Effect of motor control training on hip muscles in elite football players with and without low back pain

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Abstract

Objectives: Previous research has shown that motor control training improved size and function of trunk muscles in elite football players with and without low back pain (LBP). Imbalances in hip muscles have been found in athletes with LBP and it is not known if motor control training can change these muscles. This study investigated if a motor control intervention program affected hip muscle size in elite football players with and without LBP.

Design: Panel-randomised intervention design

Methods: Forty-six players from one club in the Australian Football League (AFL) participated in a motor control training program delivered across the season as a stepped-wedge intervention design with 3 treatment arms: 15 weeks intervention, 8 weeks intervention and a wait-list control who received 7 weeks intervention toward the end of the playing season. Presence of LBP was assessed by interview and physical examination. Cross-sectional areas of iliacus, psoas, iliopsoas, sartorius, gluteus minimus, and gluteus medius muscles were measured from magnetic resonance images taken at 3 time points during the season.

Results: Iliopsoas, sartorius and gluteus medius muscle size increased for players who received intervention (p < 0.05). For players with current LBP, sartorius and gluteus medius muscle size increased for those who received motor control training (p<0.05).

Conclusions: Motor control training programs aimed at the lumbo-pelvic region also benefit the hip muscles. For players with current LBP, the intervention mitigated sartorius muscle atrophy and increased gluteus medius muscle size. These findings may help guide the management of LBP in elite football players.

Keywords: Magnetic Resonance Imaging, Ultrasound Imaging, Exercise, Intervention Study, Iliopsoas muscle, Gluteus medius muscle
Introduction

The problem of low back pain among football players has received increasing attention in recent literature. Studies have noted a high prevalence (57-64%) and recurrence (59%) rate of low back pain (LBP) in this population \(^1, 2\). Apart from LBP affecting how athletes move \(^3\), which could have an adverse impact on performance, a 2 year prospective radiological investigation indicated that playing football is a significant risk factor for the onset of LBP and progression of intervertebral disc degeneration \(^4\). Considering the high prevalence rate and possible long-term consequences, it is important to explore modifiable factors for the prevention and management of LBP in football players.

The presence of LBP can affect the size and function of not only the trunk muscles but also the hip muscles in elite athletes. While previous research has found decreased size and altered function of the trunk muscles responsible for spinal protection in elite football players \(^5, 6\) and cricketers with LBP \(^7, 8\), a recent review has highlighted the need to consider the hip in relation to spinal function in the management of LBP \(^9\). Previous studies have found imbalances in the hip muscles and decreased hip extension strength in collegiate athletes with LBP \(^10, 11\). Together with hip abductor weakness \(^12, 13\) and hip flexor weakness \(^14\), it is apparent that LBP has an effect on hip muscle function. Only one study to date has examined the effect of LBP on hip muscle size in football players and found a decrease in piriformis muscle size in players with current LBP \(^15\). However, other hip muscles were not examined in this study. While the deep hip external rotator muscles are important for hip joint function and stability, so too are the other hip muscles \(^16\). Therefore, it is important to examine the effect of LBP on hip muscle size in elite football players.

Motor control training is an intervention program used to treat people with LBP. It targets the neuromuscular control of the lumbo-pelvic region by focussing on the recruitment and control of key muscles involved in protection of the spine and pelvis \(^17, 18\). Training neuromotor
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Control of the lumbo-pelvic region has improved the size and function of the multifidus and transversus abdominis muscles in elite cricketers and football players and has been associated with a reduction in LBP in these populations. Recent research has also shown that motor control training increased the size of the piriformis muscle in elite football players with LBP. However, it is unknown if a motor control training program affects other muscles in the lower limb kinetic chain, in particular, muscles of the hip region. Therefore, the aim of this study was to investigate the effect of a motor control training program on hip muscle size (by comparison with a control group) in elite Australian football players with and without LBP.

Methods

All players from the squad of a professional Australian Football League (AFL) club were eligible to participate in this study. This study was approved by the Medical Research Ethics Committee at The University of Queensland. Forty-six elite football players, representing the entire squad, participated in this study. Prior to participation, all players gave written informed consent and their rights were protected.

