Research Article

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Lumbar Multifidus Characteristics in University Level Athletes May be Predictors of Low Back Pain and Lower Limb Injury

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ABSTRACT

Introduction: *Low back pain (LBP) is highly prevalent in athletes, with decreased lumbar multifidus (LM) cross-sectional area (CSA) reported in athletes with LBP and lower limb injury (LLI) as well as decreased LM thickness in athletes with LLI. Previous research has only investigated connections between LM, LBP, and LLI in small samples of athletes in a single sport at a time. This study aimed to (1) examine LM morphology and function across a general sample of male and female university level varsity athletes; (2) investigate whether LM characteristics were predictors of LBP and LLI.*

Methods: *Ultrasound images of LM at L5 were acquired in prone and standing. Body composition was assessed with DEXA and a self-reported questionnaire provided demographics and history of injury. Paired t-tests and independent t-tests compared LM measurements between the sides and sex, respectively. Univariate and multivariate logistic regression analyses were used to assess possible LM characteristic predictors of LBP and LLI.*

Results: *134 university varsity athletes were evaluated. LM CSA was larger on the non-dominant side in prone. Increased LM thickness was associated with decreased odds of LBP in the previous 4-week (OR=0.49 [0.27, 0.88], p=0.02) and 3-month (OR=0.43 [0.21, 0.89], p=0.02) in the multivariable model, while a greater number of years playing at the university level was associated with increased odds of LBP (OR=1.29 [1.01, 1.65], p=0.04). Greater LM CSA asymmetry (OR=1.14 [1.01, 1.28], p=0.03) and sport (OR=1.44 [1.04, 1.96], p=0.02) were significant predictors of LLI in the previous 12 months.*

Conclusion: *Leg dominance may play a role in unilateral differences. LM thickness and LM CSA asymmetry were predictors of injury. Preseason screening of LM morphology and function could help identify athletes at risk of LBP and LLI, allowing coaches, medical staff, and training staff to target these individuals and provide specific injury prevention programs.*

Keywords
Lumbar multifidus, Low back pain, Athletes, Ultrasound.

Abbreviations
LBP: Low Back Pain, LM: Lumbar Multifidus, CSA: Cross-Sectional Area, LLI: Lower Limb Injury, AFL: Australian Football League, DEXA: Dual Energy X-ray Absorptiometry, US: Ultrasound, CAL: Contralateral Arm Lift, EI: Echo Intensity, BMI: Body Mass Index.

Introduction
Low back pain (LBP) has been a leading medical complaint for nearly three decades [1], reaching as high as 94% in the athletic population despite increased training time and intensity [2,3]. LBP is defined as any pain between T12 and the gluteal fold, which may be accompanied by neurological symptoms in one or both legs [4]. Several risk factors for LBP in athletes include type of sport, level of competition, over- and under-training, previous LBP, decreased mobility, strength, and endurance of the lumbar region, and, high body weight [5,6].

The lumbar multifidus (LM) is a deep local spinal muscle providing segmental stabilization of the lumbar spine at rest and proprioceptive control during movement [7,8] and plays a key role in force transferal from the extremities through the kinetic chain [9]. Previous imaging studies noted decreased LM cross-sectional area (CSA), [10-16] increased LM CSA asymmetry [10,16], and decreased thickness in athletes with LBP [10,11,16]. However, some studies found increased LM CSA or no relationship [17,18]. Thus, changes in LM morphology in athletes with LBP are still conflicting and may be sport dependent. Anthropometric factors such as sex, height, weight, % body fat, and lean mass were also reported to affect LM characteristics in both the general population [19,20] and athletes [10-13,21]. Furthermore, LM morphology at the L5 segment was consistently stated as a strong predictor of lower limb injury (LLI) in elite Australian Football League (AFL) players [14,22-24], with LM CSA predicting up to 83.3% of all hip, groin, and thigh injuries [24].

Given the prevalence of LBP and LLI in athletes, defining the role of LM characteristics in different sports warrants additional attention, especially with increased forces placed on LM during competition. To date, most studies examined LM morphology and function in prone [10-13,21] with a lack of data in regard to more functional positions. Furthermore, previous studies have only examined single sports with small sample sizes, making it difficult to translate findings across various sports. Therefore, this study aims to (1) examine LM morphology and function across a general sample of male and female university varsity athletes in prone and standing positions at rest and in contracted states; and (2) investigate if LM morphology and function are predictors of LBP and LLI in university varsity athletes. We hypothesized that smaller LM CSA and greater LM asymmetry and % thickness change will be predictors of LBP and LLI in university level varsity athletes.

