Medicine & Science in Sports & Exercise

Ultrasonography of Lumbar Multifidus Muscle in University American Football Players

--Manuscript Draft--

Manuscript Number:	MSSE-D-19-00749R2
Full Title:	Ultrasonography of Lumbar Multifidus Muscle in University American Football Players
Article Type:	Original Investigation
Corresponding Author:	Maryse Fortin, PhD, CAT(C) Concordia University Montreal, Quebec CANADA
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Concordia University
Corresponding Author's Secondary Institution:	
First Author:	Alexa Schryver
First Author Secondary Information:	
Order of Authors:	Alexa Schryver
	Hassan Rivaz, PhD
	Amanda Rizk, PhD
	Stephane Frenette
	Mathieu Boily, MD
	Maryse Fortin, PhD, CAT(C)
Order of Authors Secondary Information:	
Funding Information:	

DISCLAIMER

Medicine & Science in Sports & Exercise

The Official Journal of the American College of Sports Medicine
www.acsm-msse.org

. . . Published ahead of Print

Ultrasonography of Lumbar Multifidus Muscle in University American Football Players

Alexa Schyver[1], Hassan Rivaz[2,3], Amanda Rizk[1], Stephane Frenette[3],
Mathieu Boily[3,4], Maryse Fortin[1,3,5]

[1]Concordia University, Department Health, Kinesiology & Applied Physiology, Montreal, Quebec, Canada; [2]Concordia University, Department of Electrical & Computer Engineering, Montreal, Quebec, Canada; [3]PERFORM Centre, Concordia University, Montreal, Quebec, Canada; [4]McGill University Health Center, Department of Diagnostic Radiology, Montreal, Quebec, Canada; [5]Centre de Recherche Interdisciplinaire en Réadaptation (CRIR), Montreal, Quebec, Canada

Accepted for Publication: 24 January 2020

Abstract

Purpose: The primary objective of this study was to examine and compare lumbar multifidus (LM) muscle size, asymmetry and function in university football players with and without low back pain (LBP). A secondary objective was to examine the relationship between LM characteristics and body composition in football players. **Methods:** Ultrasound assessments of the LM muscle were performed in 41 university football players during the preseason. LM muscle cross-sectional area (CSA), echo-intensity (e.g. indicator of fatty infiltration and connective tissue), thickness at rest, and thickness during submaximal contraction (e.g. contralateral arm lift) measurements in prone and standing positions were obtained bilaterally at the L5-S1 level. Body composition measures were acquired using dual X-ray absorptiometry (DEXA). A self-administered questionnaire was used to obtain LBP history data. **Results:** The LM muscle thickness at rest in prone and in standing was significantly smaller in football players who reported the presence of LBP in the previous 3-months. The LM CSA in prone was significantly and positively correlated with weight, height, lean body mass, total fat mass, and total % body fat. LM echo-intensity was strongly correlated with total % body fat and total fat mass and negatively correlated with the % thickness change during contraction. **Conclusion:** The results of this study provide novel information on LM muscle morphology and activation in football players in prone and standing and suggest that players with LBP in the previous 3-months had smaller LM muscle thickness. LM morphology was strongly correlated with body composition measurements.

Ultrasonography of Lumbar Multifidus Muscle in University American Football Players

Alexa Schyver[1], Hassan Rivaz[2,3], Amanda Rizk[1], Stephane Frenette[3],
Mathieu Boily[3,4], Maryse Fortin[1,3,5]

[1]Concordia University, Department Health, Kinesiology & Applied Physiology, Montreal, Quebec, Canada; [2]Concordia University, Department of Electrical & Computer Engineering, Montreal, Quebec, Canada; [3]PERFORM Centre, Concordia University, Montreal, Quebec, Canada; [4]McGill University Health Center, Department of Diagnostic Radiology, Montreal, Quebec, Canada; [5]Centre de Recherche Interdisciplinaire en Réadaptation (CRIR), Montreal, Quebec, Canada

Running title: Multifidus muscle in American Football

Corresponding author:
Maryse Fortin, Concordia University, 7141 Sherbrooke St W, L-SP 165-29, H4B 1R6, email: maryse.fortin@concordia.ca, Ph: 514-848-2424, ext. 8642.

The PERFORM Centre (Concordia University) and the R. Howard Webster Foundation provided funding for this project. **Conflict of Interest:** The authors declare that there are no conflicts of interest. There exist no professional relationships with companies or manufacturers who will benefit from the results of this study. The results of the present study do not constitute endorsement by ACSM. The results of this study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

Abstract

Purpose: The primary objective of this study was to examine and compare lumbar multifidus (LM) muscle size, asymmetry and function in university football players with and without low back pain (LBP). A secondary objective was to examine the relationship between LM characteristics and body composition in football players. **Methods:** Ultrasound assessments of the LM muscle were performed in 41 university football players during the preseason. LM muscle cross-sectional area (CSA), echo-intensity (e.g. indicator of fatty infiltration and connective tissue), thickness at rest, and thickness during submaximal contraction (e.g. contralateral arm lift) measurements in prone and standing positions were obtained bilaterally at the L5-S1 level. Body composition measures were acquired using dual X-ray absorptiometry (DEXA). A self-administered questionnaire was used to obtain LBP history data. **Results:** The LM muscle thickness at rest in prone and in standing was significantly smaller in football players who reported the presence of LBP in the previous 3-months. The LM CSA in prone was significantly and positively correlated with weight, height, lean body mass, total fat mass, and total % body fat. LM echo-intensity was strongly correlated with total % body fat and total fat mass and negatively correlated with the % thickness change during contraction. **Conclusion:** The results of this study provide novel information on LM muscle morphology and activation in football players in prone and standing and suggest that players with LBP in the previous 3-months had smaller LM muscle thickness. LM morphology was strongly correlated with body composition measurements.

