Published in final edited form as:

J Strength Cond Res. 2015 February ; 29(2): 290–296. doi:10.1519/JSC.0000000000000729.

Muscle Size, Quality, and Body Composition: Characteristics of Division I Cross-Country Runners

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Abstract

The primary purpose was to identify the relationship between muscle cross sectional area (mCSA), echo intensity (EI), and body composition of Division I cross-country runners. The secondary purpose was to examine differences in these variables in athletes stratified based on stress fracture (SFx) history. Thirty-six athletes were stratified based on sex and previous SFx history. A panoramic scan vastus lateralis (VL) was performed using a GE logiq-e B-mode ultrasound (US). Echo intensity and mCSA were determined from the scan by using a grayscale imaging software (Image-J). Body composition measures were determined using dual-energy xray absorptiometry (DEXA). For females, mCSA was significantly correlated with left leg lean mass (LM; $R=0.54$) and EI ($R=-0.57$). Lean mass was significantly correlated with bone mineral density (BMD; $R=0.58$) and content (BMC; $R=0.56$), while BMC was also correlated with leg LM ($R=0.72$). For males, mCSA was significantly correlated with leg LM ($R=0.66$), BMD ($R=0.50$), and BMC ($R=0.54$). Leg LM was significantly correlated with BMD ($R=0.53$) and BMC ($R=0.77$). Personal best times for males were significantly correlated with FM ($R=0.489$) and %fat ($R=0.556$) for the 10 kilometer and 5 kilometer races, respectively. Female and male athletes with previous history of SFx were not significantly different across any variables when compared to athletes with no previous history. These correlations suggest more muscle mass may associate with higher BMD and BMC for stronger bone structure. Modifications in training strategies to include heavy resistance training and plyometrics may be advantageous for preventing risk factors associated with stress fracture reoccurrence.

Keywords

ultrasound; sex; lean body mass; dual x-ray absorptiometry

INTRODUCTION

In high volume sports, such as long distance running, overuse injuries can keep an athlete out of play for long periods of time or be season ending (16,29). Incidences of lower-extremity injuries in distance runners and track athletes have been reported to range from

3.4% to 39.3% with injuries of the lower leg to be the most common, and injuries of the ankle and hip/pelvis less common (10). Stress fractures (SFx) in this population are serious overuse injuries that typically occur in the foot and lower leg. Early detection of risk factors by coaches, athletic trainers, and practitioners may enable quicker treatment, return to play, and prevention of more serious musculoskeletal injuries through strength training in athletes (24). Previously identified risk factors for musculoskeletal injuries have included: previous injuries, disproportionate increases in training volume, nutritional deficiencies, and hormonal irregularities. Several of these risk factors may be difficult to identify for professionals working with athletes (3,10). Expanding on the physiological norms for high-volume athletes may help identify more common-sport specific considerations for musculoskeletal injury.

Measuring muscle characteristics with an ultrasound (US) may assist in identifying athletes at risk for injury and for tracking changes during rehabilitation. These measurements are also low cost, have no health risks, and are easy to apply in clinical assessments (25). In comparison to other muscle characteristic measurements, US devices are portable, and are commonly found in clinical and training facilities. To evaluate muscle quality, muscle cross-sectional area (mCSA) and echo intensity (EI) can be measured by ultrasound imaging where mCSA is a direct measure of muscle thickness (25). Echo intensity is measured using a brightness scale of an ultrasound image and may indicate muscle quality through a gray scale analysis estimating intramuscular fat and connective tissue (9). An increase in intramuscular fat and connective tissue, and a decrease in muscle fiber size and number may increase risk of injury and decrease functionality (6). Determining muscle size and quality may help professionals working with athletes identify an appropriate resistance training program to help improve athletic performance and injury prevention by improving muscle size and quality. Ultrasound measurements of mCSA and EI have been demonstrated as reliable and effective methods for analyzing muscle characteristics (7,19). Previous research has also shown that mCSA and EI are correlated to muscle strength and power, and are a measure of muscle quality (1,6,26). To date, no research has examined these muscle characteristics in cross-country athletes.

