Small Multifidus Muscle Size Predicts Football Injuries

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Background: In Australian football, lower limb injuries have had the highest incidence and prevalence rates. Previous studies have shown that football players with relatively more severe preseason and playing season hip, groin, and thigh injuries had a significantly smaller multifidus muscle compared with players with no lower limb injuries. Rehabilitation of the multifidus muscle, with restoration of its size and function, has been associated with decreased recurrence rates of episodic low back pain and decreased numbers of lower limb injuries in football players. Assessment of multifidus muscle size and function could potentially be incorporated into a model that could be used to predict injuries in football players.

Purpose: To examine the robustness of multifidus muscle measurements as a predictor of lower limb injuries incurred by professional football players.

Study Design: Cohort study; Level of evidence, 2.

Methods: Ultrasound examinations were carried out on 259 male elite football players at the start of the preseason and 261 players at the start of the playing season. Injury data were obtained from records collected by the Australian Football League (AFL) club staff during the preseason and the playing season.

Results: Decreased size of the multifidus muscle at L5 consistently predicted injury in the preseason and playing season. Asymmetry of the multifidus muscle and low back pain were significantly related to lower limb injuries in the preseason, and having no preferred kicking leg was related to season injuries. Seasonal change in the size of the multifidus muscle indicating a decrease in muscle mass was linked to injury. Sensitivity and specificity of the model were 60.6% and 84.9% for the preseason and 91.8% and 45.8% for the playing season, respectively.

Conclusion: A model was developed for prediction of lower limb injuries in football players with potential utility for club medical staff. Of particular note is the finding that changes in muscle size from the preseason to the playing season predicted injury.

Clinical Relevance: As size of the multifidus muscle has been shown to be modifiable with training and has been associated with reduced pain and occurrence of injuries, this information could be incorporated in current programs of injury prevention.

Keywords: football; injury; multifidus muscle; ultrasound imaging

The premier professional football competition in Australia is the Australian Football League (AFL), which is played each year from March to September. The AFL commenced injury surveillance in 1992, and all teams have been included since 1996. Data on injuries are accessible to researchers through the AFL research board, providing a unique research opportunity for those interested in football injuries and the identification of risk factors. The most common injury in the AFL is hamstring injury, and these injuries are responsible for the most games missed through injury.[29] Over the past 10 AFL playing seasons (2003-2013), lower limb injuries have consistently had the highest incidence, prevalence, and recurrence rates of all injury groups.[28]

There are a number of predisposing factors that could be associated with lower limb injuries in football players. In soccer, it is accepted that previous injury and inadequate rehabilitation are 2 strong key risk factors for reinjury.[2,7] Timing of the injury in relation to the playing season is

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another factor to consider. In rugby union and rugby league, the preseason period involves a higher training load than the playing season and has been shown to be associated with an increased risk of injuries.[9,23,35] It has been proposed that a major contributing factor is the sudden change in training intensity from the off-season to preseason.[8,10] A preseason study conducted on soccer players also showed participants to be at greater risk of minor, overuse, and lower leg injuries in this time period.[8] In the AFL, the majority of injuries occur during matches rather than in the preseason period.[29] It would be an advantage to study football players across both the preseason and playing season to examine whether there are predisposing factors that consistently predict injuries in the training season and competition playing season.

Researchers have taken different approaches to predict injuries in athletes. Prospective laboratory studies that have investigated neuromuscular control of the trunk have shown deficits in this area to predict lower limb injuries.[36,37] Zazulak et al[36] showed that increased trunk displacement in response to sudden trunk force release (factors related to lumbopelvic stability) was predictive of knee and anterior cruciate ligament injuries in female athletes. The proposed rationale was that decreased neuromuscular control of the trunk, coupled with high ground reaction forces directed toward the body's center of mass, compromised the dynamic stability of the knee joint and increased knee injury risk. Researchers have also used observation of fundamental movement patterns to predict injury in the preseason among professional football players.[22] Other studies have focused on measuring the size of key trunk muscles such as the lumbar multifidus in AFL players.[13,18]

