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Physical performance and body composition reference values for modern US Marine Corps women

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ABSTRACT

Women's roles in the US military have progressively changed over the past several decades. Previously women were barred from combat roles. Recent change in policy allow women into combat roles in the Marine Corps, and this has led to women being trained for combat specialties.

Objectives This observational cross-sectional study describes body composition and performance values for modern Marine Corps women.

Methods Volunteers were 736 Marine women who were assessed for body composition and physical performance; (age 29.5±7.3 (18–56) years; height 163.6±6.8 (131.0–186.1) cm; body mass 68.3±9.2 (42.0–105.3) kg; years in the military 8.9±6.8 (0.5–37) years-in-service). Body composition measures were obtained using dual-energy X-ray absorptiometry and single-frequency bioelectrical impedance analyses. Performance measures were obtained from official physical and combat fitness test scores (PFT; CFT) as well as from data on measured countermovement jumps (CMJ) on a calibrated force platform.

Results Mean body composition metrics for Marine women were: 47.5±5.7 fat free mass (FFM) (kg), 30.1%±6.4% body fat (%BF), 2.6±0.3 bone mineral content (kg), and 25.5±2.8 body mass index (kg/m^2); performance metrics included 43.4±3.2 maximal oxygen uptake (VO2max; mL.kg.min), 22.4±7.1 CMJ height (cm) and 2575±565.2 CMJ peak power (W). Data showed strong correlations (r) (≥0.70) between PFT and VO2max scores (0.75), and moderate correlations (≥0.50) between CFT and VO2max scores (0.57), CFT and PFT scores (0.60), FFM and CMJ peak power (W) (0.68), and %BF to VO2max (−0.52), PFT (−0.54), CMJ-Ht (−0.52) and CMJ relative power (W/kg) (−0.54).

Conclusion Modern Marine women are both lean and physically high performing. Body composition is a poor predictor of general physical performance.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Physical readiness metrics have not been well studied in women.
⇒ Military women are strong and carry high lean mass.

WHAT THIS STUDY ADDS

⇒ High-performing Marine women averaged 30% body fat (5th–95th percentile: 20%–40%).
⇒ Body composition did not predict performance.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Study establishes 'ideal' body fat for healthy active women.
⇒ These values cannot be simply extrapolated from men.

INTRODUCTION

In 1918, the Secretary of the Navy authorised Women to join the Marine Corps in administrative roles, allowing more Marine men to fight in combat; Opha May Johnson became the first Woman to enlist, followed by hundreds of other women.[1] In 1942, the Secretary of the Navy authorised the creation of the Marine Corps Woman's Reserve and the Marine Corps enlisted nearly 19 000 women in officer and enlisted ranks; however, at the end of World War II, the Marine Corps Women's Reserve was disbanded.[2 3] Finally, the Women's Armed Services Integration Act of 1948 authorised women to serve in the regular Marine Corps, but still not in combat roles.[3–5] In 1994, the Direct Ground Combat Definition and Assignment Rule formalised restriction of women in any roles linked to direct ground combat, and this remained in effect for 20 years until the exclusion of women in combat roles was rescinded in 2013. In response to the rescission, the Marine Corps devised strict standards to ensure they did not sacrifice military readiness, but there were women who met these standards and by 2017, Private First Class (PFC) Maria Daum became the first woman to enlist into the Marine Corps infantry; Lieutenant Marina Hierl became the first woman commissioned officer to graduate from the USMC Infantry Officer

Table 1 Body composition measures of US Marine Corps women

	Mean±SD	Skewness	5th	10th	25th	50th	75th	90th	95th
Height (cm)	163.6±6.8	0.1	153.3	155.4	159.0	163.5	168.2	172.2	176.0
Body mass (kg)	68.3±9.2	0.5	54.3	56.8	61.8	67.9	74.1	79.6	83.7
FFM (kg)	47.5±5.7	0.5	39.0	40.5	43.5	47.2	51.0	54.9	57.2
Fat mass (kg)	20.8±6.4	0.8	11.5	13.2	16.2	20.5	24.7	29.1	31.7
Body fat (%)	30.1±6.4	0.0	19.2	21.7	25.2	30.1	34.7	38.4	40.6
BMC (kg)	2.58±0.3	0.5	2.04	2.18	2.36	2.54	2.77	2.99	3.17
BMD (gm/cm^2)	1.282±0.1	0.3	1.115	1.153	1.212	1.279	1.341	1.419	1.466
TBW (L)	33.9±3.9	0.3	27.8	29.3	31.2	33.6	36.6	38.9	40.5
%TBW/FFM	71.6±3.8	0.3	65.9	66.9	69.2	71.2	74.0	76.2	78.4
%BMC/FFM	5.5±0.5	0.4	4.7	4.9	5.1	5.4	5.8	6.0	6.2

Calculated from single frequency BIA (TBW).
BIA, bioelectrical impedance analyses; BMC, bone mineral content; BMD, bone mineral density; BMI, Body Adiposity Index; FFM, fat free mass; TBW, total body water.

