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Seasonal Changes in Lumbar Multifidus Muscle in University Rugby Players

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Abstract:

Purpose: Although smaller lumbar multifidus muscle (LMM) was reported to be a strong predictor of lower limb injury (LLI) in Australian Football League (AFL) players, LMM morphology has not been investigated in rugby athletes. This study examined seasonal changes in LMM in rugby players and whether LMM characteristics were associated with low back pain (LBP) and LLI. **Methods:** Ultrasound examinations of the LMM were acquired in 21 university level rugby players (12 females, 9 males) at preseason and end-season. LMM cross-sectional area (CSA), thickness at rest, and thickness during submaximal contraction (e.g. contralateral arm lift) measurements in prone and standing were obtained bilaterally at the L5-S1 level. The percent change in LMM thickness during contraction was calculated as: [(thickness$_{\text{contracted}}$-thickness$_{\text{rest}}$)/thickness$_{\text{rest}}$ x 100]. Self-reported questionnaires were used to acquire data on LBP and LLI. **Results:** There was no significant difference in LMM characteristics between preseason and end-season measurements ($p>0.05$). Preseason LMM CSA, side-to-side CSA asymmetry, thickness at rest or during contraction were not associated with LBP or LLI. However, a lower % thickness change in the standing position was significantly associated with having LBP during the preseason ($p=0.01$) and playing season ($p=0.001$), as well as LLI during the preseason ($p=0.03$). **Conclusions:** This study provides preliminary evidence that LMM contractile ability and behavior during functional movement, such as standing, may have important implications for the susceptibility to injury among rugby athletes.

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Running title: Multifidus muscle in rugby players

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INTRODUCTION

Rugby is a high-intensity sport involving a combination of repetitive skills such as kicking, jumping, tackling, passing and sprinting. While rugby and Australian Football have many similarities, each sport has specific rules and requires a different level of physicality and physical profile. Low back pain (LBP) and lower limb injury (LLI) are extremely common among rugby league and Australian Football League (AFL) players (1-4). Although sport injuries result from a complex interaction of multiple factors, the risk of injury is inevitably higher in contact sports (5). Previous injury, LBP and lumbar multifidus muscle (LMM) morphology (e.g. size and asymmetry) have been suggested to increase the risk of LLI in AFL players (4). The LMM plays a critical role to optimize spinal stiffness and movement of the lumbar neutral zone. Its unique morphology and high muscle fiber density produces a large amount of force over a small range, providing segmental control and stabilization (6). Lumbopelvic stability is decreased in athletes with LBP, which leads to alterations in the kinetic force chain across the trunk and extremities and increases the risk of further injury (7). Although previous studies have assessed LMM characteristics (e.g. size, asymmetry, voluntary contraction) as predictors of injury in AFL players, this relationship has not been examined in rugby players despite the difference in physical demands of each sport (8).

The size of deep local muscles, including LMM and transverse abdominis was reported to decrease significantly in AFL players over a playing season (9). AFL players with more severe quadriceps, hamstrings or adductor muscle injuries during the preseason were also found to have significantly smaller LMM cross-sectional area (CSA) at the L5 level as compared to players with no LLI (10). Accordingly, smaller LMM was reported to be a strong predictor of LLI during the preseason and playing season in AFL players (3,4). LMM asymmetry, seasonal decrease in LMM size and LBP were also significantly linked to injury (4). It remains unclear, however, whether similar LMM morphological changes and associations occur in rugby players.

Given that LMM plays a critical role in lumbopelvic stability, seasonal variations of this muscle might have important clinical implications for players' susceptibility to injury. A better understanding of LMM characteristics and implications in different sports and level of competition may provide valuable insight for preseason-screening assessment and more effective and targeted rehabilitation. Therefore, the primary objective of this study was to investigate seasonal changes in LMM characteristics (e.g. size, asymmetry, contraction) in university level rugby players. A secondary objective was to examine whether LMM characteristics are associated with LBP and LLI during the preseason and playing season. We hypothesized that significant changes in LMM size would occur during the season, and that preseason LMM size and asymmetry would be associated with LBP and LLI during the preseason and season.

METHODS

Participants

A total of thirty-four rugby players from the XX University varsity volunteered to participate in this study and were assessed during the preseason (beginning of September 2016); from these 21 players (12 females and 9 males) were available and assessed at the end of the playing competitive season (end of November 2016) and included in the current study. Players were excluded if they had a previous history of severe trauma or spinal fracture, previous spinal surgery, observable spinal abnormalities and pregnancy. This study was approved by the XX. All players signed an informed consent acknowledging that their data would be used for research.