Materials & Methods
Study design & participants
This was a retrospective secondary analysis of a cross-sectional study approved by the Research Ethical Committee of the Institution and by the Central Ethics Committee of the Quebec Minister of Health and Social Services. Ice hockey players (32; 18 female, 14 male), football players (41; all male), soccer players (27; 12 female, 15 male), and rugby players (34; 20 female, 14 male) varsity team players from Concordia University were included in the current study for a total of 134 participants (50 female, 84 male). All available players were invited to participate if over 18 years old to maximize the sample size. The exclusion criteria included previous severe trauma or spinal fracture, previous spinal surgery, and observable spinal abnormalities. Pregnancy was an additional exclusion criterion as participants were required to undergo a DEXA scan. All players provided a written informed consent.

Self-Reported Outcomes
At the start of the preseason (beginning of September 2016), participants completed a self-administered questionnaire regarding player demographics and history of LBP prior to assessment. Athletes were also asked about leg dominance (e.g., right, left or either) with those choosing "either" being considered right leg dominant for analysis [14,24]. 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 in the past three months (off season) [10-13]. Players who answered "yes" to the presence of LBP completed Numerical Pain Rating Scale [10-13] to assess average LBP intensity in addition to indicating LBP location (centered, left, right) and duration (in months). Participants were also asked to fill out whether they experienced or suffered a LLI within the last 12 months causing them to miss at least one practice or game as well as the location of the injury.

Ultrasound assessments
Ultrasound (US) B-mode images of LM were acquired using a LOGIQ e ultrasound machine (GE Healthcare) with a 5MHz curvilinear transducer. The imaging parameters were kept consistent for all acquisitions (frequency: 5MHz, gain: 60, depth: 8.0cm). Bilateral transverse images of the right and left LM CSA at L5 were obtained simultaneously in both prone and standing positions, except for athletes with larger muscles, where the right and left sides were imaged separately. Three images per side were obtained. Parasagittal images of the right and left were used to assess L5 LM thickness at rest and during a submaximal contraction via contralateral arm lift (CAL) in both prone and standing positions. The handheld weight used for the CAL was based on the participant's body weight (<68.2kg = 0.68kg weight, 68.2-90.9kg = 0.9kg weight, >90.0kg = 1.36kg weight). The measurement techniques used are described in detail elsewhere [10]. Three images at rest and contracted for the right and left sides were obtained. US images were stored and analyzed offline using OsiriX imaging software (OsiriXLiteVersion 9.0). LM CSA were obtained by tracing the muscle borders on both sides on each image (see Figure 1) and the average of the three

measurements (on three different images) was used in the analysis (LM borders: paraspinals, laminae, and thoracolumbar fascia) [10-13]. The relative % asymmetry in CSA between right and left sides was calculated using the following formula: [(larger side – smaller side)/larger side]x100%. LM thickness at rest and contracted in both prone and standing was obtained using linear measurements from the tip of the L5/S1 zygoapophyseal joint to the inside edge of the superior muscle border (see Figure 2) [10-13]. Each measurement was performed on 3 different images and the average was used in the analyses. The following formula was used to assess LM contraction: $[(\text{thickness}_{contraction} - \text{thickness}_{rest})/\text{thickness}_{rest}] \times 100$. LM echo intensity (EI) was measured using grayscale analysis imaging (ImageJ, National Institute of Health, USA, Version 1.49) by tracing a region of interest representing LM CSA in prone. A standard histogram function of pixels was used (0=black, 255=white). All measurements were taken by an experienced researcher and the rater was blinded to the players' characteristics and LBP history.

