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original research

Self-Managed Exercises, Fitness and Strength Training, and Multifidus Muscle Size in Elite Footballers

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Context: Low back pain (LBP) and lower limb injuries are common among Australian Football League (AFL) players. Smaller size of 1 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 programs. Among AFL players, supervised motor-control training has also been shown to reduce the 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: To investigate the effect of self-managed exercises and fitness and strength training on MF muscle size in AFL players with or without current LBP.

Design: Cross-sectional study.

Setting: Professional AFL context.

Patients or Other Participants: Complete data were available for 242 players from 6 elite AFL clubs.

Intervention(s): Information related to the presence of LBP and 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 fitness and strength training. Ultrasound imaging of the MF muscle was conducted at the start and end of the preseason.

Main Outcome Measure(s): Size of the MF muscles.

Results: An interaction effect was found between performance of MF exercises and time ($F = 13.89$, $P \leq .001$). Retention of MF muscle size was greatest in players who practiced the MF exercises during the preseason ($F = 4.77$, $P = .03$). Increased adherence to fitness and strength training was associated with retained MF muscle size over the preseason ($F = 5.35$, $P = .02$).

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

Key Words: Australian Football League, motor-control training, ultrasound imaging, independent exercise, lumbar muscles

Key Points

- Self-managed training was effective in mitigating multifidus muscle changes seen in elite Australian Football League players with or without low back pain.
- Daily fitness and strength training had a positive effect on size of the multifidus muscles in Australian Football League players.

Australian rules football is a high-intensity, fast-paced game. Many activities performed during football, such as running, jumping, and cutting, require neuromuscular control to maintain stability.[1,2] A stable lumbopelvic complex is central to athletic function.[3] Optimal athletic function is best achieved by the coordinated, sequenced activation of body segments that places the distal segment in the optimal position and enhances velocity and timing to produce the desired athletic task.[4] Additionally, 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.[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 activity, 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.[5] Stability of the lumbopelvic region involves both good dynamic neuromuscular control and intact passive structures.[6] A key provider of active support is the lumbar multifidus (MF) muscle. The segmental fibers of the MF muscle contribute to the stability of the lumbopelvic complex by supporting and controlling the motion of intervertebral segments,[7,8] providing proprioceptive feedback,[9] and controlling the lumbar lordosis.[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[7,10] as well as to increase the tolerance of shear and compressive forces on the lumbar spine.[11]

For many codes of football, the preseason involves a higher training load than the playing season.[12,13] For this reason, activities such as weight training and running could increase the size of the MF muscles over the preseason. Hypertrophy of the MF muscles occurs in response to increased loading during weightlifting,[14] and maintenance of a neutral spine recruits the MF muscle in deadlifting and squatting.[15] The MF muscle has been shown to be active during running to control sagittal-plane motion of the trunk.[16] However, a longitudinal study[17] 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 cause injury to any segment of the kinetic chain.[18]

Alteration in the morphology of the MF muscle has been associated with low back pain (LBP), prediction of injury, and the type of activity performed. Selective and localized atrophy of the MF muscle has been documented in patients with acute or chronic LBP.[19,20] This has most commonly been demonstrated at the L5 vertebral level.[19–21] Despite being very active and fit, elite athletes still experience LBP.[22,23] A recent article[23] reported that 38% of players had LBP at the start of an AFL preseason. Although few players miss games during the playing season due to LBP alone, players with LBP had increased odds of a lower limb injury in the preseason period.[23] A decrease in the cross-sectional area (CSA) of the MF muscle during the AFL preseason and playing season predicted lower limb injuries in elite players.[23,24] Among elite AFL players, a decrease in MF muscle size occurred in response to playing football, most likely in association with AFL being a flexor-dominant sport.[17,25] A longitudinal study[17] showed that by the end of the playing season, the CSA of the MF muscle had decreased, whereas the size of the internal oblique muscle had increased, possibly representing the development of muscle imbalance. Therefore, decreases in MF muscle size have been associated with LBP and playing football and predict lower limb injury during the playing season.

