisposing risk factors and proper implementation of safeguards.[5,12-15] Key risk factors include dehydration, lack of acclimatization, recent illness,[16,17] certain classes of medication,[18] and prior

EHS.[3,13,14,16,17,19] Additionally, poor aerobic power and high percentage of body fat, two of the strongest risk factors for EHI in the military,[20-22] may be of particular concern for women.

Since men in combat military training typically engage in more physically demanding activities under many environmental conditions than women, the prevalence of EHS is higher in men than women.[3,4,23,24] In 2013, 324 cases of EHS and 1,701 additional EHI were reported in the US armed forces, which represented a decline in EHI over the previous few years.[3] The incidence rate of EHS was higher among men (0.24 per 1,000 person-years) than women (0.15). However, for all other EHI, women had a higher rate (1.30) than men (1.19). Thus, when baseline rates are corrected for gender participation, women have a slightly higher incidence of EHI (not EHS) than men, both in the military[3,4,25] and in the general population.[23,24]

Although men and women thermoregulate internal temperature in a similar manner, key sex differences exist in how they respond to heat.[26,27] Most notably, women have a higher baseline core temperature,[28,29] especially during the luteal phase of the menstrual cycle.[30,31] Thus, women begin to sweat at a higher core temperature than men.[32] Women typically have a lower body surface area, but a higher body surface area-to-mass ratio than men, which may provide more efficient body heat dissipation in certain environments (eg, very humid weather).[33] Taken together, these differences may place women at a slight advantage in hot and humid climates, and a slight disadvantage in hot and dry climates, relative to men.[32,33] However, the net effect of these sex differences on EHI risk is generally considered to be negligible, especially in comparison to larger differences in aerobic power and anthropometrics, particularly percentage of body fat.[26,30,31]

One approach to assessing the capacity to thermoregulate is to expose individuals to a designated heat challenge during exercise, and the Israeli heat tolerance test (HTT) is one valuable tool for use in the laboratory. The HTT, designed over decades of iterative studies, is used as a clinical test to guide return to duty decisions for Warfighters in the Israeli Defense Force (IDF) who have suffered an EHS event.[5,34] Between 2008 and 2010, 26% of men and 67% of women in the IDF who had been diagnosed with EHS (or EHS was suspected) were classified as heat intolerant by their criteria,[35] which suggests sex differences.

Importantly, the HTT was originally developed using male Warfighters. Thus, if their HTT is to be used in our military, and particularly as women enter combat military occupational specialties, it will be necessary to know how they respond to the HTT, with and without a prior EHI. Additionally, the IDF did not have data on either aerobic power or body composition,[35] which could be key in assessing risk of EHI.[20-22,36] Thus, the purposes of the present study were to examine the responses of men and women to the HTT and to compare their classification results. Additionally, we assessed both aerobic power and body composition to help explain any sex differences observed with the HTT.

Methods

Subjects

Fifty-five male and 20 female participants were recruited from military and university communities to participate in a standardized HTT. Inclusion criteria included: (1) aged 18 to 45 years; (2) waist circumference less than 39.4 inches (100 cm); (3) systolic and diastolic blood pressure below 140 mmHg and 90 mmHg, respectively; (4) no previous history of malignant hyperthermia; (5) not pregnant or lactating; (6) not anemic; (7) not using glucose-lowering agents, prednisone, or beta blockers; and (9) not presently being treated for any mental health disorder. Participants included those with and without a history of EHI. Participants who had a previous clinically documented EHS (n=20, of which 19 were male) were tested 6 weeks or more after their EHS. Each participant underwent a thorough telephone health screen and on-site medical examination to ensure that inclusion criteria were met. All participants were informed of the study's purposes and procedures, and then provided written consent prior to participation. Approval was obtained from the Uniformed Services University Institutional Review Board, and the data presented herein are a subset of a larger study.

Baseline Screening and Anthropometric Testing

Participants underwent a medical examination, several anthropometric evaluations (body mass, height, waist circumference, and percentage of body fat), and a maximal aerobic graded exercise test to assess aerobic power. After completion of a medical history and other questionnaires, physiological measures of heart rate (HR), blood pressure (BP) (Criticare Systems Inc.; Waukesha, WI) and electrocardiographic activity (Philips StressVue Testing System with Trackmaster Full Vision Inc. Treadmill, Waltham, MA) were obtained at rest. Participant body mass was measured with a calibrated metric scale to the nearest 0.1 kg, and height was measured to the nearest 0.1 cm while the participant was wearing light clothing and no shoes. Body mass index was calculated from height and mass, and waist circumference was determined with a tape measure by standard techniques.[37] Body surface area and surface-to-mass ratio were calculated by standard methods.[38]

Percentage of body fat was determined using 2 techniques: skinfold measurements and bioelectrical impedance analysis (BIA). Skinfolds were used to allow comparison with previous analyses from the present study[36] and similar research.[39,40] The BIA was used due to concern about reliability/validity of skinfold measurements, especially for sex comparisons. Skinfold thickness was quantified with a skinfold caliper (Cambridge Scientific Industries Inc, Cambridge, MD) at 4 sites (biceps, triceps, subscapular, and suprailiac) on the right side of the body and BF% was computed by using the Durnin and Womersley calculation.[41] In order to combine data from a previous pilot study,[36] 3 skinfold sites were used for 36% of participants based on ACSM guidelines,[37] using chest, triceps, and subscapular for men, and triceps, abdomen, and suprailiac for women. The BIA was conducted using RJL Quantum II (RJL Systems, Clinton Township, Michigan), with participants lying down, arms at a 30° angle from body, and legs not touching. Based on recent research comparing BIA equations to estimate BF% among a military sample,[42] equations published by Segal et al[43] were selected (using the equations generalized across body fat levels). The correlation between the skinfold and BIA-derived BF% values was 0.76 (P<.001).

During the second visit, subjects underwent a standardized HTT, which consisted of walking on a treadmill for 2 hours in an environmental chamber as described below.

Determination of VO_2max

The VO_2max was determined by a maximal aerobic graded exercise test on a motorized treadmill through indirect calorimetry. Expired respiratory gases were collected continuously and analyzed by open-circuit spirometry (Oxycon Mobile portable system, Viasys Healthcare Inc, Yorba Linda, CA). The test used in this study, adapted from a protocol previously described by our laboratory,[44] consisted of a 5-minute warm-up (5.0 km/h and a 2.0% grade) followed by a running portion, at a constant speed of 7.7-13.7 km/h (based on HR achieved during warm-up), with incline starting at 0% and increasing 2.5% every 2 minutes, until the subject could no longer continue or VO_2 plateaued with an increase in workload.

Heat Tolerance Testing

All HTTs were conducted in the morning with participants wearing shorts and athletic shoes; none wore a t-shirt, but women wore a sports bra. The HTT consisted of walking on a treadmill at 5.0 km/hr at a 2% grade for 2 hours at 40°C and 40% relative humidity. Women were tested between days 3 and 9 of their follicular phase. To ensure adequate hydration before testing, urine specific gravity was measured with a hand held refractometer. If urine specific gravity was 1.02 units or more, the participant was provided water to hydrate until it was less than 1.02. Participants were instructed to void their bladder, and then nude body mass was measured. From this point on, all urine was collected in a 3.0 L polypropylene collection container. During the HTT, participants were permitted to hydrate with water ad libitum (up to one L/hr). Core temperature (T_c) was measured by using a rectal thermometer inserted 10 cm beyond the anal sphincter; skin temperature was measured with skin sensors placed at 4 different sites (shoulder, chest, thigh, and calf). The T_c was measured using either a thermistor-based system (64% of participants) (MEAS Temperature Probes (Measurement Specialties Inc, Dayton, OH) with Sensor Interface Box Model 93200 (Deban Enterprises Inc.; Beavercreek, OH)) or a thermocouple system for more recent participants (Type T Thermocouples with Thermes WiFi, Physitemp, Clifton, NJ). The HR was assessed by a Polar HR monitor (Polar Team 2 Pro, Polar USA Inc, Lake Success, NY). The HR, T_c and skin temperatures were continuously monitored and recorded throughout the test; the physiological strain index was calculated from changes in final and baseline HR and T_c, as suggested by Moran et al.[45] Physiological strain index values range from 0-10, and are classified as follows: minimal (values of 0-2), low (3-4), moderate (5-6), high (7-8), and very high (9-10) strain. Sweat rate was estimated based on the difference in nude body mass before and after the test corrected for fluid intake and urine output. Most HTTs were conducted in the summer (49%), followed by the fall (24%), spring (20%), and winter (7%). Baseline and maximum physiological measures for HR and T_c did not differ by season.

The HTT was discontinued if any participant met one of the following criteria: (1) T_c greater than 39.5°C; (2) HR above 170 bpm; (3) experienced nausea, weakness, or dizziness; or (4) requested early test termination. Heat intolerance was defined as T_c greater than 38.5°C, HR above 150 bpm, or failure to plateau,[5,34] with the latter defined by a rise in T_c of greater than 0.45°C during the second hour of the HTT.[46]

Data Analyses

Sample characteristics are provided for men and women in Table 1, with independent-samples t tests used to identify differences between men and women, and heat tolerant vs heat intolerant participants. Cohen's d is used

Table 1. Participant Characteristics (mean±SD) by Sex.

Variable	Women (n=20)	Men (n=55)	All (n=75)
Age (yrs)	28.6±5.2	28.7±6.3	28.7±6.0
Height (cm)	163.8±5.5	178.3±6.6*	174.4±9.0
Weight (kg)	63.8±7.5	84.3±11.2*	78.8±13.8
BMI (kg/m^2)	23.8±2.5	26.5±3.0*	25.8±3.1
Body surface area (m^2)	1.69±0.11	2.02±0.16*	1.93±0.21
Body surface/mass ($m^2 \cdot kg^{-1} \cdot 10^2$)	2.67±0.16	2.41±0.18*	2.48±0.21
Skinfold BF%	28.4±5.1	18.7±5.1*	21.3±6.7
BIA BF%	30.1±21.6	21.6±5.1*	23.8±6.2
Waist circumference (cm)	72.4±4.8	84.6±7.0*	81.4±8.5
$VO_{2}max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	45.3±6.8	52.3±7.4*	50.5±7.8

BIA=bioelectrical impedance analysis
*P<.05

Table 2. Physiological Measurements (mean±SD) During HTT by Sex.

Variable	Women (n=20)	Men (n=55)	All (n=75)
Core Temperature, T_c (°C)			
Baseline T_c	37.1±0.4	36.9±0.4	37.0±0.4
Max T_c	38.1±0.4	38.1±0.4	38.1±0.4
ΔT_c (over min 60-120)	0.26±0.19	0.28±0.11	0.27±0.18
Heart rate, HR (bpm)			
Baseline HR	76±15.0	68±12.1*	70±13.3
Max HR	137±20.1	122±20.2†	126±21.1
ΔHR (over min 60-120)	7.5±7.2	4.6±8.2	5.3±8.0
Physiological strain index	5.2±1.4	4.7±1.3	5.3±8.0
Sweat rate (L/h)	0.81±0.28	1.10±0.31†	1.03±0.33

*P<.05
†P<.01

as a measure of effect size (small effect=0.2; moderate=0.5; and large>0.8).

Logistic regression models were developed to predict HTT performance. For the regression models, sex was entered into a first block, and additional predictors were entered into a second one. The primary HTT outcome was heat tolerance classification (with heat intolerance defined as T_c>38.5°C or HR>150 bpm). To allow for a more granular assessment of heat tolerance, logistic regressions were also conducted to predict elevated T_c (>38.5°C) and elevated HR (>150 bpm) separately.

Linear regression models were developed to predict continuous HTT outcomes. These additional models, even though similar to those above, were run because cutoffs for heat tolerance are being debated[47] and dichotomization reduces statistical power, especially with small sample sizes. Continuous HTT outcomes included maximal values for physiological strain index, HR, and T_c.

Results

Demographic, anthropometric, and aerobic power characteristics are presented in Table 1. As expected, women had lower $VO_{2}max$, body surface area, waist circumference, and body mass index and higher body surface area-to-mass ratio and BF% compared to men. Women were also 3.68 times more likely to be classified as heat intolerant than men (95% CI, 1.21, 11.24; χ^2=6.85, P<.01, d=0.63), such that 45% of women (9 out of 20) were intolerant, compared to 18% of men (10 out of 55). Sex differences in other HTT outcomes are presented in Table 2 and graphically in Figures 1 and 2. During the HTT, women demonstrated higher maximum HR than men (t_{73}=2.27, P<.01, d=0.76); in contrast, sex differences between maximum T_c did not reach statistical significance (t_{73}=0.71, P>.05).

Heat intolerant participants (34% of sample) had lower $VO_{2}max$ (t_{73}=2.28, P<.05, d=0.60) and higher BF% than heat tolerant ones, shown in Table 3. However, group differences in BF% were statistically significant for skinfold BF% (t_{73}=2.30, P<.05, d=0.57), but not for BIA BF% (t_{73}=1.51, P=.15). Because $VO_{2}max$ and BF% were strongly correlated (skinfold: r=-0.55; BIA: r=-0.56; P<.001), they were assessed in separate regression models to predict HTT outcomes. For each regression, sex was entered into a first block (Block 1), followed by either $VO_{2}max$ (Block 2A), skinfold BF% (Block 2B), or BIA BF% (Block 2C).

In the logistic regression models (Table 4, column 1), sex initially predicted heat tolerance, however its effect became nonsignificant when $VO_{2}max$ and BF% were entered into the model. In the linear regression models, sex was related to maximum HR when it was the only variable; its effect also became nonsignificant in subsequent blocks. Meanwhile, the standardized beta-coefficients for $VO_{2}max$ as predictors of HR_{max} (assessed dichotomously and continuously) and maximal physiological strain index were much greater than sex (maximum HR: $VO_{2}max$=-0.48 vs sex=0.14 and physiological strain index: $VO_{2}max$=-0.34 vs sex=0.03). On the other hand, skinfold BF% only exceeded sex in relation to maximum HR (sex=0.14 vs skinfold BF%=0.28), and this did not hold for BIA BF% (sex=0.15 vs BIA BF%=0.03).

Comment

Our results suggest that although women are classified as heat intolerant to a greater extent than men, $VO_{2}max$ appears to account for most, if not all, of this sex difference. When heat tolerance was broken down into 2 components, HR and T_c, the sex findings held for HTT outcomes related to HR, but not T_c. Thus, cardiovascular strain is far more important than thermal strain. This finding contributes to the literature by suggesting that a relatively fit, representative sample of a military population can be risk stratified for a military setting by participating in an HTT.[5] As women are integrated into combat military occupational specialties, risk profiles for exertional and physical injuries must be determined to assist in developing gender-specific training requirements,[2] as combat exposures will be gender neutral. The present study results suggest that when standard risk factors are controlled for, particularly aerobic power, women do not appear to be at greater risk for EHI than men.

Aerobic power and BF% serve key roles in thermoregulation,[48] risk for EHI,[14,19-21] and military performance.[49] Importantly, poor aerobic power and high BF% are the 2 most studied risk factors for EHI.[20-22] Even though aerobic power and body fat are strongly negatively correlated, they may both directly relate to EHI risk.[21,22] Individuals with poor aerobic power need to work at a higher relative intensity for a given workload than individuals with high aerobic power. This increases their relative physiological strain, which, in turn, decreases peripheral blood flow, hinders thermoregulation, and increases heat absorption.[14,50] Higher body fat also increases metabolic heat and hinders heat dissipation.[7,14] Since aerobic power and BF% also differ by sex, it is important to clarify their independent contributions to thermoregulation, especially as women are officially integrated into combat roles. In fact, proposed algorithms to stratify EHI risk typically include aerobic power and percentage of body fat.[22,51] These algorithms are useful screening tools for warfighters and athletes. But a full HTT is often warranted among EHS patients,[5] particularly when gradual return to physical activity may be problematic.[19,52]

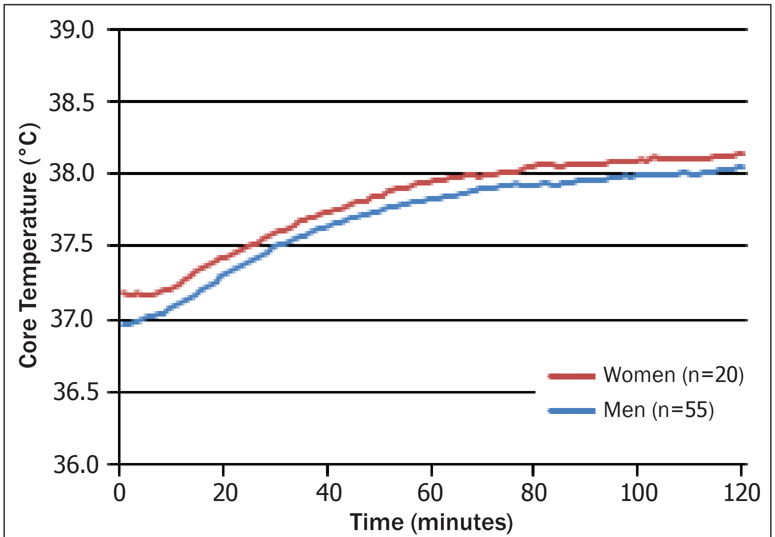

Figure 1. Mean core body temperature response to the heat tolerance test displayed by sex.

