MILITARY MEDICINE, 189, S2:74, 2024

A Sex Comparison of the Physical and Physiological Demands of United States Marine Corps Recruit Training

Bridget A. McFadden, PhD[*,†]; *Harry P. Cintineo, PhD*[*,‡]; *Alexa J. Chandler, MS*[*]; *Gianna F. Mastrofini, MS*[*]; *Caroline S. Vincenty, MS*[*]; *Patrick Peterson, MA*[§]; *Mita Lovalekar, MBBS, PhD, MPH*[§]; *COL Bradley C. Nindl, MSC, USAR, PhD, FACSM*[§]; *Shawn M. Arent, PhD, FISSN, FACSM, FNAK*[*]

ABSTRACT

Introduction:

The U.S. Marine Corps (USMC) recruit training is a 13-week preparatory period for military service men and women. Differences in absolute performance capabilities between sexes may impact physical and physiological responses to the demands of recruit training. The purpose of this study was to monitor U.S. Marine Corps recruits throughout recruit training to comparatively assess workload, sleep, stress, and performance responses in men and women.

Materials and Methods:

A total of 281 recruits (men = 182 and women = 99; age = 19 ± 2 years) were monitored and tested. Workload, sleep, and stress assessments occurred at week 2, week 7/8, and week 11 of training. Workload (energy expenditure per kg body mass [EE_{REL}], distance [DIS], steps) and sleep (continuity and duration) were tracked over 72-hour periods using wearable accelerometry and heart rate technology. Stress responses were determined through salivary cortisol analyses. Performance testing, consisting of countermovement vertical jump (CMJ) and isometric mid-thigh pull (IMTP) performance relative to body mass, occurred at weeks 2 and 11. Linear mixed models were used to test for sex, time, and sex-by-time interactions ($\alpha < .05$).

Results:

On average, recruits covered 13.0 ± 2.7 km/day, expended 3,762 ± 765 calories/day, and slept 6.2 ± 1.1 hours/night. Sex-by-time interactions were found for DIS, steps, sleep duration, cortisol, and CMJ_{REL} performance ($P < .05$). Planned contrasts revealed that men covered more DIS than women at week 7/8 ($P < .001$). Women experienced greater step counts compared to men at week 11 ($P = .004$). Women experienced no significant change in sleep duration ($P > .05$), whereas men increased sleep duration from week 2 to week 7/8 ($P = .03$). Women experienced greater sleep duration at week 2 ($P = .03$) and week 11 ($P = .02$) compared to men. Women exhibited higher cortisol levels than men at week 2 ($P < .001$) and week 11 ($P < .001$). Women experienced declines in cortisol at week 7 compared to week 2 ($P < .001$). Men experienced no changes in cortisol response at any timepoint ($P > .05$). Both sexes experienced declines in CMJ_{REL} from week 2 to week 11 ($P > .001$). Sex main effects were observed for EE_{REL}, DIS, CMJ_{REL}, and $IMTP_{REL}$ ($P < .05$) with men experiencing greater overall workloads and producing greater strength and power metrics. Sex main effects were also found for sleep continuity and cortisol ($P < .05$), for which men experienced lower values compared to women. Time main effects were observed for EE_{REL}, DIS, steps, cortisol, CMJ_{REL}, and $IMTP_{REL}$ ($P < .05$).

Conclusions:

This study not only highlights the known sex differences between men and women but also sheds light on the different physical and physiological responses of each sex to military training. Interestingly, the greatest physical demands incurred earlier in the training cycle. Despite declining workloads, the stress response was maintained throughout the training, which may have implications for adaptation and performance. In addition, average sleep duration fell notably below recommendations for optimizing health and recovery. Effectively monitoring the demands and performance outcomes during recruit training is essential for determining individual fitness capabilities, as well as establishing the effectiveness of a training program. Individual performance assessments and adequately periodized workloads may help to optimize recruit training for both men and women.

[*]Department of Exercise Science, University of South Carolina, Columbia, SC 29208, USA

[†]Department of Family, Nutrition, and Exercise Science, Queens College, CUNY, Flushing, NY 11367, USA

[‡]Department of Kinesiology, Lindenwood University, Saint Charles, MO 63301, USA

[§]Neuromuscular Research Laboratory, University of Pittsburgh, Pittsburgh, PA 15203, USA

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the DoD, U.S. Marine Corps, or Marine Corps Training and Education Command.

doi:https://doi.org/10.1093/milmed/usae071

INTRODUCTION

The U.S. Marine Corps (USMC) recruit training consists of a 13-week program of instruction designed to instill physical fitness, military discipline, familiarization with Marine Corps history, and inculcate core values in new recruits. Both men and women experience a variety of physical and psychological stressors throughout this period intended to prepare the recruits for military service. Assessing and profiling the physical and physiological demands during this period are valuable when seeking to optimize recruit training and mitigate injury risk. However, as men and women are known to possess differences in absolute performance capabilities,[1,2] the question remains as to whether sex differences occur in relation to the physical and physiological demands of recruit training.

Strenuous training demands and social environment stressors can increase psychological and physiological stress and impact performance outcomes.[3] Workload and recovery assessments can aid in optimizing performance and decreasing injury risk by providing an objective evaluation of overall training demands, recruit adaptation to the imposed training demands, and fatigue status.[4] Physiological demands, termed internal workload, can be assessed via heart rate (HR) monitoring to determine caloric expenditure,[4,5] whereas physical demands, termed external workload, can be assessed by accelerometry and/or global positioning systems to determine the distance covered (DIS) and number of steps taken.[4] In addition to assessing workloads, sleep is an important aspect of recovery.[6] Adequate sleep quantity and quality may act to enhance adaptation and simultaneously buffer the negative effects of increased training demands. Conversely, inadequate sleep may lead to a worsened state of fatigue with significant negative effects on performance, perceived effort, cognition, and other biological functions.[7,8] Wearable technologies unobtrusively monitor internal and external workloads, along with sleep, making this a feasible method to assess both physical and physiological demands of recruit training.[9,10]