Keywords: low back pain; American Football; ultrasound; lumbar multifidus; dual-energy X-ray absorptiometry

INTRODUCTION

American football is a high impact, high physical demand sport, and one of the most popular and practiced sports in North America. This sport is played at all levels, ranging from youth leagues to high school, university and professional leagues such as the National Football League (NFL) or the Canadian Football League (CFL). Football consists of a multitude of positions, each requiring a specific physical profile, but most involving violent impacts and collisions. Given the high impact nature of this sport, injury rates are unarguably among the highest across all sports (1,2). Low back pain (LBP) is a common complaint among American Football players, with 30% of college players reporting missing playtime due to LBP (3). Additionally, the presence of chronic LBP continues well into retirement (4). While blocking and tackling, players must absorb and transfer large amounts of force from the upper body to the lower body. Compressive forces at the L4-L5 segment can reach values above 8600 Newtons when players block one another (5,6). Additionally, players who continue to play beyond 2 seasons (beginning at the high school level) have an increased risk of developing LBP and degenerative disk disease regardless of the position played (5). While spinal abnormalities such as spondylolysis, degenerative disc disease and disc space narrowing are significant risk factors for LBP in this group of athletes, spinal instability (defined as the amount of angular or translational displacement on lateral view radiographs) is also an important contributing factor (7).

The lumbar multifidus (LM) muscle plays a critical role in providing spinal stability and segmental control, and is mostly responsible for spinal stiffness in the neutral position (8). This muscle also plays a key role in lumbopelvic dynamic stability, assisting in the production and transfer of forces through the kinetic chain (9,10). The presence of LBP has been associated with changes in LM muscle morphology (e.g. size, asymmetry, and fatty infiltration) and function (e.g. ability to contract) in both athletic and non-athletic populations. LM atrophy was reported in ballet (11), gymnastics (12), Australian Football League (AFL) players (13), soccer (14), and hockey (15), athletes with LBP, while LM side-to-side asymmetry (e.g. atrophy) at the affected level and symptomatic side was observed in cyclist, cricket and judo athletes with unilateral symptoms (16). A decrease in LM function (e.g. % change in LM thickness during contraction) was also observed in gymnastic athletes with a sway-back posture (12).

While ultrasound allows to conveniently assess muscle size, function and quality (e.g. echo-intensity, EI), few imaging studies have evaluated LM muscle EI and/or examined LM characteristics in more functional positions, such as standing. EI is measured using the ultrasound brightness scale (gray scale analysis) and can be used as an indicator of muscle quality by estimating intramuscular fat and connective tissue (17,18). Previous studies also reported that muscle EI is correlated to muscle strength and power (19-22). As increased paraspinal muscle fatty infiltration was reported in subjects with chronic LBP, it is intuitive that such change in muscle quality would negatively impacts overall muscle function (23,24). Despite the high incidence of LBP in American football players, we are not aware of any studies that have examined LM characteristics in this group of athletes. Furthermore, the influence of body composition measurements on LM muscle morphology and function also deserve further attention. While it is well established that muscle morphology is influenced by anthropometric factors, such as age, sex, physical activity levels and body composition (25-27), body mass index (BMI) remains the most frequently used variable to adjust for inter-subject variability in both anthropometric and body composition differences. BMI is, however, a poor indicator of body composition, especially in athletic populations, due to its inability to differentiate between lean and fat mass.

Therefore, the primary objective of this study was to examine and compare LM muscle size, asymmetry and function in university football players with and without LBP. A secondary objective was to examine the relationship between LM muscle characteristics and body composition in football players. We hypothesized that players with LBP will have a smaller LM muscle, greater side-to-side asymmetry and will have a lower ability to contract the LM muscle. We also hypothesized that greater lean muscle mass and greater % body fat will be positively associated with LM muscle size and echo-intensity (EI), respectively.

METHODS

Participants

Forty-one football players from the Concordia University varsity team were assessed during the preseason (end of August 2016) and included in the current study. The exclusion criteria were previous history of severe trauma or spinal fracture, previous spinal surgery, and observable/known spinal abnormalities. The Central Ethics Research Committee of the Quebec Minister of Health and Social Services approved this study. All players provided informed consent acknowledging that their data would be used for research purposes.

Procedures

During the preseason, each player participated in one testing session lasting approximately 30 minutes. Subjects completed a self-administered questionnaire to collect information regarding players' demographics and history of LBP. LBP was defined as pain localized between T12 and the gluteal fold. Players were asked to answer "yes" or "no" to the presence of LBP during the past 3-months (off-season) prior to the assessment. Players who answered "yes" to the presence of LBP completed a numerical Visual Analogue Scale (VAS) (e.g. score 0 to 10) to assess average LBP intensity, and were also asked about pain location (e.g. centered, right side, left side) and pain duration (in months).

Ultrasound

Ultrasound B-mode images assessment of the LM muscle were acquired using a LOGIQ e ultrasound machine (GE Heathcare, Milwaukee,WI) with a 5-MHz curvilinear transducer during the preseason. The imaging parameters were kept consistent in all acquisitions (frequency: 5MHz, gain: 60, depth: 8.0cm). Previous studies have established the reliability and validity of ultrasound imaging to assess LM muscle size and thickness, with repeatable, reliable and valid imaging technique when performed by trained assessors (28,29). All ultrasound measurements were obtained by an experienced rater with over 10 years of experience in spine imaging analysis, and was also previously trained by a senior musculoskeletal ultrasound radiologist prior to the beginning of this study.

Prone lying measurements

To assess LM muscle cross-sectional area (CSA), participants were placed in a prone position, on a therapy table, with a pillow placed under their abdomen to minimize lumbar lordosis and instructed to relax the paraspinal musculature. The spinous process of L5 was palpated and marked on the skin with a pen prior to imaging. Three images were captured on the right and left sides.

This L5 level was selected based on a previous study reporting that decreased LM muscle CSA and increased side-to-side asymmetry at this level was a predictor of LBP and lower limb injury in elite AFL players (13). Acoustic coupling gel was applied to the skin and the ultrasound transducer was placed longitudinally along the midline of the lumbar spine to confirm the location of the L5 level. Then, bilateral transverse images of LM muscle at L5 were obtained to assess LM CSA (Figure 1), with the exception of larger muscles, where the left and right sides were imaged separately.