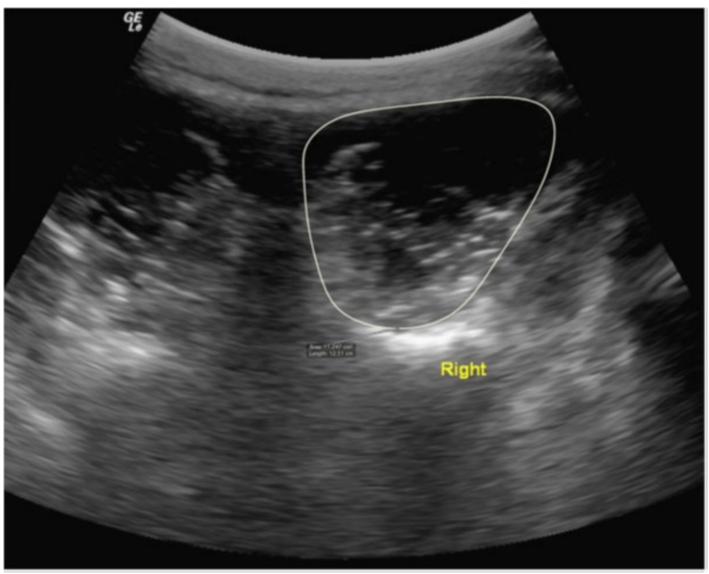

Figure 1: LM CSA measurement in a male soccer player at the L5 vertebral level in prone. Permission has been acquired for use of this photo [13].

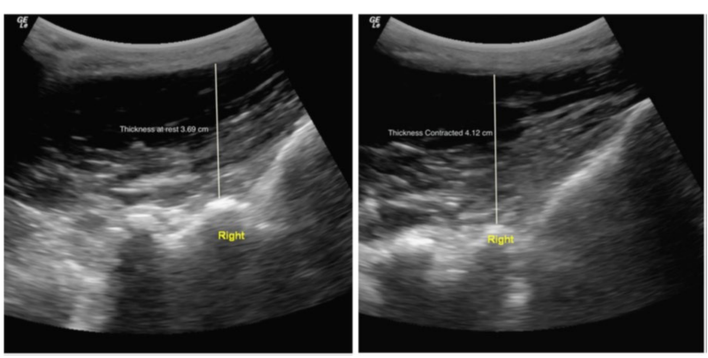

Figure 2: LM thickness measurement in a male soccer player at L5-S1 at rest (left) and during contraction (right) via a CAL in prone. Permission has been acquired for use of this photo [13].

Dual-energy x-ray absorptiometry

All participants had a full body DEXA scan (Lunear Prodigy Advance, GE) performed by a certified medical imaging technologist. Participants removed any metal and wore loose fitting clothing to avoid interference with the scan. Age, height, weight, and ethnicity were entered into the computer program prior to imaging. Participants were supine in the centre of the scanner. Their arms were held slightly away from the body with thumbs pointed upwards and their legs were slightly apart with toes pointed upwards. Total lean mass, total bone mass, total fat mass, and total % body fat were obtained.

Statistical Analysis

Means and standard deviations were calculated for athletes' characteristics and LM measurements of interest. Paired t-tests were used to examine the difference in LM characteristics (e.g. CSA, EI, CSA asymmetry, thickness at rest and during contraction both in prone and standing positions) and between the dominant and non-dominant sides, separately by sex. Independent t-tests were used to assess the difference in LM characteristics between male and female athletes. Logistic regression was used to determine if LM characteristics of interest were predictors of LBP. Similarly, a separate logistic regression analysis was conducted for LLI. To account for inter-individual anthropometric difference, a ratio variable was created of LM characteristics using the strongest body composition predictor. Accordingly, LM CSA and thickness measurements were divided by lean body mass or weight and LM EI by % body fat. Associations were first examined using univariate logistic regression. Sex, sport, number of years playing sport at a competitive level, and body composition measurements were also tested as possible covariates. A purposeful selection strategy was used and variables with a p-value <0.02 in the univariate analysis were tested for the multivariate logistic regression models. Variables with a p-value >0.05 were then removed from the models after being assessed as possible cofounders (e.g., variable leading to ± 15% change in regression coefficients of significant variables in the model). The assumptions were tenable for each model and model's collinearity was verified.

Results

All 134 participants were retained for analysis.

Player Characteristics

Participants' characteristics are presented in Table 1. The mean ± SD age, height, and weight in females were 21.2 ± 1.8 years, 166.6 ± 6.5 cm, and 68.4 ± 8.5 kg, respectively. The mean ± SD age, height, and weight in males were 20.9 ± 1.4 years, 179.6 ± 6.4 cm, and 86.7 ± 17.0 kg, respectively. A total of 41% (n=55) reported having LBP in the previous four weeks and 39.5% (n=53) reported the presence of LBP in the previous three months. A total of 44% (n=59) of players reported having a LLI within the last year, with 26.1% (n=35) reporting a LLI in the previous four weeks.

Table 1: Participants' characteristics (mean ± SD).