Course, and the following year became the first Woman Marine to lead an infantry platoon.[5,6]

The progressively changing roles of Marine women have been coupled with an increased focus on sex-appropriate fitness and body composition standards that enhance and do not compromise physical readiness. For example, Marine women demanded that they be tested for time in a 3 mile run as the men were (instead of 1.5 miles) but this included sex-appropriate scoring. The changes in combat roles have caused changes in how women were selected and trained, and this has resulted in changes in body composition and performance capabilities of modern Marine Women. The Marine Corps has the lowest percentage of women at 9%, compared with the other services (Air Force 21.1%; Navy 20.4% and Army 15.5%).[7] That number continues to increase but, with a primary combat force mission, most Marine Corps jobs were not previously open to women and representation started from a smaller base. While early standards for Marine women enlistment were much simpler in the WWII era, to include height of ≥60 inches (152.4 cm), body mass (BM) of ≥95 pounds (40.8 kg), good vision and teeth[2]; modern standards are rapidly evolving as data driven, relevant to the current needs of the Corps and focused on optimisation of the force.[8] This manuscript characterises the body composition and physical performance of these elite women warfighters.

METHODS

Volunteers

From March 2021 to March 2022, a representative sample of Marine women were recruited from three locations, from within the National Capital Region (Quantico, Virginia, USA), Camp Lejeune, North Carolina, USA and Camp Pendleton, California, USA. Volunteer eligibility required individuals to be on active duty, to be medically cleared for physical activity, and not be pregnant at the time of study. Participants were provided a rapid pregnancy test to confirm absence of detectable pregnancy before study procedures (~3 uGy).

Seven hundred and thirty-six (n=736) Marine Women were enrolled into the study. The sample simple characteristics (mean±SD, ranges), were: age 29.5±7.3 (18–56) years, height 163.6±6.8 (131.0–186.1) cm, BM 68.3±9.2 (42.0–105.3) kg, years in the military 8.9±6.8 (0.5–37) years-in-service. This sample size represents nearly 5% of the entire active duty USMC population of women, which was achievable and representative, and matched

Table 2 Body circumference measures

	Mean±SD	r to %BF	Skewness	5th	10th	25th	50th	75th	90th	95th
Neck (NC; cm)	33.1±1.6	0.27	0.5	30.5	31.2	32.0	33.0	34.1	35.1	35.8
AB1 (WC; cm)	75.8±6.4	0.67	0.4	65.6	67.9	71.5	75.2	79.9	84.3	87.0
AB2 (cm)	79.1±7.4	0.66	0.4	68.0	70.6	74.1	78.5	83.7	88.9	91.7
AB3 (cm)	80.5±7.3	0.65	0.4	69.2	71.5	75.3	79.9	85.0	90.1	93.0
Hips (HC; cm)	100.4±6.6	0.66	0.1	89.6	91.7	96.0	100.4	105.0	108.5	111.0

Note: AB1 measures are used to describe WC. Pearson's correlation coefficient (r) to measured %BF by DXA.
%BF, per cent body fat; DXA, dual-energy X-ray absorptiometry; HC, hip circumference; NC, neck circumference; WC, waist circumference.

Table 3 Allometric indices

	Mean±SD	Skewness	5th	10th	25th	50th	75th	90th	95th
BMI (kg/m^2)	25.5±2.8	0.1	20.9	21.8	23.6	25.4	27.2	28.9	30.2
FFMI (kg/m^2)	17.7±1.5	0.4	15.2	15.8	16.7	17.6	18.7	19.6	20.4
WC/Ht	0.46±0.04	0.3	0.40	0.41	0.44	0.46	0.49	0.52	0.53
BAI	30.1±3.5	0.2	24.5	25.5	27.6	30.0	32.4	34.4	35.7

BAI, body adiposity index; BMI, body mass index; FFMI, Fat Free Mass Index; WC/Ht, waist circumference/height ratio.

approximately the age and ethnicity/race demographics of the force.