When assessing military readiness, it is important to consider the combined psychological and physiological effects of both the training stimulus and the environment. Biological markers of stress and recovery can provide unique insight into adaptation and readiness to perform.[11] Biomarker changes in conjunction with social and environmental conditions may have implications for performance outcomes, given the cumulative stress they represent. For instance, previous research has reported negative changes in physical performance, body composition, and anabolic and catabolic biomarkers following 3 weeks of military field training.[12] This suggests that the overall stress is high during military training thereby pointing to the utility of monitoring stress responses during recruit training. One useful biomarker to assess may be cortisol. Monitoring resting cortisol values throughout recruit training can give an indication of how the recruit is responding to the overall training environment and has previously been shown to be related to physical performance changes with training.[13]

Resting cortisol concentrations provide information pertaining to the stress response, with chronic elevations indicative of hypothalamic–pituitary–adrenal (HPA)-axis maladaptation and impaired ability to recover from training.[11] One study examining biomarker responses associated with a competitive soccer season reported cortisol concentrations remained above the normal clinical range throughout the entire season, indicating a heightened HPAl-axis response to continuous high workloads.[14,15] Further, men and women demonstrated different cortisol responses despite comparable relative workloads, with women experiencing greater cortisol concentrations throughout the entire season compared to men.[14] Additionally, another study reported that although men and women have been shown to express similar performance decrements following a 6-day military training exercise, women experienced greater physiological stress.[16] This includes larger increases in cortisol and declines in insulin-like growth factor-1 compared to men completing the same physical tasks.[16,17] Taken together, these studies indicate that men and women may experience differences in biomarker response to training stress, which may have implications for optimal recovery strategies for each sex.

In addition to potential differences in biomarker responses, when comparing performance metrics between sexes, women have lower absolute strength, anaerobic power, and aerobic capacity compared with their male counterparts.[2,18] These differences are in part the result of inherent physiological differences leading to disparities in body composition, with men exhibiting lower body fat percentages and greater absolute muscle mass.[19] On an absolute basis, women typically demonstrate half the upper body strength and two-thirds the leg strength as men,[20,21] but these differences are somewhat lessened when strength is expressed relative to body mass[22] and further lessened when expressed relative to fat-free mass.[23] However, absolute performance outcomes are often not assessed using these caveats, particularly in a military setting, potentially putting women at a disadvantage. Women also have lower power capacity, shown by significantly lower vertical jump heights than those of men[2,16] even when accounting for fat-free mass. Additionally, aerobic capacity has been shown to be 15 to 30% lower in both trained and untrained women compared with men of similar age,[24–26] which may be attributable to cardiovascular system differences (i.e., heart size, blood volume, and stroke volume differences).[20,22] Although men tend to exhibit greater energy expenditure (EE) than women because of larger body mass,[27] these differences are minimized when expressed on a relative basis (per kg body mass).[2]

Men and women express differences in absolute performance capabilities which may impact responses to the physical and physiological demands of recruit training. The data for the current study were derived from a larger study, the USMC Gender-Integrated Recruit Training study, the aim of which was to provide data-driven recommendations to increase gender integration during USMC recruit training.[28] The purpose of the current analysis was to monitor USMC recruits throughout recruit training and to assess and compare workload, sleep, stress, and performance responses between sexes. We hypothesized that men and women would respond differently to USMC recruit training as expressed through disparities in these metrics.

METHODS

Subjects

A total of 281 recruits (M = 182 and W = 99; Age = 19 ± 2 years) were monitored and tested throughout USMC recruit training. Tables I to III include a breakdown of the number of participants monitored per week, accounting for attrition and missing data. Written informed consent was obtained under the direct supervision of an ombudsperson to further minimize the risk of coercion. The study (STUDY20120069) was approved by the University of Pittsburgh Institutional Review Board and the USMC Human Research Protection Office.

Experimental Design

USMC recruits were monitored throughout recruit training to assess the physical and physiological responses to training. Three gender-integration models were evaluated to provide an overall view of the demands of recruit training. Although it is acknowledged that gender is a social construct and sex is a biological variable, the USMC refers to training men and women together as gender integration, and therefore, the term gender is used when referencing the integration models and ways to improve integrated training based on the USMC nomenclature. The first gender-integration model was the Series Track at Marine Corp Recruit Depot (MCRD) Parris Island, which consisted of separate companies with female series (2 platoons of female recruits) training alongside a male company (6 platoons of male recruits). In the Series Track model, a male company is paired with a female company. Recruits complete the training cycle in parallel and come together for major training events. However, recruits live in different barracks on the installation, eat separately, and may do physical training activities, such as the obstacle course, separately. Series Track recruits also march to integrated training events from separate locations. Second, an Integrated Company was evaluated at MCRD Parris Island, which consisted of a recruit company that had 2 female platoons and 4 male platoons. Recruits are housed in the same barracks but live in squad bays on different floors. Integrated companies eat at the same time in the same chow hall and march to every training event or activity together. Lastly, a Male-only company was evaluated at MCRD San Diego. Regardless of integration model, recruits were given the same opportunities to eat, sleep, and hydrate throughout the observed data collection period (see Supplemental Data Tables S1-S7 for workload,

