Do self-managed exercises and strength/fitness training affect multifidus muscle size in elite footballers?

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Abstract

Context: Low back pain (LBP) and lower limb injuries are common among Australian Football League (AFL) players. Smaller size of one key trunk muscle, the lumbar multifidus (MF), has been associated with LBP and injuries in footballers. The size of the MF muscle has been shown to be modifiable with supervised motor control training (MCT) programs. Among AFL players, supervised MCT has also been shown to reduce incidence of lower limb injuries and was associated with increased player availability for games. However, the effectiveness of a self-managed MF exercise program is unknown.

Objective: This study investigated the effect of self-managed exercises, and strength and fitness training on MF muscle size in AFL players with and without current LBP.

Design: Cross-sectional repeated measures study

Setting: Professional AFL context

Participants: Complete data were available for 242 players from six elite AFL clubs.

Intervention: Information related to the presence of LBP and prior history of injury was collected at the start of the preseason. At the end of the preseason, data were collected regarding performance of MF exercises as well as strength and fitness training. Ultrasound imaging of the MF muscle was conducted at the start and end of the preseason.

Main Outcome Measures: Size of the MF muscles was used as the outcome measure.

Results: An interaction effect was found between performance of MF exercises and time (F=13.89, p= <0.001). Retention of MF muscle size was greatest in players who practised the MF
exercises during the preseason (F = 4.77, p = 0.03). Increased adherence to strength and fitness training also retained MF muscle size over the preseason (F = 5.35, p = 0.02).

Conclusions: Increased adherence to a self-administered MF exercise program and to strength and fitness training was effective in maintaining the size of the MF muscle in the preseason.

Keywords: Australian Football League, motor control training, ultrasound imaging, independent exercise, lumbar muscles
Australian Rules Football is a high intensity, fast paced game. Many activities performed in football, such as running, jumping, and cutting, require neuromuscular control to maintain stability.\textsuperscript{1, 2} A stable lumbopelvic complex is central to athletic function.\textsuperscript{3} Athletic function is best produced by the coordinated, sequenced activation of body segments that places the distal segment in the optimum position, velocity and timing to produce the desired athletic task.\textsuperscript{4} 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.\textsuperscript{5} 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 a vertical jump.\textsuperscript{5} Stability of the lumbopelvic region involves both good dynamic neuromuscular control and intact passive structures.\textsuperscript{6} A key provider of active support is the lumbar multifidus (MF) muscle. The segmental fibres of the MF muscle contribute to stability of the lumbopelvic complex by supporting and controlling the motion of intervertebral segments,\textsuperscript{7, 8} providing proprioceptive feedback,\textsuperscript{9} and controlling the lumbar lordosis.\textsuperscript{7} From a biomechanical perspective, control of the lordosis during loaded activities such as squatting, running, jumping and cutting is important to distribute forces efficiently between the lower limbs and trunk,\textsuperscript{7, 10} and to increase the tolerance of shear and compressive forces on the lumbar spine.\textsuperscript{11}

For many codes of football, the football preseason period involves a higher training load than the playing season.\textsuperscript{12, 13} For this reason, activities such as weight training and running could potentially increase the size of the MF muscles over the preseason. Hypertrophy of the MF
muscles has been shown to occur in response to increased loading in weightlifting and maintenance of a neutral spine has been shown to recruit the MF muscle in deadlifting and squatting. The MF muscle has been shown to be active in running to control sagittal plane motion of the trunk. However, a longitudinal study showed that the size of the MF muscles decreased over an Australian Football League (AFL) playing season. It may therefore be an aim of preseason training to increase the size of the MF muscles over the preseason training period, in preparation for the playing season, as deficits in either passive or dynamic structures within the lumbopelvic region may potentially cause injury within any segment of the kinetic chain.

Alteration in the morphology of the MF muscle has been shown to be associated with low back pain (LBP), prediction of injury and the type of activity performed. Selective and localised atrophy of the MF muscle has been documented in patients with acute and chronic LBP. This has most commonly been demonstrated at the L5 vertebral level. Elite athletes still suffer LBP despite being very active and fit. At the start of an AFL preseason, a recent paper reported that 38% of players had LBP. While not many players miss games during the playing season due to LBP alone, players with LBP showed increased odds of a lower limb injury in the preseason period. A decrease in cross-sectional area (CSA) of the MF muscle during the AFL preseason and playing season has been found to be predictive of lower limb injuries in elite players. Among elite AFL players, a decrease in MF muscle size has also been shown to occur in response to playing football, most likely in association with AFL being a flexor dominant sport. Results of a longitudinal study showed that by the end of the playing season, CSA of the MF muscle had decreased, while size of the internal oblique muscle had
increased, possibly representing development of muscle imbalance. Therefore, decreases in MF muscle size have been found to occur in association with LBP and playing football and are predictive of lower limb injury in the playing season.