Although all trunk muscles can contribute to protection of the lumbopelvic region, the lumbar multifidus muscle has been the focus of several investigations due to evidence that it contributes to localized control of segments of the lumbar spine and thereby controls the lumbar lordosis.[3,4] Control of the lordosis is important from a biomechanical perspective, as by being curved, the lumbar spine is protected to an appreciable extent from compressive forces and shocks.[5] By controlling the amount of vertebral rotation, the segmental multifidus can control load transmission to various anatomical structures and affects the capacity of the spine to bear axial loads.[5] The multifidus muscle also plays a key role in neuromuscular control of the trunk, which is reliant on feedback control. This feedback role is ascribed predominantly to the multifidus muscle due to the fact that it is dense in muscle spindles.[27] Athletic function is most often produced by the coordinated, sequenced activation of body segments that places the distal segment in the optimum position at the optimum velocity with the optimum timing to produce the desired athletic task.[31] Additionally, it has been demonstrated that training athletes to achieve and hold a position of lordosis and then add limb loading was as effective in enhancing vertical takeoff velocity as leg strength training or the combination of trunk exercises and leg strength training.[6] The rationale for this finding was that training trunk muscles in this way may provide a more stable pelvis and spine from which the leg muscles can generate action, may better link the upper body to the lower body, or may enhance leg muscle activation, thus promoting optimal force production during sporting activities such as a vertical jump.[6] It is therefore possible that deficits in control of the spine could be associated with injuries further down the kinetic chain, in the lower limb.

Two studies of AFL players have used measurements of trunk muscle size to predict injuries.[13,18] The first study examined size of trunk muscles at the start and end of the football preseason, including the cross-sectional areas (CSAs) of the multifidus, psoas major, and quadratus lumborum muscles, as well as change in trunk CSA due to the action of voluntarily contracting the transversus abdominis muscle. Results showed that players with more severe preseason injuries had significantly smaller CSAs of the multifidus muscle at the L5 vertebral level compared with players with no injury. No relationship was found for size or asymmetry of the quadratus lumborum or psoas major muscles or ability to contract the transversus abdominis muscle through "drawing in" of the abdominal wall.[13] Baseline CSA of the multifidus muscle at the L5 vertebral level predicted hip, groin, and thigh injuries in 83.3% of cases. Another recent study also examined muscle size of multifidus, psoas major, quadratus lumborum, and transversus abdominis over the playing season and showed similar results in that a smaller size of the multifidus muscle (odds ratio [OR], 2.38) was predictive of a lower limb injury in the playing season.[18] However, the main limitations of these studies were that player numbers were limited and that a consistent relationship between muscle size and injury occurrence across the preseason and playing season was not established. The robustness of the results would be improved if studies could be performed across both the preseason and playing season. In addition, a study with a greater number of players from more than 1 team could show that the previous results were not due to a type II error, and the findings could be generalized for all AFL players.

This study was designed to examine the consistency of multifidus muscle measurement as a predictor of lower limb injuries incurred by AFL football players across the preseason and playing season. The primary aims were (1) to test a range of measures related to the size, asymmetry, and contraction of the multifidus muscle and determine which multifidus measurements were related to subsequent injury and (2) develop a model that maximizes the power to predict which players incur lower limb injuries.

MATERIALS AND METHODS

Participants

Players from 6 AFL clubs participated in the study. All players in the full training squad for each club, including new recruits, were eligible for the study (N = 275), of whom 27.7% played in the forward positions, 9.9% played primarily as ruckmen, 32.8% played in midfield positions, and 29.6% played as defenders. Preseason measurements were completed for 259 players available on the assessment day for their respective club, representing 94.2% of the eligible sample. Measurements at the start of the playing season were completed for 261 players, representing 94.9% of the eligible sample. Club training commitments had precedence, and some players could not be scheduled for assessment. The mean ± standard deviation [mean ± SD] of players' ages, heights, and weights were 21.9 ± 3.6 years, 188.4 ± 7.3 cm, and 90.4 ± 56.3 kg, respectively. The participants had been playing elite football for an average of 3.9 ± 3.7 years. This study was approved by the relevant ethics committee of the host institution.