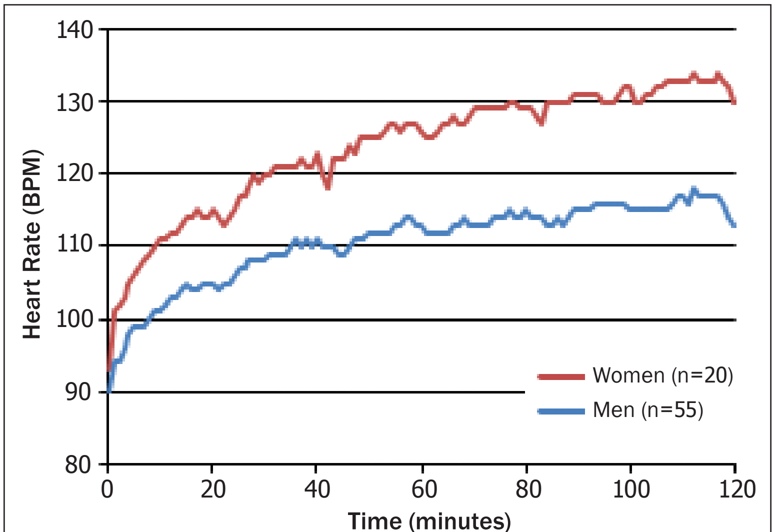

Figure 2. Mean heart rate response to the heat tolerance test displayed by sex.

Laboratory exercise studies have consistently demonstrated that sex differences in thermoregulation in the heat become minimal after controlling for aerobic power and body fat.[32,39,40,53,54] Other demographic differences in heat thermoregulation, such as age, may be explained by these factors as well.[55,56] Nevertheless, previous studies have used relatively small sample sizes and varied protocols, which make comparisons difficult. Protocols differ in exercise type (eg, walking, cycling), acclimatization procedures, and test conditions, depending on the particular research aims. Results from most studies indicate that women are not at a thermoregulatory disadvantage compared to men when matched for body composition and when performing tasks appropriate for their aerobic power level. In the military, fitness and body composition standards are often relative to sex, and in some military occupational specialties, physically demanding tasks cannot be customized to the Warfighter's sex. Certainly in the deployed setting, task assignment cannot be based on gender.

Combat fitness, as defined by Epstein et al,[2] is an individual's ability to effectively perform military-oriented tasks and be able to accomplish all aspects of a combat mission, while staying healthy and uninjured. Combat fitness requires not only the traditional aspects of fitness (cardiovascular endurance, muscular strength, and flexibility), but also neuromuscular motor (hand-eye coordination, agility, speed, and power) and environmental (heat acclimatization) fitness. To partially address these questions, each service and operational specialty is reevaluating occupational fitness requirements for gender neutrality, while at the same time maximizing successful outcomes, regardless of whether the service member is male or female.

Thermoregulatory differences between men and women can likely be attributed to physical characteristics rather than other inherent metabolic/regulatory differences.[2] Given that women are at higher risk for EHI, efforts should focus on improving intrinsic and extrinsic modifiable risk factors. On average, when matched for age, men have greater lean body mass and less fat mass compared to women.[57] A smaller body mass and higher BF% will increase T_c.[58] Additionally, when compared to men, women have lower relative and absolute aerobic power, which may contribute to earlier fatigue compared to men.[2] Clearly, sex differences in performance variables, such as muscle mass and VO_{2max}, affect combat fitness. Cardiovascular and resistance training programs for women can improve physical performance through increases in strength, power, and endurance.[59] The challenge of operating in hot environments is compounded by the use of protective gear and body armor, which inhibit sweat evaporation and heat dissipation, and increase thermoregulatory and cardiovascular strain. Although performance requirement criteria may become gender-neutral for certain combat military occupational specialties, new training practices will be needed to help overcome modifiable sex differences.

Table 3. Characteristics (mean±SD) of Heat Tolerant versus Heat Intolerant Participants.

Independent Variable	HTT Outcome		
	Heat Tolerant (n=56)	Heat Intolerant (n=19)	*t*
VO_{2max} (ml·kg^{-1}·min^{-1})	51.6±7.5	47.0±7.9	2.28*
Skinfold BF%	20.3±6.1	24.3±7.6	2.30*
BIA BF%	23.2±5.4	25.7±8.2	1.51
BMI (kg/m^2)	25.9±3.0	25.2±3.4	0.89
Body surface area (m^2)	1.96±0.21	1.85±0.19	1.93
Body surface/mass (m^2·kg^{-1}·10^2)	2.46±0.21	2.54±0.22	1.55
Waist circumference (cm)	82.4±8.4	78.2±7.9	1.92

BIA indicates bioelectrical impedance analysis.
*P<.05

Limitations to the present study include the sample size and debate regarding the IDF HTT. The number of women in the present study was larger than some previous studies,[32,33,35,39,40,53,54] but still somewhat limited. Future studies should include a greater number of female subjects to allow for more robust sex comparisons and the use of other statistical techniques such as propensity score matching/adjustment.[60] In addition, there is controversy with regard to the construct of heat tolerance in general[61] and the standardized use of the HTT in particular.[62] Alternatives to the IDF HTT include measuring heat tolerance over the course of a multiday acclimation protocol,[62] or customizing a HTT's exercise intensity to the individual being tested.[63] Since many of the EHI patients in the study visited the laboratory from other locations and were on temporary physical activity restrictions, it was not feasible to assess and control for heat acclimation status. More advanced techniques to measure BF% would have also benefitted the study due to concerns about validity and reliability of skinfolds and to a lesser degree BIA, which often vary across sex.[42] Additionally, other key variables, such as fluid and salt losses, may be important to consider.[64]

Table 4. Adjusted Odds Ratios (95% CI) from Hierarchical Logistic Regression Predicting Dichotomous HTT Outcomes.

Independent Variable	HTT Outcome		
	Heat Tolerant	Core >38.5°C	HR ≥150 BPM
Block 1			
Gender	3.7 (1.21-11.24)*	2.0 (0.56-6.90)	3.5 (0.98-12.56)
Block 2A			
Gender	2.5 (0.75-8.54)	1.7 (0.43-6.86)	1.5 (0.35-6.47)
VO_{2max} (ml·kg^{-1}·min^{-1})	0.9 (0.87-1.02)	0.9 (0.90-1.07)	0.9 (0.76-0.96)†
Block 2B			
Gender	2.2 (0.49-9.87)	1.1 (0.18-6.63)	1.8 (0.33-10.16)
Skinfold BF%	1.1 (0.95-1.18)	1.1 (0.98-1.31)	1.0 (0.89-1.13)
Block 2C			
Gender	3.5 (0.82-15.09)	2.0 (0.39-10.54)	1.6 (0.30-8.19)
BIA BF%	1.0 (0.90-1.12)	1.0 (0.88-1.13)	1.1 (0.96-1.27)

BIA indicates bioelectrical impedance analysis.
*P<.05
†P<.01

The IDF HTT remains the most widely used and clinically useful test to assess Warfighter return to duty following EHS,[5,52] as it simulates the conditions of many military EHI scenarios.[65] Importantly, it correlates with risk factors for EHS in the military,[36] for men and women. As women are integrated into combat military occupational specialties, their risk for EHS will increase, and physicians will have to decide whether to return them to duty following such an event. The IDF HTT can help, but research on how women perform has been lacking. Based on the present study and previous work by Druyan et al,[35] women demonstrate a much higher failure rate on the test. As with any high stake test, it is important to determine whether group differences are due to underlying differences in the latent variable.[66] Since the sex differences appear mostly attributable to aerobic power and perhaps BF%, they likely reflect women's increased risks for EHI. These findings should not be surprising to those familiar with human thermoregulation research, as they are consistent with a long line of previous research.[26-29,32,33,39,40] In the present context, however, these results will be crucial for physicians tasked with interpreting IDF HTT scores for men and women, and may inform broader military policy.

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Effects of Basic Combat Training on Iron Status in Male and Female Soldiers: A Comparative Study

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Abstract

Objective: Iron is an essential micronutrient known to affect physical and cognitive performance. Studies indicate a significant reduction in iron status in female Soldiers immediately following military training, although the comparative effects of military training on iron status between male and female Soldiers have not been examined. The objective of this study was to compare the longitudinal effects of US Army basic combat training (BCT) on iron status indicators in a group of male and female Soldiers.

Methods: A total of 154 male and female Soldiers (89 and 65, respectively) completed the study. Blood was collected at 4 time-points during BCT (weeks 0, 3, 6, 9) and dietary iron intake was assessed at weeks 0 and 9. Iron status indicators included hemoglobin, serum ferritin (SF), soluble transferrin receptor (sTfR), and transferrin saturation (TS).

Results: Iron status was greater in male Soldiers than female Soldiers, as hemoglobin and SF levels were higher ($P<.05$) and sTfR levels were lower ($P<.05$) in males as compared to females at each time-point. Despite a mean increase of greater than 25% in iron intake (mg/day) among both male (15±13 to 20.2±14.4) and female Soldiers (12.8±9.7 to 16±6.2) over the course of BCT, iron status declined in both groups. As compared to baseline, SF declined ($P<.05$) by 21% and 47%, sTfR increased ($P<.05$) by 17% and 30%, and TS declined ($P<.05$) by 23% and 54% in male and female Soldiers, respectively, over the course of BCT.

Conclusions: These data indicate that although dietary iron intake improves, iron status declines in both male and female Soldiers during BCT, and the decline in female Soldiers is of a greater magnitude. Future studies should aim to determine the mechanism by which iron status declines during military training, with a focus on functional outcomes affecting Soldier health and performance.

Iron, a nutrient found in food sources of both vegetable (nonheme) and animal (heme) origin, is an essential mineral that confers function in a number of biological processes, to include physical and cognitive performance,[1] immunity,[2] and energy metabolism.[3] Iron deficiency (ID, reduced iron stores) and iron deficiency anemia (IDA, reduced iron stores coupled with diminished hemoglobin) are a worldwide public health concern, affecting billions of individuals.[4] Additionally, poor iron status has been associated with decreased physiological and cognitive performance in both civilian and military populations.[5,6]

Recent data from the United States and the United Kingdom indicate an ID prevalence of 16% and 21%, respectively, among premenopausal women,[7-9] and approximately 2% to 5% among males aged 12-69 years.[9] Although poor iron status is less common in males than females, athletes and others, including Warfighters who engage in strenuous physical activity, are known to be at increased risk for decrements in iron status. Such declines may be caused by several contributing factors including hemolysis and iron sequestration due to the effects of inflammation.[10,11]

Iron deficiency, with or without the presence of anemia, may reduce both physical work capacity and cognitive performance. As the vast majority of body iron is distributed in hemoglobin and developing erythroid cells,[3] poor iron status impairs physiological performance as iron is required for oxygen transport to peripheral tissues.[10] Although there is evidence that physical activities such as military training may cause declines in iron status[12-15] resulting in an increased prevalence of ID and IDA, the definitive mechanism remains unknown.

Iron status has been reported to decline during military training in recent studies among female Soldiers,[16,17] however, reports investigating changes in iron status during military training among male Warfighters are limited.[15,18] Further, dietary iron intake has not been assessed during initial military training. As such, the objective of the present study was to evaluate and compare sex differences in dietary iron intake, iron status, and inflammatory responses during US Army basic combat training (BCT) in an effort to determine whether changes in iron levels are similar between the sexes, and to quantify the relative contribution of dietary iron intake to iron homeostasis during military training.

Methods

This study was approved by the Human Use Review Committee at the US Army Research Institute of Environmental Medicine and conducted at Fort Jackson, South Carolina. Human subjects participated in this study after providing their free and informed voluntary consent. The study was conducted in compliance with *Army Regulation 70-25*[19] and *US Army Medical Research and Materiel Command Regulation 70-25*[20] on the use of volunteers in research. The data presented in this manuscript were collected in association with a larger study investigating the effects of military training on cardiometabolic risk.[21]

Volunteers

A total of 209 Soldiers (118 male, 91 female) volunteered for this longitudinal study during a 10-week BCT course. Baseline data (time-point 1) were collected within one week of arrival at BCT (week 0), followed by 3 additional data collections as follows: weeks 3, 6, and 9 (time-points 2, 3, and 4, respectively). During BCT, volunteers were engaged in physical and military specific training. Physical training requirements include aerobic activities such as road marching with weighted packs, obstacle courses, distance running, and sprinting. Energy costs associated with BCT have been published previously.[22]

Anthropometric (height, weight, body mass index (BMI), and body fat percentage) characteristics were determined at baseline and week 9. Weight was recorded to the nearest 0.01 kg on a calibrated digital scale (A&A Scales, Prospect Park, NJ), and height was measured to the nearest 0.01 cm using a stadiometer (Creative Health Products, Plymouth, MI). Body mass index was calculated by dividing the individual's weight by the square of his/her height ($kg•m^{-2}$). As previously reported,[21] skinfold thickness was assessed at the chest, triceps, and subscapular sites for men, and at the triceps, suprailiac, and abdominal sites for women using Lange calipers (Beta Technology, Santa Cruz, CA). Body fat percentage was calculated from body density using 3-site skinfold equations.[23-25] Body composition was assessed under similar experimental conditions (fasted, similar attire) by the same trained technician.

Dietary iron intake was assessed using a validated food frequency questionnaire (FFQ) (Block 2005 FFQ; NutritionQuest, Berkeley, CA) administrated by registered dietitians. The FFQ was administered at baseline and at the end of BCT to estimate usual dietary intake prior to and during the 10-week training course. Mean daily iron intake was calculated from the USDA Food and Nutrient Database for Dietary Studies version 1.0 (http://www.ars.usda.gov/Services/docs.htm?docid=12089). Notably, dietary supplements are not permitted during BCT.

Blood samples were collected at each time-point after an overnight fast. Samples were obtained through antecubital venepuncture into tubes containing the appropriate anticoagulants, including EDTA for the collection of samples used in whole-blood assays (Vacutainer; Becton-Dikinson, Franklin Lakes, NJ). Hemoglobin was determined in whole blood using a hematology analyzer (Medonic CA 620, Boule Medical AB, Stockholm, Sweden). Serum was isolated, frozen, and shipped to the Pennington Biomedical Research Center (Baton Rouge, LA) for iron status indicator assays. Serum ferritin (SF) was measured using an automated immunoassay instrument (Siemens Medical Solutions, USA, Inc, Malvern, PA) and soluble transferrin receptor (sTfR) was determined using a commercially available immunoassay (Quantikine IVD, R&D Systems Inc, Minneapolis, MN). Serum iron and total iron-binding capacity were measured using the DXC 600 Pro system (Beckman Coulter, Fullerton, CA). Transferrin saturation (TS) was determined by dividing serum iron by total iron binding capacity. Serum interleukin 6 (IL-6) concentrations were measured with a multiplex assay with a lower detectable limit of 0.6 pg/mL (Milliplex MAP, Millipore, Billerica, MA) and high sensitivity C-reactive protein (hsCRP) concentrations were measured with an automated immunoassay instrument with a lower detectable limit of 0.2 mg/L (Siemens Medical Solutions USA Inc).

Data were analyzed with SPSS Version 20.0 (IBM Corp, Armonk, NY). Normal distribution of variables was determined using the Shapiro-Wilks test. Descriptive statistics are presented as the mean (±SD). Comparisons of anthropometric measures and dietary iron intake were made using Student's *t*-tests. Two-factor repeated measures analysis of variance (ANOVA) was used to test main effects of sex and time and biomarker by time interactions. When a significant interaction was observed (time X group interaction= T X G), post hoc analyses with Bonferroni adjustments were conducted to identify those differences. Correlations between changes in dietary iron intake and indicators of iron status were performed using Spearman's rho. Differences between percentage changes in iron status between groups were computed using Student's t tests. Significance level was set at $P<.05$.

Results

A total of 89 male and 65 female volunteers (75% and 71%, respectively) completed the 4 data collection timepoints throughout BCT. There were no significant differences in age, anthropometrics, or any of the baseline biomarkers between those who completed the study and those who did not. As shown in Table 1, in comparison to men, women were shorter, weighed less, had a lower BMI, and had a greater body fat percentage ($P<.05$). Over the course of BCT, men lost weight and reduced BMI whereas women did not, although both men and women experienced reduced ($P<.05$) body fat.

At baseline (week 0), significant differences in iron status were observed between sexes. In comparison to females, males had greater levels of hemoglobin ($P<.05$) and SF ($P<.05$), coupled with reduced sTfR levels ($P<.05$).

Throughout the course of BCT, there were significant changes in many of the biochemical indicators of iron status in both male and female Soldiers, shown in Table 2, suggesting a decline in iron status. Changes in the iron status indicators SF, sTfR, and TS differed between men and women during BCT (interaction $P<.05$). Changes in female Soldiers were apparent by week 3, as SF levels had decreased by 34% ($P<.05$), sTfR levels had increased 26% ($P<.05$), and TS decreased by 37% ($P<.05$). Hemoglobin and SF in male Soldiers declined and sTfR increased at week 3 ($P<.05$), although TS was not affected. Declines in iron status persisted through the training period, as all status indicators were significantly affected ($P<.05$) in both male and female Soldiers by week 6.

Similarly, at the end of BCT (week 9), all indicators of iron status (with the exception of hemoglobin in female Soldiers) had declined significantly in both male and female Soldiers as compared to baseline. The magnitude of this decline was significantly greater ($P<.05$) in female Soldiers in comparison with male Soldiers as reflected by sharper declines in SF and TS coupled with a steeper increase in sTfR (Figure 1).

Inflammatory biomarkers did not change over the course of BCT (data not shown; $P>.05$).

Dietary Iron Intake

Dietary iron intake increased in both male (35%, $P<.05$) and female Soldiers (25%, $P<.05$) over the course of BCT. By week 9, iron intake was significantly greater ($P<.05$) in male Soldiers as compared to female Soldiers (20.2±13.0 mg/day vs 16.0±6.2 mg/day, respectively).