Research has shown that size of the MF muscle is modifiable with motor control training (MCT) when delivered to people with LBP, elite cricketers with LBP, and elite AFL players. In patients with LBP, motor control exercises have been shown to restore the size of the MF muscle, decrease pain, and reduce recurrence of LBP symptoms. In elite cricketers with LBP, MCT restored MF muscle size and was associated with a reduction in LBP. In AFL players, MCT increased the size of the MF muscle and was shown to be associated with a reduction in the incidence of lower limb injuries and number of games missed during the playing season. Using a rehabilitation protocol that involved progression from MCT to high-load exercise has been shown in prior studies on athletes and non-athletes to lead to hypertrophy of the MF muscle. A goal of the program performed by elite AFL players was to improve spinal awareness and train players to achieve and hold a lumbar lordosis/thoracic kyphosis posture, especially when load was added. Recent studies have demonstrated that the lumbar lordosis/thoracic kyphosis posture preferentially recruits the MF muscle. Careful attention to spinal position when load was added and during weight training would explain the documented increases in MF muscle size that were reported in this study. With respect to the effect of MCT on injury, it is possible that the rehabilitation, which targeted deficits in the neuromuscular control of the lumbopelvic region, allowed improved dynamic trunk control, with safe production, transfer, and control of forces to the distal segments of the kinetic chain. Good control of the lumbopelvic area is likely to be required to meet the high demands imposed on
AFL players. In these previous studies, subjects have received the motor control intervention under the supervision of a qualified physiotherapist. The effectiveness of independent practice of this form of exercise is unknown.

Self-management of LBP can include a range of activities from education to self-managed exercise programs. After initial training by a physiotherapist, MCT can be practised as a self-managed exercise program. For patients with non-specific LBP, the effect of self-management was found to be relatively small when compared with minimal intervention, however, of the trials included in this meta-analysis, none investigated the effect of independent practice of MCT. For athletes, while there is evidence to support the implementation of self-managed interventions within a training program, to our knowledge, the effect of a self-managed exercise program on maintenance of the size of the MF muscles in athletes with and without LBP, has not been investigated previously. Therefore, the aim of this study was to determine the effects of a self-managed MF exercise program and strength and fitness training on size of the MF muscle in a cohort of elite AFL players with and without LBP during the preseason.

Methods
Participants
Players from six professional AFL clubs aged 18-40 years were invited to participate in the study (N= 275). Due to club training commitments, some players were not available for assessment at both time points in the study. Measurements of 242 players were completed at the start (Timepoint 1: T1) and end (Timepoint 2: T2) of the preseason period, which lasted 16-20
weeks. The host institution’s Human Research Ethics Committee approved this study, and
guidelines outlined by the National Health and Medical Research Council were followed.
Participation in the study was voluntary, and informed written consent was obtained from all
study participants.

Questionnaires
A self-administered questionnaire was used at T1 to collect information on participant
demographics (e.g. age, height, weight, dominant kicking leg). Players were asked whether they
were currently suffering from LBP (‘yes’ or ‘no’). At T2, players were questioned about
performance of motor control exercises and training undertaken during the preseason. Regarding
MCT, participants were asked if they had been formally taught how to voluntarily contract their
MF muscle (by lying in a prone position, and slowly and gently performing a voluntary,
isometric contraction of the MF muscle with a hold of 10 seconds for 10 repetitions) and if they
performed these exercises during the preseason period (‘yes’ or ‘no’). Information on strength
and fitness training was also sought, as hypertrophy of the MF muscle has been shown to occur
in response to weightlifting, and the MF muscle is recruited in activities such as running. For
training, participants were asked how often they performed strength and fitness training (such as
weight or cardiovascular training) during the preseason period: ‘few times a week’, or ‘daily’.