	All (n = 134)	Female (n = 50)	Male (n = 84)
Age (yr)	21.0 ± 1.5	21.2 ± 1.8	20.9 ± 1.4
Height (cm)	174.8 ± 9.0	166.6 ± 6.5	179.6 ± 6.4
Weight (kg)	79.9 ± 16.9	68.4 ± 8.5	86.7 ± 17.0
Total lean mass (kg)	59.6 ± 12.1	47.3 ± 5.5	66.9 ± 8.6
Total bone mass (kg)	3.4 ± 0.6	2.8 ± 0.3	3.7 ± 0.5
Total fat mass (kg)	17.5 ± 9.0	18.7 ± 5.8	16.8 ± 10.4
Total body fat %	22.3 ± 8.0	28.0 ± 6.2	19.0 ± 7.1
BMI	26.0 ± 4.1	24.6 ± 2.7	26.8 ± 4.6
Dominant leg (n)[a]			
Right	109	42	67
Left	17	7	10
Either	7	0	7
Competitive level (yr)	9.0 ± 3.7	7.3 ± 3.7	8.6 ± 3.9
University level (yr)	2.0 ± 1.5	2.2 ± 1.5	1.5 ± 1.6
LBP 4 weeks prior (n)	55	19	36
LBP location 4 weeks prior (n)[b]			
Centered	21	6	15
Bilateral	12	4	8
Unilateral	21	9	12
VAS LBP (0-10) 4 weeks prior	4.2 ± 1.9	4.1 ± 1.4	4.3 ± 1.8
LBP 3 months prior (n)	53	16	37
LBP location 3 months prior (n)[b]			
Centered	23	8	15
Bilateral	14	4	10
Unilateral	15	4	11
VAS LBP (0-10) 3 months prior	4.4 ± 1.9	4.0 ± 2.0	4.7 ± 1.7
LBP last competitive year (n)[c]	39	14	25
LLI 4 weeks prior (n)[d]	35	9	26
LLI 12 months prior (n)	59	22	37

[a] – One missing data from the female group; [b] – One missing data from the male group; [c] – Five missing data from the male group; [d] – Two missing data from the female group; VAS – visual analog scale; LBP – low back pain; LLI – lower limb injury.

LM Characteristics in Male and Female Players

LM characteristics of dominant and non-dominant leg in males and females are presented in Table 2. LM CSA was significantly larger on the non-dominant side in prone in both males and females (p<0.05). LM thickness was significantly greater on the non-dominant side in prone both at rest (p<0.05) and contracted (females: p<0.05; males: p<0.001). There were no significant differences in % thickness change on dominant and non-dominant sides in either prone or standing.

Table 2: Dominant and non-dominant leg LM characteristics in female and male athletes (mean ± SD).

	Female		Male	
	Dominant	Non-Dominant	Dominant	Non-Dominant
PRONE				
CSA (cm²)	8.11 ± 1.33*	8.26 ± 1.32	10.34 ± 1.58*	10.54 ± 1.55
CSA asymmetry (%)	3.82 ± 3.33		4.50 ± 3.09	
EI	72.39 ± 17.21	70.82 ± 16.64	51.88 ± 15.61	51.99 ± 15.13
Thickness (cm)				
Rest	2.77 ± 0.40*	2.85 ± 0.41	3.34 ± 0.54*	3.41 ± 0.54
Contracted	3.20 ± 0.46*	3.26 ± 0.45	3.80 ± 0.54**	3.90 ± 0.54
% change	15.52 ± 6.81	14.74 ± 7.47	14.57 ± 8.68	15.11 ± 8.68
STANDING				
CSA (cm²)	9.57 ± 1.58	9.65 ± 1.44	11.77 ± 1.51	11.91 ± 1.62
CSA asymmetry (%)	3.54 ± 2.84		2.92 ± 2.56	
Thickness (cm)				
Rest	3.22 ± 0.46	3.26 ± 0.43	3.85 ± 0.57	3.85 ± 0.57
Contracted	3.32 ± 0.46	3.36 ± 0.47	3.98 ± 0.56	4.01 ± 0.58
% change	3.55 ± 4.69	3.31 ± 4.66	3.58 ± 4.13	4.32 ± 4.99

* = p<0.05, **=p<0.001 indicating a significant difference within male of female; CSA – cross-sectional area; EI – echo intensity.