At the start of BCT, daily iron intake among men was 188% of the Recommended Dietary Allowance (RDA)[26] (15.0 mg/day vs 8 mg/day, respectively). Women did not

Table 1. Volunteer demographics and anthropometrics (mean±SD): males, n=89; females, n=65.

	Week 0	Week 9	Effect
Age (years)			
Males	23.1±5.4		
Females	23.1±6.0		
Height (cm)			
Males	176.1±7.0*		
Females	162.8±5.8		
Weight (kg)			
Males	83.5±15.9*	79.8±11.9*†	T X G
Females	66.2±8.5	66.3±7.5	
BMI (kg•m^{-2})			
Males	26.9±4.6*	25.7±3.3†	T X G
Females	25.0±2.8	25.0±2.3	
Body fat (%)			
Males	14.2±4.9*	12.3±3.5*†	T X G
Females	26.6±5.7	22.6±5.0†	

*Significant differences between males and females ($P<.05$).
†Significantly different from baseline ($P<.05$).
T X G indicates time X group interaction ($P<.05$).

Table 2. Longitudinal changes (mean±SD) in iron status indicators during BCT among male and female Soldiers: hemoglobin (Hgb), serum ferritin (SF), soluble transferrin receptor (sTfR), and transferrin saturation (TS).

	Week 0	Week 3	Week 6	Week 9	Effect
Hgb (g/dL)					
Males (n=77)	14.7±0.8*	14.1±0.8*†	13.9±0.8*†	14.0±0.9*†	T X G
Females (n=56)	12.7±0.9	12.4±1.0†	12.3±1.0†	12.4±1.2	
SF (ng/mL)					
Males (n=84)	129.5±79.8*	121.5±81.3*†	105.7±68.6*†	101.9±66.3*†	T X G
Females (n=65)	35.6±27.1	23.4±16.1†	20.2±13.4†	18.9±14.2†	
sTfR (nmol/L)					
Males (n=82)	16.8±3.6*	19.7±4.8*†	19.7±4.6*†	19.6±4.7*†	T X G
Females (n=65)	18.9±7.2	23.9±8.4†	24.6±8.6†	24.6±8.5†	
TS (%)					
Males (n=89)	31.6±11.7	31.4±11.6*	25.3±9.7*†	24.1±10.5*†	T X G
Females (n=65)	28.5±13.8	18.0±9.1†	15.8±7.9†	13.2±6.3†	

*Significant differences between males and females ($P<.05$).
†Significantly different from baseline ($P<.05$).
T X G indicates time X group interaction ($P<.05$).

meet dietary recommendations, as intake met only 71% of the requirement (12.8 mg/day vs 18 mg/day, respectively). Daily iron intake increased in both male and female Soldiers over the course of BCT. By the end of the course, overall daily iron intake met 253% and 89% of the RDA for men and women, respectively (Figure 2). Although there were no correlations between changes in dietary iron intake and indicators of iron status in male Soldiers, there was a significant negative association ($P<.05$) between changes in dietary iron intake and change in SF in female Soldiers.

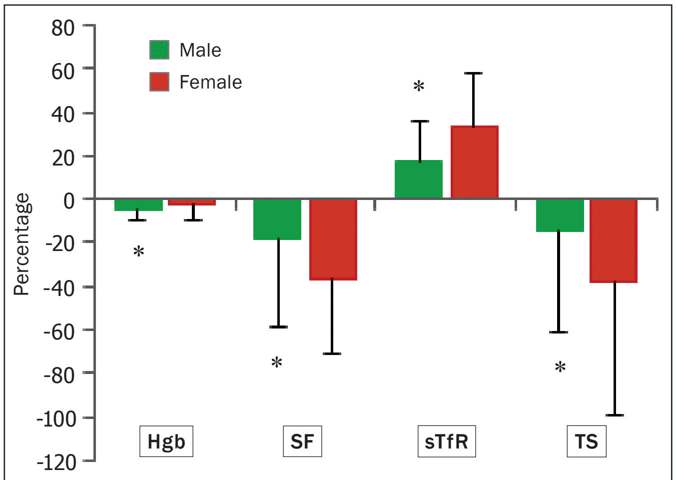

Figure 1. Percentage changes (week 0 vs week 9) in iron status indicators during BCT in male and female Soldiers: hemoglobin (Hgb), serum ferritin (SF), soluble transferrin receptor (sTfR), and transferrin saturation (TS). Note: * indicates significant differences between males and females ($P<.05$).

Comment

The objective of this study was to evaluate changes in iron status, markers of inflammation, and dietary iron intake during a 10-week US Army BCT course among male and female Soldiers. The major finding of the study was that iron status declined in both sexes during military training, regardless of improvements in dietary iron intake. Although several studies have examined iron status among military recruits on induction day,[27,28] and throughout military training courses,[18,29] this is the first study to comprehensively examine differences between the sexes in iron intake and metabolism during initial military training in the US Army.

While both men and women experienced a significant decline in iron status during BCT, the influence of BCT on iron status was more pronounced among females. Data from the current study indicate that the activities associated with military training may contribute to declines in iron status, as iron intake significantly increased over the course of BCT, and most Soldiers were meeting dietary requirements for iron. Improved dietary iron intake during BCT was a novel finding, as previous studies have not assessed micronutrient intake during the training course. Although the relative contribution of particular food items to iron intake was not assessed, previous work indicates that dietary patterns (reflective of nutrient density) improve in Soldiers during BCT as compared to the period prior to enlistment, especially among individuals who enter military service with the least favorable eating habits.[30]

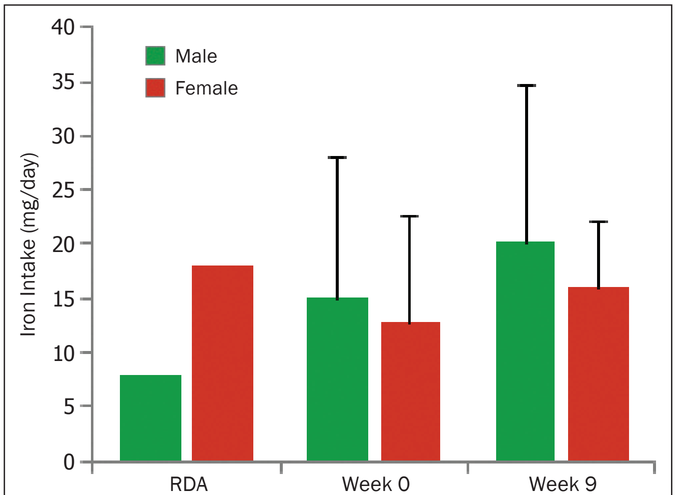

Figure 2. Daily iron intake (mg/day) at the beginning (week 0) and the end (week 9) of BCT among males (n=89) and females (n=65) in comparison to the Recommended Dietary Allowance (for males and females aged 19-30 years). Note: significant effects of time and group ($P<.05$).

Decreases in iron status have been observed previously among physically active populations.[31] As observed in our study population, decreases in SF and TS coupled with an increase in sTfR were evident in both male and female Soldiers, although the decrement experienced in female Soldiers was nearly double that experienced by their male counterparts. These differences between the sexes are reflective of previous studies conducted with integrated military platoons or professional athletes, although limited data are available with regards to iron status in males.[32,33] These studies indicated a greater prevalence of overuse injuries and sharper declines in hematological parameters during BCT and physical training periods among females exposed to the same absolute physical demands as males.[31,34,35] It is possible that female Soldiers experience a relatively higher physiological strain in comparison to their male counterparts when exposed to similar absolute strains, which may contribute to the declines in iron status.[36]

As previously described in the scientific literature, the inflammatory response to exercise is mediated by the increased expression of several cytokines, including

IL-6, and acute phase proteins such as CRP, and is correlated with the intensity of the activity.[37] Hepcidin, a key regulator of iron homeostasis, increases in response to the inflammation associated with exercise and results in the sequestering of iron in enterocytes and macrophages, preventing iron from becoming available for incorporation into proteins and enzymes that support physical performance and energy metabolism.[11] A recent study conducted on 12 physically active women (aged 19 to 32 years) found that hepcidin was increased 3 hours after either a 60-minute or 120-minute run at 65% of maximal oxygen uptake (VO_2max), while IL-6 levels increased immediately after the end of the exercise bout.[38] In the current study, elevations in hsCRP and IL-6 occurred over time in both male and female Soldiers, although increases were not statistically or clinically significant. These findings were contrary to our hypothesis; a greater inflammatory response to BCT may have been expected in female Soldiers given the greater decrement in iron status markers. However, the short half-life of acute phase proteins and cytokines may cause difficulties in assessing the physiological influence of these markers when collected chronically, especially following an overnight fast.[11] Recent studies have demonstrated the acute effects of military training on the IL-6 and hepcidin response in male personnel during intense operational exercises,[15] although future studies should more carefully investigate the nature of this response to activities encountered during BCT in both male and female Soldiers.

Despite the data demonstrating a considerable decrease in iron status in this study population regardless of dietary iron intake, the functional consequences of poor iron status and effective countermeasures to prevent declines in iron status remain unclear. It appears that the decline in iron status is of much greater concern for female Soldiers, as male Soldiers began the training course with more robust iron stores, and experienced an attenuated decline in iron status as compared to female Soldiers. Although this study did not assess the relationship between iron status and physical or cognitive performance, previous studies have demonstrated a relationship between declines in iron status and running performance and mood in female Soldiers.[14,16] Further, effects of both IDA and iron deficiency without anemia on physical performance have been noted in civilian populations.[6] Effects of iron deficiency without anemia could be of significant operational concern during military training, especially in female Soldiers, as the observed declines in SF and TS coupled with increases in sTfR could approach values known to affect performance. The relationship between declining iron status and performance in male Soldiers during military training has not been studied and may warrant further exploration.

Dietary countermeasures may be effective for preventing declines in iron status during military training as indicated by recent studies demonstrating the efficacy of both iron supplements[14] and fortified foods[39] for attenuating the decline in iron status in female Soldiers during BCT. However, data from the present study indicate that consuming iron at levels well beyond the RDA through the diet during BCT does not protect against declines in iron status. As such, questions remain regarding the mechanism by which iron status declines in response to military training, which may drive the development of effective nutritional or pharmacologic methods for preventing the negative consequences of poor iron status in Warfighters during training. Future studies should address limitations of the current study, to include further exploration of the mechanism responsible for the decline in iron status including the incorporation of a more detailed panel of proinflammatory cytokines, assessment of activities the day prior to blood collection, and greater control for menstrual phase in female volunteers. Lastly, future studies should assess iron status in both male and female Soldiers during periods subsequent to BCT, such as advanced individual training, including associations with physical and cognitive performance, with a focus on female Soldiers that may begin these activities with degraded iron status.

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Female Combat Amputees Have Higher Rates of Posttraumatic Stress Disorder Disability

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Abstract

Background: The civilian trauma literature suggests that the sexes differ in physical and mental health outcomes following traumatic injury. In order to determine if the reaction to combat injury is different between the sexes in a specific war wounded population, service members with amputations, we examined the disability profiles of male and female amputees.

Methods: All US combatants who sustained a major extremity amputation between October 2001 and July 2011 were examined for demographic and injury information from the Department of Defense Trauma Registry and for disability outcomes in the service specific Physical Evaluation Boards. The proportions of women versus men with various disabling conditions were compared using Fisher's Exact Test and the mean disability ratings for each condition were compared using student's *t* tests.

Findings: Among 1,107 amputees, 21 were female. There was no difference in the average age, military rank, or Injury Severity Score between the sexes. While the most common military occupation of male amputees was infantry service, the most common occupation for the female amputee was military police. The overall disability ratings between females and males were not different (82% for females, 75% for males). Female amputees had more frequent disability from posttraumatic stress disorder (PTSD, 8/21 [38%] vs 168/818 [17%]). Disability ratings from PTSD tended to also be higher in women.

Conclusions: Outside of variable occupational descriptions, both male and female amputees were exposed to explosions resulting in their injuries. Consistent with many civilian trauma and veterans' population studies, female amputees have higher frequencies of disability from PTSD. These results support the need for additional effort and attention directed towards optimizing physical and mental fitness following deployment in order to reduce disability and promote return to duty. Because certain conditions, such as PTSD, may be more or less common in men versus women veterans, postdeployment fitness may need to be tailored in a gender specific way.

Women currently comprise 15% of the total active duty population and 10% of brigade units.[1] The number of female war veterans from current military conflicts is expected to rise accordingly.[2] While the study of the female veterans as a distinct population lags behind the study of the overall veteran population, there is evidence that the female veteran reacts to combat trauma differently than males.[3] This is consistent with several reports in the literature describing sexual dimorphism in outcomes in the civilian trauma population.[4,5] Evidence from prior wars suggests that female veterans have higher incidence of reproductive health issues compared to females who never served in the military.[6,7] Outside of the physical toll of trauma, mental health outcomes also differ between men and women in the civilian trauma literature. Posttraumatic stress disorder (PTSD) rates are higher for women in civilian accidents and for women who witness death or injury versus men.[8,9] Some studies support that female veterans experience similar rates of PTSD compared to male veterans.[10,11] However, the most common cause of evacuation of deployed women service members from both recent wars in Iraq and Afghanistan was and is mental health condition.[12,13]

A recent publication on disability following combat injuries highlights the importance and frequent nature of orthopaedic related disability.[14] This is certainly so for service members with combat related amputations and the ensuing disability related to the amputation. The disability outcomes for female veterans, including females with combat related amputations specifically, have not been determined. We aim to determine what differences exist, if any, in the disability profiles of women who sustained a combat related amputation versus male veterans with amputations. Because mental health disorders such as PTSD are known to adversely affect outcomes following trauma and because the PTSD rates for female veterans may be higher than for male veterans, differences in male and female disability profiles for both physical and mental health conditions may exist.[15] Based on prior literature that supports different mental health outcomes and a variable reaction to trauma, we hypothesize that female amputees will have different disability profiles compared to male amputees.

Methods

This study was conducted in accordance with a research protocol approved by the Brooke Army Medical Center Institutional Review Board. All military patients who sustained a major limb amputation between October of 2001 and July 2011 were queried in the Department of Defense Trauma Registry (DoDTR, Joint Base San Antonio Fort Sam Houston, Texas) for demographic and injury information to include age, sex, military rank, mechanism of injury, and Injury Severity Score (ISS). Major limb amputation was defined as an amputation occurring proximal to the carpus in the upper extremity and proximal to the tarsal bones in the lower extremity. Injury and demographic data were cross-checked for the female amputees in the Military Orthopaedic Trauma Registry (MOTR, Joint Base San Antonio Fort Sam Houston, Texas). We then queried the resultant subjects in the service specific Physical Evaluation Board databases which are maintained separately for the Army, Air Force, and Navy (including Marine Corps). The Physical Evaluation Board (PEB) is responsible for determining an ill or injured service member's fitness for duty after an adequate period of recovery which is determined by the various treating physicians. If the service member is not able to perform his or her active duty job description, the PEB helps determine if the service member should be medically separated or retired from the military, or be retained temporarily for additional treatment or recovery. The high physical demands of military service make the PEB determinations important following orthopaedic injury.

Table 1. US Military Combatants with Major Extremity Amputations who underwent Physical Evaluation Board Review, October 2001–July 2011 (N=1,007)

	Women (n=21, 2%)	Men (n=986, 98%)
Age (mean±SD)	27±5	25±5
Rank (median, range)	E-6 (E3-O3)	E-7 (E1-O6)
Battle Injury	20, 95%	976, 99%
ISS (mean±SD)	19±7	21±10

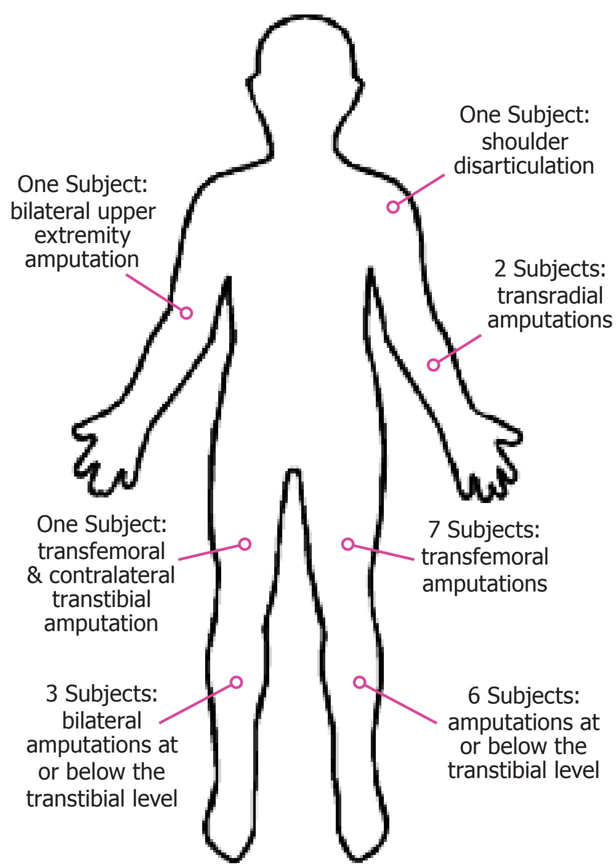
Subjects with complete DoDTR injury data who were medically retired or separated from active duty service by the PEB were included in this analysis. For service members who are medically retired by the PEB, the diagnoses that affect their inability to return to duty are called "unfitting" or disabling conditions. Each disabling condition is also assigned a percentage on a continuous spectrum from 0% to 100% to reflect how much that individual condition contributes to the service member's inability to perform his or her active duty position. For example, for a service member with a transtibial amputation, the PEB assigned a percent disability to the amputation diagnosis of 40%. This indicates that the amputation diagnosis detracts 40% of military fitness and readiness for that service member's ability to perform his or her job. The percent disability can therefore be evaluated on a spectrum of severity. The disability rating for each of the separate conditions is totaled according to the Veterans Affairs (VA) Schedule for Rating Disabilities formula to yield a total percent disability. While the PEB rating is different from the service connected disability designation a veteran receives from the VA, the VA rating scheme is used by the PEB for this Department of Defense disability rating.