Procedures

Self-report questionnaires administered at the start of the preseason and at the start of the playing season were used to collect information regarding player demographics, position played, number of years playing professional football in the AFL, leg dominance, recent history of injury, and recent low back pain. Preseason and playing season injury data were obtained from records collected by staff at the AFL clubs. CSA and thickness of the multifidus muscle were assessed at the start of the preseason and start of the playing season using ultrasound imaging. Ultrasound imaging was conducted on site at the football clubs involved by 3 physical therapists with experience in ultrasound imaging.

Multifidus Muscle Assessment

Ultrasound imaging was used to assess the multifidus muscle at vertebral level L5 as per the protocols described previously by Hides et al[14] and Wallwork et al.[33] Previous studies conducted by the research team have established the reliability and validity of using ultrasound imaging to assess multifidus size, showing it to be a repeatable, reliable, and valid imaging technique in the hands of trained assessors.[14,16,20,33] A study conducted prior to the current investigation demonstrated between day and operator reliability for ultrasound measurements of the multifidus muscle at all lumbar vertebral levels (ultrasound between-day coefficient of variation, 3.58%; root mean square error, 0.17).[16] Validity was demonstrated using comparison with magnetic resonance imaging, which is known as the gold standard for measurements of muscle CSA.[16] With regard to in-house training of assessors, results of training in measurement of the multifidus muscle using ultrasound imaging showed intrarater reliability with a mean intraclass correlation coefficient (ICC) of 0.929 over 24 different multifidus measurements and nonsignificant systematic change. Interrater reliability was also achieved, showing a mean ICC of 0.935.

The ultrasound imaging apparatus (GE LOGIQ *e*; GE Healthcare) was equipped with a 5-MHz convex array transducer. Subjects were positioned in a prone position. The lumbar spinous processes were palpated and marked with a pen prior to imaging. Subjects were instructed to relax the paraspinal musculature, electroconductive gel was then applied, and the transducer placed transversely over the relevant spinous process. Bilateral transverse images of the multifidus muscle were obtained where possible except in the case of larger muscles, where left and right sides were imaged separately (Figure 1A). The thickness of

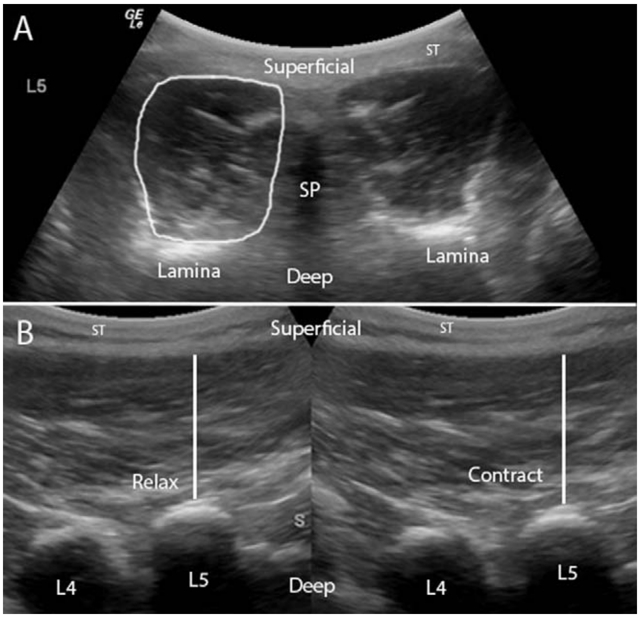

Figure 1. (A) Transverse image of the multifidus muscle and cross-sectional area measurement at L5. SP, L5 spinous process; ST, subcutaneous tissue. (B) Parasagittal image of the multifidus muscle and thickness measurements of the muscle at rest and on contraction. S, sacrum (used to indicate direction of image); ST, subcutaneous tissue.