TABLE I. Body Mass, Internal and External Workloads

Sex	*n*	Week	Body mass (kg)	*D*	Energy expenditure (kcal)	*d*	Energy expenditure$_{relative}$ (kcal/kg)	*d*	Distance (km)	*d*	Steps	*d*
Men	180	2	$73.9 \pm 10.4^{\wedge}$	—	$4,494 \pm 739^{\wedge}$	—	$61.2 \pm 7.9^{\wedge}$	—	$14.5 \pm 2.7^{\wedge}$	—	$23,704 \pm 4,103$	—
Women	98	2	61.7 ± 8.1	—	$3,677 \pm 692$	—	60.0 ± 10.6	—	13.6 ± 2.6	—	$23,715 \pm 3,803$	—
Men	158	7/8	—	—	$3,920 \pm 498^{\wedge,\#}$	−0.78	$53.4 \pm 6.0^{\wedge,\#}$	−0.77	$13.1 \pm 2.4^{*,\wedge,\#}$	−0.52	$21,163 \pm 3,796^{\#}$	−0.62
Women	83	7	—	—	$3,185 \pm 444^{\#}$	−0.71	$51.7 \pm 6.3^{\#}$	−0.49	$10.9 \pm 2.0^{\#}$	−1.04	$19,679 \pm 3,317^{\#}$	−1.06
Men	150	11	$72.7 \pm 8.7^{\wedge,\#}$	−0.11	$3,605 \pm 486^{\wedge,\#}$	−1.20	$49.8 \pm 5.9^{\wedge,\#}$	−1.44	$12.5 \pm 2.6^{\wedge,\#}$	−0.74	$20,866 \pm 4,251^{\#}$	−0.69
Women	77	11	$61.2 \pm 7.1^{\#}$	−0.06	$2,922 \pm 480^{\#}$	−1.09	$47.9 \pm 6.4^{\#}$	−1.14	$11.7 \pm 3.0^{\#}$	−0.73	$21,853 \pm 5,110^{*,\#}$	−0.49

Data are presented as mean ± SD. All effect sizes (*d*) are compared to week 2.
kg = kilograms, kcal = calories, kcal/kg = calories per kilogram body weight, km = kilometers.
*Indicates a sex-by-time interaction.
∧Indicates a sex main effect.
#Indicates a time main effect.

TABLE II. Sleep Metrics: Duration and Continuity

Sex	*n*	Week	Sleep duration (hr)	*d*	Sleep continuity (au)	*d*
Men	180	2	$6.1 \pm 0.9^{*}$	—	$3.4 \pm 0.7^{\dagger}$	—
Women	98	2	6.2 ± 0.8	—	4.2 ± 0.7	—
Men	158	7/8	$6.4 \pm 1.2^{*}$	0.33	$3.5 \pm 0.8^{\dagger}$	0.14
Women	83	7/8	6.0 ± 0.9	−0.25	4.0 ± 0.7	−0.29
Men	150	11	$6.3 \pm 1.0^{*}$	0.22	$3.3 \pm 0.8^{\dagger}$	0.14
Women	77	11	6.4 ± 1.2	0.25	4.0 ± 0.7	−0.29

Data are presented as mean ± SD. All effect sizes (d) are compared to week 2.
hr = hours, au = arbitrary units.
*Indicates a sex-by-time interaction.
†Indicates a sex main effect.

sleep, and stress variables broken down by gender-integration model).

Workload monitoring occurred over 72-hour periods starting on Monday morning during the start of week 2 (phase 1 [P1]), week 7 (MCRD Parris Island) or week 8 (MCRD San Diego) (Phase 2 [P2]), and week 11 (Phase 3 [P3]) to encompass the 3 phases of training recruits undergo before becoming a Marine. These phases consist of P1 which includes tasks such as: receiving, bucket issue (standard equipment), rifle issue, initial strength test, introduction to Marine Corps martial arts program, weapons safety, close order drill; P2: combat water survival, physical and combat conditioning, martial arts, academic instruction; and P3: fundamentals of marksmanship, basic warrior training, field skills, the Crucible.

The different mid-points at MCRD Parris Island and San Diego were used to control for the difference in training schedule activities between locations. Cortisol sampling occurred on the Monday of week 2 (P1), week 7/8 (P2), and week 11 (P3). Human performance testing (countermovement vertical jump [CMJ] and isometric mid-thigh pull [IMTP]) occurred at the start of week 2 (P1) and at the start of week 11 (P3) of USMC recruit training. The Series Track (MCRD Parris Island) was evaluated starting in early June 2021, 99 (52% female), the Integrated Company (MCRD Parris Island) starting in late June 2021 with 97 (49% female) recruits, and the Male-only company (MCRD San Diego) starting in early September 2021 with 85 recruits.

Wearable Tracking

Recruits were provided a wrist-worn wearable tracking device (Polar GritX, POLAR Electro, Kempele, Finland) which was programmed with individual recruit information including age, height, weight, and sex. Recruits were instructed to wear the device covered with a sweatband for 3 consecutive days and nights until collected by the research team. Settings and displays on the wearable screen were locked throughout the duration of use. The device also indicates if and when the watch was worn and when it was taken off in order to calculate compliance. The device combines accelerometry, global positioning systems, and HR (via photoplethysmography) technologies in order to determine EE, DIS, steps taken, sleep duration, and sleep continuity. Two male participants and one female participant were excluded at week 2 (P1); and 3 male participants and one female participant were excluded at week 11 (P3) because of missing data.

EE is estimated from continuous HR data combined with movement/activity and surface area (a function of height and weight) calculations and expressed on an absolute and per kg body mass basis (EE_{REL}). EE_{REL} for weeks 7/8 (P2) were calculated based on body mass assessments from week 2 (P1). Total DIS and steps taken are calculated using data derived from the internal accelerometer sensors. Sleep duration is assessed by 3D acceleration measurements and is determined as the time between falling asleep and waking up. Measurement of the times between successive heart beats and analysis of their variation is used for the classification of sleep into the different sleep stages. A Polar sleep algorithm classifies 30-second epochs during this period into light sleep, deep sleep, REM sleep, or interruptions. The sleep continuity score is based on an evaluation of continuous sleep using patterns of interruptions and sleep bouts assessed by the wearable monitors during the night. This score is expressed on a Likert scale of 1 to 5, where 1 reflects fragmented sleep and 5 reflects continuous sleep.