Study design

Anthropometric measures were obtained from for height (Ht; cm) and BM (BM; kg) using a stadiometer and calibrated electric scale (Seca, Chino, California, USA). An anthropometric measuring tape (MyoTape, AccuFitness, Denver, Colorado, USA) was used to obtain body circumference measurements in triplicate to report average measures from the neck, hips, as well as for three abdomen circumference measures (AB1, AB2 and AB3). The neck, AB1 (waist, WC) and hips circumferences (HC) form the basis of current Department of Defense estimation of female per cent body fat (%BF) for compliance with body composition standards. Neck circumference (NC; cm) measures were taken just below the laryngeal prominence. HC; cm measures were taken around the largest protrusion of the buttocks. Abdomen/WC measurements were taken from the narrowest circumference between the bottom of the rib cage and the iliac crest (AB1; cm), from the natural waist bisecting the navel (AB2; cm), and at the medial aspect of the iliac crest for (AB3; cm). For reporting, AB1 measures are used to describe WC; cm.[9–11]

Direct body composition measures for fat mass (FM), soft-tissue fat free mass (FFM) and bone were obtained from dual-energy X-ray absorptiometry (DXA) (iDXA, GE Healthcare, Madison, Wisconsin, USA), where data analyses relied on manufacturer supplied algorithms (Encore, V.13.5, Lunar, Madison, Wisconsin, USA).[12 13]

Following the DXA scan, each volunteer remained in a relaxed recumbent position on an insulated pad and were assessed using single frequency bioelectrical impedance analyses (SF-BIA) (Quantum IV, RJL Systems, Clinton Township, Michigan, USA). The SF-BIA assessed total body resistance, from electrodes placed on the left hand and left foot, using a 50 kHz current. This SF-BIA was used to estimate total body water (TBW; L) and provided a second confirmatory method estimating BF.[14]