We present demographic and injury descriptions compared between the sexes. The proportions of related disabling conditions between men and women were compared using Fisher's Exact Test. The mean percent disabilities (continuous variables from 0% to 100% reflecting a disability spectrum) per group of disabling conditions were compared between the sexes using unpaired student's *t* tests. Calculations were performed using Graph Pad Prism 6 software (GraphPad Software, Inc, La Jolla, CA).

Results

Of the 1,107 amputees who were evaluated by the PEB, 21 were female and 986 were male. Average age, median military rank, and average ISS were not different between the sexes as shown in Table 1. A majority of both women and men sustained their amputations in a battle injury of explosion mechanism. One female sustained a transtibial amputation in a nonbattle machinery accident. The distribution of amputation sites were also similar with the majority of amputations being of the lower extremities as illustrated in the Figure. Because of certain restrictions on women serving in direct combat roles, job descriptions for males and females did differ as most male amputees served in infantry units. Ten of the females with amputations served as Military Police, 4 in supply/transport, 3 as mechanics, 2 in human resources, one as an explosive ordinance officer, and one as an aviation officer. All of the female amputees served in the Army.

The frequencies of orthopaedic related disabling conditions were not different between the sexes. Outside of the disability received for the amputation diagnoses, posttraumatic arthritis was the most common condition affecting male amputees and the second most common condition affecting female amputees. Among the nonorthopaedic conditions, female amputees had a higher proportion of PTSD related disability compared to male amputees, with PTSD being the most common disabling



Amputation levels of 21 female amputees.

condition in women aside from the amputations themselves as shown in Table 2.

The overall disability ratings and the percent disability rating assigned to upper extremity amputations tended to be higher for women but not significantly so as shown in Table 3. The average percent disability ratings assigned to individual orthopaedic and nonorthopaedic conditions were also not different for males versus females, shown in Table 4. While all females were deemed unfit for duty and eligible for medical retirement based on their disability ratings, 3 women were able to continue on active duty in a limited or altered job description through a Continuation on Active Duty (COAD) appeals process. Females who COAD were of average age 23 years old and enlisted rank E-4, while the 89 males who returned to duty or were able to COAD were of average age 28 and enlisted rank E-7. None of the women who were COAD were assigned disability related to PTSD; and only one male who was COAD had a PTSD disability.

Table 2. Service Disqualifying Conditions per Sex

	Women N=21 (n, %N)	**Men** N=986 (n, %N)	***P* Value**
PTSD	8, 40%	168, 17%	.0193
Scar	4, 20%	89, 9%	.1207
TBI	4, 20%	99, 10%	.2605
Arthritis	7, 35%	247, 25%	.4453
Back Pain	1, 5%	20, 2%	.3605
Abdomen/Pelvic Condition	1, 5%	20, 2%	.3605
General Pain	1, 5%	30, 3%	.4849
Muscle Condition	2, 10%	79, 8%	.6832
Nerve-Loss of Function	3, 15%	150, 15%	1

Two-tailed *P* value calculated using Fisher's Exact Test.
PTSD indicates posttraumatic stress disorder; TBI, traumatic brain injury.

Comment

Among a population of wounded service members who sustained similar injuries by similar mechanisms, a comparison of resultant disabilities is possible. We found that general demographics in this specific injured population, with the expected differences in job description, are similar for male and female combat amputees. Consistent with prior literature in the civilian population, we found that female amputees have a higher proportion of PTSD diagnoses compared to similarly injured males. The disability percentage ratings, however, were not different between the sexes. The high proportion of posttraumatic arthritis being similar between the sexes is notable, though, as idiopathic osteoarthritis is more common in females than males.[16-18]

Current literature on the veteran population is mixed regarding the presence or absence of difference in rates of PTSD in male and female veterans. Haskell et al found that the female sex was negatively correlated with a positive screen for PTSD or VA service connected disability for PTSD, while other studies have found no difference between the sexes.[10,11,19] However, studies that account for other levels of interpersonal trauma, prior history of trauma, and sexual trauma in the military indicated that personal history and type of trauma exposure contributed to higher rates of PTSD and depression in female veterans.[20-23] A recent study of homeless veterans found that homeless women were more likely than men to have PTSD, but were less likely to have substance abuse and incarceration histories.[24] Studies of PTSD rates use variable methods for measuring and diagnosing PTSD, making a firm conclusion about dimorphism in PTSD rates difficult.[25]

We found a higher rate (40%) of PTSD in our cohort than previously published or expected based on recent epidemiologic studies of veterans.[26,27] We believe this study shows a true difference in the frequency of PTSD among female service members when the injury mechanism and injury pattern are considered. Because of the similarities across the board in our male and

Table 3. Mean Overall Disability Ratings (range)

	Women	Men	*P* Value
Upper Extremity Amputation	85% (70%-100%)	76% (40%-100%)	.2933
Lower Extremity Amputation	66% (40%-100%)	65% (40%-100%)	.9781
Overall Combined Disability	82% (40%-100%)	75% (40%-100%)	.2042

Disability ratings assigned as a continuous variable between 0 and 100%. Two tailed *P* value comparing means were calculated using student's *t* test.

Table 4. Mean Disability Ratings per Condition (range)

	Women	Men	*P* Value
PTSD	49% (10%-80%)	44% (0-70%)	.5553
Nerve-Loss of Function	45% (10%-80%)	33% (0-40%)	.4636
Muscle Condition	40% (40%)	29% (0-70%)	.4142
Arthritis	33% (10%-40%)	22% (0-40%)	.2527
TBI	30% (10%-40%)	40% (0-100%)	.4968
Scar	27% (10%-50%)	30% (0-70%)	.3893
Back Pain	20%	13% (0-20%)	n/a
Abdomen/Pelvic Condition	20%	58% (0-80%)	n/a
General Pain	0%	15% (0-30%)	n/a

Disability ratings assigned as a continuous variable between 0 and 100%. Two tailed *P* value comparing means were calculated using student's *t* test. PTSD indicates posttraumatic stress disorder; TBI, traumatic brain injury.

female cohorts, the comparison of frequencies is useful. Additionally, in order for a condition to be deemed a disabling condition, the service member must have undergone an adequate time for treatment and recovery and have undergone subspecialty evaluation and diagnosis, making this rate of persistent PTSD reflective of physician diagnosed disorders rather than self-reported incidences. The disability percentages were not different among the sexes, suggesting that the severity of the injuries and resultant disability are no different, even in light of frequency differences for PTSD.

Other studies on female veterans demonstrate other possible sex differences following trauma. Female veterans from multiple prior wars have reported increased issues in reproductive health including higher incidence of birth defects, higher incidence of severe premenstrual symptoms, and a more difficult time becoming pregnant.[6,7,28] Other studies demonstrate higher rates of anxiety and depression among female service members.[19,29] One study by Nunes et al demonstrated higher rates of psychological diagnoses in civilian female amputees versus males.[30] Other studies have found that female veterans have more pain disorders and higher healthcare utilization for pain versus male veterans.[31,32] Our study did not demonstrate higher frequencies of other mental health diagnoses, pain disorders, or gynecological problems in this cohort. In this small population of amputees, however, this likely reflects the conditions that are evident to the PEB a relatively short time following injury, whereas some issues may arise later or be amplified with time as suggested in some studies published from the VA.

One unique finding about this small population of female amputees is the number and characteristics of the women who were able to return to an active duty role through the COAD process. COAD is an appeals process that allows select service members to be retained on active duty in limited or altered job roles despite being deemed medically unfit by the PEB. Prior studies on return to duty after a variety of orthopaedic injuries have found that the service members who were able to continue on active duty in some fashion were typically older and higher rank.[33-35] This makes the 3 female amputees on COAD unique as their average age was 23 and median military rank E-4. We speculate that the ability for these young soldiers to continue active duty service in a new job description is related to job descriptions which might be amenable to an altered level of physical activity. For example, the most common job description for the male amputee, infantry, would rarely be achievable for the duties required of the young, junior-enlisted infantryman.[36] The new job roles to which the COAD soldiers returned to duty were not available for analysis. However, the absence of PTSD may also have contributed to these women's ability and desire to return to duty.

Our study does have several limitations. For one, the PEB results and disposition are unique to the military and may be difficult to extrapolate to civilian trauma setting. We believe that with the rising number of combat veterans from our most current wars, military related disability will become an increasingly important issue in the VA and in treatment centers outside the VA. Furthermore, the PEB system serves as essentially a workman's compensation system comparable to that found in the civilian trauma environment. Secondly, our data is limited to retrospective evaluations which limits our ability to demonstrate causation. We have attempted to limit the deficiencies in this data as best as possible by validating the demographic and injury information in our Military Orthoapedic Trauma Registry which was designed specifically for capture of orthopaedic specific injury, treatment, and complication information. Finally, our most concerning limitation is the small sample size of female amputees making statistical inference difficult when comparing the sexes. While this remains the largest cohort of female amputees to be reported from the most comprehensive combat injury registry available, this is a limitation of the patient population, but we believe the information is useful by further supporting other military and civilian amputee literature.

Summary

In a cohort of recent combat veterans with similar injury mechanisms and patterns over a 10-year span, the disability profiles between female and male amputees is not entirely different. Female amputees are more likely to have PTSD as a service disqualifying condition than male amputees, though the severity of the PTSD is not statistically different between the sexes. Proportions and severities of the orthopaedic disabling conditions were not different between the sexes. There appears to be a demographic difference in female amputees who were able to continue on active duty which may be related to military occupation specific factors. These findings in a small cohort of female military amputees add additional information on the importance of understanding differences in response to combat injury for both physical and mental disorders such as PTSD in the female veteran population.

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Comparison of Female and Male Casualty Cohorts from Conflicts in Iraq and Afghanistan

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Abstract

Although there has been interest in the literature regarding the casualties within the recent US military conflicts in Iraq and Afghanistan, very little to date has looked specifically at a difference between the sexes. As the role of the female Soldier has changed over the years, so have the risk and the nature of the female casualty. Combat injuries in women are an important medical consideration that has yet to be studied. For the purposes of this study, the following questions pertained:

Do female and male casualties from the US military in recent conflicts differ in age, service, rank, military operation, or other demographic characteristics?

Do female and male casualties from the US military in recent conflicts differ in their injury characteristics such as Injury Severity Score (ISS), Abbreviated Injury Score (AIS), injury type (blunt versus penetrating), injury cause (mechanism of injury), and injury date?

The Department of Defense Trauma Registry (DoDTR) was queried, returning results for 425 female and 14,982 male subjects who sustained musculoskeletal injuries from October 2003 (beginning of hostilities in Iraq) to December 2012.

The female and male cohorts were compared and analyzed for significance in demographics (age, service, rank, and military operation) and injury characteristics (ISS, AIS, injury type, injury cause, and injury date).

Female casualties differ from their male counterparts in that they are slightly younger (F=26.11, M=27.83 years; *P*<.001), proportionally more female casualties were in the Army (F=81.5%, M=72.2%; *P*<.001), and proportionally more women were injured during Operation Iraqi Freedom (F=75.6%, M=63.2%; *P*<.001).

Female casualties showed on average lower ISS (F=7.49; M=9.68; *P*<.001) and lower AIS specific to the skeletal anatomic region (F=2.06; M=2.36; *P*<.001); however when broken down into battle versus nonbattle injury, the difference disappeared. Women were less likely to be injured in battle (F=33.1%; M=70.9%; *P*<.001) and less likely to be injured due to an explosive device (F=27.7%, M=55.2%; *P*<.001).

Women comprised 2.75% of the DoDTR casualties during the studied time frame and were less likely to be involved in explosions or during battle. The ISS were significantly different when comparing battle and nonbattle injuries for both of the sexes. However, since men were more likely to be injured in battle, their total ISS mean was higher.

The United States has been involved in armed conflicts in Iraq and Afghanistan over the last 12 years,[1] and during this time there have been changes in the nature and severity of casualties, especially as compared to previous US conflicts.[2-4] There is previous literature which addressed treatment of casualties based on mechanism of injury such as blast injuries that have been common in these conflicts due to the use of improvised explosive devices.[2,4,5] Further studies looked into prevention of injury including body armor and eye protection[3] and further treatment of severe extremity trauma through the use of tourniquets.[6,7] Less research has focused on identifying differences in the individuals being injured. There are some studies looking specifically at demographic information, especially when comparing military branches.[8,9] However, there is very little that can be found from any investigation into casualty differences between the sexes.

Some studies in the civilian trauma literature indicate that there is a difference in survival rates for women versus men with similar injury patterns.[10] Both animal studies and retrospective reviews of civilian trauma data have indicated that women may have a biological advantage when it comes to surviving trauma,[10-12] at least if there are no medical complications after the sustained trauma. This is in contrast to Cross et al who studied mortality in combat which indicated that female casualties with battle injuries of a similar severity to their male counterparts were more likely to die of their injuries.[13] This disparity indicates that more research is needed to further understand the impact that sex may have on wartime casualty survival.

Women currently serve in the military in many countries around the world including Israel, which is the only nation that mandates service for all citizens, men and women alike.[14] Today women comprise approximately 15% of the US military,[15,16] and their contributions are recognized as vital to readiness. This has not always been the case. Prior to and during World War II, women serving in support roles for the troops were not considered to be a part of the military itself. This changed in 1948 when federal legislation mandated that women would be part of the US military services.[16] The first matriculation of women at military academies occurred in 1976, and a small contingent of women was deployed to Grenada in 1983.[16] During the first Gulf War (1990-1991), approximately 40,000 women were deployed. However, this effort was soon followed in 1994 by a Pentagon policy that established a ban on assignment of women to ground combat units considered to be "front-line" positions.[16] Despite this, current conflicts have demonstrated that women's invaluable contributions to the military are no longer required only behind the front lines of fighting as in previous wars. The Secretary of Defense acknowledged this fact in 2013 when he lifted the 1994 prohibition, allowing women to hold direct combat positions, including infantry and even potentially special forces roles.[15,17]

Given these changes in the role of the female service member, it is more important than ever to learn if there are any differences between the sexes in casualty treatment and/or survival. In order to provide the best care, physicians must not only look at the injuries sustained but also the individual being treated. We do not yet know what the differences might be between men and women injured during conflict.[13]

For the purposes of this study, the following questions pertained:

- Do female and male casualties from the US military in recent conflicts differ in age, service, rank, military operation, or other demographic characteristics?
- Do female and male casualties from the US military in recent conflicts differ in their injury characteristics such as Injury Severity Score (ISS), Abbreviated Injury Score (AIS), injury type (blunt versus penetrating), injury cause (mechanism of injury), and injury date?

Methods

This retrospective study of existing data was conducted under and in accordance with a protocol approved by the US Army Institute of Surgical Research Institutional Review Board. We performed a retrospective collection of casualty data, which was then placed into one of 2 cohorts, females and males. These cohorts were then compared with a variety of characteristics.

We studied male and female service members who served and were injured in Operation Iraqi Freedom (OIF), Operation Enduring Freedom (OEF) in Afghanistan, or Operation New Dawn (OND) between October 2003 (the beginning of hostilities in Iraq) and December 2012. The Department of Defense Trauma Registry (DoDTR) was queried for all musculoskeletal related casualties, defined as any injury related to bone, joint, or muscle in the upper extremities, lower extremities, or the spine. This search resulted in the identification of 425 female and 14,982 male subjects who met the criteria. All female and male casualties identified were included.

Age, branch of military service, military rank, military operation (OIF, OEF, or OND), ISS, body-specific AIS, injury type, injury cause, and injury date were collected from the DoDTR on each subject. Each subject was also marked as either injured either during battle or in a nonbattle related incident. The body-specific AIS scores rate the severity of injury to 6 different body regions: (1) the head, neck, and cervical spine; (2) the face; (3) the chest and thoracic spine; (4) the abdomen and lumbar spine; (5) the extremities and bony pelvis; and (6) external injuries to the integument.

Because the casualty data is entered into the DoDTR consecutively as information of casualties is received and processed, the data pulled from this database provides a consecutive sample of all casualties for the above defined time period. Less than 1% of the male subjects were missing information on cause of injury (had "other" listed), while this information was complete for all female subjects.

Using IBM SPSS Statistics Version 19.0 (IBM Corp, Armonk, NY), the female and male cohorts were compared and analyzed for significance in demographics (age, service, rank, and military operation) and injury characteristics (ISS, AIS, injury type, injury cause, and injury date). We used the Shapiro-Wilk test to determine whether the data were randomly distributed. The variables were not normally distributed among men, so a nonparametric test was required; the Spearman rank correlation was used. This was used to compare age, combined ISS, individual AIS values between the groups male and female. Contingency tests (Pearson χ^2 and Fisher's Exact Test) were used to compare proportions of the male and female groups in military branch, battle and nonbattle injuries, and explosion versus non-explosion mechanisms of injury.

The study population is comprised of all active duty, activated reservist, and National Guard service members in the US military, with all branches included: Army, Marine Corps, Navy, Air Force, and Coast Guard. As in the study parameters, there are 425 females and 14,982 males. They ranged in age from 18 to 60 years and included military ranks from E-1 through O-9.