Ultrasound Imaging and measurement
Ultrasound imaging of the MF muscles was conducted at T1 and T2. Players of each club
were imaged on one day. Previous clinical trials have shown that ultrasound imaging is a valid
and reliable method for objectively evaluating the size of the MF muscle. Using a procedure
that has been published previously, the MF muscle was imaged at the L4 and L5 vertebral levels using real-time ultrasound imaging apparatus, equipped with a 5-MHz convex transducer (LOGIQ e, GE Healthcare). Participants were positioned in prone lying, with a pillow placed under their abdomen, and the L4 and L5 lumbar spinous processes were identified by manual examination and marked with a pen. Subjects were instructed to relax the paraspinal musculature (by breathing in and out and relaxing their muscles on exhalation of their breath), conductive gel was applied, and the transducer placed transversely over the relevant spinous process. A single image of the left and right MF muscle at each vertebral level (L4 and L5) was captured for each subject (Figure 1), except in the case of larger muscles, where the left and right sides were imaged separately. Ultrasound images were captured, saved, de-identified and stored offline for subsequent image analysis. OsiriX (http://www.osirix-viewer.com/) was used for image visualisation and measurement. CSAs of the left and right MF muscles at vertebral levels L4 and L5 were calculated by tracing the inner portion of the fascial borders of the muscle (Figure 1). The left and right sides for each level were then averaged to give MF muscle CSA at L4 and L5.

Statistical Analysis

SPSS (V 22; IBM Corp) was used for data analysis. A repeated measures analysis of covariance (ANCOVA) with a type I sums of square model was used to determine the effects of MCT, as well as strength and fitness training on MF muscle size in players with and without LBP. Age, height and weight were included as covariates in the model as they were considered likely to have effects on muscle size, and the analysis would then show which factors were significant. The within subjects factor was ‘time’ (T1 and T2). The between subjects factors used in the analysis were (1) self-managed MF muscle training (coded as ‘no’ or ‘yes’) (2)
amount of strength and fitness training (coded as ‘few times a week’ or ‘daily’) and (3) presence of current self-reported LBP (coded as ‘LBP’ or ‘no LBP’). Separate models were conducted for each of the L4 and L5 vertebral levels for the CSA of the MF muscle.

Results

Measurements of 242 players were completed at T1 and T2. The cases included in this study represent 88% of the eligible sample population. The age, height and weight (mean, SD) were as follows: age- 21.9, 3.6 years; height- 188.4, 7.3cm; and weight- 86.9, 8.6 kg. At the start of the preseason period, 111 players (45.9%) reported having current LBP.

Results of the ANCOVA showed that age, height and weight did not significantly affect MF muscle CSA (p>0.1). The model showed that the changes in the CSA of the MF muscle across the preseason period were related to self-managed training of the MF muscle and self-reported current LBP. A significant two-way interaction was found between MF muscle CSA and MF muscle exercises over time at the L5 vertebral level (F= 13.89, p= <0.001) but not at the L4 level (F = 2.63, p = 0.11). The results shown in Table 1 indicate that the decrease in muscle size experienced from T1 to T2 was different between those who did and did not practise the MF muscle exercises during the preseason period. The size of the MF muscle at the L5 vertebral level was preserved (decreased by only 2.8%) in players who practised the MF muscle exercises, compared with a decrease of 9.8% in the players who did not. There was also a significant three-way interaction between MF muscle size, LBP and MF muscle exercises over time for the L5 vertebral level (F= 4.77, p= 0.03) but not for the L4 level (F= 0.02, p= 0.89). The effect size of self-managed training, compared with no training, on muscle size decrease over the preseason
was 0.44, which represents a small effect size (0.2-0.49). There was a significant difference for changes in CSA of the MF muscle in players with and without current LBP (Figure 2). Loss of MF muscle size was larger in players who did not perform the MF exercises (current LBP = 11.7%, no LBP = 7.9%). Size of the MF muscle was essentially preserved in those who did the MF exercises (no current LBP = 4.4% decrease, current LBP = 1% decrease).

Results of the ANCOVA also showed a change in the size of the MF muscle across the preseason, which was related to the amount of strength and fitness training performed. Significant interactions were found between MF muscle CSA and preseason strength and fitness training over time for the L5 vertebral level (F= 5.35, p= 0.02) but not for the L4 level (F= 2.00, p= 0.16). The size of the MF muscle was better maintained in those who performed strength and fitness training ‘daily’, compared with a ‘few times a week’, with decreases of 8.5% and 4.3% respectively (Figure 3). There was no significant interaction between MF muscle CSA, LBP and preseason strength and fitness training over time for the L5 vertebral level (F= 0.217, p= 0.642) or the L4 level (F= 1.61, p= 0.21).