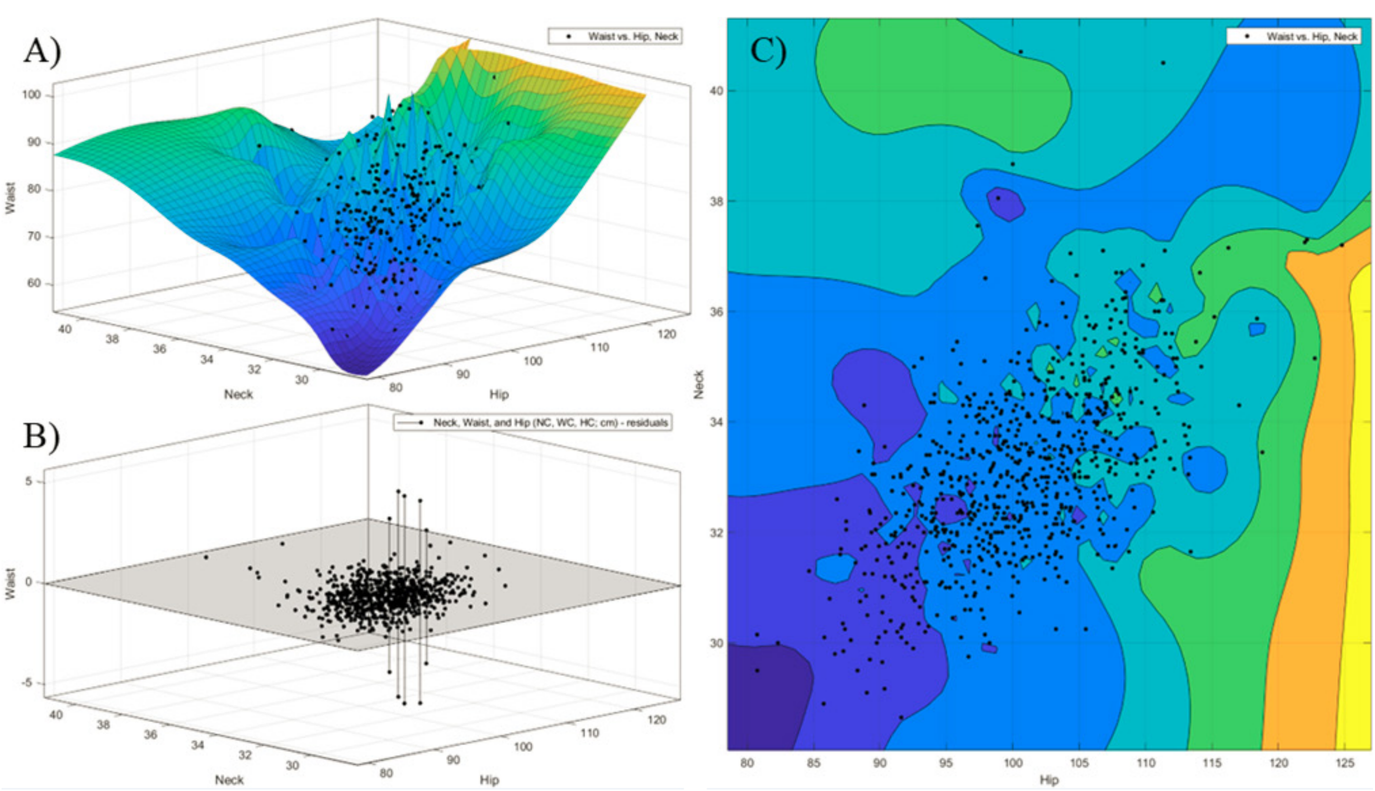

Figure 1 Surface plot (A), residuals (B) and two-dimensional relationships of body circumference measures from neck, hips and waist circumference (NC, HC, WC; cm) (C).

Physical Fitness Test (PFT) and Combat Fitness Test (CFT) scores and component measurements for each volunteer were provided based on most recent official records (≤6 months from testing). Calculations for both the PFT and CFT were each based on scoring of three components each for maximal scores of 300 (100-point potential for each component). The PFT scored three components included: (1) a time-based measure for a 3 mile run, (2) repetitions of pull-ups or pushups and (3) repetitions of crunches or timed planking. Calculation of CFT scores included: (1) a timed repetition for a 30 lb (13.6 kg) ammunition can lifted from the ground to overhead, (2) a timed 880-yard (804.7 m) sprint ('movement to contact') and (3) a timed movement over a 300-yard (274.2 m) obstacle course that included a series of military activities ('manoeuvre under fire').

Lower body force (peak power) and jump height was assessed via countermovement vertical jump (CMJ) while wearing socks without shoes, on a calibrated force platform (AMTI, Watertown, Massachusetts, USA). Volunteers first completed a standardised dynamic warm-up protocol prior to execution of study procedures, where they conducted 10 body weight squats, five progressive body weight squat jumps and three maximal body weight CMJs before data collection. Next, volunteers were asked to step onto the force platform and remain still for a period of 5 s. Volunteers were then asked to jump vertically for maximal height and land with both feet striking the platform simultaneously. Each volunteer was provided with a 1 min rest period after the warm-up and 15 s of rest between each of the three jumps. Raw data and processed calculations were captured using the commercial software (AccuPower Solutions). Calculated CMJ height (cm) based on flight time, peak power (W) and proportional power (W/kg) were reported.

Maximal oxygen uptake calculations

Calculations for individual maximal oxygen uptake (VO2max; mL.kg.min) were made based on recorded 3 mile run times using an adapted equation from Mello *et al*.[15] A scaled calculation from the original 2 mile run time equation was used, where the original for females was empirically set as 72.9–0.0295×runtime (in seconds) and then scaled for 3 mile run time as 72.9–0.0197×runtime. This conservative approach could be refined to include a decay factor for additional distance that would slightly increase the calculated VO2max per individual by an average of 1.08 mL.kg.min.[16]

Statistical analyses

Analyses were performed using a combination of SPSS (V.26, IBM, Chicago, Illinois, USA), MATLAB (2019b, The MathWorks, Natick, Massachusetts, USA) and Excel (Microsoft Corporation, Redmond, Washington, USA). Descriptive data are presented with statistics for normality, means, SD and percentile distributions. Additionally, comparisons of accuracy between methods are conducted using calculated bias, root mean squared error, mean absolute error and Pearson's correlation coefficient (r).

RESULTS

Sample descriptive statistics (mean±SD, skewness, percentiles) are shown for body composition determined by DXA, and TBW determined from SF-BIA (table 1). It is notable that the mean and median relative %BF is ~30% but with a wide range of 20% between 5th (19.2%) and 95th (40.6%) percentiles for this active physically fit cohort. Bone mineral content was >5% of the total FFM. SF-BIA calculated TBW averaged 71%–72% of DXA-determined FFM, consistent with textbook FFM hydration values.