Cortisol

After distributing wearable devices at ∼04:00 to 05:00 hours for Series and Integrated Tracks and at ∼04:30 to 05:00 hours for the Male-only track, saliva was collected by passive drool method. Recruits were provided with a cryovial and salivary collection straw and were instructed to allow the saliva to pool in the mouth. Then, with head tilted forward, recruits were instructed to gently guide saliva through the straw into the vial until the vial was filled with approximately 1.5 mL of saliva. Samples were frozen at or below −20 °C immediately after collection and then shipped to Salimetrics, LLC (Carlsbad, CA, USA) for the analysis of salivary cortisol via enzyme-linked immunosorbent assay. Samples were thawed to room temperature, vortexed, and then centrifuged for 15 minutes at approximately 3,000 revolutions per minute (RPM) (1,500 × g) immediately before performing the assay. Sample test volume was 25 μl of saliva per determination. The

TABLE III. Performance Testing (Countermovement Vertical Jump and Isometric Mid-thigh Pull)

Sex	Week	*n*	Peak power (W)	*d*	Relative peak power (W/kg)	*d*	Peak force (N)	*d*	Relative peak force (N/kg)	*d*
Men	2	176	$3,699 \pm 624^{*,\wedge}$	—	$49.9 \pm 6.2^{*,\wedge}$	—	$2,587 \pm 477^{\wedge}$	—	$34.6 \pm 5.3^{\wedge}$	—
Women	2	98	$2,329 \pm 372$	—	37.6 ± 4.9	—	$1,734 \pm 363$	—	27.5 ± 4.6	—
Men	11	129	$3,290 \pm 533^{*,\wedge,\#}$	−0.66	$44.7 \pm 5.2^{*,\wedge,\#}$	−0.84	$2,654 \pm 458^{\wedge}$	0.14	$36.3 \pm 4.8^{\wedge,\#}$	0.32
Women	11	70	$2,201 \pm 342^{\#}$	−0.34	$35.7 \pm 4.2^{\#}$	−0.39	$1,736 \pm 357$	0.01	$28.0 \pm 4.8^{\#}$	0.11

Data are presented as mean ± SD. All effect sizes (*d*) are compared to week 2.

W = watts, W/kg = watts per kilogram body weight, N = newtons, N/kg = newtons per kilogram body weight.

*Indicates a sex-by-time interaction.

∧Indicates a sex main effect.

#Indicates a time main effect.

assay has a lower limit of sensitivity of 0.007 μg/dL, with a standard curve ranging from 0.012 to 3.0 μg/dL. Samples were run in duplicate with a coefficient of variation of 3.6%. Two female participants were missing cortisol samples at week 2 (P1), and 4 male participants and one female participant were missing cortisol samples at week 7/8 (P2) and were not included in the cortisol analysis.

Performance Testing

Recruits performed all tests dressed in standard physical training uniform and athletic footwear. Before testing, body mass and height were assessed using a stadiometer and calibrated scale. Recruits performed a 5-minute standardized dynamic warm-up consisting of squats, hip hinges, lunges, and jumping movements.

Countermovement vertical jump

Recruits were instructed to jump "as high and as fast as possible" with hands akimbo at all times. Three maximal CMJ repetitions were performed, and the highest jump height recorded. Trials were separated by approximately 2 minutes rest to ensure adequate recovery. Tests were performed on bilateral force platforms (FDLite Forcedeck dual force platforms; VALD Performance, Sydney, Australia) sampling at a frequency of 1,000 Hz. Peak power was recorded as the maximal power output achieved during the CMJ, and that value was then normalized to body mass to attain relative peak power (W/kg).

Isometric mid-thigh pull

IMTP was performed on a custom fabricated steel testing apparatus equipped with bilateral force platforms (FDLite Forcedeck dual force platforms; VALD Performance, Sydney, Australia) at a sampling frequency of 1,000 Hz. Weightlifting straps were used to limit the effect of grip strength. The height of the steel apparatus was adjusted so that knee flexion was approximately at 125 to 145 degrees and hip flexion was approximately 140 to 150 degrees as measured by a handheld goniometer.[29] The height at which optimal joint angles were achieved was recorded for each recruit to be repeated at subsequent testing. Familiarization repetitions of 3 seconds in duration were administered at 50, 75, and 90% of perceived maximal effort. Testing consisted of 2 maximal repetitions of 5 seconds in duration separated by approximately 2 minutes rest. Recruits were instructed to "pull as hard and as fast as possible" to attain peak force (Ns). A third trial was administered if >250 N difference in peak force was observed between trials.[29] Values were then normalized to body mass to attain relative peak force (N/kg).

Statistical Analysis

Mean values for all measures from wearables were calculated for each individual during each observation period. Individuals with at least one full day of wearable data were included in the analyses. If data from one of the 3 days were incomplete (because of recruit taking off the watch or battery not charged), the incomplete day was excluded, and the remaining days were averaged based on the full days information only. Linear mixed models were used to test for sex and time main effects as well as sex-by-time interactions for workload variables, sleep variables, and cortisol for weeks 2 (P1), 7/8 (P2), and 11 (P3), as well as for performance variables for weeks 2 (P1) and 11 (P3). Significant interactions were followed up with a planned contrast of time within sex comparisons back to week 2 (P1). Significant sex and time main effects were also followed up with planned contrasts of sex or time, respectively, using week 2 (P1) as the comparison point. Gender-integration model was inputted as a fixed effect covariate in all statistical models to adjust for the effect of this variable on the outcome variables. Cohen's *d* was used to calculate effect sizes. Using Cohen's conventions, ES of 0.20, 0.50, and 0.80 were considered indicative of small, medium, and large effects, respectively.[30] All effect sizes are compared to week 2 (P1). All analyses were conducted using R Studio (version 4.1.0) with the lme4 (version 1.1-27.1) and emmeans (version 1.6.201) packages.

RESULTS

Body Mass

No sex-by-time interaction was observed ($P = .307$) throughout the USMC recruit training. A significant sex main effect was found ($P < .001$) as men exhibited greater body mass than women. A significant time main effect ($P < .001$) was observed, and planned contrasts revealed declines in body mass from week 2 (P1) to week 11 (P3). Body mass data are presented in Table I.

Workload Variables

Energy expenditure

No sex-by-time interaction was found ($P = .269$). A significant sex main effect ($P < .001$) was observed with men experiencing greater EE than women throughout the USMC recruit training. A significant time main effect ($P < .001$) was observed revealing that EE was significantly lower than week 2 (P1) at week 7/8 (P2) ($P < .001$) and week 11 (P3) ($P < .001$).