**Discussion**

This study aimed to determine the effect of self-managed MF muscle exercises, and strength and fitness training on size of the MF muscle in AFL players with and without LBP over the preseason. The primary finding of this study was that a self-managed MF exercise program maintained MF muscle size at the L5 vertebral level during the preseason period. Results also showed that increased adherence to preseason strength and fitness training also maintained MF muscle size.
Effects of Self-Managed Exercise Programme on MF Muscle Size

Our finding that maintenance of muscle size was evident in players who independently practised MF muscle exercises during the preseason period is consistent with previous studies, which have shown that specific MCT maintained size of the MF muscle in AFL players. A recent study examined changes in MF muscle size across the preseason and showed that change in size over the preseason period was a possible risk factor for injury in the season. Players with small MF muscle size at the start of the preseason whose muscle size decreased further, had relatively higher odds of a season injury. Players injured in the preseason on average had smaller MF muscles before the injury. Players with larger MF muscle size who retained their MF muscle size tended to incur fewer injuries in the preseason or playing season. Notably, among players who had a preseason injury, those who recovered their MF muscle size tended not to incur further injury, but additional loss of MF muscle size was related to another injury in the playing season. While a supervised motor control intervention was shown to be effective in mitigating loss of MF muscle size in previous studies, the current study indicates that positive results can also be achieved when exercises are self-managed. The relevance of this finding is that the concomitant decreases in MF muscle size which occur during the playing season could potentially be mitigated by performing self-managed MF muscle exercises in the playing season. Whilst our study was focussed on the preseason, so does not allow us to examine this, it could be an important consideration for future studies, as players undertake less strength and fitness training during the playing season than during the preseason period.
An interesting finding from the current study was that even for players with LBP, MF muscle size was able to be preserved in those who practised the exercises over the preseason period. At the end of the preseason, players with LBP who did not practise the exercises had the smallest MF muscles of all the players assessed. These results parallel a randomised controlled trial, which involved individuals with LBP, and showed that LBP was associated with a decrease in the size of the MF muscle, and specific exercise therapy targeting the MF muscle was commensurate with recovery of muscle size. In the present study, mechanisms of perceived pain or reflex inhibition could have been responsible for the small size of the MF muscle observed in the group of players with LBP who did not perform MF muscle training during the preseason. As the presence of LBP has shown to increase the risk of more severe lower limb injuries among elite AFL players, it is important to consider interventions that are effective for those with LBP. Our results demonstrated that changes in size of the MF muscle can be mitigated by self-managed exercises in AFL players with LBP and therefore may represent a beneficial approach for this population.

**Effects of Strength and Fitness Training on MF Muscle Size**

The results of the current study, while preliminary, indicate that a dose-response relationship exists between strength and fitness training in the preseason and MF muscle size. Previous research has largely focused on rehabilitation of patients with LBP, and studies of the effects of strength and fitness training on MF muscle size for the athletic population are sparse. In the current investigation, increased amounts of strength and fitness training had a positive effect on size of the MF muscle in AFL players. These results are consistent with previous research, which has shown that hypertrophy of the MF muscle occurs in response to increased
loading in weight lifting.\textsuperscript{14} Possible explanations for the effectiveness of strength and fitness training on MF muscle size include increased MF muscle recruitment during neutral spine positions and performance of exercises involving high loads. A previous study using fine wire electromyography (EMG) showed that MF muscle activity was greatest during maintenance of a lumbar lordosis/thoracic kyphosis posture\textsuperscript{10} and another showed that maintenance of a neutral spine during global multi-joint exercises such as the deadlift or squat recruited the MF muscle.\textsuperscript{15}

Consequently, if players in the present study performed exercises with correct technique and appropriate loads, the increased amount of strength and fitness training may have provided a sufficient stimulus to mitigate MF muscle loss over the preseason period. However, we cannot be certain that this was the case in the present study, as spinal kinematics and intensity of exercise were not examined.

It is interesting to note that the results were significant for the CSA of the MF at the L5, but not the L4 vertebral level. Similar results have been published previously in AFL players, elite cricketers and patients with LBP. In a study which examined prediction of lower limb injuries in the preseason for elite AFL players, CSAs of the MF muscles were reported for the L3, L4 and L5 vertebral levels. The size of the MF muscle at the L5 vertebral level predicted more cases of injury than the other vertebral levels measured.\textsuperscript{24} The CSA of the MF muscles has also been measured at multiple levels (L2-5) in patients with chronic LBP.\textsuperscript{21} Atrophy of the MF muscle was greatest at the L5 vertebral level, and there was a trend towards significance at the L4 vertebral level. In addition, patients with chronic LBP were less able to contract the MF muscle voluntarily at the L5 vertebral level. The MF muscles of elite cricketers with and without LBP have also been assessed at multiple vertebral levels (L2-L5).\textsuperscript{22} Localised changes in CSA of
the MF muscle specific to the L5 vertebral level were also reported in this study. Intervention resulted in increases in CSA of the MF muscle at the L5 vertebral level, and this was associated with decreases in LBP. Anatomically, the size of the lumbar MF muscle is largest at the lumbosacral junction\textsuperscript{37} where biomechanical forces are high.\textsuperscript{11} As L5/S1 represents the link between the lower extremities/pelvis and the vertebral column, it is perhaps understandable why deficits occur at this specific vertebral level, and why these are important to address.