Overall LM characteristics (e.g., average of dominant and non-dominant sides) in prone vs. standing in male and female players are presented in Table 3. LM CSA was significantly smaller in prone compared to standing (p<0.001). LM CSA asymmetry was greater in the prone position compared to standing but was only significant in males (p<0.001). LM thickness at rest and contracted were significantly greater in the standing position compared to prone (p<0.001). The % thickness change was significantly smaller in the standing position compared to prone (p<0.001). Males had significantly larger LM CSA and thickness at rest and contracted in both prone and standing positions compared to females (p<0.001). Females had significantly higher EI than males (p<0.001). There was no significant difference in CSA asymmetry or % change in thickness between male and female athletes in prone or standing.

Table 3: LM characteristics in female and male athletes in prone vs standing (mean ± SD).

	Female		Male	
	Prone	Standing	Prone	Standing
CSA (cm²)	**8.18 ± 1.31***	**9.35 ± 1.40**	10.41 ± 1.55*	11.86 ± 1.52
CSA asymmetry (%)	3.82 ± 3.33	3.56 ± 2.87	4.53 ± 3.11*	2.97 ± 2.57
EI	**71.61 ± 16.31**		52.14 ± 15.30	
Thickness (cm)				
Rest	**2.18 ± 0.40***	**3.24 ± 0.43**	3.37 ± 0.53*	3.82 ± 0.55
Contracted	**3.24 ± 0.45***	**3.35 ± 0.45**	3.85 ± 0.52*	3.97 ± 0.55
% change	15.16 ± 6.66*	3.51 ± 3.56	15.20 ± 8.22*	3.98 ± 3.73

Bold = p<0.001 indicating a significant difference between female and male; * = p<0.001 indicating a significant difference within female or male; CSA – cross-sectional area; EI – echo intensity.

LM characteristics and LBP

Univariate and multivariate logistic regression for LBP in the previous four weeks and three months is presented in Table 4. Univariate logistic regression analysis revealed years played at the university level and LM thickness at rest in prone were significant predictors of LBP in the previous four weeks (p≤0.05) and weight, BMI, and LM CSA, thickness at rest and contracted in prone and standing were significant predictors of LBP in the previous three months (p ≤ 0.05). Thickness at rest in prone (OR=0.49 [0.27, 0.88], p=0.02) and years played at the university level (OR=1.29 [1.01, 1.65], p=0.04) remained significant in the multivariable analysis and associated with a 51% decreased and 29% increased odds of having LBP in the previous four weeks, respectively. While smaller side of LM thickness at rest in prone (OR=0.43 [0.21-0.89], p=0.02) remained significant in the multivariable analysis model and was associated with a 57% decreased odds of having LBP in the previous three months, along with weight (OR=1.01 [0.99, 1.04], p=0.27) and years played at the university level (OR=1.26 [0.97, 1.61], p=0.08) which were confounders.

LM characteristics and LLI

Univariate and multivariate logistic regression for LLI in the previous four weeks and 12 months is presented in Table 5. Univariate logistic regression analysis revealed only sport was a significant predictor of LLI in the previous four weeks (p=0.02) and sport and LM CSA asymmetry in prone, were significant predictors of LLI in the previous 12 months (p ≤ 0.02). There were no significant predictors retained in the multivariate logistic

Table 4: Player and LM characteristics in athletes with and without LBP in the previous 4 weeks and 3 months.