The size of the MF muscle is modifiable with motor-control training (MCT) when delivered to people with LBP,[20,26] elite cricketers with LBP,[22] and elite AFL players.[25] In patients with LBP, motor-control exercises have restored the size of the MF muscle, decreased pain, and reduced the recurrence of LBP symptoms.[20,26] In elite cricketers with LBP, MCT restored MF muscle size and was associated with a reduction in LBP.[22] In AFL players, MCT increased the size of the MF muscle and was associated with a reduction in the incidence of lower limb injuries and the number of games missed during the playing season.[25,27] In studies of athletes[22,25] and nonathletes,[28] a rehabilitation protocol that involved progression from MCT to high-load exercise led 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.[25] The lumbar lordosis-thoracic kyphosis posture preferentially recruits the MF muscle.[10] 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.[25] With respect to the effect of MCT on injury, it is possible that the rehabilitation protocol, which targeted deficits in the neuromuscular control of the lumbopelvic region, improved dynamic trunk control, with safe production, transfer, and control of forces to the distal segments of the kinetic chain.[3] Good control of the lumbopelvic area is likely required to meet the high demands imposed on AFL players. In these previous investigations, participants have received motor-control interventions 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 practiced as a self-managed exercise program. For patients with nonspecific LBP, the effect of self-management was relatively small compared with that of minimal intervention; however, of the trials included in this meta-analysis, none investigated the effect of independent practice of MCT.[29] For athletes, although evidence supports the implementation of self-managed interventions within a training program,[30] to our knowledge, the effect of a self-managed exercise program on maintenance of the size of the MF muscles in athletes with or without LBP has not been investigated previously. Therefore, the aim of our study was to determine the effects of a self-managed MF exercise program and fitness and strength training on size of the MF muscle in a cohort of elite AFL players with or without LBP during the preseason.

METHODS

Participants

Players aged 18 to 40 years from 6 professional AFL clubs 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 (time point 1: T1) and end (time point 2: T2) of the preseason period, which lasted 16 to 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 (eg, age, height, weight, dominant kicking leg). Players were asked whether they were currently experiencing LBP (*yes* or *no*). At T2, players were questioned about performance of motor-control exercises and training 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

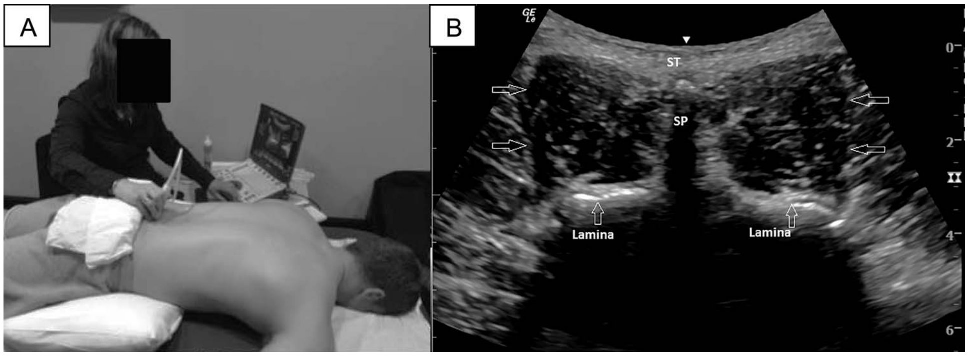

Figure 1. A, Ultrasound imaging of the multifidus muscle with the participant positioned prone and the transducer placed transversely over the relevant spinous process. B, Ultrasound image of the left and right multifidus muscles in transverse section at the L5 vertebral level. Arrows indicate the lateral borders of the muscle. Lamina indicates the hyperechoic vertebral lamina. Abbreviations: SP, "shadow of the tip" of the spinous process; ST, subcutaneous tissue.

muscle with a hold of 10 seconds for 10 repetitions) and if they performed this exercise during the preseason period (*yes* or *no*). Information on fitness and strength training was also sought, as hypertrophy of the MF muscle occurs in response to weightlifting,[14] and the MF muscle is recruited in activities such as running.[16] For training, participants were asked how often they performed fitness and strength training (such as weight or cardiovascular training) during the preseason period: *few times a week* or *daily*.