Energy expenditure$_{REL}$

No sex-by-time interaction was found ($P = .600$). Significant sex ($P = .028$) and time ($P < .001$) main effects were observed for EE_{REL}. Planned contrasts revealed higher EE_{REL} in men compared to women. In addition, relative EE_{REL} was greatest at week 2 (P1) and declined at week 7/8 (P2) ($P < .001$) and week 11 (P3) ($P < .001$) in both men and women. EE and EE_{REL} data are presented in Table I.

Distance covered

A significant sex-by-time interaction ($P < .001$) was observed for DIS throughout the USMC recruit training. Planned contrasts revealed that men covered more DIS than women at week 7/8 (P2) ($P < .001$). There were no sex differences at week 2 (P1) or week 11 (P2) ($P > .05$). In addition, significant sex ($P < .001$) and time ($P < .001$) main effects were found. On average, DIS was greater in men compared to women. Both men and women experienced significant declines in DIS at week 7 (P2) ($P < .001$) and week 11 (P3) ($P < .001$) compared to week 2 (P1). DIS data are presented in Table I.

Steps taken

There was a significant sex-by-time interaction ($P < .001$) for total steps taken throughout the USMC recruit training. Planned contrasts revealed that women experienced a greater step count compared to men at week 11 (P3) ($P = 0.004$), while no differences were found at week 2 (P1) or week 7/8 (P2) ($P > .05$). A time main effect was also found ($P < .001$), indicating that the step count was highest at week 2 (P1) and declined at week 7/8 (P2) ($P < .001$) and week 11 (P3) ($P < .001$) for both men and women. No sex main effect was observed ($P > .05$). Steps data are presented in Table I.

Sleep

Sleep duration

A significant sex-by-time interaction was found for sleep duration ($P = .014$). Planned contrasts indicated that women experienced no change in sleep duration throughout recruit training, whereas men experienced increased sleep duration from week 2 (P1) to week 7/8 (P2) ($P = .03$) but no changes from week 2 (P1) at week 11 (P3) ($P = .22$). In addition, women experienced greater sleep duration at week 2 (P1) ($P = .03$) and week 11 (P3) ($P = .02$) compared to men. No sex differences in sleep duration were seen at week 7/8 (P2) ($P > .05$). No sex ($P = .09$) or time ($P = .09$) main effects were observed. Sleep duration data are presented in Table II.

Sleep continuity

No sex-by-time interaction ($P = .060$) or time main effect ($P = .098$) was observed for sleep continuity. A significant sex main effect was found for sleep continuity ($P < .001$), whereby women experienced greater sleep continuity throughout the USMC recruit training. Sleep continuity data are presented in Table II.

Cortisol

A significant sex-by-time interaction ($P = .01$) was observed for cortisol responses. Planned contrasts revealed women exhibited higher cortisol levels than men at week 2 (P1) ($P < .001$) and week 11 (P3) ($P < .001$) but no differences at week 7/8 (P2) ($P = .09$). In addition, women experienced significant declines in cortisol at week 7 (P2) compared to week 2 (P1) ($d = -0.50$; $P < .001$) but no changes in cortisol

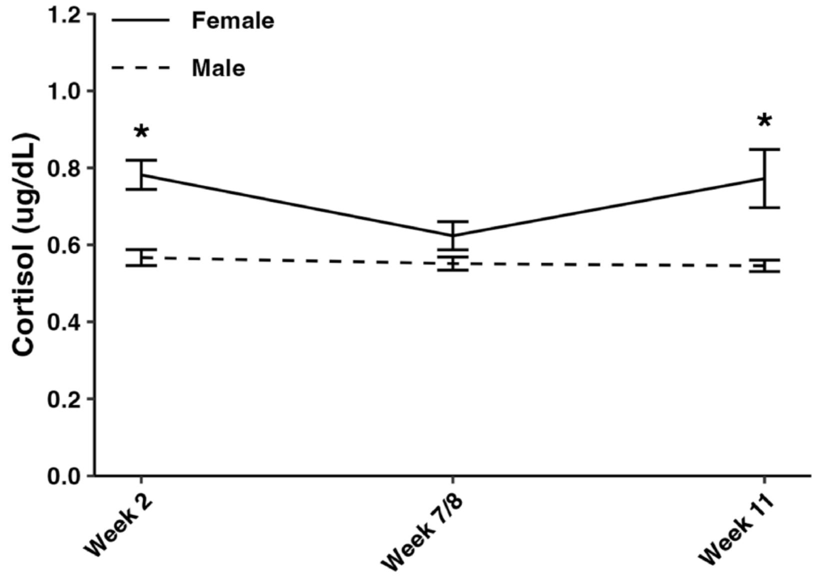

FIGURE 1. Cortisol responses between men and women throughout the USMC recruit training. Data are presented as means ± standard error. μg = micrograms, dL = deciliter. *Indicates a sex-by-time interaction.

response at week 11 (P3) compared to week 2 (P1) ($d = 0.00$; $P > .05$). Men experienced no changes in cortisol response at any timepoint ($P > .05$). Sex ($P = .001$) and time ($P < .001$) main effects were also observed. Women had higher cortisol than men throughout basic training. Cortisol changes are presented in Figure 1.

Performance

Countermovement vertical jump

A Significant sex-by-time interaction ($P < .001$) was observed for CMJ. Planned contrasts revealed men exhibited greater peak power compared to women at week 2 (P1) ($P < .001$) and 11 (P3) ($P < .001$). Significant declines in peak power were seen from week 2 (P1) to week 11 (P3) in women ($P < .001$) and men ($P < .001$). Significant sex ($P < .001$) and time ($P < .001$) main effects were also observed. Peak power was greater in men compared to women ($P < .001$). Regardless of sex, peak power decreased from week 2 (P1) to week 11 (P3).

When assessed relative to body mass, a significant sex-by-time interaction ($P = .001$) was observed. Planned contrasts revealed that men expressed greater relative peak power outputs at week 2 (P1) ($P < .001$) and week 11 (P3) ($P < .001$) compared to women. Significant declines in CMJ peak power performance were seen from week 2 (P1) to week 11 (P3) in women ($P > .001$), and men ($P < .001$). Further, significant sex ($P < .001$) and time ($P = .001$) main effects were found. Relative peak power was greater in men compared to women ($P < .001$). Regardless of sex, relative peak power decreased from week 2 (P1) to week 11 (P3) ($P = .001$). Peak power and relative peak power data are presented in Table III.