Results

The collected data revealed that women comprised 2.75% of the overall casualties. Female casualties were on average slightly younger with a mean age of 26.11 (range 18-55) years, while males have a mean age of 27.83 (range 18-60) years with a $P<.001$. Among the military branches, the Army as a whole had the greatest percentage of both men and women, depicted graphically in Figure 1. However, with a χ^2 comparison, it was shown that a greater proportion of female casualties were from the Army (81.5%) while a greater proportion of male casualties were from the Marine Corps (21.2%) ($P<.001$), When comparing casualties in each conflict, again a higher percentage of female and male casualties were in Operation Iraqi Freedom (females at 75.6% and males at 63.2%). A χ^2 analysis showed that proportionally more female casualties were in OIF while OEF produced more male casualties ($P<.001$).

The analysis of the injury characteristics also showed several statistical differences. All subjects, both male and female, showed higher Injury Severity Scores (ISS), with a higher score being related with more severe injury, in battle-related trauma (mean 11.53, range 1-75) as compared to nonbattle injury (mean 5.20, range 1-59) ($P<.01$). Women on average showed lower ISS but only when comparing the mean of all casualties together ($P<.01$). Mean ISS for females was 7.49 with a range from 1 to 50; mean ISS for men was 9.68 with a range from 1 to 75. Both sexes averaged higher ISS in battle injuries (F=12.01, M=11.52) as compared to nonbattle injuries (F=5.28, M=5.19) ($P<.001$). Females also averaged a lower AIS specific to the skeletal anatomic region for all casualties together (F=2.06; M=2.36) ($P<.03$). In comparing battle versus nonbattle-related injury, women were less likely to be injured in battle than the male casualties with 33.1% of female and 70.9% of male casualties being recorded as battle-related. As shown in Figure 2, women were less likely to be injured due to an explosive device; 27.7% of female casualties were related to an explosion as compared to 55.2% of male casualties. However, the most common cause of battle-related injury for both sexes was an explosion, and the most common cause of nonbattle injury for both sexes was a fall. No differences were found between the sexes when comparing date of injury.

Comment

This study endeavored to address in quantifiable metrics the overarching question: are female casualties different from their male counterparts? This does not address female and male Soldiers or other service members pre-injury, but rather questions if their injuries were sustained and/or treated differently in any way. Previous information presented on female mortalities in the US military indicated that the casualty death rate in women may be higher than that of men.[13] There are also earlier studies looking specifically at psychiatric illness, some of which suggested that women may be more likely to exhibit signs of psychiatric illness during deployment.[18-20] However, we were not able to find any studies directly addressing questions involving comparisons of cause and severity of physical trauma between the sexes.

This study had several limitations. First, we were able to identify only basic information about the service members and their injuries with descriptors of general injury characteristics such as blunt versus penetrating, but not identify specific injury patterns such as type or number of fractures. Therefore we do not know what elements

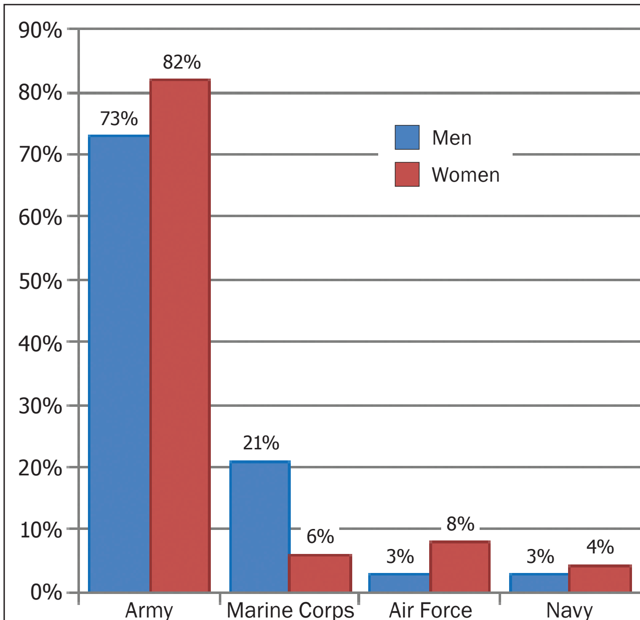

Figure 1. Distribution by gender of all casualties examined in the study across the military services.

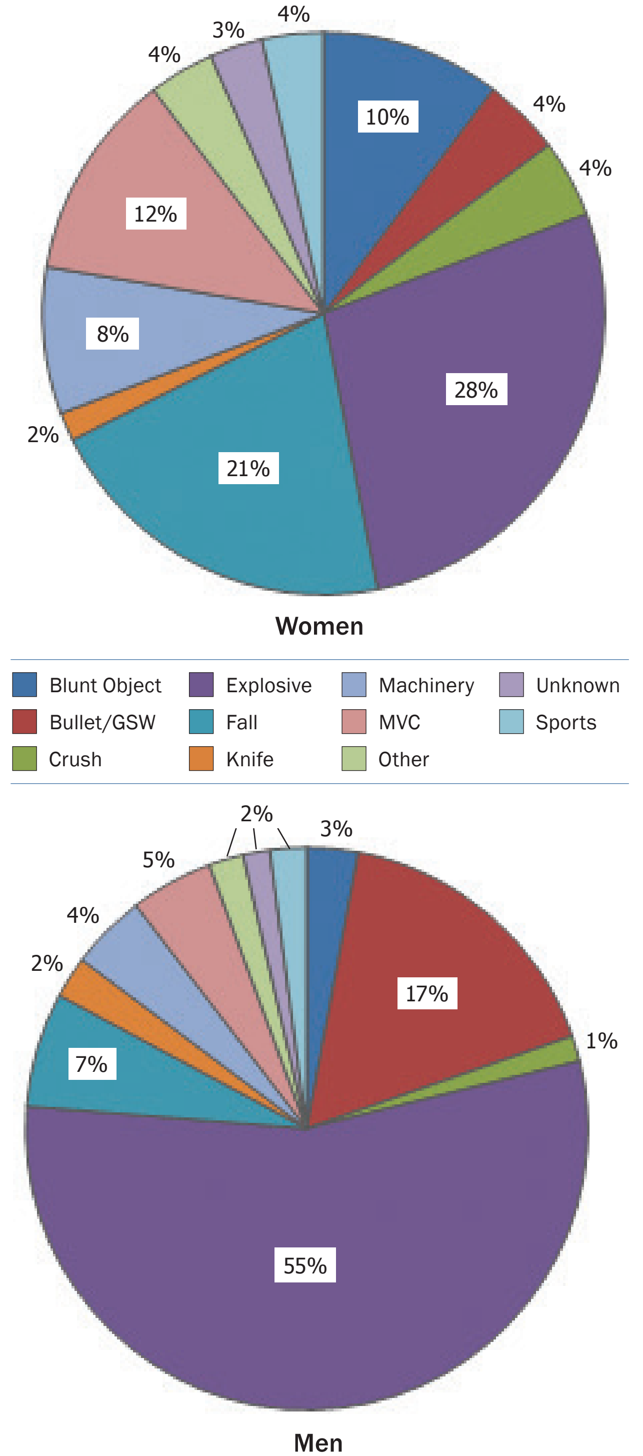

Figure 2. Distribution of the most common causes of injury to male and female servicemembers respectively. GSW indicates gunshot wound; MVC, motor vehicle collision.

contributed to the final ISS assigned each casualty. Second, the significant difference in sample size (by a factor of 100) between our 2 cohorts makes a subtype analysis of specific causes of injury less reliable. As demonstrated above, a comparison of mean ISS between the sexes in battle and nonbattle injuries individually reveals no statistical difference between the sexes. However, because of the number of males injured in battle, the mean ISS as a whole does show statistical significance. Third, the study is not inclusive of all casualties but rather focused on musculoskeletal trauma. Many of the subjects in the database had other injuries as well (abdominal, facial, etc), but they were not included in the study if they did not have a musculoskeletal diagnosis. This limits the generalizability of our data to all casualties.

The percentage of casualties who are female in our study was 2.75%, which is consistent with previous papers that showed 2.4% of deaths and 1.9% of casualties were female.[9,13] One previous study showed the female case fatality rate for OEF to be higher than OIF, but this is not directly comparable to our investigation of total casualty comparison between the conflicts.

The difference shown in age with females being slightly younger may be due to the age range, in that there are fewer women past the age of 40 still within the military.[9,21] This may also explain the discrepancy in casualty percentage between the sexes in the Army versus Marine Corps, since the Marine Corps has the lowest percentage of women of any of the US military branches.[9,21,22] The fighting tactics used by the military in Iraq and Afghanistan are inherently different due to the nature of the battle and the terrain. As a result, it can be hypothesized that there were potentially more special forces troops in Afghanistan than Iraq. This could contribute to the difference seen in casualty rates between OIF and OEF since women were not allowed to be assigned to direct combat roles during the entire studied timeframe, including special forces and other specialized ground troops.

Regarding injury characteristics, there is no related previous study to which we can compare our results. The previous work on female mortalities showed high ISS scores for those who died (mean of 24.5), but there was no male cohort comparison in that study.[13] Cross et al did show that 39.5% of female casualties were injured in battle, which is consistent with the 33.1% of female injuries incurred in battle in our study.[13] When looking at the mean ISS between the sexes, there is a statistical difference with males showing higher ISS on a whole. However, when this is broken down into battle and nonbattle groups, there is no statistical difference in the mean between men and women. What appears to be more important is that both sexes show significantly higher mean ISS when they sustain battle related injury compared to nonbattle injury. The difference demonstrated comparing all females to all males is due to a higher percentage of males injured in battle related incidents.

Further research to investigate any differences is still needed. The same pool of data is being used to age-match males and females for a cohort study where more specific injury patterns can be compared between the sexes.

Conclusions

The statistical analysis comparing female to male US military casualties from the recent conflicts in Iraq and Afghanistan showed differences between the sexes in relation to both demographics (age and service) and injury characteristics (ISS, AIS, and MOI). Females comprised 2.75% of the DoDTR casualties during the studied timeframe and were less likely to be involved in explosions or during battle. Thus, this population has received little attention in the literature to date. Despite lower rates of battle-related and explosion-type injuries, female casualties sustained similar ISSs when broken down into battle and nonbattle means. The main difference found in ISS is not in comparing the sexes but comparing battle and nonbattle injuries. When our data is paired with previous evidence that the case fatality rate may be higher for females, it is apparent that additional investigation is required to further study the effect of battle and nonbattle injuries among our female casualty population.

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Creating and Sustaining a Military Women's Health Research Interest Group

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Abstract

In 2008, four doctorate military nurse scientists representing the triservices (Army, Navy, and Air Force) identified a common interest in the health and care of all women in the armed forces. For 7 years, the team's shared vision to improve servicewomen's health inspired them to commit to a rigorous schedule of planning, developing, and implementing an innovative program that has the capability of advancing scientific knowledge and influencing health policy and practice through research. The ultimate goal of the Military Women's Health Research Interest Group (MWHRIG) is to support military clinicians and leaders in making evidence-based practice and policy decisions. They developed a 4-pronged approach to cultivate the science of military women's healthcare: evaluate the existing evidence, develop a research agenda that addresses gaps in knowledge, facilitate the collaboration of multidisciplinary research, and build the bench of future researchers. The MWHRIG has been a resource to key leaders; its value has been validated by multiservice and multidisciplinary consultations. However, the journey to goal attainment has only been achieved by the enduring commitment of these MWHRIG leaders and their passion to ensure the health and wellbeing of the many women who serve in the United States military. This article describes their journey of dedication.

The number of women in the military has steadily increased since the Selective Service draft ended in 1973 and now comprises 15% of the active duty military population and 10% of the deployed population.[1] Congress mandated that, starting in January 2016, military women would be afforded the same opportunities for combat assignments as men. As a result, women could be serving in the most austere conditions. Women will compete with men for these once restricted combat assignments under the same physical and performance standards. In order to ensure the health and well-being of women as they progress in military roles and/or optimize their health in their current military roles, military health care professionals and leaders should consult current evidence-based knowledge on women's health issues and care. The research that is currently available is typically published in peer reviewed journals, yet is not readily accessible to military care providers and decision makers. The Military Women's Health Research Interest Group (MWHRIG) was founded to address the lack of a consolidated review.

In 2008, four officers (2 Army Nurse Corps, one Navy Nurse Corps, and one Air Force Nurse Corps) identified the need to compile all peer reviewed research publications on military women's health issues and care in the past decade to promote awareness in the professional military community. The initial goal of the MWHRIG was to identify and grade existing research and build a database with the results that could be searchable and accessible to military clinicians and leaders charged with making evidence-based decisions. To advance the science of military women's health, the next steps were to perform a systematic review of the published literature, examine utilization of the Military Healthcare System (MHS), and identify the gaps in knowledge. Finally, they strove to create a military women's health research agenda that would guide future research. Not only is it paramount that research be available, but it must also be highly relevant to guide decision-making as the Department of Defense (DoD) embarks on this significant demographic shift and force multiplier.

Establishing the Purpose of the MWHRIG

The MWHRIG founders first established the need for the systematic review and gap analysis efforts with a strong position paper. The MWHRIG foundational paper was entitled, "A Call to Action for Evidence-Based Military Women's Health Care: Developing a Women's Health Research Agenda that Addresses Sex and Gender in Health and Illness."[2] The article highlighted female gender-specific deployment and in-garrison health care disparities based on the Armed Forces Health Surveillance Center's *Medical Surveillance Monthly Reports* from 2007-2009. These reports identified health effects related to deployment to Operation Iraqi Freedom and Operation Enduring Freedom, as well as utilization trends by female service members within the MHS. The article emphasized the dearth of scientific-based information relevant to military women's occupational risks, training requirements, and gender-specific health promotion programs. It was concluded that this absence of information could contribute to the lack of essential preventive medicine and interventions to improve the health, safety, and performance of military women. The authors postulated that there may be a requirement for changes in policies that reflect gender specific health care needs of women, particularly as they move into expanded military roles. The article described the need for a concerted effort to synthesize the literature on women's health care needs and thus designated the genesis of the MWHRIG. The role of the MWHRIG in conducting a comprehensive identification of gaps in knowledge about military women's health issues and the subsequent development of research priorities were described. The ultimate goal was to identify gaps in the literature to inform future research and policy changes.

While the primary objectives of the MWHRIG were to systematically conduct an extensive literature review and evaluate published articles related to military women's health, they also endeavored to create an online searchable database of the reviewed literature. A centralized online repository will be vital in supporting military women's health needs through evidence-based practice and policies. This database will assist scientists with research proposal development and funding efforts by providing a search for the state of the science on any given women's health topic relevant to service women.

Building the Team

Realizing that implementing a systematic review of a decade's worth of literature that is relevant to the health of women in all of the military services would require support, the MWHRIG reached out to the Veterans Administration (VA) Greater Los Angeles Health Services Research and Development (HSR&D) Center of Excellence Agenda Planning Group for guidance in the systematic review process. In 2006, the VA Greater Los Angeles HSR&D Center of Excellence had conducted a systematic review and developed an online database for veteran women's health research that the MWHRIG felt was appropriate to replicate. Since the MWHRIG envisioned an analysis with goals comparable to the VA Women's Health Research Agenda,[3] they contacted the VA's Agenda Planning Group for guidance in the systematic review process. Besides the expertise in the review process, the MWHRIG hoped to foster collaboration with the VA HSR&D that would enhance the possibility for combined efforts in the future. With the initial guidance from the VA women's health research agenda leaders, the MWHRIG adopted a similar 4-step approach to conducting the review of the literature and gap analysis.

In addition to developing a research agenda, the MWHRIG initiated simultaneous efforts to create a community of scientists dedicated to advancing military women's health through research. They enacted 2 avenues of approach to cultivate the science of military women's healthcare: facilitate the collaboration of multidisciplinary research, and build the bench of future scientists. With the original four military nurse scientists identified as MWHRIG Core Leaders, the MWHRIG built a team by recruiting the most experienced research scientists in the United States who conducted and published research studies about U.S. military women's health. With volunteer members from every military service, as well as the VA, and academia, the MWHRIG developed a base of 64 Subject Matter Experts (SMEs) whom they could employ in the conduct of the systematic review of literature.

Supporting Agencies

In the fall of 2008, the MWHRIG Core Leaders met with representatives from the Triservice Nursing Research Program (TSNRP),* a component of the Office of Research at the Uniformed Services University of the Health Sciences in Bethesda, Maryland, to discuss the group's purpose and planned goal attainment. The goals of the MWHRIG meshed seamlessly with the mission and strategic goals of the TSNRP, which are to facilitate nursing research, optimize the health of military members, expand the cadre of military researchers, build an infrastructure to support nursing research, and foster collaborative research. It was at this meeting that the MWHRIG's vision for cataloging and grading research to identify gaps in military women's health and facilitate future research became a possibility. In order to substantiate their efforts, the MWHRIG created a charter and developed a timeline for achieving milestones. A year later, TSNRP agreed to sponsor the group in its ambitious endeavor and the TSNRP Resource Center Program Manager joined the team. The TSNRP Resource Center assisted the MWHRIG by lending infrastructure to support and sustain the efforts of the MWHRIG, technology to support strategic communication of research interest group members, and the coordination for the development of partnerships with academic and other research institutions.

As the core leaders initiated the first phase of the systematic review—gather and catalog all peer reviewed literature on military women's health research from 2000-2010—they requested assistance from several talented Army, Navy and Air Force medical librarians. Given the volume and workload this generated, TSNRP recognized the group's need for the technical support of a research group program coordinator. As a result, TSNRP utilized the Henry M. Jackson Foundation to hire a

*http://www.usuhs.mil/tsnrp/AboutTSNRP/WhoWeAre/mission.php master's prepared civilian nurse with extensive research experience as the program coordinator. In addition to the program coordinator provision, TSNRP financially supported the MWHRIG core leaders to attend research courses and conferences, telecommunications, interactive video conference lines for frequent virtual meetings, licenses for technical tools for work flow support, and logistical costs for dissemination of key MWHRIG products.