Ultrasound Imaging and Measurement

All players in each club underwent ultrasound imaging of the MF muscles on single days at T1 and T2. Previous clinical trials[31–33] have shown that ultrasound imaging is a valid and reliable method for objectively evaluating the size of the MF muscle. Using a published procedure,[31] we imaged the MF muscle at the L4 and L5 vertebral levels using a real-time ultrasound imaging apparatus equipped with a 5-MHz convex transducer (model LOGIQ e; GE Healthcare, Chicago, IL). Participants were placed in a prone position with a pillow under the abdomen, and the L4 and L5 lumbar spinous processes were identified by manual examination and marked with a pen. Participants 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 was 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 person (Figure 1), except in the case of larger muscles, where the left and right sides were imaged separately. Ultrasound images were captured, saved, deidentified, and stored offline for subsequent image analysis. OsiriX (http://www.osirix-viewer.com; Pixmeo, Geneva, Switzerland) was used for image visualization and measurement. We calculated the CSAs of the left and right MF muscles at vertebral levels L4 and L5 by tracing the inner portion of the fascial borders of the muscle (Figure 1). The left and right sides at each level were then averaged to give the MF muscle CSA at L4 and L5.

Statistical Analysis

We used SPSS (version 22; IBM Corp, Armonk, NY) for data analysis. A repeated-measures analysis of covariance (ANCOVA) with a type I sums of squares model was used to determine the effects of MCT, as well as fitness and strength training, on MF muscle size in players with or without LBP. Age, height, and weight were included as covariates in the model as they were considered likely to affect muscle size, and the analysis would then show which factors were significant.[25,34] The within-subject factor was time (T1 and T2). The between-subjects factors were (1) self-managed MF muscle training (coded as *no* or *yes*); (2) amount of fitness and strength 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 the CSA of the MF muscle at the L4 and L5 vertebral level.

RESULTS

Measurements of 242 players were completed at T1 and T2. The players included in this study represented 88% of the eligible sample population. The age, height, and weight (mean $\pm$ standard deviation) were 21.9 $\pm$ 3.6 years, 188.4 $\pm$ 7.3 cm, and 86.9 $\pm$ 8.6 kg, respectively. At the start of the preseason period, 111 players (45.9%) reported having current LBP.

The ANCOVA showed that age, height, and weight did not affect MF muscle CSA ($P > .1$). The model indicated that the CSA changes in the MF muscle across the preseason period were related to self-managed training of the MF muscle and self-reported current LBP. A significant 2-way interaction was found between MF muscle CSA and MF muscle exercises over time at the L5 vertebral level ($F = 13.89$, $P \leq .001$) but not at the L4 level ($F = 2.63$, $P = .11$). The decrease in muscle size experienced from T1 to T2 was different between those who did and those who did not practice the MF muscle exercises during the preseason period (Table). The size of the MF muscle at the L5 vertebral level was preserved (ie, decreased by only 2.8%) in players who practiced the MF muscle exercises, compared with a decrease of 9.8% in the players who did not. A significant 3-way interaction among MF muscle size, LBP, and MF muscle exercises over time was noted for the L5 vertebral level ($F = 4.77$, $P = .03$) but not for the L4 level ($F = 0.02$, $P = .89$). 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).[35] A difference was present for

Table. Multifidus Muscle Cross-Sectional Area at the L5 Vertebral Level at the Start and End of the Preseason in Players Who Did or Did Not Practice Multifidus Exercises

Multifidus Muscle Training?	Cross-Sectional Area, cm^2 ± Standard Error[a]		Change From Time 1 to Time 2, %
	Time 1	Time 2	
No	9.20 + 0.15	8.30 + 0.13	9.8
Yes	8.85 + 0.22	8.60 + 0.19	2.8

[a] Mean cross-sectional area measurements are adjusted for age, height, and weight.

changes in the CSA of the MF muscle in players with or without current LBP (Figure 2). Loss of MF muscle size was greater 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 performed the MF exercises (no current LBP = 1% decrease, current LBP = 4.4% decrease).

