HHS Public Access

Author manuscript

Int J Sports Med. Author manuscript; available in PMC 2016 November 17.

Published in final edited form as:

Int J Sports Med. 2015 November ; 36(13): 1087–1092. doi:10.1055/s-0035-1555781.

Body composition, muscle quality, and scoliosis in female collegiate gymnasts

Eric T. Trexler, **Abbie E. Smith-Ryan**, **Erica J. Roelofs**, and **Katie R. Hirsch**

Exercise and Sport Science, University of North Carolina, Chapel Hill, NC USA

Abstract

Research has demonstrated an elevated prevalence of body weight concerns and scoliosis among female gymnasts. The purpose of the current study was to evaluate relationships between body composition, muscle quality, and performance in female collegiate gymnasts (n=15), and to evaluate the prevalence of scoliosis. Dual-energy X-ray absorptiometry was used to evaluate body composition and lateral spinal curvature using a modified version of the Ferguson method. Echo intensity (EI) and cross-sectional area (CSA) of the vastus lateralis were determined from a panoramic cross-sectional ultrasound image. For returning athletes (n=9), performance scores from the previous season were averaged to quantify performance. Average performance score was correlated with lean mass of the arms (R=0.714; P=0.03) and right leg (R=0.680; P=0.04). Performance was not correlated with total mass, fat mass, or body fat percentage (P>0.10). Scoliosis was identified in three of fifteen scans (20%). Echo Intensity and CSA of the vastus lateralis were inversely correlated with each other (R= −0.637, P=0.01), but not with other measures of body composition or performance. Results suggest that limb LBM may be a determinant of performance in competitive gymnasts. It may be preferable for gymnasts to prioritize the accretion of LBM in the offseason.

Keywords

Dual-energy X-ray absorptiometry; body fat percentage; ultrasonography; spine; echo intensity

Introduction

In a number of sports, low body fat levels are thought to benefit performance by enhancing efficiency of movement, aesthetic presentation, or strength-to-mass ratio [5]. Gymnastics is one such sport, in which leanness is thought to provide aesthetic and biomechanical advantages [1,3,8]. Previous research has identified leanness as a contributor to success in gymnastics, with body fat (BF%) levels generally ranging from 13–16% amongst elite female gymnasts [3]. While much of the current body of gymnastics literature pertains to the international level of competition, Falls and Humphrey [8] observed significantly lower body fat in placers compared to non-placers in a collegiate gymnastics meet. Such observations may contribute to unhealthy weight loss practices in gymnasts. Research has documented an

Corresponding Author: Abbie E. Smith-Ryan, PhD, Assistant Professor, University of North Carolina, Chapel Hill, NC 27599, 919-962-2574, abbiesmith@unc.edu.

increased prevalence of eating disorders amongst athletes engaged in aesthetic sports [5], with a high prevalence of pathogenic weight control habits observed in collegiate female gymnasts [20,21]. In this population, Rosen and Humphrey [20] surveyed 42 athletes and found that 100% were currently attempting to diet, and two thirds had been told by a coach that they were too heavy. Sherman et al. [24] reported an inverse relationship between body mass index (BMI) and gymnastics performance, but described a curvilinear relationship in which excessively low BMI may hurt performance. In the interest of health and performance, it is important to investigate relationships between body composition and performance in female collegiate gymnasts.

If body composition influences gymnastics performance, assessments of body composition may be effective tools for improving health and performance in gymnasts. Body composition of gymnasts has previously been assessed using a number of methods, including dual-energy X-ray absorptiometry (DXA) [6,17]. In addition to providing reliable estimates of lean and fat mass, DXA may provide gymnasts with meaningful information pertaining to skeletal health, such as bone density and spinal curvature. Spinal health is a common concern amongst gymnasts, who display an increased prevalence of back injury and pain [13]. Tanchev et al. [26] reported an elevated prevalence (12%) of scoliosis in a sample of over 100 rhythmic gymnasts, while prevalence in the general population is estimated at roughly 1–3% [2,26]. Authors proposed that a triad of factors may contribute to this finding, including increased joint laxity, delayed growth and maturity, and chronic asymmetrical loading of the spine in gymnasts [26]. Meyer et al. [16] have questioned a causative relationship between gymnastics participation and scoliosis development, suggesting that individuals with greater joint laxity, which is associated with idiopathic scoliosis, may gravitate toward gymnastics and excel due to greater articular flexibility. Recently, Taylor et al. [27] validated a novel technique for identifying scoliosis using DXA. To our knowledge, this technique has not yet been applied to female gymnasts, and may offer a convenient method for simultaneously evaluating body composition and spinal curvature.