	LBP 4 Weeks				**LBP 3 Months**			
	Univariate		**Multivariate**		**Univariate**		**Multivariate**	
	OR (95% CI)	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**
Age	1.07 (0.85-1.34)	0.58			1.07 (0.85-1.34)	0.58		
Sex	1.22 (0.60-2.50)	0.58			1.67 (0.80-3.49)	0.17		
Sport	1.01 (0.75-1.35)	0.97			1.01 (0.75-1.36)	0.96		
Height (cm)	1.01 (0.97-1.05)	0.54			1.04 (1.00-1.08)	0.08		
Weight (kg)	1.01 (0.99-1.03)	0.37			1.03 (1.00-1.05)*	0.02	1.01 (0.99-1.04)	0.27
BMI	1.04 (0.95-1.13)	0.42			1.09 (1.00-1.19)	0.05		
Yrs Competitive	1.07 (0.97-1.17)	0.17			1.01 (0.92-1.11)	0.81		
Yrs Concordia	1.27 (1.00-1.61)	0.05	1.29 (1.01-1.65)*	0.04	1.24 (0.98-1.57)	0.08	1.26 (0.97-1.62)	0.08
% body fat	2.45 (0.03-178.19)	0.68			0.66 (0.01-50.00)	0.85		
PRONE								
CSA (cm^2)								
Average[a]	0.88 (0.76-1.01)	0.06			0.86 (0.75-0.99)*	0.04		
Asymmetry (%)	1.05 (0.94-1.17)	0.37			0.99 (0.89-1.11)	0.90		
Small side[a]	0.88 (0.77-1.01)	0.08			0.87 (0.76-1.01)	0.06		
EI[b]	0.92 (0.57-1.48)	0.73			1.12 (0.70-1.80)	0.64		
Thickness at rest (cm)								
Average[c]	0.50 (0.28-0.89)*	0.02	0.49 (0.27-0.88)*	0.02	0.37 (0.20-0.69)*	<0.01		
Asymmetry	0.36 (0.03-4.92)	0.45			5.62 (0.43-73.07)	0.19		
Small side[c]	0.51 (0.29-0.91)*	0.02			0.36 (0.19-0.67)*	<0.01	0.43 (0.21-0.89)*	0.02
Thickness contracted (cm)								
Average[a]	0.76 (0.54-1.07)	0.11			0.62 (0.43-0.89)*	0.01		
Asymmetry	0.34 (0.03-3.64)	0.37			1.79 (0.19-17.34)	0.62		
Small side[a]	0.77 (0.55-1.07)	0.12			0.64 (0.45-0.91)*	0.01		
% Thickness Change								
Average	1.02 (0.98-1.07)	0.31			1.03 (0.99-1.08)	0.19		
Asymmetry	1.07 (0.98-1.18)	0.15			1.10 (1.00-1.21)	0.05		
Small side	1.01 (0.97-1.06)	0.67			1.02 (0.98-1.07)	0.37		
STANDING								
CSA (cm^2)								
Average[a]	0.90 (0.79-1.01)	0.08			0.87 (0.77-0.99)*	0.04		
Asymmetry (%)	0.99 (0.87-1.14)	0.92			1.08 (0.94-1.23)	0.29		
Small side[a]	0.89 (0.79-1.01)	0.07			0.87 (0.77-0.99)*	0.03		
Thickness at rest (cm)								
Average[a]	0.75 (0.53-1.06)	0.10			0.63 (0.44-0.91)*	0.01		
Asymmetry	0.33 (0.03-4.26)	0.40			2.36 (0.19-28.87)	0.50		
Small side[a]	0.76 (0.54-1.08)	0.13			0.63 (0.43-0.90)*	0.01		
Thickness contracted (cm)								
Average[a]	0.77 (0.55-1.08)	0.13			0.63 (0.44-0.90)*	0.01		
Asymmetry	0.54 (0.04-8.07)	0.66			4.07 (0.28-59.44)	0.31		
Small side[a]	0.76 (0.54-1.07)	0.11			0.61 (0.42-0.87)*	0.01		
% Thickness Change								
Average	0.98 (0.89-1.08)	0.69			0.95 (0.86-1.05)	0.30		
Asymmetry	1.05 (0.95-1.15)	0.35			1.03 (0.94-1.13)	0.56		
Small side	0.97 (0.89-1.06)	0.46			0.95 (0.87-1.04)	0.25		

*= p<0.05; [a]Adjusted for total lean body mass; [b]Adjusted for %body fat; [c]Adjusted for weight; CSA – cross-sectional area; EI – echo intensity.

Table 5: Player and LM characteristics in athletes with and without LLI in the previous 4 weeks and 12 months.