Directly assessed body circumference measures are shown in table 2, to include each measures' univariate correlation with %BF. Table 3 validates the use of AB1 as a WC measure for use in evaluating or estimating %BF, having the higher r value of the three abdomen measures (r=0.67). Additionally, figure 1 shows a surface plot representation of the data NC, WC and NC, WC, HC; cm. Figure 1 shows these data as they are interrelated for each woman, but also highlighting the individual variabilities with these combined measures. Figure 1 explicitly shows individual variations and highlights the complication of using less than these three measures for estimates of individual characterisations (eg, anthropometry-based predictions of %BF currently used by the US Marine Corps[11]).

Computed indices of body mass index (BMI), Fat Free Mass Index (FFMI), WC/Ht and body adiposity index (BAI) are summarised in table 3. More than half of this sample had BMI; kg/m^2 >25 kg/m^2, implying that more than half of healthy fit Marine women would be classified as clinically 'overweight' by outdated national health guidelines; very few women in this sample would achieve >30 kg/m^2, the threshold for clinically 'obese' classification. Means and medians also indicate high FFMI (>17.5 kg/m^2) and low WC/ht ratio (0.46), describing large but lean women, with abdominal girths well below thresholds for both female and male classifications for obesity and metabolic syndrome.[17–21]

Comparisons of BMI, WC/Ht and BAI are plotted to %BF values from DXA (figure 2). There is a large scatter of individuals in the relationship between BMI and BAI to %BF by DXA with a SE of the estimate (SEE) of 4.89 %BF (BMI) and 4.89 %BF (BAI), highlighting the poor predictive value of these anthropometric indices for body composition. The WC/Ht relationship to %BF by DXA was linear within this relatively narrow range of %BF values although it would be expected to curve upward with increasing abdominal fat distribution in women with higher relative fat than the individuals represented by active duty Marine women (SEE=4.70 %BF). A threshold WC/Ht value of 0.5 is associated here with the higher end of 40%–45% BF.

Performance measures are outlined in table 4, to include calculated VO2max (ml.kg.min), PFT and CFT

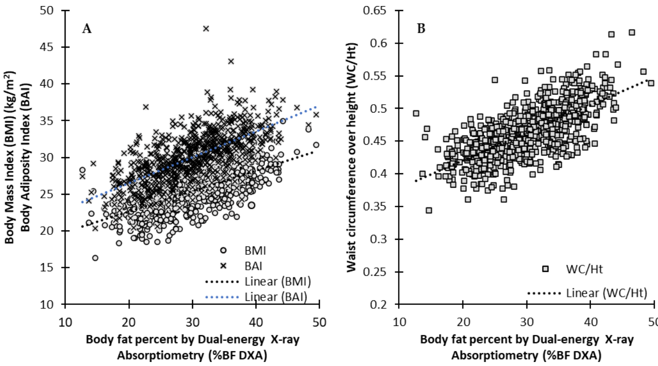

Figure 2 Comparison to %BF by DXA for BMI, BAI (A) and the ratio of WC/Ht (B).

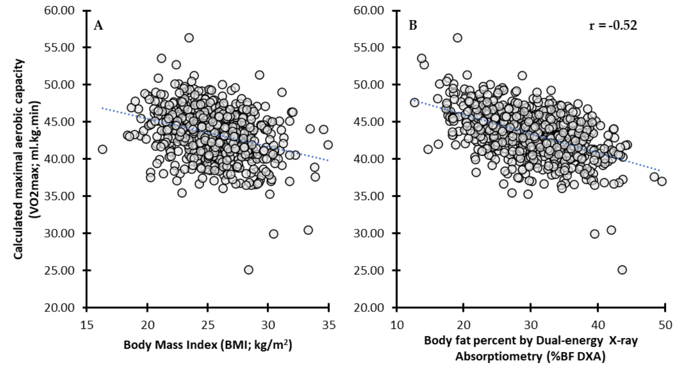

Figure 3 Comparison of calculated maximal oxygen uptake (VO2max) to BMI; kg/m^2 (A) and to %BF by DXA (B).

scores, and CMJ height (cm), peak power (W), and relative power (W/kg). Comparisons of VO2max to %BF and BMI are plotted in figure 3 and CMJ peak power to %BF and BMI are shown in figure 4. Figures 3 and 4 show there is only a minor observable relationship between both BMI and %BF to calculated VO2max values and CMJ peak power. Correlations (r) were calculated between each of the performance values to each other as well as to body composition measures from the DXA (%BF and FFM). A correlation matrix is shown in table 5, outlining strong correlations (≥0.70) between PFT and VO2max scores (0.75), moderate correlations (≥0.50) between CFT and VO2max scores (0.57), CFT and PFT scores (0.60), FFM and CMJ peak power (W) (0.68), and %BF to VO2max (−0.52), PFT (−0.54), CMJ-Ht (−0.52) and CMJ relative power (W/kg) (−0.54).