Ultrasonography has emerged as an imaging modality to quantify muscle size and quality. Research has identified ultrasonography as a reliable method of determining muscle cross-sectional area (CSA) and echo intensity (EI) using a panoramic cross-sectional scan of the muscle belly [15,19,22]. Echo intensity, a measurement of muscle quality, is determined by performing a quantitative grayscale analysis of the pixels within a muscle belly from the ultrasound image [18]. Adipose and connective tissue within a muscle belly result in a brighter image, which increases the EI value, indicating a lower degree of muscle quality [18]. Research has suggested that ultrasound measurements of muscle size and quality may relate to strength, power, and injury risk [4,10,19]. However, CSA and EI of the vastus lateralis (VL) were not significantly correlated with running times in collegiate cross country runners [19], and Melvin et al. [15] found no relationship between VL CSA or EI and starter status in collegiate football players. In collegiate soccer players, pre-season values of CSA and EI of the VL were not significantly different between starters and nonstarters [12]. To our knowledge, these measurement techniques have not been used in collegiate gymnasts, and may provide meaningful information to gymnasts interested in maximizing the strength-to-mass ratio.

The purpose of the current study was to evaluate relationships between body composition, muscle quality, and performance in female collegiate gymnasts, and to evaluate the prevalence of scoliosis in this population. It was hypothesized that leanness (BF%), lean body mass, CSA of the VL, and muscle quality would be associated with higher average performance scores. It was also hypothesized that the prevalence of scoliosis in this sample would exceed that of the general population.

Materials & Methods

Subjects

Female NCAA Division I gymnasts (n=15) participated in the current study. Participant descriptive characteristics are presented in Table 1. Research was conducted in accordance with international ethical standards [11]. All procedures were approved by the University's Institutional Review Board, and all participants signed an approved informed consent document prior to participation.

Experimental Design

The current study consisted of a cross-sectional evaluation of body composition and muscle quality. Participants completed one 30-minute testing session. Participants arrived to the laboratory two hours fasted and at least 12 hours post-exercise, where height and weight were measured upon arrival (Health-o-meter, McCook, IL, USA). Questionnaires evaluating health, exercise, and nutrition status were completed to verify compliance with pre-assessment guidelines. Dual-energy X-ray absorptiometry was performed to determine fat mass (FM), lean body mass (LBM), BF%, bone mineral density (BMD), bone mineral content (BMC), and to identify the presence of scoliosis. A brightness-mode (B-mode) ultrasound was used to perform a panoramic scan at the midpoint of the right thigh, and ImageJ software was used to determine CSA and EI of the vastus lateralis (VL). Data collection took place during the offseason (August); for a subset of returning athletes (n=9), performance data were obtained by averaging all reported scores for each event from the previous season.

Dual-Energy X-Ray Absorptiometry (DXA)

A whole-body scan was performed using DXA (Hologic Inc., Bedford, MA, USA). Participants removed all metal objects and other items that may have interfered with the scan, and were positioned in the center of the scanning table with their arms placed palm-down at their sides. Age, height, weight, sex, and ethnicity were entered into the computer, and the device's default software (Apex Software Version 3.3) was used to determine indices of body composition, including LBM, FM, BF%, BMD, BMC, trunk fat, legs LBM, arms LBM, and the LBM of each limb. Each scan was performed by the same certified DXA technician, and previous data from this lab indicate high test-retest reliability for FM (intraclass correlation coefficient (ICC)=0.98, standard error of measurement (SEM)=0.85 kg), LBM (ICC=0.99, SEM=1.07 kg), and BF% (ICC=0.98, SEM=1.06 %).