the multifidus muscle was also imaged in the parasagittal (longitudinal) section (Figure 1B), allowing visualization of the L5/S1 zygapophyseal joints, multifidus muscle bulk, and thoracolumbar fascia.[33] Prior to testing contraction of the multifidus muscle, all subjects received an initial explanation of the type of contraction required, which was isometric and voluntary. Subjects were instructed to take a relaxed breath in and out, pause their breathing, and then try to "swell" or contract the muscle. For the isometric contraction, players were instructed not to move their spine or pelvis when they contracted the muscle. Ultrasound images were stored for offline analysis and subsequently measured by a member of the research team. OsiriX (http://www.osirix-viewer.com/) was used for image visualization and measurement. For measurements of multifidus CSA, the border of the muscle was traced on both sides. For thickness measurements, the multifidus muscle was measured using linear measurements from the tip of the L5/S1 zygapophyseal joint to the inside edge of the superior border of the multifidus muscle at rest[33] and on contraction.[34]

Injury Assessment

Injury data were obtained from records collected by the AFL club staff during the preseason (late November to mid-March) and the playing season (mid-March to end of August). An injury was defined as a physical condition related to football training or playing that prevented a player from completing a full training session or game. Injuries were diagnosed by team medical staff who advised on a player's ability to participate. The incidence of players incurring 1 or more lower limb injury was used for the quantitative analysis. Injuries that occurred after the muscle assessments at the start of the preseason and start of the playing season were included in the analysis.

A recent history of injury at the start of the preseason was coded as either "no injury" (29.9%) or "injury" (70.1%) in the past 12 months based on self-report. History of injury obtained at the start of the playing season was coded as either "no injury" (64.0%) or "injury" in the preseason (36.0%) based on club records obtained over the course of the study.

A recent history of low back pain at the start of the preseason was coded as either "no low back pain" (61.2%) or "low back pain" (38.8%) in the off-season (past 3 months). Similarly, a recent history of low back pain at the start of the season was coded as either "no low back pain" (61.7%) or "low back pain" (38.3%) in the preseason (past 3 months).

Statistical Analysis

Data were subjected to a predictive analysis using the binomial logistic regression procedure of SPSS (v 20; IBM Corp). Complete data were available for 256 cases in the preseason and 243 cases in the playing season. The initial analysis was designed to compare the effects of multifidus muscle size and asymmetry on the occurrence of lower limb injuries, for measures of CSA, thickness, and amount of contraction. Injury groups were coded as "no injury" or "injury" separately for the preseason and the playing season. The multifidus muscle measurements used in this analysis were (1) size (CSA averaged across vertebral side[13,18]), amount of asymmetry in size (absolute between-side difference in CSA), direction of asymmetry in size (smallest side ipsilateral or contralateral to preferred kicking leg, with ambidextrous players coded as right preference); (2) thickness (averaged across side), amount of asymmetry in thickness (absolute difference), direction of thickness asymmetry (smallest side ipsilateral or contralateral to preferred kicking leg); and (3) amount of voluntary isometric contraction of the multifidus muscle (difference in muscle thickness in the contracted and relaxed condition averaged across side), absolute amount of asymmetry in contraction across side and direction of asymmetry in the contraction (smaller side ipsilateral or contralateral to preferred kicking leg). Club number was entered as a categorical covariate to adjust for differences across the 6 clubs.