Age-matched comparisons of VO2max to reference values from the American College of Sports Medicine[22] and categorisation based on these references are shown in table 6. Table 6 shows nearly all the women in the sample (95.5%) had VO2max values characterised as 'superior', 'excellent' or 'good' by reference measures, of this a majority were either 'superior' or 'excellent' (71.7%), and only a minor portion were classified as 'poor' or 'very poor' (1.1%). Career Marine Corps women (ie, the older women in this sample) tended to have well-above average aerobic fitness.

Figure 5 shows comparisons of PFT and CFT scores for context compared with %BF. This shows the relatively low correlations of these measures to %BF (r≤−0.54; R^2≤0.30). While figure 6 shows the relationship between FFM and CMJ total power (W) and power relative to BM (W/kg). This shows the low correlation between FFM and relative power (W/kg) (r=0.27; R^2=0.07) but a moderate correlation to total power (W) (r=0.68; R^2=0.47)

DISCUSSION

This study represents a significant step towards characterising this uniquely fit population. Changes to the available military specialties for women have undoubtedly influenced the performance and body composition capabilities of this group but, unfortunately, there is no good earlier baseline against which to compare. The earlier cohorts of Marine women did not serve in combat roles, nor did they train for such roles, and they were even fewer in number. Additional assessments of the psychological and psychosocial profiles of this changing group could also provide unique insights into ideal selection, stressors and readiness of military women.[23 24]

The women in this study are representative of the modern Marine Corps with data collection at several main Marine Corps bases; nevertheless, this was a voluntary sample and not a mandated random selection of current active duty women. In an attempt maximise representative participation, volunteers were assured that their data and information would be kept confidential to the research team and not available to their military command. These data demonstrate healthy body composition values that are complemented by strong performance measures.

Table 4 Performance measures

	Mean±SD	Skewness	5th	10th	25th	50th	75th	90th	95th
VO2max (mL.kg.min)	43.4±3.2	0.4	38.1	39.2	41.4	43.5	45.6	47.3	48.4
PFT (0–300)	255.2±31.8	1.0	197.3	213.0	237.3	258.5	280.0	292.0	298.0
CFT (0–300)	278.7±21.8	1.3	236.8	249.0	267.0	285.0	297.0	300.0	300.0
CMJ—Height (cm)	22.4±7.1	0.8	12.5	14.5	17.4	21.6	26.0	31.8	35.6
CMJ—Power (W)	2575.0±565.2	0.6	1716.4	1898.9	2184.3	2510.2	2933.2	3327.4	3606.5
CMJ—Power (W/kg)	37.4±7.3	0.5	26.6	29.2	32.3	36.5	41.8	47.7	51.1

CFT, combat fitness test; CMJ, countermovement jump; PFT, physical fitness test; VO2max, maximum oxygen upake.

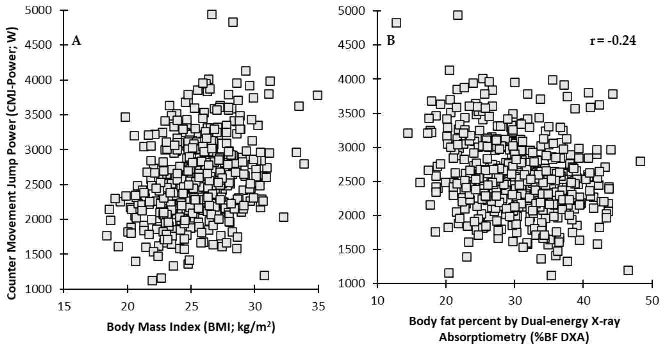

Figure 4 Comparison of CMJ-Power to BMI; kg/m^2 (A) and %BF by DXA.

Comparisons to the civilian populations confirm that the majority of these high-performing women boast high aerobic fitness (via runtimes and calculated VO2max values) as well as power-based performance scores (via CMJ and CFT events). A planned second study at bases in Okinawa, sampling Marines preparing for actual deployment or returning from recent deployment, may reveal an even stronger leaner cohort of women.