Evaluation of Spinal Curvature

Whole-body DXA scans were used to identify spinal curvature using methodology similar to Taylor et al. [27]. Each scan was examined offline to identify lateral curves in the spinal column. Scans with curvature were first evaluated for possibility of positioning error. Using Adobe Reader XI software (Adobe Systems Inc., CA, USA, Version 11.0.03), a single line was drawn from the pubic symphysis to the L5 vertebra, and extended to continue above the head and below the feet (Figure 1A). Positioning error was considered evident when the ankles, shoulders, or hips were not symmetrically aligned to the center line (Figure 1B). For scans in which positioning error was identified, curvature could not be attributed to the presence of scoliosis (n=2). For all other scans, the angles of lateral curves were measured using a modified version of the Ferguson method [9,27]. A normal spine line was drawn through the center of the spine, and a second line was drawn through the apex of the lateral curve. The angle tool of ImageJ software (National Institute of Health, MD, USA, Version 1.37) was used to measure the angle at the intersection of these lines; scoliosis was defined as a curvature of 10° or greater [27].

Ultrasound Measurements

A GE Logiq-E B-Mode ultrasound device (GE Healthcare, WI, USA) was used to determine CSA and EI of the VL. Prior to ultrasonography, participants laid supine with the right leg extended and relaxed for 3–5 minutes to allow fluid compartments of the leg to achieve balance. The midpoint of the thigh was defined as the midpoint between the inguinal crease and the proximal patella. A foam pad was placed at this location to standardize measurements. A small amount of ultrasound conductive gel was applied to the leg, and the ultrasound probe (GE: 12L-RS) was held perpendicular to the tissue and swept from the lateral border of the VL to the medial fascia separation using even pressure. All scans were performed by the same laboratory technician using standardized settings (Frequency: 26 Hz, Gain: 68, Depth: 4.5 cm). Echo intensity and CSA of the VL were determined from the same ultrasound image using ImageJ software. As described by Cadore et al. [4], the outline of the VL was traced by the same trained laboratory technician as close as possible to the fascial border while capturing only the muscle (Figure 2). Each image was calibrated prior to analysis by measuring the number of pixels within a known distance (1 cm). ImageJ software measures EI by performing a grayscale analysis of pixels in the image ranging from 0 to 255. These procedures have been used previously in this lab [15,19]; test-retest reliability for the current study was calculated for both CSA (ICC=0.925, SEM=0.96 cm^2) and EI (ICC=0.906, SEM=2.44 arbitrary units [a.u.]).

Performance Data

While collegiate performance data were not available for incoming freshmen, data from the previous season were available for a subset of returning athletes (n=9). For returning athletes, all reported scores (on a 10-point scoring scale) from each event completed in the previous season were averaged to quantify performance.

Statistical Analysis

Bivariate correlations were used to evaluate relationships between indices of body composition, muscle quality, and performance. Statistical analyses were performed using SPSS software (Version 20, IBM, Armonk, NY, USA), with statistical significance set *a priori* at $\alpha \leq 0.05$.

Results

Mean values for measures of body composition, ultrasound, and performance are listed in Table 1. The correlation between bone density z-score and LBM was not significant (R=0.468; P=0.08). Performance (average score) was significantly correlated with arms LBM (R=0.714; P=0.03), left arm LBM (R=0.772; P=0.02), and right leg LBM (R=0.680; P=0.04). Although not significant, total LBM (R=0.638; P=0.07), left leg LBM (R=0.584; P=0.10), and legs LBM (R=0.633; P=0.07) presented similar R-values. Performance was not significantly correlated with total body mass (R=0.494, P=0.176), fat mass (R=0.184; P=0.64), or BF% (R= −0.078; P=0.84).

Fifteen DXA scans were evaluated for the presence of scoliosis; two were excluded due to positioning error. Scoliosis was detected in three out of 15 scans (prevalence = 20%).

Echo Intensity and CSA of the VL were significantly and inversely correlated with each other (R= −0.637, P=0.01), but not with other measures of body composition or performance (R=0.016 – 0.344; P>0.05).