LM function was then assessed by obtaining thickness measurements at rest and during sub-maximal contraction (Figure 2). The LM muscle was imaged bilaterally, in the parasagittal section, allowing for the visualization of the L5/S1 zygapophyseal joints. Participants were instructed to relax and 3 images were captured bilaterally, at rest. Participants were then instructed to perform a contralateral arm lift to induce submaximal contraction (28-30). Each participant was given a handheld weight [based on subject body weight: 1) <68.2kg = 0.68kg weight, 2) 68.2-90.9kg=0.9kg weight, 3) >90.9kg=1.36kg weight] (30), and instructed to raise the loaded arm 5 cm off the examination table with the shoulder in 120° of abduction and elbow 90° of flexion. The handed weight was designed to load the LM to approximately 30% of maximal voluntary isometric contraction (30). Participants were instructed to hold their breath at the end of normal exhalation (minimize the effect of respiration on thickness measurement) and maintain the contraction for 3 seconds. Each player had a practice trial, followed by 3 contralateral arm lifts on each side.

Standing measurements

Players were asked to stand barefoot on the floor with their arms relaxed on each side. In order to achieve a habitual standing posture, they were instructed to march on a spot for a few seconds and remain on the position where their feet landed. The same procedure as described above was conducted to obtain LM CSA and thickness measurements at rest. To contract the LM muscle, each participant was asked to perform a contralateral arm lift, with the shoulder placed in 90° of flexion, elbow in complete extension and the wrist in neutral position (palm facing down) (31), while holding the previously determined hand weight and maintain the contraction for 3 seconds. Each player had a practice trial, followed by 3 contralateral arm lifts on each side.

Imaging assessment

Ultrasound images were stored and analyzed offline. LM CSA and thickness measurements were acquired using OsiriX imaging software (OsiriXLiteVersion 9.0, Geneva, Switzerland). The CSA measurements were obtained by tracing the muscle borders on both sides. The relative % asymmetry in CSA between the right and left sides was calculated using the following formula: [(larger side – smaller side)/larger side x 100]. LM muscle thickness was assessed using linear measurements from the tip of the L5/S1 zygapophyseal joint to the inside edge of the superior muscle border, at rest and during contraction in both positions (e.g. prone and standing). Each measurement was repeated 3 times (on 3 different images) on each side, and the average value was used in the analyses. LM muscle function and contractile ability in the prone and standing position was calculated as a percent change using the following formula: [(thickness contraction – thickness rest)/thickness rest) x 100]. LM muscle EI was measured using grayscale analysis imaging (ImageJ, National Institute of health, USA, Version 1.49) using the standard histogram function of pixels expressed as value between 0 (black) and 255 (white) (17). Enhanced EI is indicative of a greater amount of intramuscular fat and connective tissue (18). Prior to EI measurements, each image was calibrated by measuring the number of pixels within a known distance of 1 cm. EI was determined by tracing a region of interest (ROI) representing the LM muscle CSA (in the prone position only), avoiding the inclusion of bone or surrounding fascia (15). The average value of 3 EI measurements (on 3 different images) on each side was used in the analyses. At the time of imaging assessment, the rater was blinded to players' characteristics and history of injury. The intra-rater reliability (intra-class correlation coefficients $ICC_{3,1}$) of the rater for all LM ultrasound ranged between 0.96-0.99 for all prone measurements and 0.96-0.98 for all standing measurements.

DEXA

Each player had a full body DEXA scan (Lunear Prodigy Advance, GE) performed by a certified medical imaging technologist. Prior to imaging, all participants were asked to remove any metal and were required to wear loose fitting clothing, to avoid interference with the scan. Age, height, weight and ethnicity were entered in the computer software prior to imaging. Participants were asked to lie down supine in the center of the scanner with their arms slightly away from the body, thumbs pointing upwards, with their legs slightly apart and toes pointing upwards. Total lean mass, total bone mass, total fat mass and total percent body fat were determined using DEXA.

Statistical Analysis

Means and standard deviations were calculated for players' characteristics and body composition measurements. Paired *t*-tests were used to assess the difference in LM muscle characteristics including CSA, EI, thickness at rest and during contraction (both in prone and standing positions) between the right and left sides. Analysis of covariance (ANCOVA) was used to examine the difference in LM muscle characteristics in muscle size, quality and function (e.g. CSA, asymmetry, EI, thickness, % thickness change) between players with and without LBP 3-months prior to measurements. The variables “weight” and “height” and “total % body fat” were considered as covariates in the analyses. Players’ position was not considered as a covariate in our analysis due to the relatively small sample size, however, an exploratory univariate analysis revealed that it was not associated with LM characteristics. Pearson correlation and linear regression models were used to assess the correlation and relationship between LM muscle characteristics (e.g. CSA, EI, thickness, % thickness change) and body composition measurements. All analyses were performed with STATA (version 12.0, StataCorp, LP, College Station, Texas).

RESULTS

The players’ characteristics are presented in Table 1. The mean±SD age, height and weight was 21.0±1.1 years, 180.0±5.65 cm and 94.2±19.4 kg, respectively. The average number of years playing football was 8.6±3.1 years, and 1.44±1.3 at the university level. A total of 55.5% and 44.4% of players playing on the defense and offensive line reported the presence of LBP 3- months prior assessment, respectively.

LM muscle characteristics in American Football Players.

LM muscle measurements in prone and standing, for the right and left sides, are presented in Table 2. The thickness at rest and during contraction in the prone position was significantly greater on the left side (*p*=0.001 and *p*=0.005, respectively). Similarly, the thickness during contraction in the standing position was significantly greater on the left side (*p*=0.01). LM muscle CSA and thickness at rest and during contraction on both sides significantly increased from the prone to standing position ($p<0.001$). There was a significant decrease in LM muscle CSA asymmetry and % thickness change from the prone to standing position ($p<0.001$)

LM characteristics and LBP

LM muscle thickness at rest in the prone ($p=0.04$, F=4.30) and standing position ($p=0.02$, F=5.20) was significantly smaller in football players who reported the presence of LBP in the previous 3-months (Table 3). There were no other significant differences in LM muscle characteristics between players with and without LBP.