Self-reported outcomes

Each player participated in one testing session during the preseason (~30 minutes) and completed a self-administered questionnaire to collect information about demographic characteristics and history of injury. LBP was defined as pain localized between T12 and the gluteal fold. Players were asked is they had LBP during the past 3-months (off-season) prior to the assessment. Players who answered "yes" to the presence of LBP also completed a Numerical Pain Rating Scale (NPR) to assess average LBP intensity. Information regarding pain location (e.g. centered, right side, left side) and pain duration (in months) was also collected. Players were questioned about their history of LLI and whether they had an injury within the past 12-months, and if so, to identify which body part. Similarly, at the end of the playing competitive season, players were asked to report whether they had experienced LBP during the season or suffered a LLI.

Ultrasound assessment

Ultrasound B-mode images assessment of the LMM were acquired using a LOGIQ e ultrasound machine (GE Heathcare, Milwaukee,WI) with a 5-MHz curvilinear transducer during the preseason and end-season. The imaging parameters were kept consistent in all acquisitions (frequency: 5MHz, gain: 60, depth: 8.0cm). Previous studies have established that rehabilitative ultrasound imaging estimates of LMM CSA and thickness at rest and contracted states have good to excellent intra-rater and inter-rater reliability (11,12).

Bilateral transverse images were obtained to assess LMM CSA measurements by tracing the muscle borders on both sides (Figure 1A). When athletes had larger muscles, the right and left sides were imaged separately. LM CSA measurements were obtained both in a prone and standing positions; this technique has been described in detail elsewhere (13). 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].

Parasagital images were used to assess LMM thickness at rest (Figure 1B) and during a submaximal contraction (Figure 1C) via contralateral arm lift while the players were holding a hand weight (Figure 1D) [based on subject body weight (14): 1) <68.2kg = 0.68kg weight, 2) 68.2-90.9kg=0.9kg weight, 3) >90.9kg=1.36kg weight]. The following formula was used to calculate the % thickness change: $[((\text{Thickness}_{\text{cont}} - \text{Thickness}_{\text{rest}})/ \text{Thickness}_{\text{rest}})\text{x}100]$. All thickness measurements were also obtained in a prone and standing positions (15); this technique has been described in detail elsewhere (13).

Preseason and end-season ultrasound images were stored and analyzed offline using OsiriX imaging software (OsiriXLiteVersion 9.0, Geneva, Switzerland). Each measurement was repeated 3 times (on 3 different images) on each side, and the average value was used in the analyses. The ultrasound evaluations and measurements were acquired by an experienced athletic therapist, with over 10 years of experience in spine imaging analysis, blinded to players' characteristics and history of injury. The intra-rater reliability (intra-class correlation coefficients $ICC_{3,1}$) for all ultrasound measurements ranged between 0.96-0.99.

Statistical Analysis

Means and standard deviations were calculated for players' characteristics. Paired t-tests were used to assess the mean difference in LMM characteristics between the preseason and end-season measurements. The associations between preseason LMM characteristics and LBP and LLI during the preseason and playing season were initially examined using univariate linear regression. Height, weight, and sex were then tested as possible covariates given previous evidence of their effect on muscle morphology. These covariates were retained in the multivariable models only if they remained statistically significant ($p<0.05$) or had a confounding effect (led to a ±15% change in the beta coefficients of significant variables included in the multivariable model). 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 20.9±1.9 years, 171.9±7.5 cm and 74.5±11.1 kg, respectively. The average number of years playing rugby at a competitive level was 4.7 years, and 1.5 year at the university level. A total of 52% (n=11) reported LBP during the preseason (past 3 months) and 24% (n=5) during the playing season. Players with LBP reported an average NPR of 2.5±1.3 (range 1 to 5) for the preseason, and 3.0±1.0 (range 2 to 4) for the playing season. A total of 43% (n=9) reported having a LLI during the previous 12-months, while 48% (n=10) had a LLI during the playing season.

LMM characteristics during the preseason and end-season are presented in Table 2. There was no significant change in LMM size (e.g. CSA), side-to-side asymmetry or the thickness at rest and during contraction (in the prone or standing position) between the preseason and end-season measurements.