One of the significant findings from this work is the weak correlation between body composition and many of the performance measures. Reasons for this likely include the fact that the majority of these women are leaner and fitter than the general population, with a narrower range or more homogeneous body composition and physical performance capacity. These relationships would become stronger in a more diverse civilian population, justifying current US Marine Corps body composition standards that prevent obesity by motivating regular physical training and good nutrition habits but also attempt to select individuals within a range of body composition consistent with good physical performance. Thus, this sample of women trained and preselected by existing physical standards would not be the appropriate test sample to establish new physical readiness standards (ie, body composition and PFT standards).

Height and weight (eg, BMI) poses a challenge when used as an initial screening step to estimate body composition also when its use as a screen becomes conflated with assumptions about BMI relationship to performance of military women. The challenge with use of allometric indices for assessing athletes and military personnel are well documented from a body composition perspective[25–28]; however, specific research by Kelly and Jameson[29] showed Marine women with larger body size by BMI, on average, actually performed better than smaller women. While aerobic performance is generally inversely associated with both %BF and BMI,[8 30 31] it has also been observed that larger BM individuals typically perform well on many military performance tasks which generally have a strength component.[9 26] An inter-related element that makes body composition a challenge to correlate to performance, is that typically larger body size can translate to an available allowance for more muscle (eg, fat and muscle travel together).

Marine Corps body composition standards for women prior to these studies required an initial assessment of height and weight, to be within a BMI of ≤26.0 kg/m^2. Women who exceeded this BMI would then be assessed for %BF using a circumference-based method (the 'tape test'); where the criteria based on four age groups were 26% (ages 17–25), 27% (ages 26–35), 28% (ages 36–45) and 29% (ages 46 and older).[11] Women who had high PFT and CFT scores (250–284 for both) were given an additional 1 %BF or could be exempt of standards if they recorded superior PFT and CFT scores (≥285 for both).[11] Following the initial results of the parent study analyses, Marine Corps leaders formalised policy changes to increase the %BF allowance for women by an additional 1% for each age group and changed the assessment methods for evaluating individual body composition to standards from the circumference-based 'tape test' to a measure by an approved DXA or multifrequency BIA device.[32] Current studies are further evaluating the thresholds for %BF of fit and physically capable women as

Table 5 Correlation matrix between performance measures and key body composition variables (relative body fat (%BF), fat free mass (FFM; kg) and bone mineral content (BMC; kg))

	VO2Max	PFT	CFT	CMJ-Ht	CMJ-Power		%BF	FFM	BMC
	mL.kg.min	0–300	0–300	cm	W	W/kg	%	kg	kg
VO2Max (mL.kg.min)	1.00								
PFT (0–300)	0.75	1.00							
CFT (0–300)	0.57	0.60	1.00						
CMJ-Ht (cm)	0.23	0.31	0.29	1.00					
CMJ Power (W)	0.11	0.14	0.24	0.74	1.00				
CMJ Power (W/kg)	0.22	0.29	0.29	0.91	0.81	1.00			
%BF	0.52	0.54	0.47	0.52	0.24	0.54	1.00		
FFM (kg)	0.19	0.16	0.31	0.27	0.68	0.27	0.26	1.00	
BMC (kg)	0.09	0.07	0.21	0.11	0.46	0.10	0.09	0.76	1.00

CFT, combat fitness test; CMJ, countermovement jump; PFT, physical fitness test.

Table 6 Age-match maximal oxygen uptake (VO2max) categorisation and incidence by reference standards

		Proportions by age group			
		Ages <30	30–39	40–49	50+
	Total proportion	n=399	n=261	n=68	n=8
Superior	21.8%	14.5%	26.2%	41.2%	100%
Excellent	49.9%	48.0%	53.7%	51.5%	0%
Good	23.8%	31.9%	16.0%	7.4%	0%
Fair	3.4%	4.8%	2.0%	0.0%	0%
Poor	0.7%	0%	2.0%	0.0%	0%
Very poor	0.4%	0.8%	0.0%	0.0%	0%

Note: VO2max in mL.kg.min.

the Marine Corps continuously seeks to optimise physical readiness standards. The performance-based allowances for %BF highlight the Marine Corps' practical view of the role of BF standards in support of physical readiness. Additionally, these performance incentives have the potential benefit of inspiring positive behavioural changes related to nutrition and/or exercise.