Associations between LM characteristics and body composition

LM CSA in the prone position was significantly correlated with weight ($r=0.51$, $p<0.001$), height ($r=0.36$, $p<0.05$), lean body mass ($r=0.51$, $p<0.001$), total fat mass ($r=0.43$, $p<0.01$) and total % body fat ($r=0.52$, $p<0.001$) (Table 4). Similar significant correlations were also observed for LM thickness at rest and during contraction. LM EI was strongly correlated with total % body fat ($r=0.76$, $p<0.001$) and total fat mass ($r=0.76$, $p<0.001$). The % thickness change in the prone position was correlated to total fat mass ($r=-0.48$, $p<0.001$) and total % body fat ($r=-0.48$, $p<0.001$). LM EI was also correlated with the % thickness change in the prone position ($r=-0.32$, $p<0.05$). Similar correlations were also observed between LM characteristics in standing and body composition measurements (data not shown).

DISCUSSION

The purpose of this study was to examine and compare LM muscle characteristics in university football players with and without LBP, as well as the influence of body composition on LM characteristics. Overall, our findings provide novel information on LM characteristics and activation in prone and standing positions in American football players, and suggest that players with a history of LBP have smaller LM thickness (e.g. atrophy). Body composition measurements were strongly associated with LM morphology, suggesting that the influence of body composition on LM muscle size and quality in athletes cannot be ignored.

LM Muscle Characteristics in American Football

LM muscle CSA of our football players was much larger than the general, non-athletic population (32), but comparable to university level varsity male hockey players as well as elite AFL players (13,15). This hypertrophy is likely attributable to years of resistance training, as well as the high physical demands of this sport, which require LM activation for stability and explosiveness during running, blocking, and tackling. Furthermore, this finding may also be partly explained by the fact that football players generally have larger stature, and thus accompanying larger musculature. While there was no difference in LM CSA measurements between the right and left sides, the % asymmetry in prone (4.80±3.25%) was significantly greater than in standing (2.42±2.50%) when the LM is contracted. EI values were similar between sides, and comparable to those of university level male hockey players (15).

Our findings revealed significant side-to-side differences in LM thickness at rest and contracted in both positions (e.g. prone and standing), with the left side being consistently larger. A larger left

LM muscle is consistent with previous literature and was reported in ballet dancers as well as in the general population (11,33). Such finding may be attributed to leg dominance. As most football players begin a play with the dominant push-off leg slightly behind (typically right), and thus require strong LM activation from the contralateral leg (left side) to stabilize the pelvis and create explosive forces to sprint or block. Other studies in elite athletes, however, reported symmetrical CSAs (34,35), as well as larger LM CSA on the dominant (right) side (12,36), suggesting that LM muscle size is likely influenced by specialized movements and sport specific training effects. While there was no difference in LM percent thickness change (e.g. contraction) between left and right sides when performing a contralateral arm lift both in prone and standing positions, the percent thickness in prone was significantly larger. This is due to an already contracted LM muscle in standing, as demonstrated by the sharp increase in CSA. As such additional gain in muscle thickness and related % thickness change when performing the contralateral arm lift are much smaller. While similar % thickness changes in the standing position were reported in university varsity male hockey players (15), additional studies should investigate LM morphology and neuromuscular control in such functional and sport-related positions, as deficits may have important implications for sport performance and susceptibility to injury.

Effect of LBP on LM muscle characteristics

In accordance with previous studies (11,15), LM muscle thickness at rest was significantly smaller in athletes with LBP in prone and in standing positions. Previous literature found both smaller LM muscle CSA and thickness in subjects with LBP (8,37). Decreased LM muscle thickness while measured at rest in a prone position was also reported in hockey players (15), elite ballet dancers

(11), and non-athletic population with LBP (37). To the best of our knowledge, no previous studies investigated LM characteristics in American football players. Though, AFL players with LBP were also found to have a smaller LM muscle CSA, as well as a decreased ability to perform an abdominal draw-in maneuver (13).

Although significant LM asymmetry was reported in AFL players with LBP (13), this was not the case in our football players as the % asymmetry was comparable between players with and without LBP. There was also no difference between the % thickness change, both in prone and standing positions, between players with and without LBP. This is contrary to other studies that have found greater LM contraction (14) (e.g. % thickness change), as well as lower LM contraction (38) in athletic and non-athletic populations with LBP. Although not significant, adjusted means for LM contraction in football players with LBP were slightly larger. Such findings may reflect a maladaptive neuromuscular control strategy to splint or stiffen the spine, in order to avoid further pain (39,40). As thickness changes are highly correlated with EMG activity, it is possible that a higher % thickness change relates to a proprioceptive dysfunction of the LM muscle (30,37). Such dysfunction entails abnormalities in timing or force of contraction necessary to complete a task. Indeed, Zhang et al. recently found that average EMG activity was positively correlated with LM contractive ability, and that patients with pain had a reduced ability to voluntarily recruit the deep LM muscle while performing functional tasks (37).

Finally, no difference in EI was found between players with and without LBP, a finding congruent with university level hockey players (15). As EI is highly correlated to the level of skeletal muscle fat tissue infiltration and connective tissue (e.g. higher EI values are indicative of a greater level of fatty infiltration) (17), our results suggest that players with LBP did not present with more fatty infiltration when compared to their counterparts. This finding is also consistent with previous studies that reported no association between LBP and paraspinal muscle fatty infiltration in young adults (41,42). Furthermore, as the mean age of our football players was 21.0±1.1 years and mean VAS score was 5.08±1.8, the young age and low level of pain and disability likely explain the lack of significant fatty infiltration.