Discussion

Gymnastics is often called an aesthetic sport, in which body shape and aesthetic presentation may influence outcomes [28]. The sport also involves twists, flips, and other skilled movements resulting in a unique variety of physiological demands and adaptations [1,7]. The nature of the sport has historically led gymnasts to emphasize leanness, leading to a high prevalence of disordered eating habits [20,21]. Previous data have also indicated a high prevalence of scoliosis amongst gymnasts, possibly due to a combination of asymmetrical high-impact spinal loading, delayed maturation, and increased joint laxity [26]. Given these unique health risks and physiological demands, it is important to evaluate relationships between body composition, musculoskeletal characteristics, and performance, and to determine the prevalence of scoliosis in this population. In the current study, performance was positively correlated with LBM of the arms and right leg (P<0.05), with correlations for total LBM and leg LBM trending toward significance (P=0.07). Scoliosis, defined as a lateral spinal curvature of 10° or greater, was identified in three of 15 DXA scans, resulting in a prevalence of 20%.

Research has suggested that body composition is a determinant of success in gymnastics [3]. In the current study, performance was correlated with LBM of the arms and right leg. While these findings are supported by previous literature emphasizing the importance of strength in gymnastics, it has been suggested that the strength-to-mass ratio is more critical than absolute strength [1,23]. Excess adipose tissue is considered unfavorable, as it lowers the strength-to-mass ratio and efficiency of movement [1,3,23]. Previous studies have identified low body mass and low BF% as common characteristics among elite female gymnasts [3]. Falls & Humphrey identified lower BF% values in placers compared to non-placers in a collegiate gymnastics meet [8]. Conversely, the current study did not observe correlations between total body mass, fat mass, or BF% and performance. Body fat values of elite female gymnasts have been estimated to range from 13–16% [3,6] using a variety of measurement methods, including DXA [6]. The current sample displayed a higher mean body fat percentage (23.2 ± 3.2 %) in comparison to elite, international-level competitors in previous studies [3,6]. Nickols-Richardson [17] previously noted that BF% values in gymnasts are typically higher when using DXA and evaluating older samples. The use of DXA and age of participants may explain higher BF% values observed in the current study. The lack of an inverse correlation between adiposity and performance could be related to the relatively small, homogeneous sample tested. It is also possible that there are diminishing returns with reducing fat mass to improve gymnastics performance, with excessive leanness impeding performance [24]. A larger, more heterogeneous sample could potentially reveal significant relationships between body fat and performance in collegiate gymnasts, but more research is needed.

In agreement with previous research [7,14], the current sample displayed above-average bone mineral density (z-score = 0.85 ± 0.60), likely due to the high-impact musculoskeletal loading associated with gymnastics. While high impacts are favorable for bone density, they place large forces on the spine, leading to heightened concern regarding a number of spinal conditions [13]. Although data pertaining to scoliosis in gymnasts is scarce, Tanchev et al. [26] reported a prevalence of 12% in a sample of over 100 rhythmic gymnasts. The current study observed a higher prevalence (20%) than Tanchev et al. [26], but this number should be interpreted with caution due to small sample size. The high prevalence observed does not imply a causative relationship between gymnastics and scoliosis. As Meyer et al. [16] suggested, individuals with greater joint laxity, who are at an increased risk of developing scoliosis, may gravitate toward gymnastics. While back pain is prevalent amongst gymnasts [13], idiopathic scoliosis may not necessarily cause pain in adolescents participating in gymnastics [16]. Further, all spinal curves observed in the current study were mild in magnitude (<20°), and repetitive unilateral twists performed by gymnasts could cause musculoskeletal asymmetry in the absence of scoliosis [13]. More research is needed to determine if scoliosis is a common source of pain or dysfunction among gymnasts, and if gymnastics participation contributes to the development or progression of scoliosis.

Ultrasonography is an increasingly popular method of measuring muscle characteristics including muscle size (CSA) and quality (EI) [4,12,15,19]. Previous literature has demonstrated that CSA and EI may be related to strength, power, and injury risk [10,15,19]. These muscle characteristics could informative for gymnasts interested in maximizing the strength-to-mass ratio, and to our knowledge have not been studied in this population. In agreement with previous research [15,19], the present study found an inverse correlation between CSA and EI. This data also supports the findings of Fukumoto et al. [10] in which EI was not significantly correlated with BF%, suggesting that ultrasonography may be a practical method to provide additional, localized indices of body composition that are not revealed with more traditional methods. The current study did not reveal a significant relationship between CSA or EI and performance. Similarly, research in Division I football players [15] and female soccer players [12] found no differences in baseline VL CSA or EI between starters and non-starters. It is possible that homogenous samples engaged in the same training program may have similar EI despite differences in body composition, as research has suggested that training may influence EI values [12,25]. In contrast with previous research [15,19], the current study did not find a significant correlation between VL CSA and leg LBM; the small sample tested may have contributed to this discordant finding.