Dual-energy X-ray absorptiometry (DEXA) is a commonly used three-compartment model to evaluate body composition and is highly correlated to a more sophisticated six-compartment criterion (30). Using DEXA to obtain an accurate measure of body composition may be beneficial for identifying athletes at higher risks for injury and for tracking changes of lean mass during rehabilitation. Previous studies have used DEXA to evaluate the relationship between body composition and SFx in runners (4), but have not identified strong predictors due to varied body composition results. Kelsey et al. (2007) demonstrated lower lean mass and bone density was associated with an increased rate of SFx in female runners. In contrast, no significant differences in bone mass or body composition were linked to increased incidence of stress fractures in males (4).

Body composition measurements and quantifying muscle characteristics may be useful tools for professionals working with athletes. To date there is little research examining the relationship of muscle characteristics and body composition in cross-country runners, and no studies to our knowledge that further evaluate those with or without a history of stress

fractures. Therefore, the primary purpose of this study was to identify the relationships between mCSA, EI, and body composition in male and female Division I cross-country runners. The secondary purpose was to examine differences in these variables in athletes stratified based on previous SFx history.

METHODS

EXPERIMENTAL APPROACH TO THE PROBLEM

Each subject participated in one testing session lasting thirty minutes prior to training camp beginning (early August). At the time of testing, all athletes were not training with the team for the two months prior in the summer off-season. Subjects reported to the laboratory two hours fasted and did not participate in exercise for a minimum of two hours prior to testing. Upon arrival, height was measured using a stadiometer (Perspective Enterprises, Portage, Michigan, USA), weight was measured using a digital scale (Health-o-meter, McCook, Illinois, USA), and a questionnaire was given about exercise, diet status, and injuries to ensure the following of pre-assessment guidelines. Muscle characteristics were measured using a GE logiq-e B-mode ultrasound from a panoramic scan of the VL to determine muscle cross-sectional area and echo intensity. Body composition was measured with a whole body DEXA scan to determine bone mineral content (BMC), bone mineral density (BMD), fat mass (FM), lean mass (LM), segmental LM, and body fat percentage (%fat).

SUBJECTS

Twenty-one male (Mean $\pm$ SD; Age 19.7 ± 1.2 yrs; Height 178.7 ± 5.2 cm; Weight 67.7 ± 4.9 kg) and fifteen female (Age 19.3 ± 1.3 yrs; Height 165.3 ± 7.0 cm; Weight 53.6 ± 5.2 kg) Division I cross country athletes participated in this study. Prior to testing, all subjects signed an informed consent approved by the University's Biomedical Institutional Review Board for the protection of human subjects. Subjects were stratified first by sex and secondly by stress fracture history; previous stress fractures were diagnosed by a physician using an X-ray or MRI and were then reported by their Athletic Trainer (SFx; female $n=9$; male $n=4$), and no previous SFx (female $n=6$; male $n=17$). Stress fracture sites included the foot, tibia, femur, and sacrum. Descriptive statistics on subject groups are presented in Table 1. Personal best race times were recorded for the season following testing. For the men, 5 kilometer (5K) times averaged $15:22.34 \pm 27.14$ sec and 10K times averaged $31:32.17 \pm 82.96$ sec, while for the women, 5K and 6K times averaged $18:13.14 \pm 37.84$ sec and $21:58.58 \pm 58.16$ sec, respectively.