LM characteristics and body composition

LM muscle CSA was significantly and positively correlated with weight, height, lean mass, fat mass, % body fat, and LM muscle thickness at rest and contracted. Our results are very similar and corroborate with a previous similar study in university level hockey players (15). In accordance with Fortin et al. (15), LM muscle EI was strongly correlated with weight, total percentage body fat, total fat mass, and total lean mass, providing additional evidence that the influence of body composition on LM muscle morphology and quality (composition) should not be ignored, especially in athletes. Importantly, the correlation coefficient between EI and total percent body fat (r=0.76) was the same as reported by the study of Fortin et al. (15). EI was also negatively correlated with LM function (e.g. % thickness change), supporting the hypothesis that increased fatty infiltration/connective tissue has detrimental effects on muscle function. Moreover, significant negative correlations between LM percent thickness and weight, fat mass, % body fat, and EI were also identified, with the strongest correlations being fat mass and % fat (r=-0.48). As such, our findings suggest that athletes with a greater overall percentage body fat had a lower ability to contract the LM muscle, and provide additional evidence to suggest that body composition may influence muscle function. While others found no such association (15,24), previous research has reported increased intra-muscular fatty infiltration to be associated with decreased thigh muscle power and performance (19,43,44). Unarguably, additional studies are needed to further establish the relationship between LM muscle quality and muscle function. A limitation of this study is the relatively small sample size from only one football team. Though our study had a comparable number of asymptomatic players, which allowed for a representative comparison between players with and without LBP. Future research including larger sample size and more teams at the elite level are needed to establish the generalizability of our results. Only the LM muscle was examined in this study. Other trunk muscles contributing to segmental control and stability of the lumbar spine should be examined in this athletic population.

To conclude, this study provided novel data regarding LM muscle morphology, asymmetry and function in American football players. Players with LBP in the past 3-months showed specific deficits in LM thickness at rest, both in prone and standing positions. LM morphology and function were highly correlated with DEXA body composition measurements, providing additional evidence that body composition should not be ignored when studying this muscle in athletic populations. Rehabilitation programs aiming to improve LM muscle size and muscle voluntary control may help prevent LBP and improve performance in this athletic population. Combining ultrasound and DEXA measurements may be beneficial for team health staff and coaches and may assist in preseason screening for those at risk for LBP. Future research should evaluate the effect of LM exercise intervention specifically targeting the LM muscle, coupled with strategies to improve overall body composition on year-round prevalence of LBP in American football players.

Acknowledgements

The authors would like to sincerely thank the players and coaches for taking part in this study, as well as Karolyne Goulet, Lisa-Marie Breton-Lebreux and Sean Christensen who provided assistance with the scheduling, recruitment and conduction of this study. The PERFORM Centre (Concordia University) and the R. Howard Webster Foundation provided funding for this project.

Conflict of Interest

The authors declare that there are no conflicts of interest. There exist no professional relationships with companies or manufacturers who will benefit from the results of this study. The results of the present study do not constitute endorsement by ACSM. The results of this study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

References

1. Carter EA, Westerman BJ, Hunting KL. Risk of injury in basketball, football, and soccer players, ages 15 years and older, 2003-2007. *J Athl Train*. 2011;46(5):484-488.

2. Kerr ZY, Dompier TP, Snook EM, et al. National collegiate athletic association injury surveillance system: Review of methods for 2004-2005 through 2013-2014 data collection. *J Athl Train*. 2014;49(4):552-560.

3. Mortazavi J, Zebardast J, Mirzashahi B. Low back pain in athletes. *Asian J Sports Med.* 2015;6(2).

4. Nicholas SJ, Nicholas JA, Nicholas C, Diecchio JR, McHugh MP. The health status of retired american football players: Super bowl III revisited. *Am J Sports Med*. 2007;35(10):1674-1679.

5. Gatt Jr. CJ, Hosea TM, Palumbo RC, Zawadsky JP. Impact loading of the lumbar spine during football blocking. *Am J Sports Med*. 1997;25(3):317-321.

6. Nagashima M, Abe H, Amaya K, et al. Risk factors for lumbar disc degeneration in high school american football players: A prospective 2-year follow-up study. *Am J Sports Med*. 2013;41(9):2059-2064.

7. Iwamoto J, Abe H, Tsukimura Y, Wakano K. Relationship between radiographic abnormalities of lumbar spine and incidence of low back pain in high school and college football players: A prospective study. *Am J Sports Med*. 2004;32(3):781-786.

8. Freeman MD, Woodham MA, Woodham AW. The role of the lumbar multifidus in chronic low back pain: A review. *PM and R*. 2010;2(2):142-146.

9. Hungerford B, Gilleard W, Hodges P. Evidence of altered lumbopelvic muscle recruitment in the presence of sacroiliac joint pain. *Spine*. 2003;28(14):1593-1600.

10. Huxel Bliven KC, Anderson BE. Core stability training for injury prevention. *Sports Health*. 2013;5(6):514-522.

11. Gildea JE, Hides JA, Hodges PW. Size and symmetry of trunk muscles in ballet dancers with and without low back pain. *J Orthop Sports Phys Ther*. 2013;43(8):525-533.

12. Mahdavie E, Rezasoltani A, Simorgh L. The comparison of lumbar multifidus muscles function between gynastic athletes with sway-back posture and normal posture. *Int J Sports Phys Ther*. 2017;12(4):607.

13. Hides JA, Stanton WR, Dilani Mendis M, Franettovich Smith MM, Sexton MJ. Small multifidus muscle size predicts football injuries. *Orthop J Sports Med*. 2014;2(6).

14. Hides JA, Oostenbroek T, Franettovich Smith MM, Mendis MD. The effect of low back pain on trunk muscle size/function and hip strength in elite football (soccer) players. *J Sports Sci*. 2016;34(24):2303-2311.

15. Fortin M, Rizk A, Frenette S, Boily M, Rivaz H. Ultrasonography of the multifidus muscle morphology and function in ice hockey players with and without low back pain. *Phys Ther Sport*. 2019;37:77-85.

16. Sheikhhoseinim R., O'Sullivan K, Alizabeh MH, Sadehisani M. Altered motor control in athletes with low back pain: A literature review. *Annals Applied Sport Sci*. 2016;4(4):43.

17. Arts IMP, Pillen S, Schelhaas HJ, Overeem S, Zwarts MJ. Normal values for quantitative muscle ultrasonography in adults. *Muscle Nerve*. 2010;41(1):32-41.

18. Pillen S, Tak RO, Zwarts MJ, et al. Skeletal muscle ultrasound: Correlation between fibrous tissue and echo intensity. *Ultrasound Med Biol*. 2009;35(3):443-446.