Preseason LMM size, side-to-side asymmetry, thickness at rest or during contraction (in the prone or standing position) was not associated with LBP status during the preseason or playing season. However, a lower % thickness change in the standing position was significantly associated with having LBP during the preseason (p=0.01) and playing season (p=0.001) (Table 3). Similarly, a lower % thickness change in the standing position was also significantly associated with having had a LLI during the preseason (p=0.03) (Table 4). Height and weight were retained as significant covariates in the multivariable models. The relationship between the % thickness change in the standing position in accordance with the preseason and playing season LBP and LLI status is further illustrated in Figure 2.

DISCUSSION

The purpose of this study was to assess seasonal changes in LMM size, asymmetry and contraction among university level rugby players and whether LMM characteristics are associated with LBP and LLI during the preseason and playing season. Overall, our findings revealed no significant seasonal changes in LMM size, asymmetry or ability to contract the muscle when assessed in a prone or standing position. However, a lower ability to contract the LMM (lower % thickness change) in the standing position was associated with the presence of LBP and LLI during the preseason and playing season.

Overall, our results suggest that LMM size (e.g. CSA) and level of symmetry (in prone and standing positions) was preserved during the playing season. Atrophy of the LMM at the L4 and L5 vertebral levels during the playing season was however observed in previous longitudinal studies of AFL players, and was recovered/restored by the start of the next season (9,16). The discrepancy in results between rugby and AFL players may be partly explained by the difference in level of competition, specific physical demands of each sport, and training regimen variations between the preseason and playing season (17,18). A reduction in the ability to contract the LMM over the playing season could have potentially detrimental effects on the dynamic stability of the spine and might contribute to instability and altered forces transferred throughout the kinetic chain. Indeed, the LMM plays a critical role to optimize spinal stiffness and movement, providing segmental dynamic stability and proprioceptive support. Investigating seasonal variations in trunk muscles involved in lumbopelvic stability between elite athletes in order to identify sports specific or movement specific differences in LMM morphology warrants further investigation.

Our results showed no significant association between LMM size and LBP during the preseason or playing season. Hides et al. (2012) also reported no relationship between LBP and changes in LMM morphology in AFL players (9). While our findings corroborate with previous related studies in athletes (20-22), deficits in LMM size in elite athletes with LBP have also been reported (23,24). This discrepancy in findings suggest that some athletic populations may behave differently with regards to LMM size and LBP, possibly due to competing influences including specialized movements and specific training effects (22). In accordance with Hides et al. (2012) (9), the degree of LMM asymmetry was also not associated with the presence of LBP during the preseason or playing season in our sample of rugby athletes. However, Hides et al. (2008) (19) reported a significant association between preseason LMM asymmetry and LBP among elite cricketers. The divergent results may be partly explained by the distinctive physical demands of each sport, especially the unilateral rotational component required in elite cricketers.

Importantly, our findings revealed a significant association between a decreased ability to contract the LMM in standing and the presence of LBP during the preseason and playing season. To the best of our knowledge, this is the first study to report a relationship between LMM %thickness change in standing and LBP in athletes. When standing in a functional position (e.g. position that is representative of everyday activities), the LMM contracts involuntarily in order to provide stability to the spine and maintain an upright position, allowing for the characterization of LMM morphology while contracted in a stabilizing role. In this position, performing a contralateral arm lift with a handheld weight is expected to increase LMM activation, force and contractibility while controlling segmental motion (14,15). Our findings thus suggest that players with a greater ability to contract the LMM while standing and performing a functional movement (contralateral arm lift) had a lower chance of having LBP. Figure 2 further illustrates this relationship, showing that players who retained a greater ability to contract the LMM while standing tended not to have LBP during the preseason and playing season. Conversely, players who had a lower ability to contract the LMM while standing reported the presence (recurrence) of LBP during both the preseason and playing season.

Our results showed no significant association between LMM size and having sustained a LLI during the preseason or playing season. In contrast, a smaller LMM was reported to be a strong predictor of LLI in AFL players in the preseason and playing season (4). While we found no association between LMM asymmetry and the occurrence of LLI in rugby players, greater LMM asymmetry was significantly related to LLI during the preseason, and having no preferred kicking leg to playing season LLI in ALF players (4). Kicking leg preference was not investigated in the current study due to the smaller sample size. Importantly, we also found a significant relationship between the LMM %thickness change (contraction) in standing and LLI in the preseason. Again, to the best of our knowledge, this is the first study to investigate and report a significant relationship between the ability to contract the LMM in standing and having sustained a LLI in athletes. Figure 2 further illustrates this relationship showing that players that maintained a lower ability to contract the LMM in standing (via contralateral arm lift) reported the presence of LLI during the preseason and playing season. Contrarily, athletes who remained uninjured over the course of the season had a greater ability to contract/activate the LMM while standing.