The team reached out to their partners for guidance on the database development. The Research Programming Department at RAND Corporation had assisted the VA Women's Health Research Agenda Planning Group with their data collection for the systematic review. According to a senior research programmer analyst at RAND (E. Roth, oral communication, November 2, 2010), they used web-based systematic review program designed specifically for the screening and data extraction phases of a systematic review when collecting their VA women's health research article reviews. The MWHRIG program coordinator developed a comprehensive cost-benefit analysis for TSNRP and the MWHRIG proposed acquisition of the program. This critical component of the systematic review process was funded by TSNRP. The online data management tool allowed the core leaders and SMEs to access the uploaded full text article and input their review and grade determination. Instead of cataloging individually scanned review documents, which presented a data management nightmare for the program coordinator, the on-line system served as a real-time repository to input the systematic reviews. The on-line system allowed the team to export the evaluations to set the foundation for a searchable database.

Creating a searchable database for military researchers and leaders to query specific topics required information technology (IT) experts. With an introduction and coordination through the TSNRP Resource Center, the Uniformed Services University of the Health Sciences (USUHS) IT department provided the needed technical support to develop the website repository. Permission to use the coding behind the VA's systematic review database was granted (P. Shekelle, oral communication, June 7, 2013). Meeting with the research interest group program coordinator, the USUHS IT developers created an interface adapted from the VA's online interface coding. The Military Women's Health Research Literature database was created from work group systematic review data collection spreadsheets and served as the backbone for importing the data from the systematic review software. This program was created so that the MWHRIG database would mirror the VA Women's Health literature database making future collaboration possible.

Accomplishments of the MWHRIG

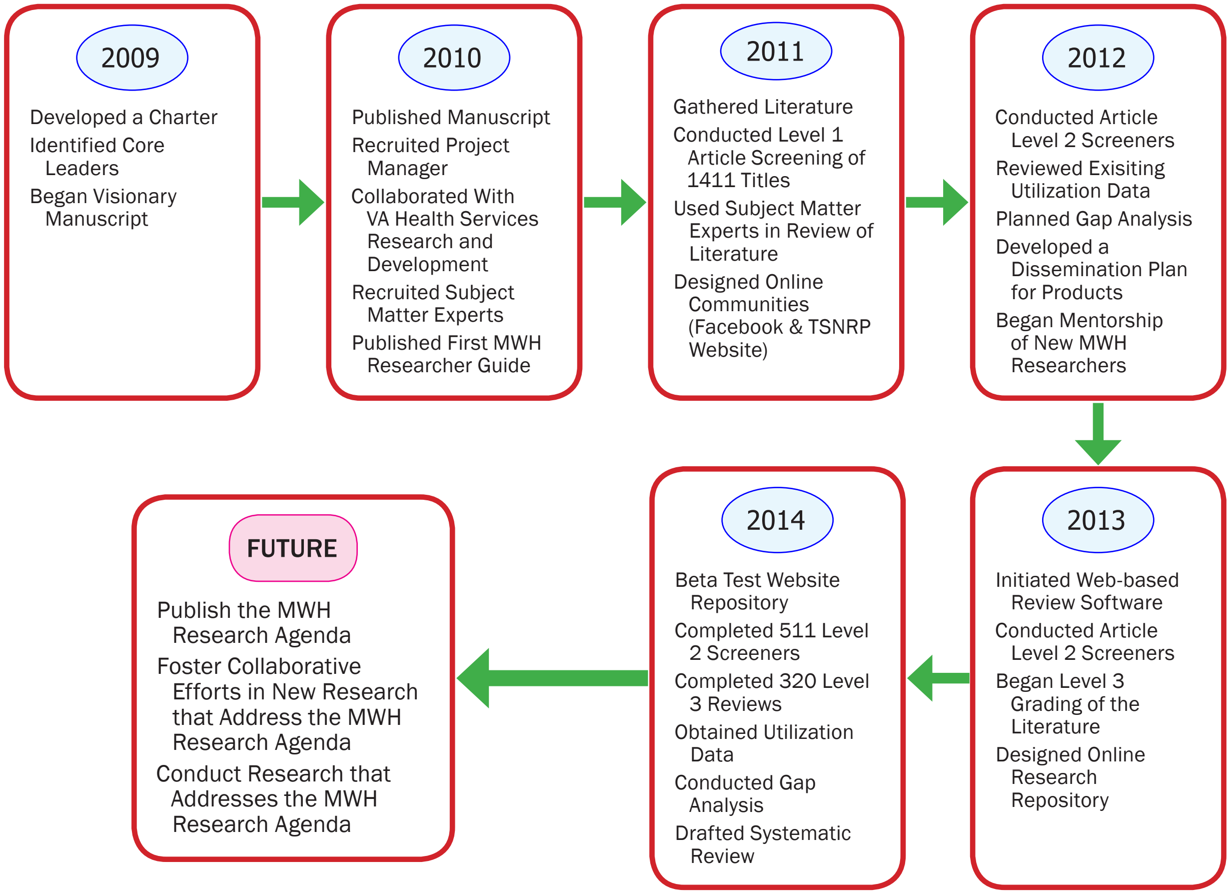
The Systematic Review

With the development of multiple synergistic relationships, the MWHRIG was able to accomplish 16 milestones as shown in the Figure. The most prominent product is the systematic review. A 3-level screening process was used to evaluate a decade's worth of scientific literature on military women's health issues. Article searches were completed using predetermined title search criteria for Level 1, abstract approval criteria for Level 2, and grading and analysis criteria for Level 3. Articles advanced to Level 3 review if all four of the core leaders agreed the article fit the project inclusion criteria based on the predetermined criteria used for the Level 2 screening. The MWHRIG garnered the support of the SMEs from the military, academic, and civilian research communities to grade the level of evidence and quality of the research studies. Both a core leader and a SME reviewed and graded each article. Finally, the same core leader established congruency between the 2 reviews and research quality grades. Once completed, these data were ready for upload into the searchable database, ultimately depicted as an article summary with a complete citation on the website. Following the completion of the database, the MWHRIG was able to draw the evidence tables from the systematic review program and produce the systematic review summary.

Encouraging Collaboration in Military Women's Health

In order to boost collaboration, the MWHRIG engaged in a multimedia approach to develop a community of research scientists with a common desire to improve military women's health and healthcare. First, the MWHRIG created a handbook, *Military Women's Health Researchers Guide*, now in its 6th version, which lists all of the MWHRIG members and SMEs, including their abbreviated curriculum vitae and publications as relevant to military women's health research. The guide serves to connect multidisciplinary research scientists with similar interests or subject matter expertise in collaborative efforts to develop and conduct research. The TSNRP Resource Center funded production of hard copies of the guide, as well as various marketing products, such as business and information cards for dissemination at conferences and scientific meetings. Second, in order to promote the connections among those interested in advancing evidence-based women's health care, the MWHRIG then created a Facebook page* where current events, publications, and news about military women's health are posted. The Facebook page fosters connections among both seasoned and aspiring researchers, links appropriate SMEs for areas of research interest,

*https://www.facebook.com/pages/Military-Womens-Health-Research-Interest-Group/117532448302481



Timeline of Progress for the Military Women's Health Research Interest Group

and provides the contact information to requesting an electronic version of the guide. Finally, in support of the MWHRIG, TSNRP developed a webpage for research interests groups, and, based on the success of the MWHRIG, inaugurated 3 more research interest group webpages (behavioral health, en route care, and anesthesia).

With support from the TSNRP through the Henry M. Jackson Foundation, MWHRIG members have presented or participated in various research, development, and collaborative forums, such as the VA Women's Health Services Research Conference, the Department of Defense Panel at the National Training Summit on Women Veterans, the Women in the Military Service for America, the Association of Military Surgeons of the United States Annual Meetings, the first Women in Combat Symposium, and multiple national women's health conferences. The MWHRIG has contributed valuable evidence on military women's health issues to guide the initiatives of the US Army Office of The Surgeon General's Women's Health Task Force and the Office of the Assistant Secretary of Defense for Health Affairs Women's Health Issues Working Group. The MWHRIG has been a resource to key proponents for the advancement of military women's health. It has been consulted by the US Government Accountability Office[4,5] on 2 reports on the health of servicewomen and by the Defense Department Advisory Committee on Women in the Services for their 2012 report[6] and recommendations on the health of deployed servicewomen.

Strength Through the Team Characteristics

In addition to the research experience of this team, over time we determined a key strength of the MWHRIG leadership is their firsthand experiences while serving on active duty. They are personally familiar with the triumphs and struggles military women face throughout the course of a military career which included many psychosocial adaptations to multiple duty station relocations, personal illnesses, illnesses of family members, births, deaths, loss of friendships and support systems, promotions with added responsibilities, the threat of war, adaptation to field assignments, geographical separations from family, and the eventual transition into the VA system upon retirement. The 4 nurse scientists are also licensed independent providers, one midwife and 3 nurse practitioners. The fact that these researchers are also clinicians helps them critique the science and its potential contribution to women's healthcare. Over the course of five years, the four core leaders experienced a total of 12 permanent changes of station (PCS) moves of which five were outside of the continental United States (OCONUS), 5 in-theater deployments to austere settings, and numerous temporary duty assignments. The multiple international assignments of group members led to scheduling challenges due to multiple time zones with up to a 14-hour time difference. Many meetings were conducted after or before the duty day in order to accommodate all members. Our TSNRP sponsored program coordinator was critical in the success of the project. She kept scheduled weekly conference lines, created meeting agendas, provided review updates, and emailed reminders to complete pending tasks.

Future of the MWHRIG

As of the time of this publication, goals for the immediate future are anticipated to be complete, including the completion and publication of the systematic review of the military women's health research from 2000 through 2010, as well as the debut of the online database. A follow-up review of literature published from 2011 through 2014 is already under way. Long term goals include obtaining support for the maintenance of the article repository and allocating responsibility as an enduring requirement to ensure that the evidence base on military women's health issues continues to be expanded. Marketing strategies are required for the multidisciplinary and triservice use of these valuable resources, as well as continued literature input and subject matter expertise. We hope the Facebook community will continue to grow strong and be the meeting place for innovative research as inspired by the military women's health research agenda.

Summary

The creation and sustainment of this team has been made possible by the vision and drive of 4 military nurse scientists who felt passionately about the advancement of women's health for the support of the inclusion of women in combat roles. The products this team has generated and continue to develop will be a sound resource to inform lawmakers and military leaders about the research gaps that must be identified and explored to fully support women as they forge new paths within the DoD. The MWHRIG will continue to be valuable resource to the triservice research community and military leaders.

Acknowledgement

The authors thank the TriService Nursing Research Program for its support of the Military Women's Health Research Interest Group. This work would not have been possible without the financial and administrative support provided by the Program.

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Complex d-TGA Status Post Rastelli Repair Presenting with Palpitations: Cardiac CTA Imaging Findings and Discussion of Long-Term Outcomes

Capt Ross Pinson, MC, USAF
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History

A man 19 years of age with a history of complex dextro-transposition of the great arteries (d-TGA) repaired during infancy presented with intermittent palpitations at rest. He denied orthopnea, edema, paroxysmal nocturnal dyspnea, and exertional chest pain.

His cardiac history is significant for d-TGA with a ventricular septal defect (VSD) and sub-valvular and valvular pulmonary stenosis palliated with a balloon septostomy on day of life zero and right modified Blalock-Taussig shunt at 10 days of age followed by a completion Rastelli repair at 10 months of age with VSD patch and placement of a right ventricle to pulmonary artery conduit. His postoperative course was complicated by left ventricular outflow tract obstruction secondary to restriction at the VSD and intermittent high-grade AV block, for which he had a pacemaker implanted. The pacemaker was subsequently removed at 4 years of age after resumption of normal sinus rhythm, however, he has retained epicardial leads. He has subsequently required multiple revisions of the pulmonary outflow shunt and pulmonary arteries, the last of which was performed at 14 years of age. Otherwise, he had been stable without symptoms for the past 5 years. His physical exam was significant for a grade III/VI harsh, crescendo-decrescendo systolic murmur at the left and right upper sternal borders and a widely split S2 with a prominent P2 component. Jugular venous distention, edema, heaves, and extra heart sounds were all absent. Electrocardiogram showed normal sinus rhythm with a right bundle branch block.

Echocardiography and cardiac computed tomography angiography were ordered to evaluate patency of his cardiovascular structures, given his history of congenital heart disease, prior pulmonary artery stenosis requiring arterioplasty, retained epicardial lead, and the symptoms described.

Imaging Findings

Figure 1 presents the volume rendered cardiac CT angiography image oriented in the left anterior oblique, cranial projection demonstrating the Rastelli conduit (open arrow) arising from the right ventricular (RV) free wall and anastomosing at the main pulmonary artery (not visualized). The left anterior descending (LAD) coronary artery (solid arrow) arises from the aorta (Ao) and courses in the anterior interventricular groove between the RV and left ventricle (LV). The lack of a branch vessel from the Ao origin coursing in the atrioventricular groove suggests an anomalous course of the left circumflex coronary artery. Figure 2 is a multiplanar reformat which demonstrates a repaired ventricular septal defect (arrow). The course of the Rastelli graft (1) immediately deep to the sternum is appreciated and the anastomosis with the main pulmonary artery is well visualized. The atrophic right pulmonary artery (∗) is also seen coursing superior to the aortic root. Additionally, a mildly obstructive left ventricular outflow tract (LVOT) is shown (2) with good appreciation of the misalignment of the aorta with respect to the LVOT. Figure 3 is an axial image which shows the bifurcation of the main pulmonary artery (1). The size disparity between the normal left pulmonary artery (2), measuring 17 mm, and the atrophied right pulmonary artery (∗), measuring 9 mm, is better appreciated. The left-sided aortic course (3) is appreciated, which is secondary to the leftward origin of the ascending aorta compared with normal anatomy.

Figures 4 and 5 depict apical 3- and 5-chamber views showing turbulence across the LVOT beginning below the aortic valve (in the baffle between VSD and aorta). Figure 6 is a high-parasternal-short-axis view showing turbulence in the RV-PA conduit. Conduits such as these are often difficult to visualize by echocardiography due to anatomical position, body habitus, or surgical scarring.

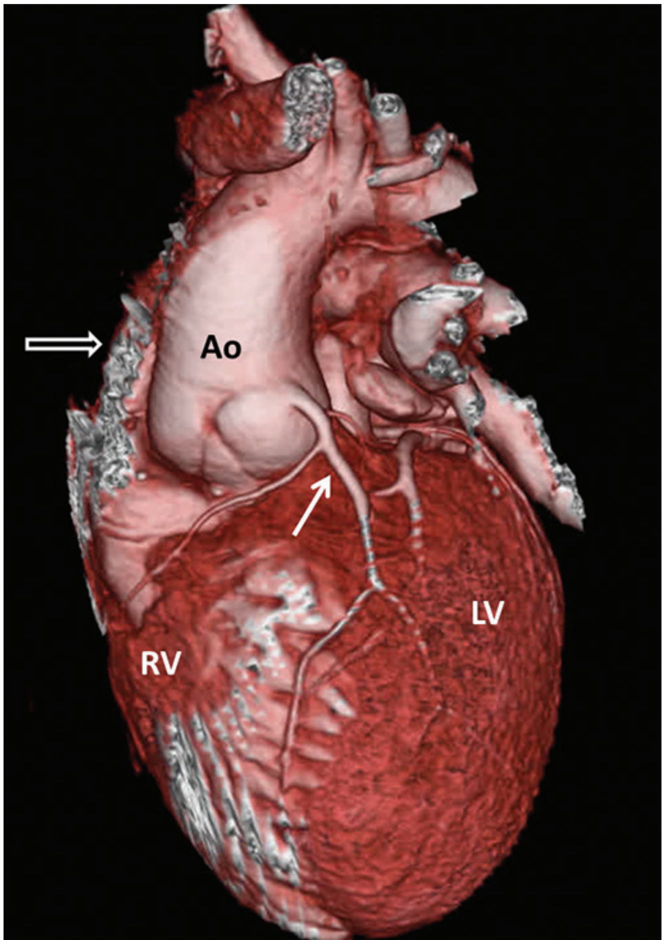

Figure 1. Volume rendered image oriented in the left anterior oblique, cranial projection demonstrating the Rastelli conduit (open arrow) arising from the right ventricular (RV) free wall and anastomosing at the main pulmonary artery (not visualized). The left anterior descending coronary artery (solid arrow) arises from the aorta (Ao) and courses in the anterior interventricular groove between the RV and left ventricle (LV).