19. Cadore EL, Izquierdo M, Conceição M, et al. Echo intensity is associated with skeletal muscle power and cardiovascular performance in elderly men. *Exp Gerontol*. 2012;47(6):473-478.

20. Fukumoto Y, Ikezoe T, Yamada Y, et al. Skeletal muscle quality assessed from echo intensity is associated with muscle strength of middle-aged and elderly persons. *Eur J Appl Physiol*. 2012;112(4):1519-1525.

21. Mangine GT, Fukuda DH, LaMonica MB, et al. Influence of gender and muscle architecture asymmetry on jump and sprint performance. *J Sports Sci Med*. 2014;13(4):904-911.

22. Mangine GT, Fukuda DH, Townsend JR, et al. Sprinting performance on the woodway curve 3.0TM is related to muscle architecture. *Eur J Sport Sci*. 2015;15(7):606-614.

23. Hildebrandt M, Fankhauser G, Meichtry A, Luomajoki H. Correlation between lumbar dysfunction and fat infiltration in lumbar multifidus muscles in patients with low back pain. *BMC Musculoskelet Disord*. 2017;18(1).

24. Le Cara EC, Marcus RL, Dempsey AR, Hoffman MD, Hebert JJ. Morphology versus function: The relationship between lumbar multifidus intramuscular adipose tissue and muscle function among patients with low back pain. *Arch Phys Med Rehabil*. 2014;95(10):1846-1852.

25. Crawford RJ, Volken T, Valentin S, Melloh M, Elliott JM. Rate of lumbar paravertebral muscle fat infiltration versus spinal degeneration in asymptomatic populations: AN age-aggregated cross-sectional simulation study. *Scoliosis Spin Disord*. 2016;11(1).

26. Fortin M, Videman T, Gibbons LE, Battié MC. Paraspinal muscle morphology and composition: A 15-yr longitudinal magnetic resonance imaging study. *Med Sci Sports Exerc*. 2014;46(5):893-901.

27. Fortin M, Yuan Y, Battié MC. Factors associated with paraspinal muscle asymmetry in size and composition in a general population sample of men. *Phys Ther*. 2013;93(11):1540-1550.

28. Larivière C, Gagnon D, De Oliveira E, Henry SM, Mecheri H, Dumas J-. Ultrasound measures of the lumbar multifidus: Effect of task and transducer position on reliability. *PM R*. 2013;5(8):678-687.

29. Skeie EJ, Borge JA, Leboeuf-Yde C, Bolton J, Wedderkopp N. Reliability of diagnostic ultrasound in measuring the multifidus muscle. *Chiropr Man Thera*. 2015;23(1).

30. Kiesel KB, Uhl TL, Underwood FB, Rodd DW, Nitz AJ. Measurement of lumbar multifidus muscle contraction with rehabilitative ultrasound imaging. *Man Ther*. 2007;12(2):161-166.

31. Sweeney N, O'Sullivan C, Kelly G. Multifidus muscle size and percentage thickness changes among patients with unilateral chronic low back pain (CLBP) and healthy controls in prone and standing. *Man Ther*. 2014;19(5):433-439.

32. Stokes M, Rankin G, Newham DJ. Ultrasound imaging of lumbar multifidus muscle: Normal reference ranges for measurements and practical guidance on the technique. *Man Ther*. 2005;10(2):116-126.

33. Pressler JF, Heiss DG, Buford JA, Chidley JV. Between-day repeatability and symmetry of multifidus cross-sectional area measured using ultrasound imaging. *J Orthop Sports Phys Ther*. 2006;36(1):10-18.

34. Sitilertpisan P, Hides J, Stanton W, Paungmali A, Pirunsan U. Multifidus muscle size and symmetry among elite weightlifters. *Phys Ther Sport*. 2012;13(1):11-15.

35. McGregor AH, Anderton L, Gedroyc WM. The trunk muscles of elite oarsmen. *Br J Sports Med*. 2002;36(3):214-217.

36. Hides J, Stanton W, Freke M, Wilson S, McMahon S, Richardson C. MRI study of the size, symmetry and function of the trunk muscles among elite cricketers with and without low back pain. *Br J Sports Med*. 2008;42(10):509-513.

37. Zhang S, Xu Y, Han X, Wu W, Tang Y, Wang C. Functional and morphological changes in the deep lumbar multifidus using electromyography and ultrasound. *Sci Rep*. 2018;8(1).

38. Wallwork TL, Stanton WR, Freke M, Hides JA. The effect of chronic low back pain on size and contraction of the lumbar multifidus muscle. *Man Ther*. 2009;14(5):496-500.

39. Dankaerts W, O'Sullivan P, Burnett A, Straker L. Altered patterns of superficial trunk muscle activation during sitting in nonspecific chronic low back pain patients: Importance of subclassification. *Spine*. 2006;31(17):2017-2023.

40. Silfies SP, Squillante D, Maurer P, Westcott S, Karduna AR. Trunk muscle recruitment patterns in specific chronic low back pain populations. *Clin Biomech*. 2005;20(5):465-473.

41. Mengiardi B, Schmid MR, Boos N, et al. Fat content of lumbar paraspinal muscles in patients with chronic low back pain and in asymptomatic volunteers: Quantification with MR spectroscopy. *Radiology*. 2006;240(3):786-792.

42. Paalanne N, Niinimaki J, Karppinen J, et al. Assessment of association between low back pain and paraspinal muscle atrophy using opposed-phase magnetic resonance imaging: A population-based study among young adults. *Spine*. 2011;36(23):1961-1968.

43. Visser M, Goodpaster BH, Kritchevsky SB, et al. Muscle mass, muscle strength, and muscle fat infiltration as predictors of incident mobility limitations in well-functioning older persons. *J Gerontol Ser A Biol Sci Med Sci*. 2005;60(3):324-333.

44. Visser M, Kritchevsky SB, Goodpaster BH, et al. Leg muscle mass and composition in relation to lower extremity performance in men and women aged 70 to 79: The health, aging and body composition study. *J Am Geriatr Soc*. 2002;50(5):897-904.