Multifidus muscle measures with a statistically significant effect were used as predictors of lower limb injury in a further stepwise logistic regression analysis. The aim was to develop a model for the preseason data that could be replicated with the data from the playing season. The risk factors used for the model were (1) step 1: demographics including age, height, weight, and player position (coded as defender, midfield, ruck, forward); (2) step 2: history including "seasons of professional AFL played" (coded as new recruit, 1-3 years, and $\geq$4 years), history of low back pain in the past 3 months, recent history of injury (coded no or yes), change in multifidus measurements (preseason minus season average CSA, season analysis only); and (3) step 3: current status including significant muscle measurements and preferred kicking leg, linked to the side of the muscle measurements (coded as right, left, or either). Club number was entered as a covariate in the analysis.

This analysis tests the mechanism of effect that injuries are preceded by muscle dysfunction. The odds ratio produced in this analysis provides an estimate of the level of risk of injury related to the risk factor, in particular muscle loss and dysfunction. The strength and robustness of the model are indicated by the sensitivity, specificity, and variance explained in the preseason and playing season injury data.

TABLE 1
Multifidus Muscle Measurements[a]

Measure	Preseason	Season
CSA, cm^2		
Average	9.14 ± 1.65	8.64 ± 1.46
Asymmetry	0.76 ± 0.58	0.59 ± 0.52
Thickness, mm		
Average	32.03 ± 3.87	32.87 ± 4.05
Asymmetry	2.32 ± 1.98	2.16 ± 1.82
Thickness Δ, mm		
Average	2.44 ± 1.81	2.57 ± 1.75
Asymmetry	1.41 ± 1.06	1.40 ± 1.07

[a]Values are expressed as mean ± standard deviation. Asymmetry, absolute difference across vertebral side; average, averaged across vertebral side; CSA, cross-sectional area; thickness Δ, change in thickness due to contraction.

RESULTS

A lower limb injury was incurred by 38.2% (n = 105) of players in the preseason and 69.5% (n = 191) of players in the playing season. Respectively, in the preseason and playing season, this included injuries to the hip, groin, thigh (n = 46, n = 107); knee (n = 20, n = 48); and shin, ankle, foot (n = 55, n = 112), with many players incurring multiple injuries. Among the players assessed in the playing season, 31% had played less than 1 year of professional AFL (rookies and new recruits), 25.2% had played 1 to 3 seasons (junior players), and 43.8% had played more than 3 seasons (senior players). The preferred kicking leg of players was right (80.3%), left (15.3%), or either leg (4.4%). The results of the muscle measurements are shown in Table 1. Correlations among the different measures of the multifidus muscle shown in Table 1 were low (all $r < 0.35$).

The comparative effects of different multifidus muscle measurements as risk factors for lower limb injury are shown in Table 2. The results show that size of the multifidus muscle, measured as CSA, predicted lower limb injuries in both the preseason and playing season. Relative to the marginal mean, across players, each 1-unit (cm^2) smaller size of the multifidus muscle resulted in players having a 25% (OR, 1.25) higher odds of an injury in the preseason and a 43% (OR, 1.43) higher odds of injury during the season. The side of muscle asymmetry (measured by linear measurements of the thickness of the muscle) was

TABLE 2
Multifidus Measures at L5 as Predictors of Lower Limb Injury[a]

Measure	Preseason			Season		
	χ^2	Odds Ratio	95% CI	χ^2	Odds Ratio	95% CI
CSA, cm^2						
Average	**4.67**[b]	**1.25**	**1.14-1.52**	**9.42**[b]	**1.43**	**1.14-1.82**
Asymmetry	0.46	0.83	0.48-1.43	0.03	1.06	0.58-1.92
Smaller side[c]	1.74	1.23	0.90-1.68	0.45	1.11	0.82-1.51
Thickness, mm						
Average	0.01	1.00	0.92-1.08	0.47	1.03	0.95-1.11
Asymmetry	0.03	0.99	0.85-1.15	1.01	0.92	0.78-1.08
Smaller side[c]	**4.00**[b]	**1.38**	**1.01-1.90**	0.37	1.10	0.81-1.50
Thickness Δ, mm						
Average	0.26	1.05	0.88-1.24	0.46	1.07	0.89-1.28
Asymmetry	0.43	1.10	0.83-1.46	0.74	1.14	0.84-1.55
Smaller side[c]	0.02	0.98	0.72-1.33	1.70	0.82	0.60-1.11