PROCEDURES

Ultrasound—Muscle cross sectional area (mCSA) of the vastus lateralis (VL) was determined using a GE logiq-e B-mode ultrasound (GE Healthcare, Wisconsin, USA) from a panoramic scan of the VL. The ultrasound settings (Frequency: 26 Hz, Gain: 68, Depth: 4.5 cm) were kept consistent for each scan. Prior to the scan, the subjects laid supine for 5 minutes. During the measurement, the right leg was extended and relaxed on the examination table with a foam pad strapped to the midpoint of the thigh to standardize measurements. The ultrasound probe (GE: 12L-RS) was held perpendicular to the tissue and swept across the skin at equal pressure from the lateral VL border to the medial fascia

separation. The same technician performed each scan. Echo intensity was determined from the panoramic scan by using a grayscale imaging software (Image-J, National Institute of health, USA, Version 1.37) in the standard histogram function of pixels ranging from 0 to 255 (Figure 1). Prior to measurement of EI, each image was calibrated by measuring the number pixels within a known distance of 1 cm. To measure EI, the same technician traced the outline of each subjects' VL along the fascia border to only capture the muscle as seen in Figure 1. Muscle characteristics test-retest reliability in our lab for EI were ICC=0.74 and SEM=4.58 and for mCSA were ICC=0.87 and SEM=2.12.

Dual-energy X-ray Absorptiometry (DEXA)—Each subject had a full body DEXA scan (Hologic Discovery W, Bedford, MA, USA; Apex Software Version 3.3) performed by the same trained DEXA technician. Prior to testing, subjects were asked to remove all metal, thick clothing, and heavy plastic to reduce interference with the scan. Age, height, weight and ethnicity were entered into the computer and subjects were placed supine in the center of the scanning table. Bone mineral content (BMC), bone mineral density (BMD), fat mass (FM), lean mass (LM), leg lean mass (leg LM), and body fat percentage (%fat) were determined using the DEXA. According to the World Health Organization (2), low BMD was identified by Z scores of ≥ 1 SD below healthy individuals of the same age. DEXA test-retest reliability in our lab were ICC=0.98 and SEM=0.85 for FM, ICC=0.99 and SEM=1.07 for LM, and ICC=0.98 and SEM=1.06 for %fat.

STATISTICAL ANALYSIS

A Pearson Product correlation was used to determine relationships between BMC, BMD, FM, LM, leg LM, %fat, mCSA, EI, and performance times. Separate one-way analyses of variance (ANOVAs) were used to analyze variables between previous SFx and no previous SFx for these variables in all subjects. All analyses were run using SPSS (Version 20, IBM, Armonk, NY, USA) with an alpha level of $p < 0.05$.

RESULTS

Body Composition and Muscle Characteristics Relationships

For the male cross-country athletes, weight was significantly correlated with leg LM ($R=0.89$, $p < 0.05$), right leg LM (0.87 , $p < 0.05$), left leg LM ($R=0.09$, $p < 0.05$), mCSA ($R=0.55$, $p=0.01$), BMD ($R=0.53$, $p=0.01$), and BMC ($R=0.77$, $p < 0.01$). Muscle CSA was significantly correlated with leg LM ($R=0.66$, $p=0.001$), right leg LM ($R=0.65$, $p=0.001$), left leg LM ($R=0.65$, $p=0.002$), BMD ($R=0.50$, $p=0.02$), and BMC ($R=0.54$, $p=0.01$). Leg LM was significantly correlated with BMD ($R=0.53$, $p=0.01$) and BMC ($R=0.77$, $p < 0.01$; Table 2). Higher personal best racing times for males in the 10K race were significantly positively correlated with FM ($R=0.489$, $p=0.042$) and 5K race times were also significantly correlated with %fat ($R=0.556$, $p=0.02$).

For female athletes, weight was significantly positively correlated with FM ($R=0.76$, $p=0.001$), BMC ($R=0.80$, $p < 0.05$), leg LM ($R=0.75$, $p=0.001$), right leg LM ($R=0.71$, $p=0.003$), and left leg LM ($R=0.77$, $p=0.001$). Muscle CSA was significantly positively correlated with left leg LM ($R=0.54$, $p=0.03$) and negatively correlated with EI ($R= -0.57$,

$p=0.02$). Lean mass was significantly correlated with BMD ($R=0.58$, $p=0.23$) and BMC ($R=0.56$, $p=0.32$), while BMC was also correlated with leg LM ($R=0.72$, $p=0.002$), R leg LM ($R=0.68$, $p=0.006$), and left leg LM ($R=0.74$, $p=0.001$; Table 3). Racing times for females were not significantly correlated with any variables.