Figure Legends

Figure 1: Transverse ultrasound image showing the cross-sectional area (CSA) lumbar multifidus (LM) measurement. Spinous process (SP) in the center of the image, echogenic laminae (La), longissimus (Lo) and thoracolumbar facia (TLF) were used as landmarks to define the LM muscle borders.

Figure 2: Parasagittal ultrasound image of the lumbar multifidus (LM) muscle showing thickness measurement at rest (left image) and during submaximal contraction (right image). The facet joints (FC) of L5-S1 were used as landmarks for the lower borders of the muscle. Sacrum (S).

Table 1

Table 1. Participants' characteristics

	All (n=41)
Age (yr)	21.0±1.1
Height (cm)	180.0±5.65
Weight (Kg)	94.2±19.4
Total lean mass (kg)	70.74±7.95
Total bone mass (kg)	3.91±3.85
Total fat mass (kg)	20.32±13.1
Total body fat %	20.8±8.6
BMI	29.0±5.3
Dominant leg (n)	
Right	34
Left	5
Either	2
Position (n)*	
Defense	22
Offense	18
Football competitive level (yr)	8.6±3.1
Football university level (yr)	1.44±1.3
LBP past 3-month (pre-season) (n)	18
LBP location 3-month (pre-season) (n)	
Centered	8
Bilateral	4
Unilateral	6
VAS LBP (0-10) past 3-months	5.08±1.8

*missing data for one player

Table 2

Table 2. LM muscle measurements of the right and left sides.

	Right	**Left**
PRONE		
CSA (cm^2)	10.74±1.85	10.87±1.64
CSA asymmetry (%)	4.80±3.25	
EI	54.47±16.56	54.20±15.96
Thickness (cm)		
Rest	**3.49±0.58**	**3.62±0.51**
Contracted	**3.94±0.55**	**4.10±0.52**
% change	14.06±8.90	13.27±8.12
STANDING		
CSA (cm^2)	11.87±1.47	12.10±1.64
CSA asymmetry (%)	2.42±2.50	
Thickness (cm)		
Rest	4.05±0.52	4.10±0.51
Contracted	**4.14±0.53**	**4.23±0.53**
% change	2.26±3.80	3.61±4.36

Bold= $p<0.05$

Table 3

Table 3. LM muscle characteristics between players with and without LBP in the past 3 months.

	No LBP (n=23)	**LBP** (n=18)
PRONE		
CSA (cm^2)[a]	11.10 (0.33)	10.43 (0.37)
CSA asymmetry (%)	4.49 (0.72)	5.07 (0.72)
EI[b]	52.38 (2.13)	56.84 (2.43)
Thickness (cm)		
Rest[a]	**3.68 (0.09)**	**3.40 (0.10)**
Contracted[a]	4.06 (0.10)	3.90 (0.14)
% change[b]	12.67 (1.69)	16.20 (1.88)
STANDING		
CSA (cm^2)[a]	12.27 (0.33)	11.59 (0.31)
CSA asymmetry (%)	2.09 (0.39)	2.90 (0.80)
Thickness (cm)		
Rest[a]	**4.20 (0.09)**	**3.89 (0.10)**
Contracted[a]	4.25 (0.09)	4.10 (0.14)
% change[b]	2.71 (0.64)	3.17 (0.73)

[a] = Adjusted means for height and weight.

[b]= Adjusted means for total percent body fat

bold=$p<0.05$

Table 4

Table 4: Correlation matrix - Body composition and LM muscle characteristics (prone position) in male football players.

	Weight	Height	Bone Mass	Lean Mass	Fat Mass	% Fat	CSA	EI	TK rest	TK Cont	% TK change
Weight	1	0.45[b]	0.48[a]	0.82[a]	0.93[a]	0.99[a]	0.51[a]	0.67[a]	0.63[a]	0.47[a]	-0.46[b]
Height		1	0.60[a]	0.51[a]	0.34[c]	0.46[b]	0.36[c]	0.39[b]	0.27	0.29	-0.11
Bone Mass			1	0.68[a]	0.27	0.48[b]	0.24	0.36[b]	0.24	0.27	0.001
Lean Mass				1	0.57[a]	0.82[a]	0.51[a]	0.34[c]	0.56[a]	0.47[b]	-0.31
Fat Mass					1	0.94[a]	0.43[b]	0.76[a]	0.56[a]	0.40[b]	-0.48[a]
% Fat						1	0.52[a]	0.76[a]	0.56[a]	0.40[b]	-0.48[a]
CSA							1	0.31	0.63[a]	0.66[a]	-0.20
EI								1	0.31	0.20	-0.32[c]
TK rest									1	0.90[a]	-0.56[a]
TK cont										1	-0.19
% TK change											1