[a]Adjusted for club differences. Asymmetry, absolute difference across vertebral side; average, averaged across vertebral side; CSA, cross-sectional area; thickness Δ, change in thickness due to contraction.
[b]Statistically significant ($P < .05$).
[c]Multifidus smaller on the side of the kicking leg.

significantly related to lower limb injuries in the preseason. Players whose multifidus was smaller on the kicking leg had a 1.38 times higher odds of a lower limb injury. Both these measures of the multifidus muscle were included in the predictive model.

Results of the logistic regression model of lower limb injury are shown in Table 3. Multifidus size at L5 consistently predicted injury in the preseason and playing season ($P < .05$). Compared with players with above average multifidus muscle size, each unit (cm^2) decrease in size below the marginal mean was related to a 26% (OR, 1.26) higher odds of a lower limb injury in the preseason and a 48% (OR, 1.48) higher odds of a lower limb injury in the playing season.

Although relatively smaller multifidus size at the start of the preseason and playing season independently predicted lower limb injuries, change in size over this time was also examined as a possible risk factor. For example, players with small multifidus size at the start of the preseason who lose further muscle mass could be at relatively higher odds of an injury. This compounding effect of change in multifidus size over the preseason, showing a relative increase in size for some players and a decrease for others, was found to be a significant predictor of injury in the playing season ($P < 0.05$) (Table 3). With regard to change in multifidus size from the start of the preseason to the start of the playing season (marginal mean ± SD, -0.56 ± 1.16 cm^2), each 1-unit decrease in multifidus size below the marginal mean increased the odds of an injury in the playing season by 63% (OR, 1.63). The preseason and playing season means for the multifidus muscle (Figure 2) depict the relationship between change in size and lower limb injury. Players injured in the preseason on average had smaller multifidus muscles before the injury. Players with larger multifidus size who retained their multifidus size tended not to incur an injury in the preseason or playing season. Notably, among players who had a preseason injury, those who recovered their multifidus size tended not to incur further injury, but additional loss of multifidus size was related to another injury in the playing season.

Other predictors differentiated preseason injuries from playing season injuries. In the preseason, recent low back pain was related to a 98% increase in the odds of a lower limb injury (OR, 1.98). In the season, "kicking leg" was a risk factor for injury. Compared with players who preferred their right leg, those who preferred to kick with their left leg were no more likely to be injured; however, players with no preference were less likely to incur lower limb injury during the season (OR, 0.13).

Development of the predictive model in this study was also aimed at increasing the power to identify the player who incurred lower limb injuries. The strength of the model can be gauged from the estimates of sensitivity, specificity, and variance explained (r^2). For the preseason data, the model correctly identified 60.6% of the players who incurred a lower limb injury (sensitivity) and 84.9% of the players who did not incur an injury (specificity). The model explained 38% of the variance in the injury scores. For playing season data, the model had a sensitivity rating of 91.8%, specificity rating of 45.8%, and accounted for 33% of the variance in the injury scores.

DISCUSSION

The overall results of this study support previous findings, which showed lower limb injuries are a common occurrence in AFL players and are more common in the playing season than the preseason.[29] The results showed that across players, smaller size of the multifidus muscle preceded a lower limb injury in both the preseason and playing season. The results for the preseason and playing season periods support and build on previous studies of AFL players,[13,18] which also showed that decreased size of the multifidus muscle was associated with

TABLE 3
Predictive Model of Lower Limb Injuries[a]