Isometric mid-thigh pull

No significant sex-by-time interaction ($P = .18$) or time main effect ($P = .43$) were found for peak force IMTP. Significant sex main effects were found for peak force ($P < .001$). Planned contrasts revealed that men exhibited greater peak force production compared to women ($P < .001$).

When expressed relative to body mass, no significant sex-by-time interaction was observed ($P = .09$). However, a sex main effect ($P < .001$) and time main effect ($P = .001$) were found. Men expressed greater peak force production compared to women ($P < .001$). Overall, peak force increased from week 2 (P1) to week 11 (P3) ($P = .001$). Peak force and relative peak force data are presented in Table III.

DISCUSSION

The USMC recruit training consists of a physically demanding fitness curriculum designed to transform recruits into Marines. Recruits covered an average of 13.0 ± 2.7 km per day, expended 3,762 ± 765 calories per day, and slept an average of 6.2 ± 1.1 hours per night throughout training. The results of this study indicate the most physically demanding time period for USMC recruits occurs during the first phase of training. During this time, EE, DIS, and steps taken were greatest compared to all other time periods evaluated. Although workloads tended to decrease as training continued, the consistently elevated resting cortisol values, particularly in women, point to the cumulative nature of training-induced stress in addition to persistent psychological demands. Despite workload demands, peak power performance declined throughout the training cycle, while strength metrics were relatively maintained from week 2 (P1) values. Although sleep continuity improved for both sexes, overall total sleep duration still fell notably below recommendations for optimizing health and recovery.[31] These findings are similar to reports of poor sleep during Army basic training with recruits averaging 6.7 hours per night.[32] Additional recovery methods may be warranted to counteract the high-stress environment of recruit training in an effort to enhance performance adaptations.

This study not only highlights the known sex differences between men and women but also sheds light on the different physical and physiological responses of each sex to military training. One of the more consistent findings was related to the differences between male and female recruits in terms of total workloads. Women experienced relatively lower internal and external loads compared to men, and these differences were further amplified in measures of strength and power. However, although workloads were reportedly lower, the stress response was greater in women during recruit training. These findings are consistent with other researchers who have found that women expend fewer calories throughout training despite greater physiological stress than men completing the same physical tasks.[17] Interestingly, both men and women experienced similar declines in power performance, with minimal changes in strength outputs. Despite differential workloads, changes in performance outcomes were similar across sexes. These findings are in agreement with other studies who have reported changes in performance outcomes between sexes pre and post basic training.[33] In fact, Sharp et al. reported a decline in vertical jump height, peak power, and mean power in both the male and female recruits.[34] Lack of changes or adverse changes may be reflective of the below optimal sleep metrics leading to a lack of recovery and adaptation. These findings have direct relevance for gender-integration implications and future integration efforts as they highlight areas of both challenge and opportunity for the Marine Corps recruit training.

Another interesting finding occurred with regard to differences in step count compared with total DIS between men and women. It is unclear as to why men cover more DIS with similar steps to women at week 7/8 (P2) of training. The incongruence between step count and DIS is further seen at week 11 (P3), where men cover more DIS with fewer steps compared to women. The authors speculate that this may relate to differences in walking/rucking and running kinematics between sexes. Because of height differences, women may have smaller stride lengths when running or under load carriage conditions such as rucking, and therefore, the type of physical training occurring at each time point may impact the accelerometry data. Although this notion needs to be investigated further, taking greater steps to cover similar DIS may have implications for increased workload and injury risk factors between sexes.

Although this study brings forth important practical applications, there are some limitations and challenges to working in a real-world military field environment. First, although the use of an ombudsmen to minimize coercion and clear instructions on the voluntary nature of the study occurred during the informed consent briefing, it is not possible to fully control for the pressure to enroll often incurred in a military setting. Further, it is important to consider the environmental and infrastructural differences that may have partially influenced the disparities in workloads seen between men and women. As a part of the gender-integration study, the USMC requested that both MCRD sites should be investigated. At the time, MCRD San Diego was only training male recruits, and therefore, all training for women was performed at MCRD Parris Island, whereas training for men occurred at both MCRD San Diego and MCRD Parris Island. Therefore, it is not possible to separate differences in MCRD terrain, layout, weather, and training schedules, which may have affected the workload and performance results between locations. Recruits at San Diego also trained at Camp Pendleton which was the site of evaluation during week 8 of wearable workload data monitoring. This location is known to have hills and mountainous terrain for hikes, which MCRD Parris Island does not. Similarly, training in South Carolina is routinely affected by temperature variations and humidity conditions that are not often experienced in southern California, making geographic location a significant limitation to study design. However, the inclusion of gender-integration model as a covariate in all analyses provides some level of statistical control and accountability for these issues. Another limitation is the proximity of the week 11 (P3) testing to the final Marine Corps test known as the "Crucible." The Crucible is a 54-hour challenge consisting of both physical and social stressors. Recruits partake in a 15 km conditioning march, 27 daytime events, and 2 nighttime events composed of a variety of military problem-solving exercises. The "Crucible" took place <48 hours before week 11 (P3) performance testing and may have impacted the decrements in power performance that were seen in recruits. In addition, in order to determine daily workloads, wearable devices used accelerometry and photoplethysmography-based technology along with algorithms to obtain sleep duration and sleep continuity. This method may neither be sensitive to differences in individual sleep patterns nor were subjective ratings of sleep collected. Although instructed to wear the watch on their wrist for 72 hours during the data collection period, there was no control for recruits taking off their watch, though observed compliance appeared high. Finally, although all recruits were provided meals prepared by the USMC dining services, diet and hydration status is known to affect workload and sleep responses, which was neither assessed nor controlled for in this study. Of particular importance, while the USMC does not allow recruits to take oral contraceptives (OCs) during training, previous OC usage among recruits was not measured. OC use has been previously shown to relate to an increased stress response during intensive training periods.[35] Future research may consider evaluating previous OC users and cortisol responses throughout a training cycle for potential residual effects. It may be further beneficial to evaluate the recency of OC stoppage in relation to entering recruit training, as hormonal fluctuations may be impacted by recruits cycling off OCs. Given the logistical challenges and demands presented by assessment in this setting while trying to be minimally intrusive, we believe that these limitations were acceptable and largely unavoidable and should not minimize the insight provided by these data.