Our findings that a decreased ability to contract the LMM while standing was associated with both LBP and LLI provide some evidence to suggest that a deficit in neuromuscular control may have important implications to increase the susceptibility to injury. Previous laboratory studies also showed that decreased neuromuscular control of the trunk was predictive of LLI (25,26). Indeed, the LMM is uniquely designed as a dynamic stabilizer, assisting with the amount of segmental movement and optimal load transmission throughout the spine as the body assumes various positions (27). Such neuromuscular feedback control is especially important for athletes to provide dynamic stability of the lumbopelvic region and properly transmit force generated through the kinetic chain in order to produce coordinated and sequenced activation of body segments. As such, the rationale of trunk muscle training is to provide a more stable pelvis and spine to improve the link between the upper and lower body and optimize force production during sport activities (4). While specific stabilization exercises were effective to restore LMM CSA and decreased LBP symptoms in a group of elite cricketers (19), whether such improvements also translate to an increased ability to contract the LMM while standing remains unknown. Though, motor control exercises were reported to increase lumbopelvic awareness in AFL players and subsequently decrease the risk of LLI (3). Further studies are needed to test the effect of motor control exercise inventions on standing LMM dynamic stabilization and their impact on the occurrence of LBP and LLI in rugby players.

A limitation of this study is the small sample size, although comparable to previous studies with elite athletes. Furthermore, although 34 players initially volunteered to take part in this study, only 21 players were available for the end-season assessment, and thus included in the current study. While this was mostly due to academic commitments as the end of the season coincided with the exam period, this may have introduced selection bias. Our study, however, included both female and male rugby players and LMM characteristics were also evaluated in both prone and standing positions to better characterize the dynamic stabilization of this muscle. Further studies are needed to confirm our results and determine whether these findings apply to other sports.

CONCLUSION

Preseason screening assessment of LMM characteristics, including neuromuscular control in prone and standing, may be useful to identify players at risk of injury and help reduce the high prevalence of LBP and LLI in rugby players. Our findings provide evidence that LMM contractile ability and behavior during functional movement, such as standing, may have important implications for the susceptibility of injury among elite athletes.

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REFERENCES

1. Hoskins W, Pollard H, Daff C, et al. Low back pain status in elite and semi-elite Australian football codes: a cross-sectional survey of football (soccer), Australian rules, rugby league, rugby union and non-athletic controls. *BMC Musculoskeletal Disord* 2011;12:158.
2. Gabbett TJ. Incidence of injury in semi-professional rugby league players. *Br J Sports Med*. 2003;37:36-43.
3. Hides JA, Stanton WR. Can motor control training lower the risk of injury for professional football players? *Med Sci Sports Exerc*. 2014; 46:762-768.
4. Hides J, Stanton W, Smith M, et al. Small Multifidus Muscle Size Predicts Football Injuries. *Orthop J Sports Med*. 2014;2(6): 2324967114537588.
5. Murphy DF, Connolly DAJ, Beynnon BD. Risk factors for lower extremity injury : a review of the literature. *Br J Sports Med* 2003;37(1):13-29.
6. Freeman MD, Woodham MA, Woodham AW. The role of the lumbar multifidus in chronic low back pain: a review. *PM R* 2010;2(2):142-146.
7. Sheikhhoseini R, O'Sullivan K, Alizadeh MH, et al. Altered Motor Control in Athletes with Low Back Pain: a Literature Review. *Ann Appl Sport Sci* 2016;4(4):43-50.
8. Varley MC, Gabbett T, Aughey RJ. Activity profiles of professional soccer, rugby league and Austalien football match play. *J Sports Sci* 2014 32(20):1858-1866.
9. Hides JA, Stanton W. Muscle imbalance among elite australian rules football players : A longitudinal study of changes in trunk muscle size. J Athletic Training 2012 ;47(3) :314-319.

10. Hides JA, Brown CT, Penfold L, et al. Screening the lumbopelvic muscles for a relationship to injury of the quadriceps, hamstrings, and adductor muscles among elite Australian Football League Players. *J Orthop Sports Phys Ther*. 2011;41(10):767-775.