Limitations and Future Directions.

The current investigation was preliminary in nature and has some limitations. The categories ‘strength’ and ‘fitness’ training were combined in the self-administered questionnaire; hence the individual effect of these types of training on MF muscle size is unclear. Moreover, training parameters such as time and load were not measured in the study, so the relation between exercise intensity and MF muscle size remains unknown. An additional limitation is that factors such as players’ lifestyles, activities and postures outside of the club environment were not assessed. For example, over the preseason period, players’ activity levels over the Christmas break period were not assessed. Future research could include assessment of the kinematics of spinal curves during strength and fitness training to determine whether these variables and quality of movement affect MF muscle size over the preseason. With respect to MCT, future research is required to assess the frequency players should practise the MF muscle exercises to achieve the most beneficial results. To guide the prescription of exercise therapy, the effects of supervised and unsupervised motor control programs could be compared.

5. Conclusion
This study provides initial evidence to support the value of a self-management program that targeted the MF muscle. Self-managed exercises were effective at mitigating changes seen in the MF muscle across the preseason.

6. Practical Implications

- Independent practice of a motor control training (MCT) program that targeted the MF muscle was effective at maintaining MF muscle size in elite AFL players with and without LBP.
- Independent practice is advantageous in that clubs do not need to provide additional resources to incorporate this approach.
- In clinical practice, the two approaches (self-managed MCT) and strength and fitness training could be combined. Motor control exercises targeting the MF muscles could be incorporated in the “warm-up”.
- As changes in size of the MF muscle were greatest at the L5 vertebral level, careful attention should be paid to control of the lumbo-sacral position in the weights room.
- Increased amounts of strength and fitness training were also beneficial for maintaining MF muscle size over the preseason period.
- Rehabilitation which involves independent MF training, and daily strength and fitness training, may be advantageous for maintaining the size of the MF muscle in athletes.


Figure Legends

Figure 1. Ultrasound imaging of the multifidus muscle with the participant positioned in prone lying and the transducer placed transversely over the relevant spinous process (A); Ultrasound image of the left and right multifidus muscles in transverse section at the L5 vertebral level with the inner border of the fascial boundaries traced to measure cross-sectional area (B).

Abbreviations: ST = subcutaneous tissue, SP = (shadow of the) spinous process; Lamina = indicates the hyperechoic vertebral lamina

Figure 2. Cross-sectional area of the multifidus muscle at the L5 vertebral level for MF muscle training and LBP groups during the preseason.

Abbreviations: LBP = low back pain; MF = multifidus muscle; Time 1 = start of preseason; T2 = end of preseason; CSA = cross-sectional area. Values are expressed as mean (cm$^2$) and the error bars represent standard error. Mean cross-sectional area measurements are adjusted to age, height and weight.

The players who did MF training during the preseason did not have a significant decrease in MF muscle CSA as indicated by the overlapping error bars. Players with no MF muscle training had significant muscle decreases, with the LBP group having the biggest decrease.

Figure 3. Cross-sectional area of the multifidus muscle at L5 vertebral level for fitness and strength training groups during the preseason.

Abbreviations: Time 1 = start of preseason; T2 = end of preseason; CSA = cross-sectional area. Values are expressed as mean (cm$^2$) and the error bars represent standard error. Mean cross-
sectional area measurements are adjusted for age, height and weight. Daily strength and fitness training contributed to less reduction in MF muscle CSA than only training a few times a week.
Table 1. Cross-sectional area of the multifidus muscle at L5 vertebral level at the start and end of the preseason period in players who did and did not practice multifidus exercises.

a Values are expressed as mean (cm²) ± standard error; Mean CSA measurements are adjusted for age, height and weight

<table>
<thead>
<tr>
<th>Training Group</th>
<th>Time 1 a</th>
<th>Time 2 a</th>
<th>% change from Time 1 to Time 2</th>
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<tbody>
<tr>
<td>No multifidus training</td>
<td>9.20 ± 0.15</td>
<td>8.30 ± 0.13</td>
<td>9.8%</td>
</tr>
<tr>
<td>Yes multifidus training</td>
<td>8.85 ± 0.22</td>
<td>8.60 ± 0.19</td>
<td>2.8%</td>
</tr>
</tbody>
</table>
Figure 1.
Figure 2.
Figure 3.