The ANCOVA also showed a change in the size of the MF muscle across the preseason, which was related to the amount of fitness and strength training performed. Significant interactions were observed between MF muscle CSA and preseason fitness and strength training over time for the L5 vertebral level ($F = 5.35$, $P = .02$) but not for the L4 level ($F = 2.00$, $P = .16$). The size of the MF muscle was better maintained in those who performed fitness and strength training daily compared with those who performed it a few times a week, with decreases of 4.3% and 8.5%, respectively (Figure 3). No interaction occurred among MF muscle CSA, LBP, and preseason fitness and strength training over time for either the L5 vertebral level ($F = 0.217$, $P = .642$) or the L4 level ($F = 1.61$, $P = .21$).

DISCUSSION

We aimed to determine the effect of self-managed MF muscle exercises as well as fitness and strength training on the size of the MF muscle in AFL players with or without LBP over the preseason. Our primary finding was that a self-managed MF exercise program maintained MF muscle size at the L5 vertebral level during the preseason period. Increased adherence to preseason fitness and strength training also maintained MF muscle size.

Effects of Self-Managed Exercise Program on MF Muscle Size

Our finding that maintenance of muscle size was evident in players who independently practiced MF muscle exercises during the preseason period is consistent with findings of previous studies,[25,27] which have shown that specific MCT maintained the size of the MF muscle in AFL players. A recent study[23] examined changes in MF muscle size across the preseason and demonstrated that change in size over the preseason period was a possible risk factor for injury during the season. Players with a small MF muscle size at the start of the preseason whose muscle size decreased further had relatively higher odds of sustaining an injury during the season. Players injured in the preseason had smaller MF muscles, on average, before the injury. Players with larger MF muscles who retained their muscle size tended to incur fewer injuries in the preseason or playing season.[23] 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.[23] Although a supervised motor-control intervention was effective in mitigating loss of MF muscle size in previous studies,[25,27] our results indicate that benefits can also be achieved when the exercises are self-managed. The relevance of this finding is that the concomitant decreases in MF muscle size that occur during the playing season could potentially be mitigated by performing self-managed MF muscle exercises during the season. Because our study focused on the preseason, it does not allow us to examine this possibility, which could be an important consideration for future studies, as players undertake less fitness and strength training during the playing season than during the preseason period.