11. Larivière C, Gagnon D, De Oliveira E Jr, et al. Ultrasound measures of the lumbar multifidus: Effect of task and transducer position on reliability. *PM R*. 2013;5(8):678-687.

12. Skeie EJ, Borge JA, Leboeuf-Yde C, et al. Reliability of diagnostic ultrasound in measuring the multifidus muscle. *Chiropr Man Therap* 2015;23:15.

13. Schryver A, Rivaz H, Rizk A, Frenette S, Boily M, Fortin M. Ultrasonography of lumbar multifidus muscle in university Americal Football players. Med Sci Sports Exerc 2020; 52(7):1495-1501

14. Kiesel KB, Uhl TL, Underwood FB, et al. Measurement of lumbar multifidus muscle contraction with rehabilitative ultrasound imaging. *Man Ther*. 2007;12:161-166.

15. 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.

16. Hides JA, Stanton WR, Mendis MD, et al. Effect of motor control training on muscle size and football games missed from injury. *Med Sci Sports Exerc*. 2012;44:1141-1149.

17. Gabbett TJ, Jenkins DG. Relationship between training load and injury in professional rugby league players. *J Sci Med Sport*. 2011;14(3):204-209.

18. Rogalski B, Dawson B, Heasman J, et al. Training and game loads and injury risk in elite Australian footballers. *J Sci Med Sport* 2013;16:499–503.

19. Hides JA, Stanton WR, McMahon S, et al. Effect of stabilization training on multifidus muscle cross-sectional area among young elite cricketers with low back pain. *J Orthop Sports Phys Ther*. 2008;38:101-108.
20. McGregor AH, Anderton L, Gedroyc WM. The trunk muscles of elite oarsmen. *Br J Sports Med* 2002;36(3):214-217.
21. Sitilertpisan P, Hides JA, Stanton WR, et al. Multifidus muscle size and symmetry among elite weightlifters. *Phys Ther Sport*. 2012; 13(1): 11-5.
22. Smyers EA, Myrer JW, Eggett DL, et al. Multifidus muscle size and symmetry in ballroom dancers with and without low back pain. *Int J Sports Med* 2018;39(8):630-635.
23. Fortin M, Rizk A, Frenette S, Boily M, Rivaz H. Ultrasonography of multifidus muscle morphology and function in ice hockey players with and without low back pain. *Phys Ther Sport* 2019;38:16.
24. Gildea JE, Hides JA, Hodges PW. Size and symmetry of trunk muscles in ballet dancers with and without low back pain. *J Orthop Sports Physi Ther*. 2013;*43*(8): 525-533.
25. Zazulak BT, Hewett TE, Reeves NP, Goldberg B, Cholewicki J. Deficits in neuromuscular control of the trunk predict knee injury risk: a prospective biomechanical-epidemiologic study. *Am J Sports Med*. 2007;35:1123-1130.
26. Zazulak BT, Hewett TE, Reeves NP, Goldberg B, Cholewicki J. The effects of core proprioception on knee injury: a prospective biomechanical-epidemiological study. *Am J Sports Med*. 2007;35: 368-373.
27. Ward SM, Kim CW, Eng CM et al. Architectural analysis and intraoperative measurements demonstrate the unique design of the multifidus muscle for lumbar spine stability. *J Bone Joint Surg Am* 2009;91(1): 176-185.

Figure legend

Figure 1: A) Lumbar multifidus cross-sectional area (CSA) measurement at the L5 vertebral level. The spinous process (SP) in the center of the image, the echogenic laminae (La) and thoracolumbar fascia (TFL) were used as landmarks to define the muscle borders. B) Lumbar multifidus thickness measurement (L5-S1 facet joint) at rest and during submaximal contraction (C), achieved via a contralateral arm lift as shown on image D).

Figure 2: Relationship between lumbar multifidus (LMM) muscle percentage thickness change in standing and low back pain (LBP) (left image) and lower limb injury (LLI) (right image) at pre-season and end-season.

Table 1. Participants' characteristics.