Despite limitations, to the authors' knowledge, this is the first study to repeatedly assess workload and laboratory-quality performance metrics in both men and women USMC recruits throughout a recruit training program. Recruits experienced high initial workloads coupled with suboptimal sleep throughout training. Despite low week 2 (P1) fitness metrics, declines in power were observed by week 11 (P3) in male and female recruits. While periods of intense training are necessary to provide an overload stimulus to maximize adaptations,[36] proper progression is also essential so that recruits can adapt to handle the high training loads experienced during initial training. Significant overload coupled with inadequate recovery may lead to underperformance, excess fatigue, and injury.[37] In fact, higher external workloads have been shown to result in greater injury occurrence during intense military training.[38] Research has also shown that the highest incidence of injury occurs in the first few weeks during basic military training.[39,40] Therefore, military training may benefit from applying the basic training principles of progressive overload.[20,41] Combined with adequate sleep and nutrition, which act to buffer the negative effects of increased training demands, a periodized training approach may help to enhance performance and reduce the risk of injury for both men and women recruits in an integrated training environment. Future research may be necessary to evaluate the effects of a periodized training programs or more progressive training that allow for adequate recovery and enhanced adaptations and associations with performance outcomes and injury risk factors. This study shows the importance of recognizing the physical capacity differences, not just between sexes, but also at the individual level. When working with heterogenic populations with respect to physical fitness and resilience, it is essential to identify limitations in abilities as well as areas of opportunity for improvement. This may help to enhance training for all recruits, allowing men and women to work together earlier in the training cycle. Appropriately structured training with greater emphasis on mobility and skill development and form may help to optimize performance across sexes. This may be particularly beneficial for those individuals with lower baseline fitness values. Finally, monitoring workload variables as well as performance outcomes is essential in determining an individual's fitness capabilities, as well as establishing the effectiveness of a training program.

ACKNOWLEDGMENTS

None declared.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Military Medicine* online.

FUNDING

USMC AWD00003104 M95494-20-C-0021; no COI.

SUPPLEMENT SPONSORSHIP

This article appears as part of the supplement "United States Marine Corps Gender-Integrated Recruit Training Study," sponsored by the University of Pittsburgh.

CONFLICT OF INTEREST STATEMENT

None declared.

DATA AVAILABILITY

The original data underlying this article cannot be shared publicly because of ethical reasons and the sensitive nature of the data.

REFERENCES

1. Ansdell P, Thomas K, Hicks KM, Hunter SK, Howatson G, Goodall S: Physiological sex differences affect the integrative response to exercise: acute and chronic implications. Exp Physiol 2020; 105(12): 2007–21. 10.1113/EP088548
2. McFadden BA, Walker AJ, Bozzini BN, Sanders DJ, Arent SM: Comparison of internal and external training loads in male and female collegiate soccer players during practices vs. games. J Strength Cond Res 2020; 34(4): 969–74. 10.1519/JSC.0000000000003485
3. McFadden BA, Walker AJ, Bozzini BN, Hofacker M, Russell M, Arent SM: Psychological and physiological changes in response to the cumulative demands of a women's division I collegiate soccer season. J Strength Cond Res 2021; 36(5): 1373–82. 10.1519/JSC.0000000000004062
4. Halson SL: Monitoring training load to understand fatigue in athletes. Sports Med 2014; 44(Suppl 2): S139–47. 10.1007/s40279-014-0253-z
5. Ceesay SM, Prentice AM, Day KC, et al: The use of heart rate monitoring in the estimation of energy expenditure: a validation study using indirect whole-body calorimetry. Br J Nutr 1989; 61(2): 175–86. 10.1079/bjn19890107
6. Samuels C: Sleep, recovery, and performance: the new frontier in high-performance athletics. Neurol Clin 2008; 26(1): 169–80. 10.1016/j.ncl.2007.11.012
7. Halson SL: Sleep in elite athletes and nutritional interventions to enhance sleep. Sports Med 2014; 44(Suppl 1): S13–23. 10.1007/s40279-014-0147-0
8. Hausswirth C, Louis J, Aubry A, Bonnet G, Duffield R, Le Meur Y: Evidence of disturbed sleep and increased illness in overreached endurance athletes. Med Sci Sports Exerc 2014; 46(5): 1036–45. 10.1249/MSS.0000000000000177
9. Li RT, Kling SR, Salata MJ, Cupp SA, Sheehan J, Voos JE: Wearable performance devices in sports medicine. Sports Health 2016; 8(1): 74–8. 10.1177/1941738115616917
10. Rentz LE, Ulman HK, Galster SM: Deconstructing commercial wearable technology: contributions toward accurate and free-living monitoring of sleep. Sensors 2021; 21(15): 5071. 10.3390/s21155071
11. Lee EC, Fragala MS, Kavouras SA, Queen RM, Pryor JL, Casa DJ: Biomarkers in sports and exercise: tracking health, performance, and recovery in athletes. J Strength Cond Res 2017; 31(10): 2920–37. 10.1519/JSC.0000000000002122
12. Ojanen T, Jalanko P, Kyrolainen H: Physical fitness, hormonal, and immunological responses during prolonged military field training. Physiol Rep 2018; 6(17): e13850. 10.14814/phy2.13850
13. McFadden BA, Walker AJ, Arent MA, et al: Biomarkers correlate with body composition and performance changes throughout the season in women's division I collegiate soccer players. Front Sports Act Living 2020; 2: 74. 10.3389/fspor.2020.00074
14. Walker A, McFadden B, Sanders D, et al: Workload, energy expenditure, and biomarker differences in division I male and