While the current study took place in the off-season, it is possible that adiposity may fluctuate between the competitive season and the offseason. We cannot rule out the possibility that in-season adiposity may be more closely related to performance outcomes. The current study did not find significant correlations between performance and body fat measurements, or between VL CSA and leg LBM. These discrepancies with previous literature may pertain to the small, homogeneous sample used in the current study. Body composition values for female gymnasts may vary between studies due to differences in assessment methods, along with the age and competition level of the samples tested. The high prevalence of scoliosis must be interpreted with caution, as a causative relationship cannot be determined from a cross-sectional study design. Further, the identification of scoliosis could be influenced by the unilateral nature of the sport, and a much larger sample is needed to determine a more valid estimate for the prevalence of scoliosis amongst collegiate gymnasts.

The strength-to-mass ratio has long been considered an important determinant of gymnastics success, leading to a widespread emphasis on fat reduction amongst gymnasts [20]. The current study associated limb LBM, but not leanness, with performance outcomes, suggesting that it may be beneficial for gymnasts to employ training and nutrition strategies that prioritize lean mass. There was an increased prevalence of scoliosis compared to the general population, with spinal curvature of 10° or greater identified in 3 of 15 total DXA scans. More research with larger samples is required to examine relationships between body composition, muscle quality, and performance in collegiate gymnasts. Future research should also seek to determine if mild scoliosis is a common source of pain or dysfunction amongst female gymnasts, and to investigate the cause of increased scoliosis prevalence in this population.

Acknowledgments

The project described was supported by the National Center for Advancing Translational Sciences, 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.

References

1. Ackland T, Elliott B, Richards J. Growth in body size affects rotational performance in women's gymnastics. Sports Biomech. 2003; 2:163–176. [PubMed: 14737925]
2. Asher MA, Burton DC. Adolescent idiopathic scoliosis: natural history and long term treatment effects. Scoliosis. 2006; 1:2. [PubMed: 16759428]
3. Bale P, Goodway J. Performance variables associated with the competitive gymnast. Sports Med. 1990; 10:139–145. [PubMed: 2237031]

4. Cadore EL, Izquierdo M, Conceicao M, Radaelli R, Pinto RS, Baroni BM, Vaz MA, Alberton CL, Pinto SS, Cunha G, Bottaro M, Kruel LF. Echo intensity is associated with skeletal muscle power and cardiovascular performance in elderly men. Exp Gerontol. 2012; 47:473–478. [PubMed: 22525196]

5. Currie A. Sport and eating disorders - understanding and managing the risks. Asian J Sports Med. 2010; 1:63–68. [PubMed: 22375193]

6. Deutz RC, Benardot D, Martin DE, Cody MM. Relationship between energy deficits and body composition in elite female gymnasts and runners. Med Sci Sports Exerc. 2000; 32:659–668. [PubMed: 10731010]

7. Dowthwaite JN, Scerpella TA. Skeletal geometry and indices of bone strength in artistic gymnasts. J Musculoskelet Neuronal Interact. 2009; 9:198–214. [PubMed: 19949278]

8. Falls HB, Humphrey LD. Body type and composition differences between placers and nonplacers in an AIAW gymnastics meet. Res Q. 1978; 49:38–43. [PubMed: 725265]

9. Ferguson AB. The study and treatment of scoliosis. Southern medical journal. 1930; 23:116–120.

10. Fukumoto Y, Ikezoe T, Yamada Y, Tsukagoshi R, Nakamura M, Mori N, Kimura M, Ichihashi N. Skeletal muscle quality assessed from echo intensity is associated with muscle strength of middle-aged and elderly persons. Eur J Appl Physiol. 2012; 112:1519–1525. [PubMed: 21847576]

11. Harriss DJ, Atkinson G. Ethical standards in sport and exercise science research: 2014 update. Int J Sports Med. 2013; 34:1025–1028. [PubMed: 24293054]