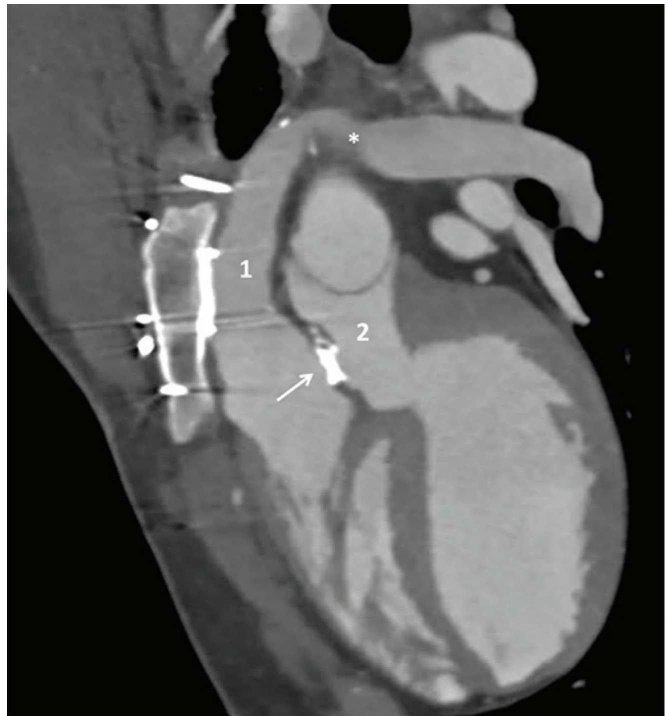

Figure 2. Multiplanar reformat demonstrating a repaired ventricular septal defect (arrow), the Rastelli graft (1) immediately deep to the sternum, and the anastomosis with the main pulmonary artery is well visualized. The atrophic right pulmonary artery (*) is also seen coursing superior to the aortic root and a mildly obstructive left ventricular outflow tract (LVOT) is shown (2) with evidence of aortic root misalignment with respect to the LVOT.

Comment

Transposition of the great arteries (TGA) is an uncommon congenital heart disease with a reported incidence of 2.3/10,000 births.[1] D-transposition (d-TGA) is a cyanotic lesion characterized by inappropriate ventriculo-arterial connections leading to parallel pulmonary and systemic circulations that is best surgically corrected very early in life.

Patients with d-TGA are dependent upon intracardiac blood mixing for survival, usually through an atrial septal defect, VSD, or patent ductus arteriosus.[2] Early, frequently severe, cyanosis is a common presenting sign, however, if there is adequate mixing, visible cyanosis maybe under recognized and the patient may present with signs of heart failure due to pulmonary over circulation within a few weeks of life.

Palliative procedures are often initially performed, including the Rashkind catheter-directed balloon septostomy and the modified Blalock-Taussig shunt (if there is inadequate pulmonary blood flow in the setting of pulmonary outflow tract obstruction). The Rashkind procedure attempts to increase intracardiac blood mixing through balloon dilation of an atrial septal defect.[3] The modified Blalock-Taussig shunt is a systemic-to-pulmonary artery shunt that uses a PTFE interposition graft between the innominate artery and the right branch pulmonary artery (with left aortic arch) to palliate until definitive correction can be achieved.[4]

Atrial switch operations, the Senning and Mustard procedures, were developed around 1960 and became the standard operative correction. These procedures created an intracardiac baffle to direct deoxygenated blood from the right atrium to the left ventricle for oxygenation via the pulmonary circulation. Then oxygenated pulmonary venous return is directed through the tricuspid valve for distribution via the right ventricle to the systemic circulation. Several long-term complications were seen with these operations, including sinus node dysfunction, arrhythmias, tricuspid regurgitation, and right ventricular failure.[5] An arterial switch procedure, developed by Jatene in 1975, offered a more definitive method of correction by transection and translocation of the great vessels, translocation of the coronary arteries, and establishment of "normal" ventriculoarterial connections.[6]

About 13% of d-TGA is complicated by the presence of pulmonary outflow tract obstruction. The Rastelli operation was developed in patients with complex d-TGA and concomitant pulmonic outflow tract obstruction and a large VSD. This procedure allows the left ventricle to develop as the systemic ventricle, patches the VSD to direct blood flow from LV through the aorta, closes the congenitally stenotic pulmonic valve, and uses a grafted conduit between the right ventricle and pulmonary artery to direct blood to the lungs for oxygenation.[7]

Regardless of the type of surgical correction, all patients should have annual clinical evaluation.[5] Postoperative imaging evaluation of complex d-TGA cases involves assessment of the pulmonic and systemic outflow tracts, branch pulmonary arteries, conduit (if present) and coronary arteries (if they were involved in the procedure).[8,9] Imaging by echocardiogram can be obtained as needed for anatomic and hemodynamic assessment.[5] Echocardiography can have limitations such as poor windows due to obesity or scarring and lack of definition of

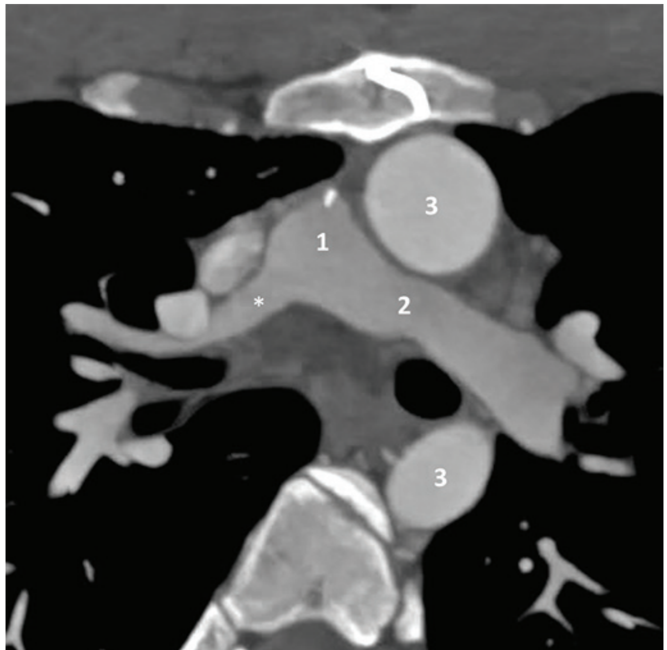

Figure 3. Axial image showing the bifurcation of the main pulmonary artery (1). The size disparity between the normal left pulmonary artery (2), measuring 17 mm, and the atrophied right pulmonary artery (∗), measuring 9 mm, is better appreciated. The left-sided aortic course (3) is appreciated, which is secondary to the leftward origin of the ascending aorta compared with normal anatomy.

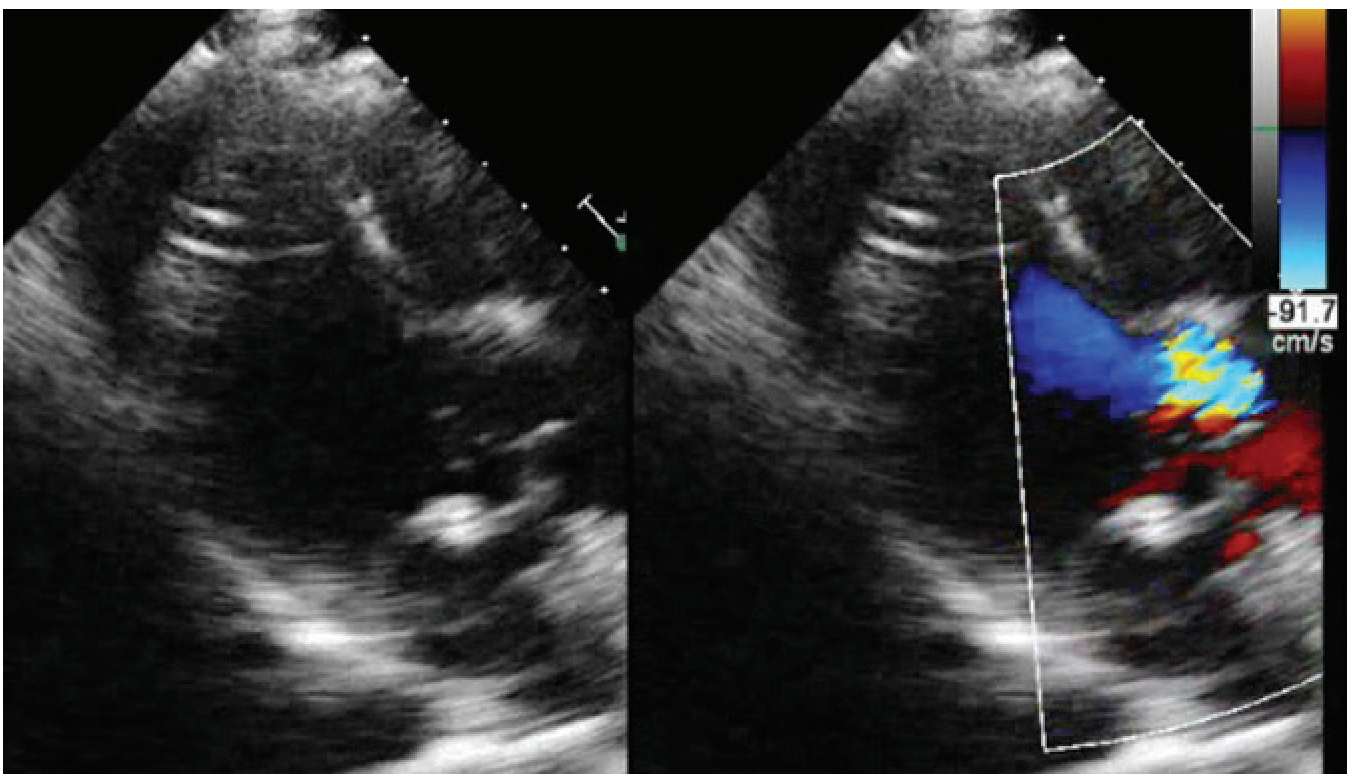

Figure 4. Apical 3- and 5-chamber views showing turbulence across the LVOT beginning below the aortic valve (in the baffle between VSD and aorta).

thoracic great vessels. Although cardiac magnetic resonance imaging (MRI) improves upon these limitations, it may be contraindicated in patients with pacemakers or significant amounts of retained metal. Patients who need further imaging in addition to echocardiography, and have contraindications to MRI can be evaluated using cardiac computed tomography angiography.[8,9]

Given the rarity of these complex lesions and the relatively recent development of new procedures and their variations such as the Nahkaido and Réparation à l'Etage Ventriculaire procedures, data on long-term outcomes of Rastelli repair for complex d-TGA is still being compiled. Studies suggest that earlier corrective surgery is associated with reduced morbidity and mortality.[10] According to Brown et al who followed 40 patients with complex d-TGA corrected with the Rastelli operation from 1988 to 2008, freedom from death or cardiac transplant was 90% at 20 years postoperation.[11] Horer et al published data on 39 patients with complex d-TGA treated with Rastelli operation from 1977-2004. Their data showed freedom from death or transplantation at 20 years was 57.5%±15.1%.[12] Between 41% and 78% of patients with Rastelli repair will require reoperation for conduit replacement with stenosis and right ventricular outflow tract obstruction being the most common justification for replacement.[11,12] A permanent pacemaker was implanted for complete AV block or sick sinus syndrome in 14% to 25% of patients by 20 years postoperation.[11,12] Right bundle branch block at 20 years was seen in 64% to 77.5% of patients.[11,12] The vast majority (96% to 97%) of patients were NYHA Class I or II at final follow-up with 3% experiencing Class III symptoms.[11-13] Other long-term issues encountered by patients status-post arterial switch operation are reduced exercise tolerance (85% of predicted), aortic regurgitation (21%), and reduced systemic ventricular function (7%).[14]

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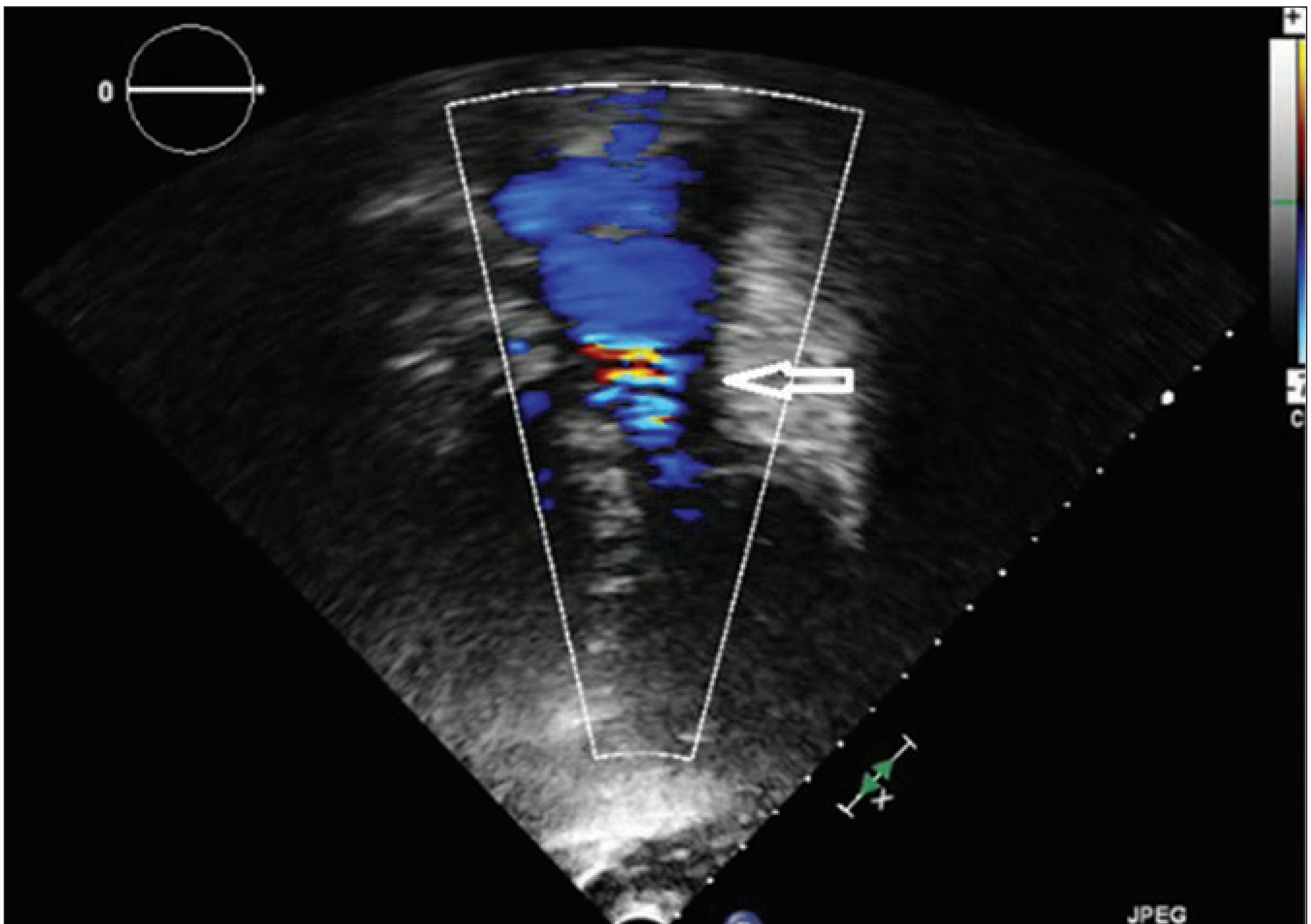

Figure 5. Apical 3- and 5-chamber views showing turbulence across the LVOT beginning below the aortic valve (in the baffle between VSD and aorta).

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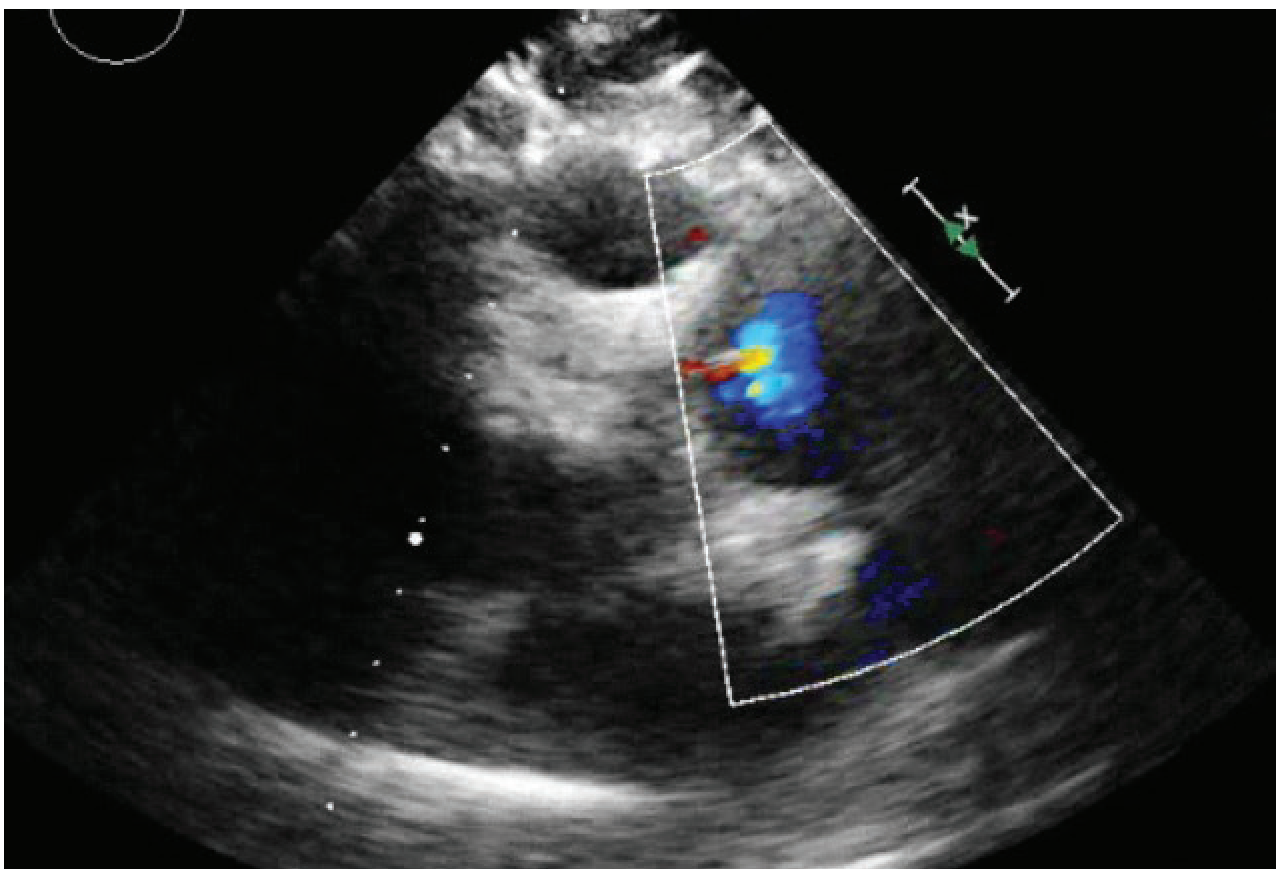

Figure 6. High-parasternal-short-axis view showing turbulence in the RV-PA conduit. Conduits such as these are often difficult to visualize by echocardiography due to anatomical position, body habitus, or surgical scarring.