female soccer players. Med Sci Sports Exercise 2017; 49(5S): 571. 10.1249/01.mss.0000518485.92630.f1
15. Walker AJ, McFadden BA, Sanders DJ, Rabideau MM, Hofacker ML, Arent SM: Biomarker response to a competitive season in division I female soccer players. J Strength Cond Res 2019; 33(10): 2622–8. 10.1519/JSC.0000000000003264
16. Vikmoen O, Teien HK, Raustol M, et al: Sex differences in the physiological response to a demanding military field exercise. Scand J Med Sci Sports 2020; 30(8): 1348–59. 10.1111/sms.13689
17. Conkright WR, O'Leary TJ, Wardle SL, Greeves JP, Beckner ME, Nindl BC: Sex differences in the physical performance, physiological, and psycho-cognitive responses to military operational stress. Eur J Sport Sci 2022; 22(1): 99–111. 10.1080/17461391.2021.1916082
18. Greeves JP: Physiological implications, performance assessment and risk mitigation strategies of women in combat-centric occupations. J Strength Cond Res 2015; 29(Suppl 11): S94–100. 10.1519/JSC.0000000000001116
19. Sanborn CF, Jankowski CM: Physiologic considerations for women in sport. Clin Sports Med 1994; 13(2): 315–27. 10.1016/S0278-5919(20)30332-X
20. McArdle WD, Katch FI, Katch VL: *Exercise Physiology: Nutrition, Energy, and Human Performance*. Lippincott Williams & Wilkins.; 2010.
21. Kraemer WJ, Mazzetti SA, Nindl BC, et al: Effect of resistance training on women's strength/power and occupational performances. Med Sci Sports Exerc 2001; 33(6): 1011–25. 10.1097/00005768-200106000-00022
22. Epstein Y, Yanovich R, Moran DS, Heled Y: Physiological employment standards IV: integration of women in combat units physiological and medical considerations. Eur J Appl Physiol 2013; 113(11): 2673–90. 10.1007/s00421-012-2558-7
23. Wilmore JH: The application of science to sport: physiological profiles of male and female athletes. J Can Des Sci Appl Au Sport 1979; 4(2): 103–15.
24. Dada EO, Anderson MK, Grier T, Alemany JA, Jones BH: Sex and age differences in physical performance: a comparison of Army basic training and operational populations. J Sci Med Sport 2017; 20(Suppl 4): S68–S73. 10.1016/j.jsams.2017.10.002
25. Sharp MA, Patton JF, Knapik JJ, et al: Comparison of the physical fitness of men and women entering the U.S. Army: 1978-1998. Med Sci Sports Exerc 2002; 34(2): 356–63. 10.1097/00005768-200202000-00026
26. Drinkwater BL: Physiological responses of women to exercise. Exerc Sport Sci Rev 1973; 1(1): 125–53. 10.1249/00003677-197300010-00009
27. Westerterp KR: Control of energy expenditure in humans. Eur J Clin Nutr 2017; 71(3): 340–4. 10.1038/ejcn.2016.237
28. Lovalekar M, Montgomery S, Arent SM, et al: Design considerations for a multidisciplinary approach to provide policy recommendations on gender-integrated recruit training in the Marine Corps. Mil Med In Press.
29. Comfort P, Dos'Santos T, Beckham GK, Stone MH, Guppy SN, Haff GG: Standardization and methodological considerations for the isometric midthigh pull. Strength Conditioning J 2019; 41(2): 57–79. 10.1519/ssc.0000000000000433
30. Cohen J: A power primer. Psychol Bull 1992; 112(1): 155–9. 10.1037//0033-2909.112.1.155
31. Hirshkowitz M, Whiton K, Albert SM, et al: National Sleep Foundation's sleep time duration recommendations: methodology and results summary. Sleep Health 2015; 1(1): 40–3. 10.1016/j.sleh.2014.12.010
32. Ritland BM, Hughes JM, Taylor KM, et al: Sleep health of incoming army trainees and how it changes during basic combat training. Sleep Health 2021; 7(1): 37–42. 10.1016/j.sleh.2020.10.005
33. Varley-Campbell J, Cooper C, Wilkerson D, Wardle S, Greeves J, Lorenc T: Sex-specific changes in physical performance following military training: a systematic review. Sports Med 2018; 48(11): 2623–40. 10.1007/s40279-018-0983-4
34. Sharp MAKJ, Patton JF, Smutok MA, Hauret K, Canham-Chervak M: Physical Fitness of Soldiers Entering and Leaving Basic Combat Training. Report Number T00-13. Natick, MA, US Army Research Institute of Environmental Medicine, 2001.
35. Bozzini BN, McFadden BA, Elliott-Sale KJ, Swinton PA, Arent SM: Evaluating the effects of oral contraceptive use on biomarkers and body composition during a competitive season in collegiate female soccer players. J Appl Physiol 2021; 130(6): 1971–82. 10.1152/japplphysiol.00818.2020
36. Gabbett TJ, Whiteley R: Two training-load paradoxes: can we work harder and smarter, can physical preparation and medical be teammates? Int J Sports Physiol Perform 2017; 12(Suppl 2): S250–S4. 10.1123/ijspp.2016-0321
37. Mujika I, Halson S, Burke LM, Balague G, Farrow D: An integrated, multifactorial approach to periodization for optimal performance in individual and team sports. Int J Sports Physiol Perform 2018; 13(5): 538–61. 10.1123/ijspp.2018-0093
38. Powell SD, Siddall AG, Needham-Beck SC, et al: Association between external training loads and injury incidence during 44 weeks of military training. Scand J Med Sci Sports 2023; 33(7): 1211–20. 10.1111/sms.14340
39. Jordaan G, Schwellnus MP: The incidence of overuse injuries in military recruits during basic military training. Mil Med 1994; 159(6): 421–6. 10.1093/milmed/159.6.421
40. Piantanida NA, Knapik JJ, Brannen S, O'Connor F: Injuries during Marine Corps Officer Basic Training. Mil Med 2000; 165(7): 515–20. 10.1093/milmed/165.7.515
41. Fry RW, Morton AR, Keast D: Periodisation of training stress—a review. Can J Sport Sci 1992; 17(3): 234–40.