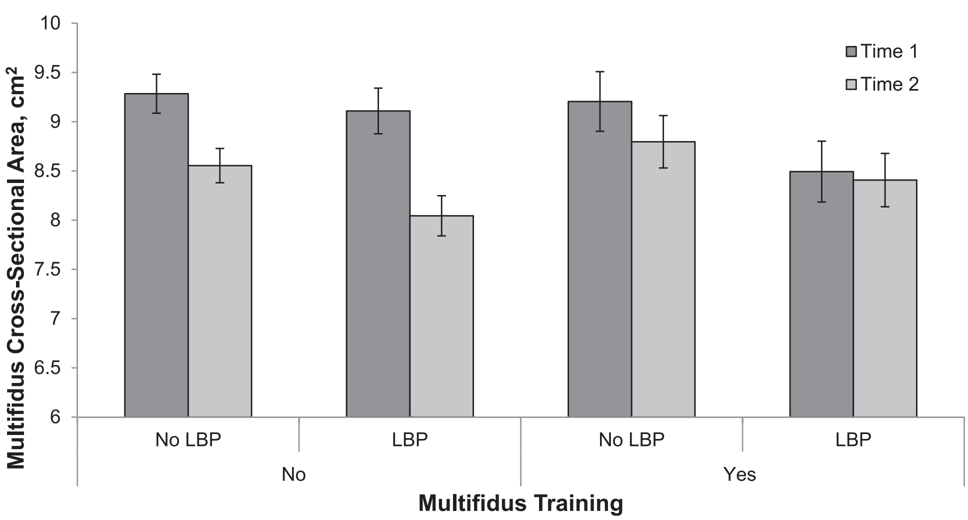

Figure 2. Cross-sectional area (CSA) of the multifidus (MF) muscle at the L5 vertebral level for MF muscle training and low back pain (LBP) groups during the preseason. Abbreviations: Time 1, start of preseason; Time 2, end of preseason. Note: Values are expressed as mean (cm^2) and the error bars represent standard error. Mean CSA measurements are adjusted for age, height, and weight. The players who did MF training during the preseason did not have a decrease in MF muscle CSA as indicated by the overlapping error bars. Players with no MF muscle training had muscle decreases, and the LBP group had the biggest decrease.

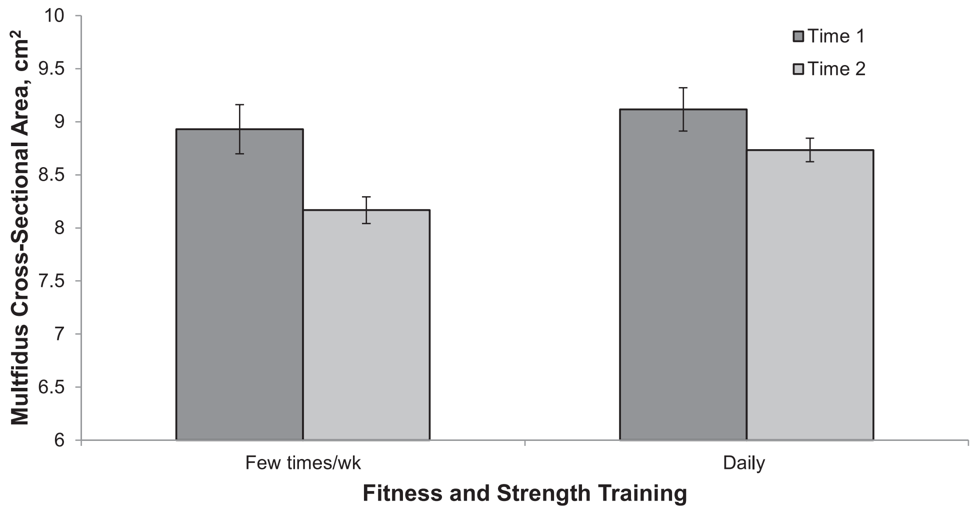

Figure 3. Cross-sectional area (CSA) of the multifidus (MF) muscle at the L5 vertebral level for fitness and strength training groups during the preseason. Abbreviations: Time 1, start of preseason; Time 2, end of preseason. Note: Values are expressed as mean (cm^2) and the error bars represent standard error. Mean CSA measurements are adjusted for age, height, and weight. Daily fitness and strength training contributed to less reduction in MF muscle CSA than training only a few times a week.

An interesting finding from the current study was that even for players with LBP, MF muscle size was preserved in those who practiced the exercises over the preseason period. At the end of the preseason, players with LBP who did not practice the exercises had the smallest MF muscles of all the players assessed. These results parallel the results of a randomized controlled trial[20,26] that involved individuals with LBP; it 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 our investigation, mechanisms of perceived pain or reflex inhibition could have been responsible for the small size of the MF muscle observed in the players with LBP who did not perform MF muscle training during the preseason.[20] As the presence of LBP has been shown to increase the risk of more severe lower limb injuries among elite AFL players,[23] it is important to consider interventions that are effective for those with LBP. Our results demonstrated that changes in MF muscle size can be mitigated by self-managed exercises in AFL players with LBP and therefore may represent a beneficial approach for this population.