	All (n=21)	Female (n=12)	Male (n=9)
Age (yr)	20.9±1.9	21.2±2.1	20.6±1.8
Height (cm)	171.9±7.5	168.0±6.1	177.0±6.0
Weight (Kg)	74.5±11.1	70.4±9.6	79.9±10.9
BMI	25.1±2.7	24.9±2.8	25.5±2.8
Dominant leg (n)			
Right	19	11	8
Left	2	1	1
Position (n)			
Forwards	11	8	3
Backs	10	4	6
Rugby competitive level (yr)	4.7±3.1	4.6±3.3	4.7±3.0
Rugby university level (yr)	1.5±1.6	1.8±1.8	1.0±1.2
LBP past 3-months (n)	11	7	4
LBP location past 3-months (n)			
Centered	3	2	1
Bilateral	2	1	1
Unilateral	6	4	2
LBP NPR (0-10) past 3-months	2.5±1.3	2.4±1.3	2.8±1.6
LLI past 12-months	9	5	4
LLI past 12-months body part			
Ankle	4	3	1
Thigh	2	1	1
Knee	3	1	2

LBP season (n)	5	3	2
LBP season location			
Centered	2	0	2
Bilateral	0	0	0
Unilateral	3	3	0
LBP NPR (0-10) season	3.0±1.0	3.0±1.0	3.0±1.4
LLI season (n)	10	4	6
LLI season body part			
Ankle	3	3	0
Thigh	1	0	1
Knee	5	1	4
Hip	1	0	1

BMI: body mass index
LBP: low back pain
NPR: numerical pain rating
LLI: lower limb injury

Table 2. Changes in LMM characteristics between the preseason and end-season.

	Preseason	End-season	p-value & 95% CI	%Change or Change
PRONE				
CSA (cm^2)	8.79±1.64	8.69±1.44	0.37 [-0.11, 0.30]	-0.52±5.53%
CSA asy (%)	4.76±3.68	3.76±3.96	0.37 [-1.28, 3.28]	-1.00±5.01
TK Rest (cm)	2.83±0.43	2.86±0.43	0.43 [-0.11, 0.05]	1.31±5.67%
TK Cont (cm)	3.30±0.61	3.26±0.58	0.29 [-0.04, 0.12]	-3.71±5.01%
TK %change	16.23±7.51	13.79±8.21	0.06 [-0.12, 5.02]	-2.45±5.66
STANDING				
CSA (cm^2)	10.19±1.94	10.04±1.90	0.08 [-0.20, 0.31]	-1.32±3.96%
CSA asy (%)	3.24±2.79	3.07±2.66	0.80 [-1.19, 1.52]	-0.17±2.97
TK Rest (cm)	3.20±0.55	3.26±0.51	0.21 [-0.13, 0.03]	2.07±6.56%
TK Cont (cm)	3.39±0.59	3.40±0.57	0.80 [-0.08, 0.06]	0.54±5.62%
TK %change	5.94±2.84	4.39±3.41	0.10 [-0.34, 3.44]	-1.55±4.17

LMM: lumbar multifidus muscle
CSA: cross-sectional area
Asy: asymmetry
TK: thickness
Cont: contracted

Table 3

Table 3. Associations between LMM characteristics and LBP during preseason and playing season.

	LBP preseason			**LBP playing season**		
	Coefficient	P-value	95% CI	Coefficient	P-value	95% CI
PRONE						
CSA (cm^2)	0.57	0.21	[0.35, 1.50]	0.15	0.77	[-0.98, 1.29]
CSA asy (%)	-1.63	0.31	[-4.91, 1.65]	-1.24	0.51	[-5.19, 2.70]
TK Rest (cm)	0.24	0.13	[-0.07, 0.57]	0.01	0.93	[-0.38, 0.419]
TK Cont (cm)	0.71	0.46	[-0.31, 0.65]	-0.03	0.89	[-0.60, 0.53]
TK %change	-3.68	0.12	[-8.43, 1.06]	-2.03	0.47	[-7.92, 3.86]
STANDING						
CSA (cm^2)	0.75	0.15	[-0.28, 1.80]	0.09	0.87	[-1.20, 1.39]
CSA asy (%)	0.63	0.27	[-0.54, 1.81]	-2.24	0.18	[-5.12, 0.62]
TK Rest (cm)	0.25	0.12	[-0.07,0.57]	-0.08	0.74	-0.60, 0.44
TK Cont (cm)	0.18	0.39	[-0.26, 0.64]	-0.24	0.34	[-0.77, 0.28]
TK %change [a]	**-3.70**	**0.01**	**[-6.55, -0.85]**	**-5.82**	**0.001**	**[-8.75, -2.88]**

[a] Adjusted for height and weight.