	LLI 4 Weeks				LLI 12 Months			
	Univariate		Multivariate		Univariate		Multivariate	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Age	1.11 (0.86-1.43)	0.44			1.09 (0.87-1.37)	0.45		
Sex	1.94 (0.82-4.59)	0.13			1.00 (0.50-2.03)	1.00		
Sport	1.51 (1.06-2.14)*	0.02	1.51 (1.06-2.14)*	0.02	1.47 (1.09-2.00)*	0.01	1.44 (1.05-1.96)*	0.02
Height (cm)	1.02 (0.98-1.07)	0.30			0.99 (0.96-1.03)	0.73		
Weight (kg)	1.00 (0.98-1.03)	0.79			1.00 (0.98-1.02)	0.73		
BMI	0.99 (0.90-1.09)	0.86			1.03 (0.95-1.15)	0.53		
Yrs Competitive	1.06 (0.96-1.18)	0.25			1.05 (0.96-1.15)	0.33		
Yrs Concordia	0.90 (0.69-1.17)	0.42			1.00 (0.80-1.25)	0.99		
% body fat	0.29 (0.00-37.44)	0.62			0.50 (0.01-35.54)	0.75		
PRONE								
CSA (cm^2)								
Average[a]	0.97 (0.84-1.13)	0.72			0.92 (0.80-1.05)	0.21		
Asymmetry (%)	1.10 (0.97-1.23)	0.13			1.14 (1.02-1.28)*	0.02	1.14 (1.01-1.28)*	0.03
Small side[a]	0.95 (0.82-1.11)	0.55			0.91 (0.80-1.04)	0.17		
EI[b]	0.59 (0.32-1.09)	0.09			0.67 (0.41-1.10)	0.11		
Thickness at rest (cm)								
Average[c]	1.10 (0.60-2.01)	0.77			1.22 (0.71-2.10)	0.46		
Asymmetry	0.61 (0.03-11.24)	0.74			4.29 (0.34-54.70)	0.26		
Small side[c]	1.12 (0.61-2.08)	0.71			1.20 (0.70-2.07)	0.51		
Thickness contracted (cm)								
Average[a]	1.04 (0.72-1.50)	0.83			1.06 (0.76-1.47)	0.73		
Asymmetry	0.28 (0.02-4.49)	0.37			0.66 (0.07-6.45)	0.72		
Small side[a]	1.08 (0.75-1.55)	0.67			1.08 (0.78-1.49)	0.63		
% Thickness Change								
Average	1.03 (0.98-1.08)	0.29			0.99 (0.95-1.04)	0.75		
Asymmetry	1.05 (0.95-1.16)	0.36			1.03 (0.94-1.13)	0.53		
Small side	1.02 (0.98-1.08)	0.34			0.99 (0.95-1.04)	0.78		
STANDING								
CSA (cm^2)								
Average[a]	0.89 (0.78-1.03)	0.11			0.93 (0.83-1.04)	0.22		
Asymmetry (%)	0.96 (0.82-1.12)	0.60			0.98 (0.86-1.12)	0.80		
Small side[a]	0.89 (0.77-1.02)	0.09			0.93 (0.83-1.04)	0.19		
Thickness at rest (cm)								
Average[a]	1.04 (0.72-1.52)	0.82			1.11 (0.80-1.55)	0.55		
Asymmetry	0.39 (0.02-7.04)	0.53			0.57 (0.05-6.90)	0.66		
Small side[a]	1.06 (0.73-1.54)	0.76			1.12 (0.81-1.56)	0.50		
Thickness contracted (cm)								
Average[a]	1.01 (0.70-1.45)	0.97			1.05 (0.76-1.44)	0.79		
Asymmetry	1.76 (0.09-33.86)	0.71			4.76 (0.33-69.10)	0.25		
Small side[a]	0.99 (0.69-1.42)	0.95			1.06 (0.77-1.46)	0.73		
% Thickness Change								
Average	0.92 (0.82-1.02)	0.12			0.97 (0.88-1.06)	0.49		
Asymmetry	1.02 (0.91-1.13)	0.75			0.95 (0.87-1.05)	0.34		
Small side	0.92 (0.83-1.02)	0.12			0.99 (0.91-1.08)	0.80		

*=$p<0.05$; [a]Adjusted for total lean body mass; [b]Adjusted for %body fat; [c]Adjusted for weight; CSA – cross-sectional area; EI – echo intensity.

regression model for LLI in the previous four weeks. Increased LM CSA asymmetry (OR=1.14 [1.01, 1.28], p=0.03) in prone and type of sport (OR=1.44 [1.04, 1.96], p=0.02) were significant predictors in the multivariable model for LLI in the previous 12 months and associated with 14% and 44% increased odds of having a, respectively, with football having the strongest association.

Discussion

Males had significantly larger and thicker LM compared to females, while females had significantly greater EI than males. CSA and thickness measurements were significantly greater on the non-dominant side in both males and females. All CSA and thickness measurements were significantly larger in standing compared to prone, except for CSA asymmetry and % thickness change which were smaller in a standing position. This supports the need to consider anthropometric factors when investigating LM characteristics and that leg dominance may affect these characteristics. A thicker LM at rest in prone suggested decreased odds of the presence of LBP while more years played at the university level presented with increased odds of LBP. Increased CSA asymmetry in prone and type of sport suggested increases in the presence of LLI. Thicker LM with a smaller difference between sides may result in decreased LBP and LLI experienced by university varsity athletes, whereas veteran athletes and athletes in specific sports may be at higher risk for LBP and LLI.