12. Jajtner AR, Hoffman JR, Scanlon TC, Wells AJ, Townsend JR, Beyer KS, Mangine GT, McCormack WP, Bohner JD, Fragala MS, Stout JR. Performance and muscle architecture comparisons between starters and nonstarters in National Collegiate Athletic Association Division I women's soccer. J Strength Cond Res. 2013; 27:2355–2365. [PubMed: 23719503]

13. Kruse D, Lemmen B. Spine injuries in the sport of gymnastics. Curr Sports Med Rep. 2009; 8:20–28. [PubMed: 19142076]

14. Laing EM, Massoni JA, Nickols-Richardson SM, Modlesky CM, O'Connor PJ, Lewis RD. A prospective study of bone mass and body composition in female adolescent gymnasts. The Journal of Pediatrics. 2002; 141:211–216. [PubMed: 12183716]

15. Melvin MN, Smith-Ryan AE, Wingfield HL, Ryan ED, Trexler ET, Roelofs EJ. Muscle Characteristics and Body Composition of NCAA Division I Football Players. The Journal of Strength & Conditioning Research. 2014; Published Ahead of Print. doi: 10.1519/JSC.0000000000000651

16. Meyer C, Cammarata E, Haumont T, Deviterne D, Gauchard GC, Leheup B, Lascombes P, Perrin PP. Why do idiopathic scoliosis patients participate more in gymnastics? Scand J Med Sci Sports. 2006; 16:231–236. [PubMed: 16895527]

17. Nickols-Richardson SM. Body composition issues in women's artistic gymnastics. Journal of Family and Consumer Sciences. 1997; 89:40–45.

18. Pillen S, Tak RO, Zwarts MJ, Lammens MM, Verrijp KN, Arts IM, van der Laak JA, Hoogerbrugge PM, van Engelen BG, Verrips A. Skeletal muscle ultrasound: correlation between fibrous tissue and echo intensity. Ultrasound Med Biol. 2009; 35:443–446. [PubMed: 19081667]

19. Roelofs EJ, Smith-Ryan AE, Melvin MN, Wingfield HL, Trexler ET, Walker N. Muscle size, quality, and body composition: characteristics of division I cross-country runners. J Strength Cond Res. 2015; 29:290–296. [PubMed: 25330086]

20. Rosen LW, Hough DO. Pathogenic weight-control behaviors of female college gymnasts. The physician and sportsmedicine. 1988; 16:140–144. [PubMed: 27404154]

21. Rosen LW, McKeag DB, Hough DO, Curley V. Pathogenic weight-control behavior in female athletes. The physician and sportsmedicine. 1986; 14:79–83. [PubMed: 27442823]

22. Rosenberg JG, Ryan ED, Sobolewski EJ, Scharville MJ, Thompson BJ, King GE. Reliability of panoramic ultrasound imaging to simultaneously examine muscle size and quality of the medial gastrocnemius. Muscle & Nerve. 2014; 49:736–740. [PubMed: 24038069]

23. Salmela JH. Growth patterns of elite French-Canadian female gymnasts. Can J Appl Sport Sci. 1979; 4:219–222. [PubMed: 540417]

24. Sherman RT, Thompson RA, Rose JS. Body mass index and athletic performance in elite female gymnasts. Journal of Sport Behavior. 1996; 19:338.

25. Sipila S, Suominen H. Ultrasound imaging of the quadriceps muscle in elderly athletes and untrained men. Muscle & Nerve. 1991; 14:527–533. [PubMed: 1852160]

26. Tanchev PI, Dzherov AD, Parushev AD, Dikov DM, Todorov MB. Scoliosis in rhythmic gymnasts. Spine (Phila Pa 1976). 2000; 25:1367–1372. [PubMed: 10828918]

27. Taylor HJ, Harding I, Hutchinson J, Nelson I, Blom A, Tobias JH, Clark EM. Identifying scoliosis in population-based cohorts: development and validation of a novel method based on total-body dual-energy x-ray absorptiometric scans. Calcif Tissue Int. 2013; 92:539–547. [PubMed: 23456028]

28. Werner A, Thiel A, Schneider S, Mayer J, Giel KE, Zipfel S. Weight-control behaviour and weight-concerns in young elite athletes - a systematic review. J Eat Disord. 2013; 1:18. [PubMed: 24999399]

A) B)