Bold: p<0.05

LBP: low back pain

LMM: lumbar multifidus muscle

CSA: cross-sectional area

Asy: assymetry

TK: thickness

Cont: contracted

Table 4

Table 4. Associations between LMM characteristics and LLI during preseason and playing season.

	LLI preseason			LLI playing season		
	Coefficient	P-value	95% CI	Coefficient	P-value	95% CI
PRONE						
CSA (cm^2)	0.14	0.76	[-0.87, 1.16]	1.01	0.06	[-0.05, 2.08]
CSA asy (%)	1.23	0.46	[-2.20, 4.67]	1.54	0.37	[-1.99, 5.09]
TK Rest (cm)	0.05	0.78	[-0.35, 0.46]	0.09	0.61	[-0.27, 0.45]
TK Cont (cm)	0.003	0.98	[-0.56, 0.57]	0.14	0.59	[-0.41, 0.71]
TK % change	-0.85	0.73	[-5.95, 4.24]	-3.82	0.13	[-8.88, 1.23]
STANDING						
CSA (cm^2)	0.03	0.971	[-1.80, 1.86]	0.19	0.73	[-0.98, 1.37]
CSA asy (%)	-1.41	0.26	[-3.96, 1.14]	-0.18	0.81	[-2.80, 2.42]
TK Rest (cm)	0.07	0.742	[-3.80, 0.524]	0.29	0.25	[-0.21, 0.78]
TK Cont (cm)	0.008	0.97	[-0.55, 0.57]	0.25	0.35	[-0.29, 0.79]
TK % change [a]	**-3.34**	**0.03**	**[-6.32, -0.36]**	-1.72	0.28	[-5.01, 1.55]

[a] Adjusted for height and weight.