The larger stature of males likely explains the differences in LM characteristics observed which is in accordance with previous studies in athletes [10-13,21]. As expected, females had significantly greater EI than males as females generally have a higher % body fat than males in both athletic and general populations [19,25], which is also reflected by higher intramuscular fat [26,27]. The role of body composition on LM morphology and function warrants further attention. Previous studies in athletic populations also reported larger LM CSA and thickness on the stance leg (i.e. non-dominant leg) [13,21,22]. This could be explained by the need to provide increased stability and proprioceptive control for the forces going through the kinetic chain on the stabilizing leg. However, rowers and elite weightlifters showed no LM CSA asymmetry at L5 [17,28] and elite cricketers had greater LM CSA on the same side as their dominant arm [29], indicating the differences in LM CSA asymmetry between sports may be the result of sport specific demands. Our findings with regards to LM morphology in standing may be attributed to the LM being already contracted in standing to provide appropriate stabilization and proprioceptive control of the lumbar segments [30,31]. Furthermore, % change in thickness was significantly lower in standing compared to prone in both males and females, which is corroborated in previous single sport research [10-13,21]. It is important to understand how LM modulates in functional positions due to the increased need for stability in the lumbar spine during athletic movements (e.g. change of direction, sprinting, and tackling). The greater physical demands in sport may also explain the hypertrophy observed in athletes when compared to nonathletic populations [20,32].

In previous small sample and single sport studies, significant associations between LM characteristics and LBP were also reported, however the LM characteristics associated with LBP were inconsistent between sports [10-13,15-17,21]. The inconsistent findings may be related to variations in measurement methodologies between studies [33]. With multiple sports combined as in the current study, LM thickness was the only a significant predictor of LBP suggesting this is likely the strongest predictor for LBP in athletes and should be further investigated in future studies. Athletes with thicker LM may have better contractibility and a greater capacity to produce more force during contraction, leading to a protective effect and greater stabilization of the lumbar spine during movement. Athletes who played longer at the university level also had increased odds of having LBP. The increased demands placed on the body through the kinetic chain at a higher competitive level with increased training volume and loads may explain this finding. Our findings also suggest that greater CSA asymmetry was a predictor of LLI in the previous 12-months, which is corroborated in some [22,34] but not all studies [35]. The association between LM characteristics and LLI may be sport specific or may not play as large a role in the presence of LLI as compared to LBP. When athletes are placed in more functional positions (i.e. standing), we observed a decrease in LM CSA asymmetry, regardless of the presence of injury or pain, suggesting that LM retains the ability to contract when put under increased stress [10-13,21]. Future studies should investigate whether the ability of LM to maintain a contraction over a period of time or during application of a force is associated with the risk of LLI in athletes.

Only four sports were included from a single university in this study. Other sports from several universities should be examined to provide a broader view of LM morphology and function and injury susceptibility in university varsity athletes. Furthermore, LM characteristics were only examined at one spinal level and two positions. Future studies should consider protocols for positions more closely related to stances athletes are frequently in during sport and include additional levels and trunk muscles involved in spinal stability. It may also be beneficial for future studies to examine the impact higher forces have on LM to further mimic the sport environment. While this study only investigated the potential role of LM in the presence of LBP and LLI, there are several other factors that are known to play a part, including but not limited to psychosocial factors and nociceptive processing, that should be considered in future work.

This study provides new insights on LM morphology and function in prone and standing positions in male and female university level varsity athletes and their associations with LBP and LLI. Males have larger and thicker LM compared to females in all positions. LM was also significantly larger and thicker on the non-dominant side in both males and females in the prone position, suggesting leg dominance and sport specific demands may play a role in unilateral hypertrophy. Our findings suggest LM thickness and CSA asymmetry may be significant predictors of LBP and LLI, respectively. Preseason LM ultrasound screening should focus on these parameters as possible indicators in the prevention and rehabilitation of LBP and LLI in university level athletes. Future studies should examine additional neuromuscular aspects of LM in functional positions to better understand the role of LM morphology and function in athletic populations.

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