Tables 1 and 3 show the distribution of body composition measures that are currently regulated within the Marine Corps standards (ie, %BF in table 1 and BMI in table 3). Comparisons of these percentile distributions to existing standards show a portion of Marine women to be currently outside of these standards for both %BF and BMI; as the %BF over the standard falls at the 50th percentile (30.1% vs 30% standard) and BMI at the 75th percentile (27.2 vs 26 standard). However, it is important to note that exemptions/allowances for higher performance scores make this more difficult to interpret. The sliding scale for body composition standards based on demonstrated physical performance addresses the individual variability between body composition and physical readiness.

Table 5 and figure 6 highlight the important relationship between FFM and performance. In the study we saw a moderate correlation (r=0.68) between FFM and CMJ peak total power (W). The military has focused on limits of %BF as a key metric in their readiness standards; while lean mass is not fully addressed within standards.[33]

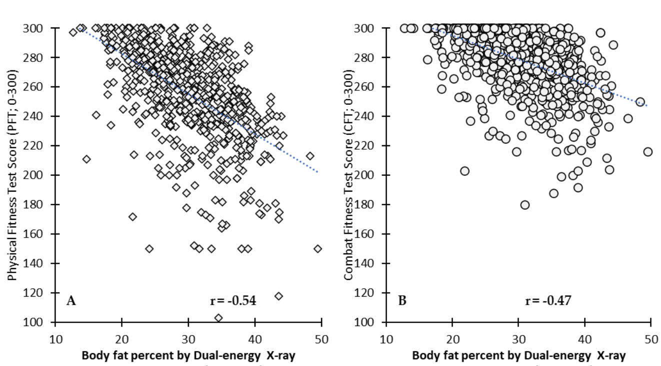

Figure 5 Comparison of PFT scores (A) and CFT scores (B) to %BF by DXA.

However, lean BM or FFM, is critically important as a body composition predictor of military performance and readiness. Harman *et al*[34 35] suggested from his data in a landmark study on women's strength training that there was a lower limit of lean BM associated with trainability in women. This is supported in figure 6, where there is a low relationship to relative power (W/kg) and a higher relationship to total peak power (W). This points to the potential importance of lean mass in women, as many military jobs have strength components and require strength capability, and trainability is related to lean mass. At the lowest end of this spectrum, are the individuals with low BM but potentially even lower associated lean BM to fat ratio (ie, metabolically obese normal weight, 'skinny fat'), when musculoskeletal injury rates may be more prevalent.[36 37]

In keeping with their strong focus on military readiness, the US Marine Corps is continuously reassessing training and selection standards to have a force that is optimised to deploy anywhere in the world on short notice. Body composition and fitness is evolving as Marine women train harder and differently than they used to and as physique changes with greater intensity and volume of strength and endurance training.[38] With more complete female integration into Marine Corps training and roles, further changes in average physical fitness and

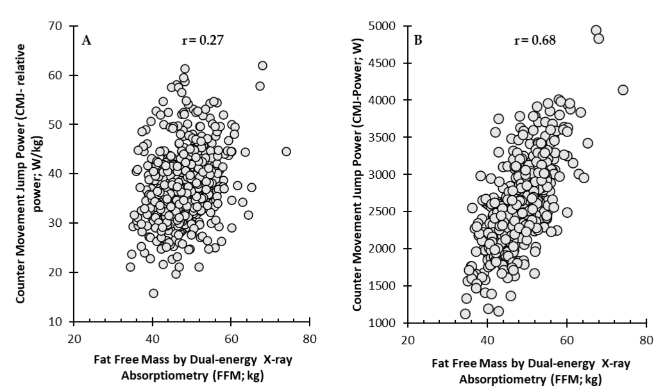

Figure 6 Comparison of CMJ relative power (W/kg) (A) and total power (W) (B) to fat free mass (kg) by dual-energy X-ray absorptiometry.

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physical performance of Marine women can be reasonably predicted. With current trajectories for obesity in the civilian population, the differences between Marine women and civilian women can also be predicted to increase. For women in this sample, 'lean' is represented by an average 30% BF with a 5th–95th percentile range of 20%–40% BF; for the US civilian population based on NHANES data, the mean is closer to 40% BF.[8]

CONCLUSIONS

Modern Marine women are lean and physically high performing. There is a low correlation between relative BF and performance measures of these Marine women. Body composition is a poor predictor of physical performance, especially in a relatively homogeneous group like this (non-obese strong women) but there are associations between these factors, where %BF is inversely related to strength, while FFM shows the opposite relationships. Marine women achieve a happy medium of optimised well-rounded physical performers ready to perform the mission of the US Marine Corps.

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