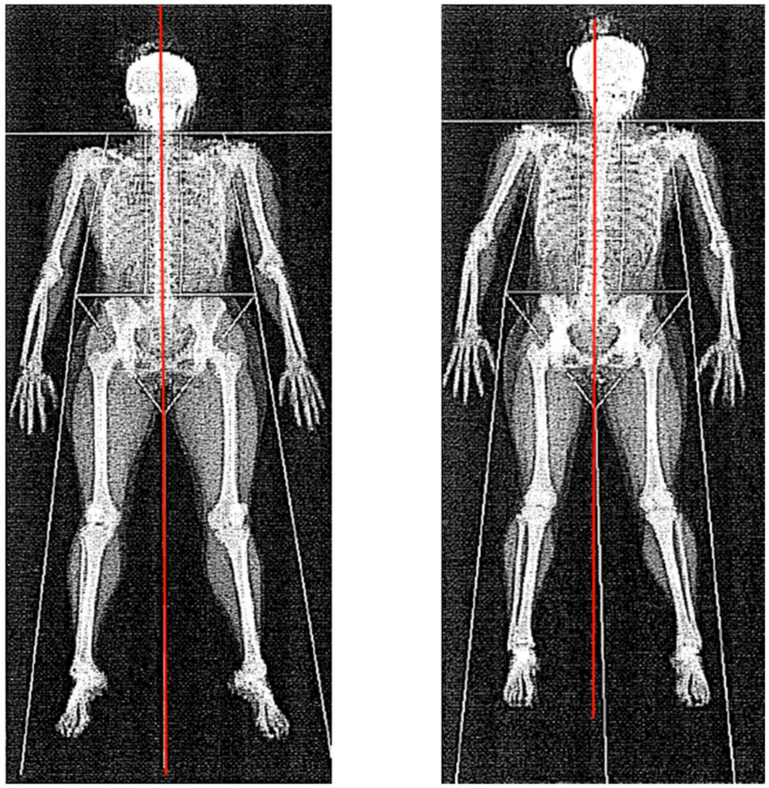

Figure 1.
A) A sample DXA scan with a normal spine line drawn. B) An example of positioning error.

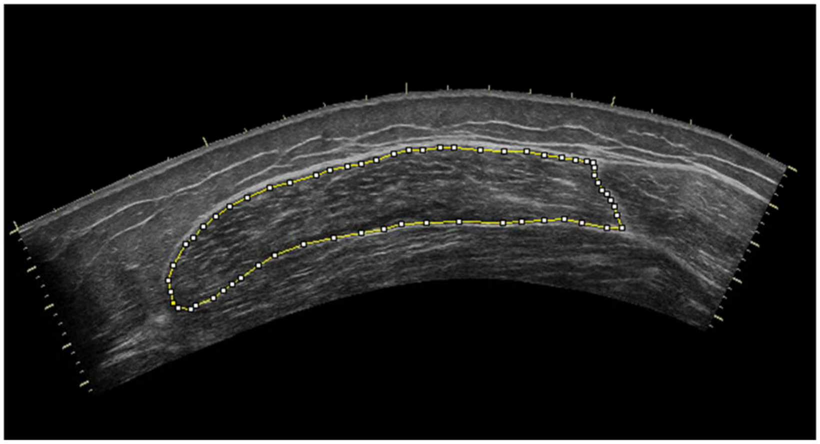

Figure 2.
An example of a panoramic ultrasound scan of the vastus lateralis (VL), with the VL border traced using ImageJ software.

Author Manuscript

Author Manuscript

Author Manuscript

Table 1

Descriptive characteristics (n=15), presented as mean ± SD.

Age (yrs)	18.7 ± 0.9
Height (cm)	157.9 ± 4.1
Weight (kg)	56.7 ± 6.8
FM (kg)	13.1 ± 3.0
LBM (kg)	40.7 ± 4.3
BF%	23.2 ± 3.2
BMC (kg)	2.2 ± 0.2
BMD (z-score)	0.9 ± 0.6
VL CSA (cm^2)	16.2 ± 2.4
VL EI (a.u.)	76.3 ± 5.5
Avg Score (Pts; n=9)	9.6 ± 0.1

FM = fat mass, LBM = lean body mass, BF% = body fat percentage, BMC = bone mineral content, BMD = bone mineral density, VL = vastus lateralis, CSA = cross-sectional area, EI = echo intensity