[a] = p≤0.001
[b] = p≤0.01
[c] = p<0.05

F

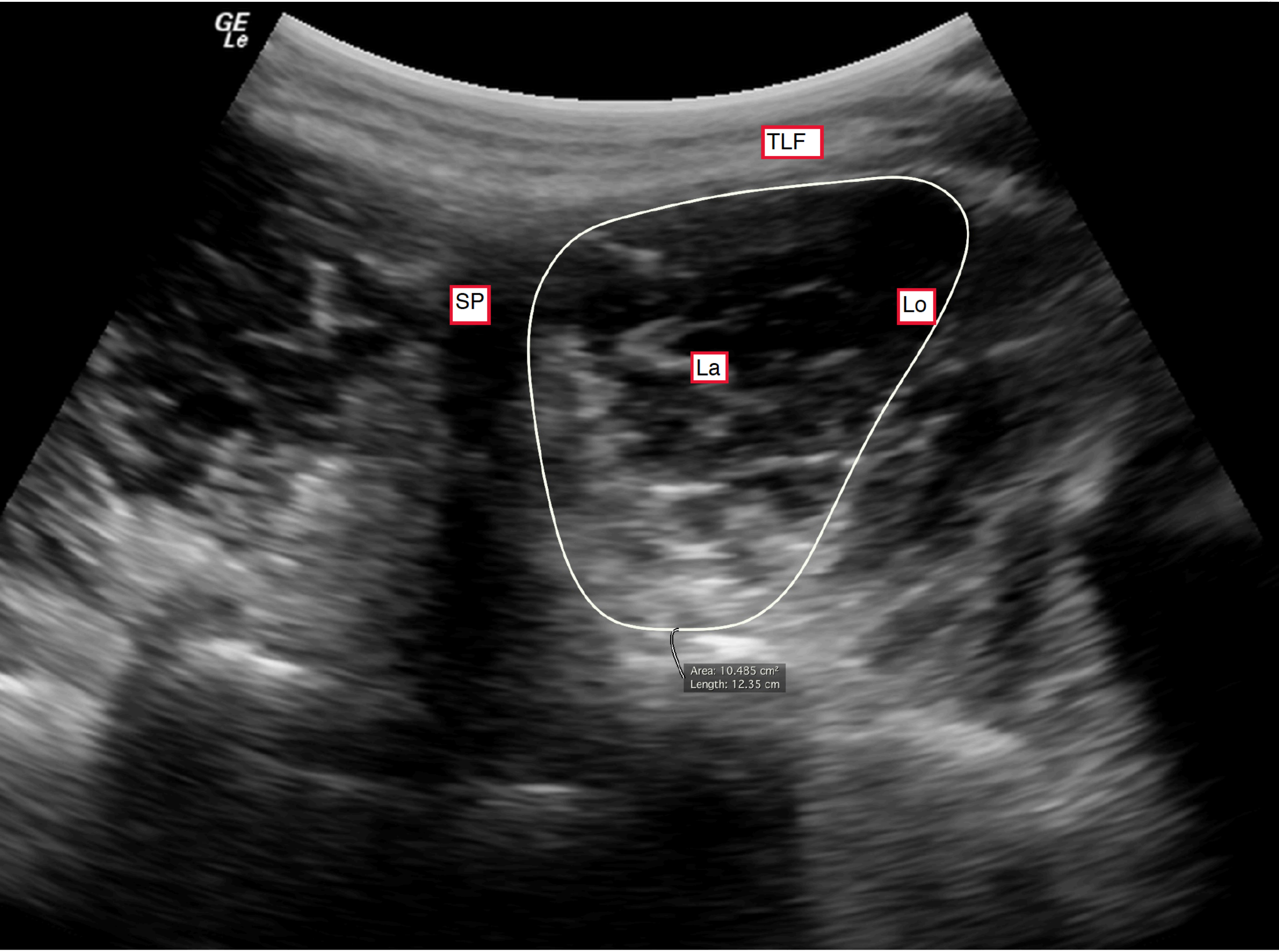
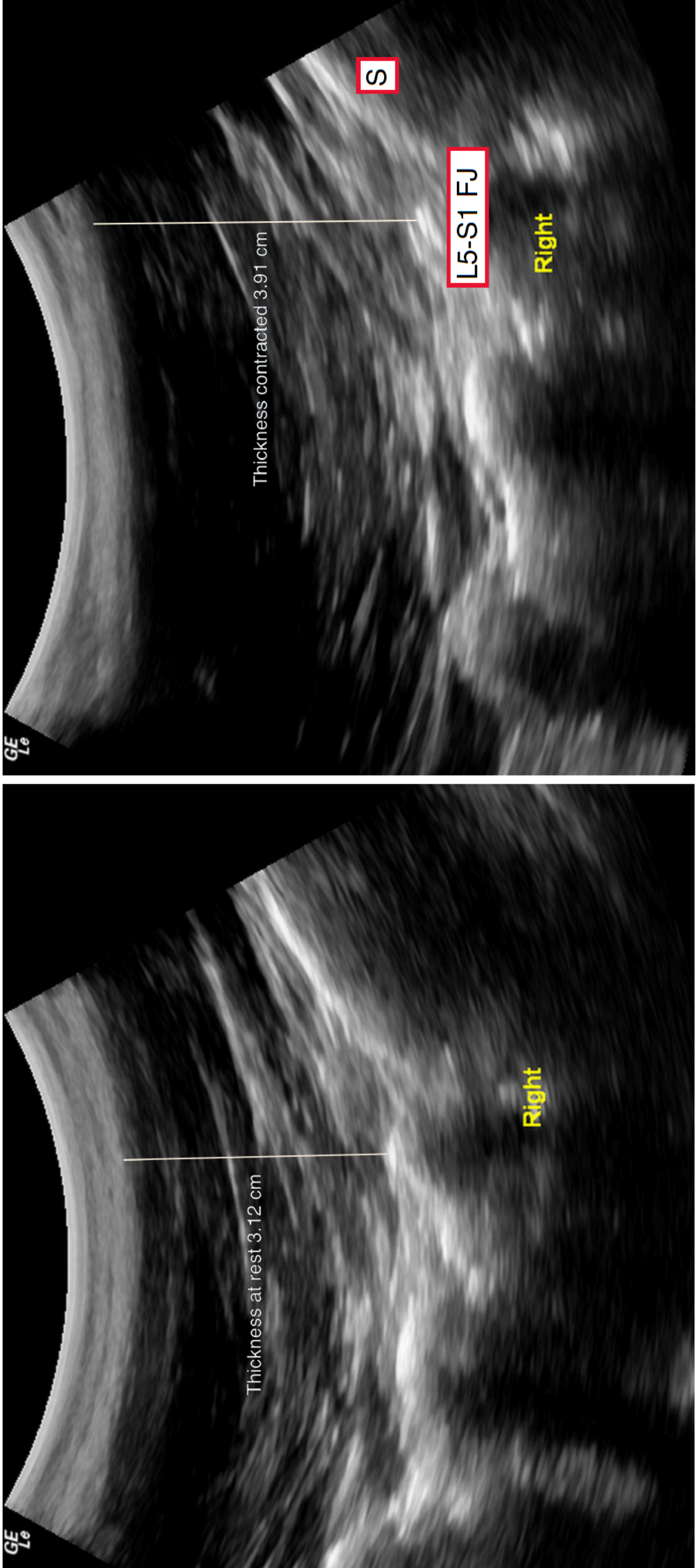


Figure 2


S
L5-S1 FJ
Thickness contracted 3.91 cm
Right
Thickness at rest 3.12 cm
Right