Stress Fracture Comparisons

Male athletes with previous history of SFx were not significantly different compared to athletes with no previous history in any variables (Table 3). In males with no SFx history, mCSA was significantly correlated with weight ($R=0.57$, $p=0.18$), leg LM ($R=0.68$, $p=0.003$), right leg LM ($R=0.69$, $p=0.002$), and left leg LM ($R=0.654$, $p=0.004$). Weight was significantly correlated with leg LM ($R=0.88$, $p<0.05$), right leg LM ($R=0.87$, $p<0.05$), and left leg LM ($R=0.87$, $p<0.05$) in males without SFx, but was not significantly correlated in males with previous history of SFx. In males with SFx history, mCSA was significantly correlated with leg LM ($R=0.98$, $p=0.02$), right leg LM ($R=0.98$, $p=0.019$), and left leg LM ($R=0.97$, $p=0.03$).

Female athletes with previous history of SFx were not significantly different compared to athletes with no previous history in any variables (Table 4). In females with no SFx history, mCSA was significantly correlated with LM ($R=0.92$, $p=0.01$), but was not significantly correlated in females with SFx. When comparing personal best racing times females with no SFx, 6K times were positively correlated with EI ($R=0.978$, $p=0.022$). Females with previous SFx, 6K times were negatively correlated with mCSA ($R=-0.783$, $p=0.037$), and 5K times were significantly correlated with %fat ($R=0.807$, $p=0.28$).

DISCUSSION

High volume repetitive-impact athletes have reported high rates of damage to the anatomical structures, resulting in musculoskeletal and bone injuries (12,25). In the current study of Division I cross-country athletes, there was a strong relationship between lean mass, muscle size, and bone integrity (BMC, BMD). For men, mCSA was moderately correlated with body mass, leg LM, right and left leg LM, BMD, and BMC. Performance times for men demonstrated slower times correlated with a higher FM and %fat. For women, LM was moderately correlated with BMD and BMC, while mCSA had a moderate relationship with left leg LM, and was inversely correlated with EI. Performance times for women had no significant correlations with muscle characteristics and body composition; however there were significances when stratified by SFx history. Overall, the current study demonstrates a potential support for improving muscle size and quality for improving athletic performance and injury prevention (23). As a result, measuring muscle characteristics, in addition to body composition, may be an important tool to utilize for identifying injury risk in high-volume athletes.

Use of ultrasound to evaluate muscle characteristics has recently emerged as a valid and useful tool for characterizing athletes (20). Previous data suggests that muscle characteristics, measured by the ultrasound, may be valuable in determining physiological differences amongst strength and size of muscle (21). A higher EI and smaller muscle size has previously been associated with greater intramuscular fat and connective tissue (26).

Previous research supports the trend reported in the current study, demonstrating a negative relationship between EI and muscle thickness in females ($R = -0.57$), which may suggest muscle size and quality both factor into muscle strength (9). Although not significant, mCSA and EI also had a negative relationship in males ($R = -0.25$, $p = 0.27$). Data supports a benefit from increasing muscle mass, specifically in the lower body, due to the ability to absorb forces transmitted to bone during running (31). In a study examining male endurance runners and sprinters, muscle strength was significantly correlated with lean body mass and mCSA (18). Similarly in the current study, mCSA was significantly correlated with leg LM in males ($R = 0.66$), but only significantly with left leg LM in females ($R = 0.54$). Left leg LM may have had a stronger association due to consistent track work with the inside leg (left leg) taking more stress on corner turns of the track.