Bold: $p<0.05$

LLI: lower limb injury

LMM: lumbar multifidus muscle

CSA: cross-sectional area

Asy: asymmetry

TK: thickness

Cont: contracted

Figure 1

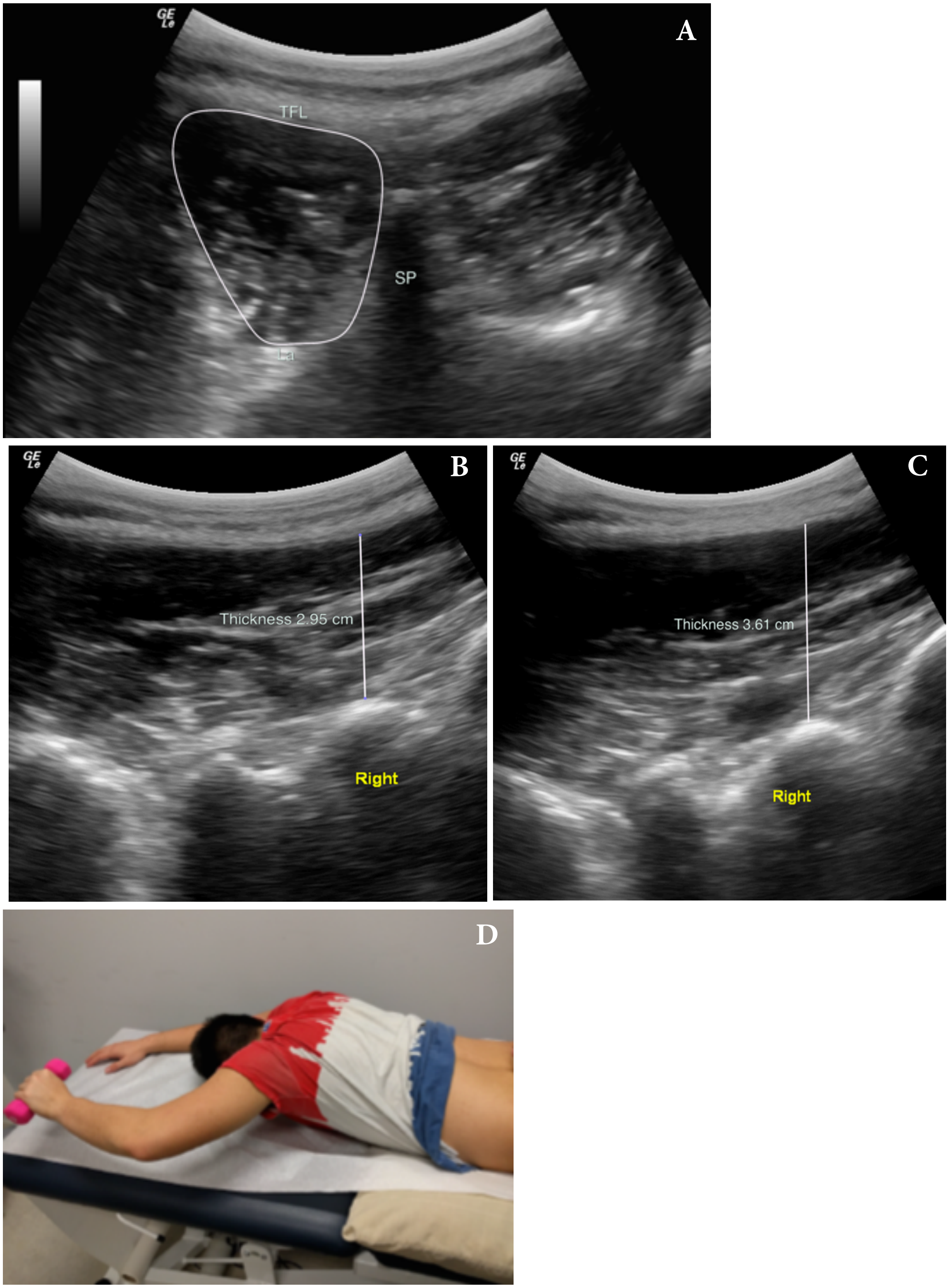
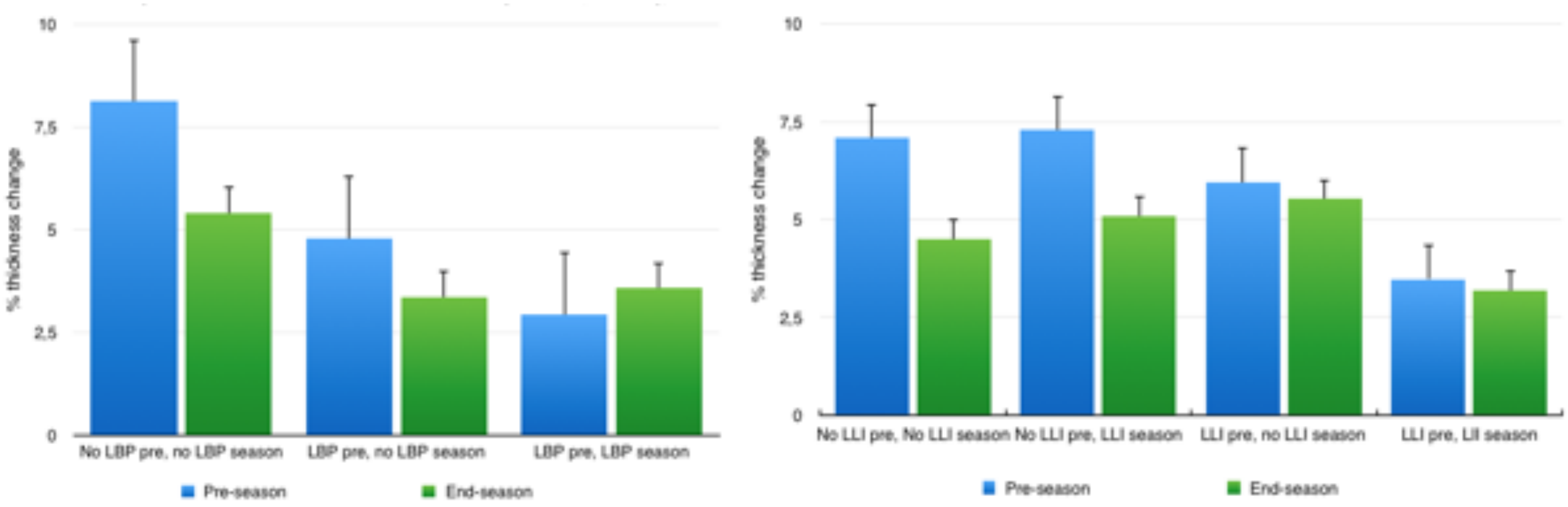


Figure 2



10
7,5
5
2,5
0
% thickness change
No LBP pre, no LBP season
LBP pre, no LBP season
LBP pre, LBP season
🟦 Pre-season
🟩 End-season
10
7,5
5
2,5
0
% thickness change
No LLI pre, No LLI season
No LLI pre, LLI season
LLI pre, no LLI season
LLI pre, LII season
🟦 Pre-season
🟩 End-season