Variable	Preseason			Season		
	χ^2	Odds Ratio	95% CI	χ^2	Odds Ratio	95% CI
Step 1: Demography						
Age, y	1.81	0.95	0.87-1.03	2.76	1.09	0.98-1.22
Height, cm	0.36	1.02	0.96-1.07	0.48	1.03	0.95-1.11
Weight, kg	0.32	1.00	0.99-1.01	0.01	1.00	0.94-1.07
Player position						
Back[b]						
Midfield	0.05	0.91	0.42-1.97	1.26	0.63	0.27-1.42
Ruck	0.20	0.75	0.22-2.60	3.31	0.30	0.08-1.10
Forward	1.68	1.66	0.77-3.57	0.39	0.77	0.34-1.75
Step 2: History						
Years in AFL						
Rookie[b]						
Junior	0.84	1.53	0.62-3.78	0.42	0.73	0.29-1.87
Senior	0.06	1.17	0.34-4.03	0.03	0.90	0.26-3.14
Recent (1 y) injury	0.11	0.90	0.48-1.71	1.57	1.59	0.77-3.26
Recent (3 mo) LBP	**8.78**[c]	**1.98**	**1.26-3.12**	0.78	1.20	0.80-1.81
MF decrease[d]	NA	NA	NA	**9.59**[c]	**1.59**	**1.19-2.13**
Step 3: Current						
MF size smaller	**5.24**[c]	**1.26**	**1.03-1.54**	**8.50**[c]	**1.48**	**1.14-1.92**
MF atrophy side[e]	3.26	1.34	0.98-1.84	0.58	1.14	0.82-1.59
Kick leg						
Right[b]						
Left	0.01	0.96	0.41-2.23	0.13	1.18	0.48-2.93
Either	0.27	0.66	0.14-3.15	**6.00**[c]	**0.13**	**0.26-0.67**

[a]Adjusted for club differences. AFL, Australian Football League; LBP, low back pain; MF, multifidus size (cm^2); NA, not applicable.
[b]Reference category.
[c]Statistically significant ($P < .05$).
[d]Change in multifidus size from start of preseason to start of season.
[e]Multifidus smaller on the side of the kicking leg.

increased lower limb injuries in the preseason and playing season.

A finding from this study that has not previously been reported relates to the compounding effect of relative change in muscle size from the start of the preseason to the start of the playing season. Although players injured in the season on average had smaller multifidus muscles before the injury, an additional significant effect was found for relative change in multifidus size over the course of the preseason (Table 3). The means shown in Figure 2 indicate that players with larger multifidus size at the start of the preseason who retained their multifidus size tended not to incur an injury in either the preseason or playing season. Among players who sustained a preseason injury, those who recovered their multifidus size were also less likely to incur further injury. In contrast, additional loss of multifidus muscle size for players who incurred a preseason injury was related to recurrence of the same or another lower limb injury in the playing season.

The findings relating to recurrence of injuries in the current investigation parallel previous results for studies investigating recurrent, episodic low back pain. Studies have shown that acute, first episode low back pain was associated with localized decreased size of the multifidus muscle, which is most commonly seen at the lumbosacral junction.[17,20] Even though the symptoms associated with the low back pain resolved and subjects resumed normal work, sport, and leisure, persistence of decreased size of the of the multifidus muscle was associated with increased recurrence of episodes of low back pain.[15] It was proposed that since one of the roles of the multifidus muscle is segmental control and joint protection of the lumbopelvic region,[3,4] deficits in this muscle may have left the spine vulnerable to reinjury and recurrence of symptoms.[15] In addition, maintenance of the lumbar lordosis,[3,4] a role also performed by the multifidus muscle, is vital for efficient load transfer. It is possible that suboptimal force transfer and inadequate protection of this vital region was a contributing factor to recurrence of lower limb injuries in AFL players with deficient muscles.