Quantifying body composition of athletes has been shown to be a beneficial determinant for health and performance (17). In the current study, slower male 5K and 10K race times were significantly correlated to higher %fat and FM values. BMC was significantly correlated with LM and leg LM in females and leg LM in males. Previous research in female distance runners also demonstrated a high correlation between BMC and lean body mass (12). Low BMC and BMD are risk factors for lower extremity overuse injuries in athletes, as well as the ratio of fat mass to BMC (27). To help increase BMD, BMC, lean mass, and lower fat mass, a plyometrics and resistance training program should be included. High impact exercise has been shown to increase bone formation, whereas running on a treadmill was unable to augment bone growth (11). Fat mass alone in the current study was only strongly correlated with weight in females ($R = 0.76$), while body fat percentage had no significant associations for females or males. Agreeably, Kelsey et al. (2007) also demonstrated little association between body fat percentage and other body composition variables in female runners. Body composition has been shown to be a potential predictor for injury risk in other types of athletes (20), with a few investigations in runners (4). Previous data suggest lower body weight may be a significant risk factor for injury in male track and field athletes (24). While in females, lower total lean mass was significantly associated with risk of injury (12). In the current study, lean mass in the legs had the strongest association with bone integrity. Additionally looking at males and weekly mileage, runners at 60-75 miles/week were significantly lower in weight compared to lower mileage runners, while still having similar BMD (15). In agreement, weight in the current study was strongly correlated with BMC and BMD for both males and females.

The secondary purpose of the current study was to evaluate differences in measureable physiological variables between athletes with and without stress-fracture history. Stress fractures are a common injury in high-volume athletes, specifically in distance runners (19). A variety of factors have been established for identifying high risk individuals for stress fractures, such as low BMD, nutritional deficiencies, menstrual irregularity in females, and previous stress fractures (12). However, several of these risk factors are not easily identifiable by a practitioner working with large numbers of collegiate athletes. In the current study, males who had previous SFx demonstrated lower weight (mean difference [MD] = -2.7 kg), FM (MD = -0.6 kg), EI (MD = -2.3 a.u.) and mCSA (MD = -1.4 cm²) values compared to males with no history of a stress fracture. Agreeably, lower body weight was reported as a significant risk factor for stress fractures in male track and field athletes

(24). In contrast, other previously reported risk factors were not significantly different between the two groups in the current study, including BMI, BMD, leg LM, and %fat. Bennell (1996) also demonstrated differences in bone mass or body composition were not linked to increased incidence of stress fractures (4). In females with previous SFx in the current study, FM and %fat were higher (MD= 0.8 kg; MD= 0.6 kg), and mCSA was lower (MD= -1.1 cm²) compared to no stress fracture history. In contrast, previous data suggest a lower %fat in athletes, as well as a higher fat to bone mineral content ratio are reported risk factors for SFx (5,21). In previous research, less lean mass in the lower limb was a significant factor for increased occurrence of stress fractures in females (4). Conversely, both males and females with previous SFx reported no significant difference in LM values when compared to the no SFx history group. However, US values of mCSA detected a potential muscle size difference between groups, with previous SFx group yielding a smaller mCSA. Additionally, slower running times were associated with a smaller mCSA and higher %fat in females with previous SFx, and a lower muscle quality in females with no SFx history.

According to Magness et al. (2011) there are two major types of SFx: fatigue fractures caused primarily from overstress, and insufficiency fractures caused primarily by low BMD. In the current study, there were no significant differences in BMD for males or females. Females with SFx history tended to have lower BMD and Z-scores (Table 4). A full-body DEXA scan was used to determine whole-body BMD in the current study, whereas many studies have used regional BMD such as foot, hip, or spine. Kelsey et al. (2007) measured BMD at the proximal femur, spine, and whole body, with all sites being highly correlated with risk of stress fractures. These results suggest site-specific measurements could be beneficial to runners, but whole body BMD may also have utility for identifying stress fracture risk and lean mass, within the same scan. Additionally, BMD and BMC values are often found to be normal in comparison to age-matched device norms (8,14,21,25). Including a year-round resistance training program in addition to a running program may be beneficial for increasing BMD. Previous data suggests that an 8-week resistance training program combined with aerobic training resulted in increases BMD of the distal tibia (14). Utilizing additional physiological variables like body composition and muscle size, may be helpful to characterize these athletes according to others sport-specific norms.