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A New Offering from the Borden Institute History Series

US Army Psychiatry in the Vietnam War

Norman M. Camp, MD

COL (Ret) US Army Medical Corps

LTC Daniel E. Banks, USA
COL (Ret) Hershell L. Moody, USA

Borden Institute's latest publication was authored by Norman Camp, a retired Army psychiatrist who led a psychiatric unit during the war in Vietnam. The result is a story that is both scholarly and intensely personal, reflecting Dr Camp's keen interest in presenting the big picture of this after action review, yet also filled with anecdotes and case histories that illustrate his perspectives and opinions, as well as the points of view of many of his professional colleagues who served in the conflict. The cover is dramatic, the presentation is first class, and the pages are replete with illustrations and correspondence from the Vietnam era. The story is presented in a fresh way—from a psychiatrist's point of view—although it is now nearly 50 years since the war was fought.

The American ground war in Vietnam lasted from 1965 to 1973. Just as the current Army has evolved in response to social issues over the past decade, the Army of the 1960s and 1970s reflected ongoing changes in the culture of the time. This was a time of upheaval—worsening racial tensions, widespread use of illicit drugs, and, of course, the antiwar movement—all coinciding in ways that posed threats to our social institutions, including the US Army. At home, the many aspects of this cultural change provoked intense media scrutiny and political controversy. Although Army morale remained high for the first few years, as the war dragged on and the Army became increasingly draftee dependent, these tensions strongly influenced those serving in Vietnam. The effects were manifest as a growing inability or unwillingness to accept the risks of combat or to acknowledge military authority, and lessening tolerance for the hardships of an assignment in Vietnam. Matters became substantially worse in 1970 when a heroin epidemic spread quickly among the lower ranks, an unprecedented problem that seriously undermined Soldier health, morale, and military preparedness. The cost of a small package of heroin in Vietnam, which in American had a street value of hundreds of dollars, was less than the cost of a package of cigarettes.

Dr Camp has set the stage for his discussion by describing the dramatic political and military events of 1968, the de facto turning point in the war; the pre-Tet years of 1963 to 1967 which encompassed the conflict's buildup under Lyndon Johnson; and the 1969 to 1973 post-Tet years during which Richard Nixon directed the withdrawal from combat. The war's bloodiest year was 1968, with more than 16,000 American casualties. On January 31, 1968, Viet Cong guerillas and North Vietnamese army elements broke the Tet (Lunar New Year) truce, launching coordinated attacks on cities and towns throughout South Vietnam. The attacks were followed by the month-long effort by US forces to retake Hue, a historic city on the border with North Vietnam, as well as American resistance during a prolonged siege of the US Marine combat base at Khe Sahn. In the month of May alone, more than 2,000 Americans were killed across South Vietnam. Although there were few tactical gains for the communist forces, the political gains were substantial. According to some, US media reports of these events as defeats for US forces led to the loss of political and popular support for the war, and the call for an end to the fighting became louder and clearer. Lyndon Johnson had proposed the end of aerial bombing and the start of peace negotiations in March 1968, and Americans began pulling out of Vietnam in mid-1969. The recognition that there could be no US victory in the conflict caused a powerful negative reaction, in both the country and the Army. The troops' commitment in the build-up years evolved into worsening morale, apathy, destructive behavior, and a breakdown in discipline.

Among many aspects of the war that placed the mental health of American service members at risk in Vietnam were the following:

- The opposition Vietnamese forces included the North Vietnamese army, who staged relatively conventional attacks, and the Viet Cong, who were most active and fought a guerilla/counterinsurgency war built on terrorizing citizens living in the villages of South Vietnam. Many South Vietnamese were too intimidated by the Viet Cong to become American allies. The enemy was elusive but often unable to deliver sustained direct fire. American Soldiers located in forward bases ventured "outside of the wire" to engage the enemy in search-and-destroy missions. There was no way to control territory. The war had evolved into a protracted, bloody, mainly guerrilla conflict, and the American fight became a war of attrition measured in "body counts" and "kill ratios."
- In the United States, Americans had become increasingly divided. The rising civil rights and black power movements, the emerging youth counterculture (illustrated by the protests at the Democratic National Convention in 1968), and an American public that increasingly showed dissatisfaction with the war were met "head on" by conservative members of the population who opposed these ideas. The members of the US military were caught in the middle.
- Instead of deploying as a unit as the Army does today, individuals deployed in fixed, individual, one-year assignments. The result was a constant shuffle of Soldiers in and out of theater and in and out of units, making it more difficult for Soldiers to bond and serve as a team. Furthermore, officers would often lead for shorter time periods, typically 3 to 6 months. These rotations were intended to give each officer a taste of command, but the policy actually resulted in diminished leadership continuity and unit cohesiveness.
- The previsouly mentioned decision to begin peace talks while the battle raged sent mixed messages to those in the fight. No matter how intensely Soldiers embraced the mission, there was to be no victory, only a brokered peace agreement. The result was a dramatic loss of morale. Soldiers clearly and openly expressed concerns regarding the reason for the fight when there could be no victory. Perhaps this was best exemplified by the abbreviated message sent by the "UUUU" graffiti throughout the war zone: "We are the Unwilling, led by the Unqualified, doing the Unnecessary, for the Ungrateful."
- Changes in American culture also affected psychiatrists and the care they provided. Over the course of the war, approximately one-third of the Army psychiatrists deployed to Vietnam were military trained, while two-thirds were civilian trained. The great majority were recent graduates of psychiatry training programs, with relatively little military experience. Perhaps this combination of psychiatrists with relatively little military background, coupled with the cultural changes that occurred in the Army as the war raged, led to the dramatic increase in rates for psychiatric out-of-country evacuation (1.9/1,000 Soldiers in 1965; 2.3/1,000 in 1968; 108/1,000 Soldiers in 1972).
- Vietnam veterans returned to an unwelcoming society. Much has been written about the many episodes of rejection by the American public of returning Soldiers. Yet the impact was even more insidious, affecting troops still in action as well. Psychiatrists practicing in Vietnam after 1968 recognized that the Soldiers still in the fight perceived blame from their countrymen back home, and this had an adverse effect on morale.

In one of the Borden Institute's strongest productions, the author has addressed a complicated subject and identified and discussed many of the tragic human and psychological aspects of the Vietnam conflict in a thoughtful manner. Dr Camp has taken the time to present cases of Soldiers with behavioral issues that show the situation these men faced, and how he and his colleagues attempted to make their lives better and remain true to Army values. This is a story about events that have been in the American military consciousness for more than a generation, with many of these ideas bubbling below the surface for years and only now being presented. We applaud Dr Camp and his fellow Vietnam War psychiatrists for addressing these issues and providing quality care to our fellow Soldiers.

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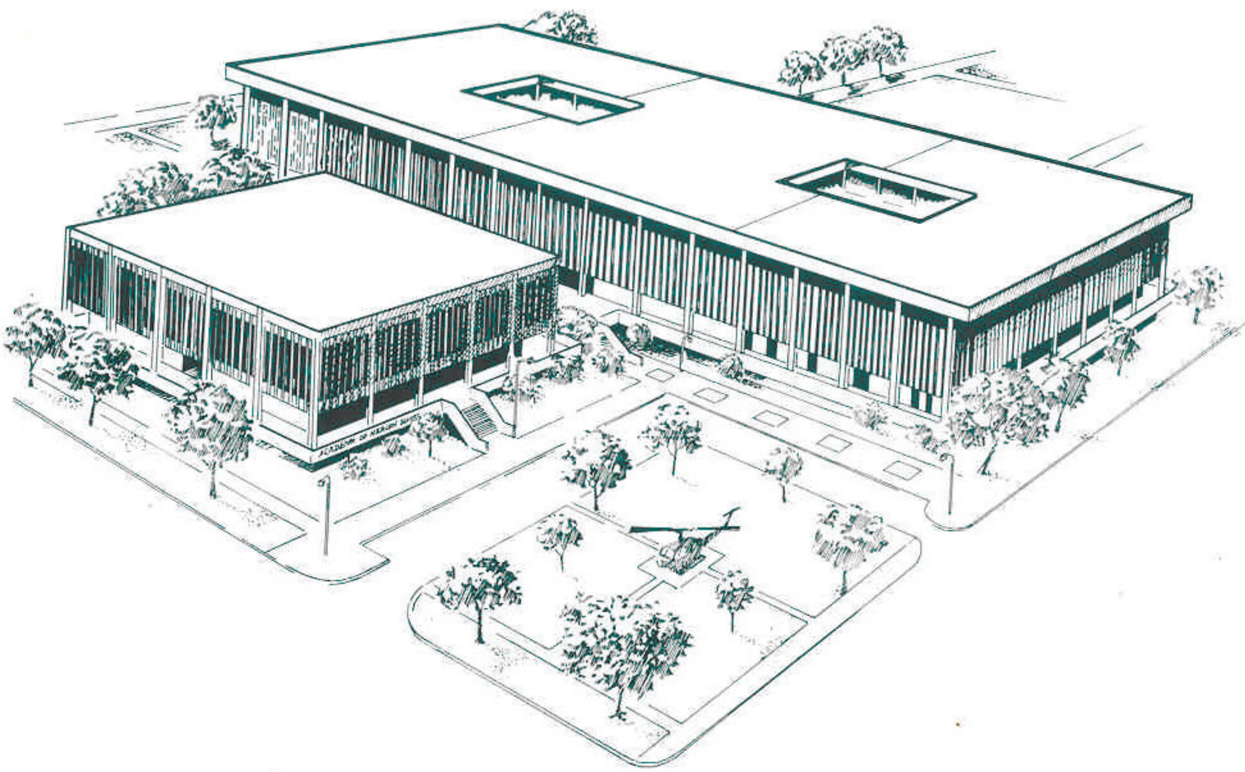
This book is available in PDF and will soon be available in iPad and Kindle formats for download on your electronic reader. The book can be ordered at no cost by those on active duty, in the National Guard, and in the Reserve by following the instructions on the Borden Institute website, http://www.cs.amedd.army.mil/borden/. It will soon be available for purchase from the US Government Printing Office.



The headquarters and primary instructional facility of the Army Medical Department Center and School, Joint Base San Antonio Fort Sam Houston, Texas.

Submission of Manuscripts to the *Army Medical Department Journal*

The *United States Army Medical Department Journal* is published quarterly to expand knowledge of domestic and international military medical issues and technological advances; promote collaborative partnerships among the Services, components, Corps, and specialties; convey clinical and health service support information; and provide a professional, high quality, peer reviewed print medium to encourage dialogue concerning health care issues and initiatives.

Review Policy

All manuscripts will be reviewed by the *AMEDD Journal*'s Editorial Review Board and, if required, forwarded to the appropriate subject matter expert for further review and assessment.

Identification of Potential Conflicts of Interest

1. **Related to individual authors' commitments:** Each author is responsible for the full disclosure of all financial and personal relationships that might bias the work or information presented in the manuscript. To prevent ambiguity, authors must state explicitly whether potential conflicts do or do not exist. Authors should do so in the manuscript on a conflict-of-interest notification section on the title page, providing additional detail, if necessary, in a cover letter that accompanies the manuscript.
2. **Assistance:** Authors should identify Individuals who provide writing or other assistance and disclose the funding source for this assistance, if any.
3. **Investigators:** Potential conflicts must be disclosed to study participants. Authors must clearly state whether they have done so in the manuscript.
4. **Related to project support:** Authors should describe the role of the study sponsor, if any, in study design; collection, analysis, and interpretation of data; writing the report; and the decision to submit the report for publication. If the supporting source had no such involvement, the authors should so state.

Protection of Human Subjects and Animals in Research

When reporting experiments on human subjects, authors must indicate whether the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. If doubt exists whether the research was conducted in accordance with the Helsinki Declaration, the authors must explain the rationale for their approach and demonstrate that the institutional review body explicitly approved the doubtful aspects of the study. When reporting experiments on animals, authors should indicate whether the institutional and national guide for the care and use of laboratory animals was followed.

Informed Consent

Identifying information, including names, initials, or hospital numbers, should not be published in written descriptions, photographs, or pedigrees unless the information is essential for scientific purposes and the patient (or parent or guardian) gives written informed consent for publication. Informed consent for this purpose requires that an identifiable patient be shown the manuscript to be published. Authors should disclose to these patients whether any potential identifiable material might be available via the Internet as well as in print after publication. Patient consent should be written and archived, either with the *Journal*, the authors, or both, as dictated by local regulations or laws.

Guidelines for Manuscript Submissions

1. Manuscripts may be submitted either via email (preferred) or by regular mail. Mail submissions should be in digital format (preferably an MS Word document on CD/DVD) with one printed copy of the manuscript. Ideally, a manuscript should be no longer than 24 double-spaced pages. However, exceptions will always be considered on a case-by-case basis.
2. The *American Medical Association Manual of Style* governs formatting in the preparation of text and references. All articles should conform to those guidelines as closely as possible. Abbreviations/acronyms should be limited as much as possible. Inclusion of a list of article acronyms and abbreviations can be very helpful in the review process and is strongly encouraged.
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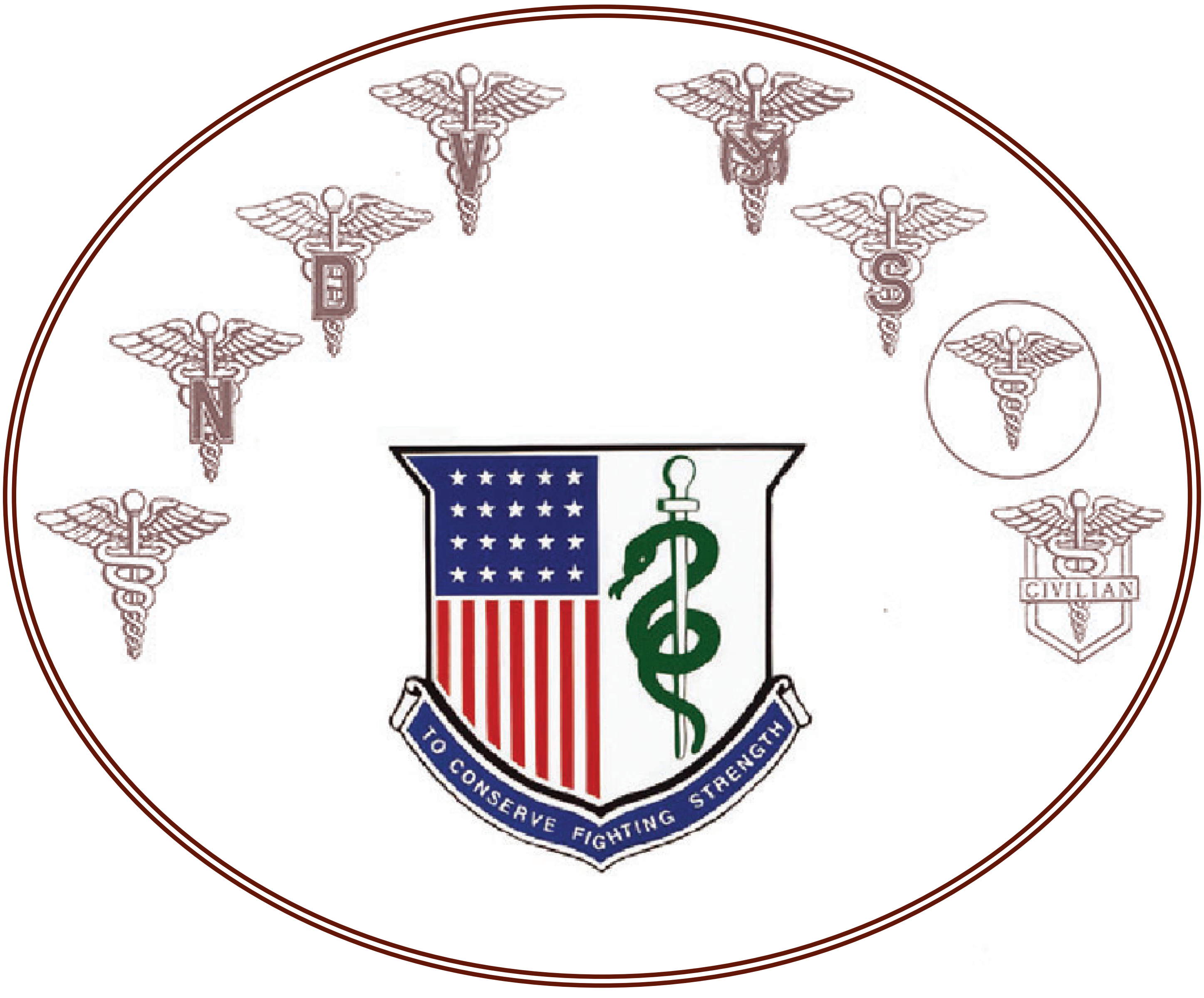

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