Effects of Fitness and Strength Training on MF Muscle Size

Although our findings are preliminary, they indicate that a dose-response relationship exists between fitness and strength training in the preseason and MF muscle size. Previous researchers[36] have largely focused on rehabilitation of patients with LBP, and studies of the effects of fitness and strength training on MF muscle size for the athletic population are sparse. In the current investigation, increased amounts of fitness and strength training had a positive effect on size of the MF muscle in AFL players. These results are consistent with those of earlier investigators,[14] who showed that hypertrophy of the MF muscle occurred in response to increased loading in weight lifting. Possible explanations for the effectiveness of fitness and strength training on MF muscle size include increased MF muscle recruitment during neutral spine positions and performance of exercises involving high loads. Using fine-wire electromyography, authors[10] noted that MF muscle activity was greatest during maintenance of a lumbar lordosis-thoracic kyphosis posture. Other researchers[15] observed that maintaining a neutral spine during global multijoint exercises such as the deadlift or squat recruited the MF muscle. Consequently, if our participants performed exercises with correct technique and appropriate loads, the increased amount of fitness and strength training may have provided sufficient stimulus to mitigate MF muscle loss over the preseason. However, we cannot be certain that this was the case, as we did not examine spinal kinematics or exercise intensity.

It is interesting to note that the results were significant for the MF CSA at the L5 but not the L4 vertebral level. Similar findings have been published for AFL players, elite cricketers, and patients with LBP. In a study[24] that examined prediction of preseason lower limb injuries for elite AFL players, the 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 injuries than at the other vertebral levels measured. The CSA of the MF muscles has also been measured at multiple levels (L2–L5) in patients with chronic LBP.[21] Atrophy of the MF muscle was greatest at the L5 vertebral level, and there was a trend toward 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 or without LBP have also been assessed at multiple vertebral levels (L2–L5).[22] Localized changes in the CSA of the MF muscle specific to the L5 vertebral level were also reported in this study. Intervention increased the CSA of the MF muscle at the L5 vertebral level, which was associated with decreases in LBP. Anatomically, the lumbar MF muscle is largest at the lumbosacral junction,[37] where biomechanical forces are high.[11] As L5-S1 represents the link between the lower extremities and 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

Our investigation was preliminary in nature and has some limitations. The categories of *fitness* and *strength* training were combined in the self-administered questionnaire; hence, the individual effects of these types of training on MF muscle size are unclear. Moreover, we did not measure training factors such as time and load, so the relationship between exercise intensity and MF muscle size remains unknown. An additional limitation is that factors such as a player's lifestyle, activities, and posture outside the club environment were not assessed. For example, over the preseason, players' activity levels over the Christmas break period were not examined. Future researchers could assess the kinematics of spinal curves during fitness and strength training to determine whether these variables and quality of movement affect MF muscle size over the preseason. With respect to MCT, investigation is required to assess the frequency with which players should practice 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.

CONCLUSIONS

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.

PRACTICAL IMPLICATIONS

- Independent practice of an MCT program that targeted the MF muscle was effective at maintaining MF muscle size in elite AFL players with or without LBP
- Independent practice is advantageous in that clubs do not need to provide additional resources to incorporate this approach.
- In clinical practice, the 2 approaches—self-managed MCT and fitness and strength training—could be combined. Motor-control exercises targeting the MF muscles could be incorporated in the warm-up.
- Changes in size of the MF muscle were greatest at the L5 vertebral level, so careful attention should be paid to control of the lumbosacral position in the weight room.
- Increased amounts of fitness and strength training were also beneficial for maintaining MF muscle size over the preseason.
- Rehabilitation that involves independent MF training, as well as daily fitness and strength training, may be advantageous for maintaining the size of the MF muscle in athletes.

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