The results from this study expand on previous literature identifying relationships between muscle characteristics and body composition in runners. In the current study of Division I cross-country athletes, there was a strong relationship between lean mass, muscle size, BMC, and BMD. For men, mCSA was correlated with body mass, leg LM, right and left leg LM, BMD, and BMC. For women, mCSA had a moderate relationship with left leg LM, and was inversely correlated with EI. Although once stratified for sex and SFx history there were no significant differences, there were trends for males with previous SFx to have lower weight and mCSA, and females with previous SFx tended to have lower mCSA, and higher FM and %fat. These relationships demonstrate a potential support for improving muscle size and quality for improving athletic performance and injury prevention for the reason that increases in intramuscular fat and connective tissue, and decreases in muscle fiber size and number may increase risk of injury and decrease functionality (6). As a result, measuring muscle characteristics with an ultrasound, in addition to body composition, may be an

important tool for practitioners working with large numbers of collegiate athletes for identifying injury risk in high-volume athletes.

PRACTICAL APPLICATIONS

Results from this study indicate improving muscle size and quality may help prevent injury prevention and improve athletic performance. Muscle characteristics, measured by the ultrasound, may be valuable in determining physiological differences amongst strength and size of muscle (21). Ultrasound measurements have no health hazards, are portable, and are applicable to athletic trainers, strength coaches, and practitioners working with athletes. Most facilities already have the device in house, so these measurements are low cost, quick to perform and analyze, and may be helpful to identify athletes at risk for musculoskeletal injury. Whole-body DEXA is also valuable due to the ability to identify segmental differences in body composition. Combining ultrasound measurements with body composition results may be beneficial for coaches, athletic trainers, and practitioners to determine specific athlete training programs. In athletics, improving muscle quality and quantity can improve athletic performance and help prevent injury through a year-round, sport-specific resistance training program (23). Modifications in training strategies to include resistance training or plyometric training during the off season and in season, as well as ensuring appropriate nutritional and recovery strategies, may be advantageous for influencing risk factors associated with overuse injury occurrence. Future research evaluating the effects of a resistance training intervention, specifically targeting the lower body, coupled with athlete nutrition profiles would be beneficial to identify the potential reduction in these risk factors for distance runners.

Acknowledgements

We would like to acknowledge Rachel Stratton, RC, CSSD for her involvement in the study. The project described was supported by the National Center for Advancing Translational Science, National Institutes of Health, through Grant *1KL2TR001109*. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH. The results of this study do not constitute endorsement by the authors or the NSCA.

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Figure 1.
An example of using Image J software to outline the vastus lateralis to determine muscle cross sectional area and echo intensity.

Table 1Descriptive statistics for male and female athletes (mean $\pm$ SD).

Group	N	Age (yrs)	Weight (kg)	Height (cm)	BMI (kg·m ⁻²)	5k PR (min:sec)	6k PR (min:sec)	10k PR (min:sec)
Female No SFx	6	19.0 $\pm$ 1.3	52.3 $\pm$ 3.3	165.1 $\pm$ 4.2	19.2 $\pm$ 0.6	18:13.14 $\pm$ 0:37.84	21:58.58 $\pm$ 0:58.16	
Female SFx	9	19.4 $\pm$ 1.3	54.4 $\pm$ 6.3	165.4 $\pm$ 8.7	19.8 $\pm$ 1.0			
Male No SFx	17	19.8 $\pm$ 1.3	68.3 $\pm$ 4.6	179.2 $\pm$ 5.6	21.3 $\pm$ 1.3	15:22.34 $\pm$ 27.14		31:32.17 $\pm$ 1:22.96
Male SFx	4	19.8 $\pm$ 1.0	65.6 $\pm$ 6.3	176.7 $\pm$ 2.0	21.0 $\pm$ 1.3			

Table 2

Body composition and muscle characteristics relationships in male cross-country athletes. R values are presented.