The preseason results from this study support the theory that focusing on regaining multifidus muscle size and ability to contract in those who incur a preseason injury would be an important strategy to include in programs aimed at decreasing injuries in the playing season. This strategy has been proven to be beneficial for people with low back pain in that they suffered less recurrence of low back pain after undertaking a

Figure 2. Relationship between lower limb injuries and change in multifidus cross-sectional area (CSA) from preseason to playing season.

rehabilitation program targeting restoration of size and ability to contract of the multifidus muscle.[15,17] In relation to occurrence of lower limb injuries, a similar rehabilitation program has been conducted on AFL players.[18,19] Results showed that the risk of sustaining a severe injury was lower for those players who received the motor control intervention.[18]

Two new findings from the current investigation may be related to muscle asymmetry. First, players with relatively smaller multifidus thickness measures for the kicking leg had higher odds for a lower limb injury in the preseason. Second, ambidextrous players (no preferred kicking leg) had lower odds for a lower limb injury in the playing season. In the AFL, players usually kick with their dominant legs. Kicking is an asymmetrical and ballistic task that involves trunk rotation and hip flexion,[1,26] and it has been proposed that kicking may contribute to muscle imbalances and induce torsion on the spine.[11] Many sports are asymmetrical in nature, and asymmetry has been thought to be possibly related to injuries.[11] Owing to the proposed undesirable consequences of asymmetry, several coaching and training sources encourage players in sports involving kicking, such as Australian rules football[30] and soccer,[25,32] to practice using both legs during training. Results from the current investigation may support this, as players with no leg preference were less likely to incur lower limb injury in the playing season. Due to the small number of ambidextrous kickers ($n = 13$), the finding in relation to kicking leg should be treated with caution. The odds ratio related to the reduced risk of injury for this factor may be an overestimate and needs to be confirmed in a larger sample.

Low back pain is quite common in AFL players. A recent study reported that of 46 players in an elite squad, 13 reported current low back pain, 14 had a history of low back pain, and 19 did not have low back pain.[19] In the current investigation, players with recent low back pain showed increased odds of a lower limb injury in the preseason. While not many players miss games during the season due to low back pain, the presence of low back pain is likely to affect performance and how players move. Low back pain has been shown in many studies to directly affect the muscles of the trunk.[12,21] One documented effect of low back pain is to increase activity of superficial muscles (splinting), thereby preventing normal spinal movement.[21] The results of the study in relation to low back pain suggest that if players report low back pain symptoms, especially in the preseason, appropriate treatment should be sought, not only to increase player comfort, but to possibly decrease the incidence of preseason lower limb injury.

Further research studies could be directed toward improving the power of this predictive model. While the results support implementation of programs that effectively rehabilitate the multifidus muscle,[19] the level of specificity obtained for the playing season may need to be increased before the model is used as a screening tool to select players who need not be treated. However, the high level of specificity and moderately high level of sensitivity for the preseason model indicate that such interventions could target players with relatively smaller multifidus muscles (adjusted for other factors in the model). Further studies are required to explain the change in sensitivity from the preseason to the playing season and examine whether this is due to a higher injury rate in the playing season due to an increased level of physical contact. In addition, future studies could consider the relationship between the multifidus and other trunk muscles that have been measured in previous studies. The reason the multifidus muscle was selected for the current investigation is that it is the largest muscle spanning the lumbosacral junction and it contributes to localized control of segments of the lumbar spine and thereby controls the lumbar lordosis.[4,24] The lumbar lordosis plays a crucial role in force distribution from the extremities.[3] A previous study of AFL players showed that while the CSA of the multifidus decreased over an AFL playing season, muscles such as the quadratus lumborum and psoas muscle increased in size.[19] Future studies could incorporate other muscles to continue development of a predictive model.

There are several factors that predispose athletes to lower limb injuries. A limitation of the current investigation is that examination of the relationship between measurements of muscle size and other factors such as performance measures, clinical tests, and training load was beyond the scope of the study. Future studies may improve this predictive model by incorporating a broader suite of measures. Another limitation is in relation to clinical applicability. Measurement of trunk muscle size using ultrasound imaging requires training in the technique and access to the equipment. Ultrasound imaging provides lower resolution images than magnetic resonance imaging, though ultrasound equipment is more portable and less expensive.

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