	FM	Weight	LM	%fat	Leg LM	R Leg LM	L Leg LM	mCSA	EI	BMD	BMC
FM	1	0.37	0.09	0.89*	0.08	0.09	0.07	0.09	0.18	0.24	0.23
Weight		1	0.24	-0.07	0.89*	0.89*	0.89*	0.55*	0.02	0.53*	0.77*
LM			1	-0.02	0.23	0.19	0.27	-0.01	-0.05	0.09	0.16
%fat				1	-0.32	-0.30	-0.34	-0.13	0.18	0.01	-0.11
Leg LM					1	0.99*	0.99*	0.66*	-0.05	0.53*	0.77*
R Leg LM						1	0.96*	0.65*	-0.09	0.58*	0.77*
L Leg LM							1	0.65*	-0.01	0.48*	0.74*
mCSA								1	-0.25	0.50*	0.54*
EI									1	-0.36	-0.24
BMD										1	0.90*
BMC											1

* Significant at the 0.05 alpha level.

Table 3

Body composition and muscle characteristics relationships in female cross-country athletes. R values are presented.

	FM	Weight	LM	%fat	Leg LM	R Leg LM	L Leg LM	mCSA	EI	BMD	BMC
FM	1	0.76*	0.34	0.90*	0.23	0.20	0.25	0.03	0.27	0.14	0.40
Weight		1	0.51	0.41	0.75*	0.71*	0.77*	0.34	0.02	0.50	0.80*
LM			1	0.14	0.46	0.45	0.44	0.46	-0.10	0.58*	0.56*
%fat				1	-0.18	-0.18	-0.16	-0.18	0.39	-0.11	0.06
Leg LM					1	0.98*	0.97*	0.47	-0.26	0.45	0.72*
R Leg LM						1	0.90*	0.39	-0.29	0.52*	0.68*
L Leg LM							1	0.54*	-0.21	0.38	0.74*
mCSA								1	-0.57*	0.41	0.35
EI									1	-0.02	-0.04
BMD										1	0.85*
BMC											1

* Significant at the 0.05 alpha level.

Table 4

Mean $\pm$ SD of DEXA body composition and muscle characteristics for stress fracture subgroups. Low BMD is identified by Z scores of ≥ 1 SD below healthy individuals of the same age.

Measurement	Female SFx	Female No SFx	Male SFx	Male No SFx
Bone Mineral Density ($\text{g}\cdot\text{cm}^{-2}$)	1.0 $\pm$ 0.1	1.1 $\pm$ 0.1	1.2 $\pm$ 0.03	1.1 $\pm$ 0.1
Fat Mass (kg)	12.1 $\pm$ 2.6	11.3 $\pm$ 2.1	9.4 $\pm$ 1.2	10.0 $\pm$ 1.8
Lean Mass (kg)	39.6 $\pm$ 4.3	32.7 $\pm$ 14.3	52.7 $\pm$ 5.5	51.6 $\pm$ 12.5
Leg Lean Mass (kg)	14.4 $\pm$ 1.6	14.2 $\pm$ 0.9	19.2 $\pm$ 2.1	19.7 $\pm$ 1.7
Muscle Cross Sectional Area (cm^2)	16.9 $\pm$ 2.4	18.0 $\pm$ 1.8	20.4 $\pm$ 0.9	21.8 $\pm$ 3.4
Echo Intensity (a.u.)	77.2 $\pm$ 6.2	77.3 $\pm$ 5.5	67.3 $\pm$ 3.5	69.6 $\pm$ 6.8
Body Fat Percentage	22.5 $\pm$ 3.4	21.9 $\pm$ 2.9	14.5 $\pm$ 1.7	14.9 $\pm$ 2.5
Z-Score	-0.7 $\pm$ 1.1	-0.5 $\pm$ 1.3	-0.03 $\pm$ 0.4	-0.4 $\pm$ 0.9