Details of the intervention protocol have been previously published. In brief, the intervention trial was delivered during the football playing season as a single blinded, stepped-wedge design in three blocks, each of 7-8 weeks duration. The main aim of the study was to compare the effects of motor control training intervention to a control group. As it was a requirement of the club that all players received the intervention during the playing season, a panel design was used which enabled one group to serve as a wait-list control for two-thirds of the season. Participants were randomly allocated into one of three groups, using a computer-generated list of numbers by a person independent to the study. Group 1 (n=17) received 15 weeks intervention in blocks 1 & 2, Group 2 (n = 15) received 8 weeks intervention in block 2 and Group 3 (n=14) was a wait-list control for Groups 1 and 2 during blocks 1 & 2. Group 3 then received 7 weeks intervention during the follow-up period for Groups 1 and 2 (block 3), thereby meeting the club’s requirements that all players receive
intervention. No participants were excluded or lost to follow-up from the trial. A Pilates exercise program (combination of a floor and reformer program done twice a week for 30 minutes duration) was performed as part of the club’s weekly training schedule from the start of the pre-season training period. Players did not do the Pilates exercise program when they were receiving the motor control training.

The motor control training program was delivered at the football club, in two 30 minute one-on-one sessions per week, by three qualified physiotherapists with expertise in motor control training and ultrasound imaging. The physiotherapists were trained in the specific intervention protocol used in this study. The motor control training program initially involved the performance of voluntary contractions of the trunk muscles (multifidus and transversus abdominis muscles) and a focus on diaphragmatic breathing, with feedback from ultrasound imaging. Training commenced in non-weightbearing positions such as supine and prone lying, and progressed to functional and sports specific positions (examples included sitting, one- or two-legged squats, hip movements in standing, single leg hop and kicking). Players were taught to focus on maintenance of their spinal curves, alignment of their lower limbs in functional positions and dissociation of hip movements from trunk movements. Resistance was added with the use of Thera-Band exercise bands (The Hygenic Corporation, Akron, OH).

An experienced musculoskeletal physiotherapist assessed all players at baseline prior to delivery of the intervention protocol. LBP was defined as pain localized between T12 and the gluteal fold and severe enough to interfere with playing games or training. Players with no experience of LBP and no positive findings on physical examination were allocated to the “no LBP” group. Players who reported a history of LBP but did not report any current LBP pain or have positive findings on examination were also included in the “no LBP” group. Players with current LBP who reported pain in the previous week and had one or more positive findings on physical assessment were included in the “current LBP” group. Positive findings included
limited range of motion or reports of pain provocation on manual tests of lumbar intervertebral joint movement.

Magnetic resonance imaging (MRI) was used to assess size of the individual hip muscles. MRI assessments were performed in a hospital setting at baseline (start of block 1, Time 1), after 15 weeks of intervention (end of block 2, Time 2) and at the end of the intervention trial (end of block 3, Time 3). Prior to imaging, a registered medical practitioner screened all players for contraindications to MRI. Height and weight of each player was measured and information regarding their age and dominant kicking leg was collected. Participants were positioned in supine lying on the imaging table with their hips and knees supported in a neutral position. Transverse MR images through the pelvis were taken from the top of the iliac crest to the hip joint using a 1.5T Siemens Magnetom Sonata MR system (Erlangen, Germany). A true fast imaging with steady state precession (FISP) sequence was used (repetition time: 4.3ms; echo time: 2.1 ms; number of averages: 1; flip angle: 45°; acquisition matrix: 384 x 512) to obtain 18 slices with a slice thickness of 7mm and an inter-slice distance of 10.5mm. Images were saved in a de-identified format for offline analysis.

Cross-sectional areas (CSA) of the iliacus, psoas, iliopsoas, sartorius, gluteus minimus and gluteus medius muscles were measured. Other hip muscles, such as the hip extensors and hip adductors, could not be measured as the imaging sequence did not extend to capture these muscles. CSAs were obtained by manually tracing muscle outlines using Image J software (version 1.4, National Institutes of Health, Bethesda, USA, http://rsb.info.nih.gov/ij/) (Figure 1). For each muscle, the CSA was taken from consecutive slices at particular anatomical landmarks to enable consistent measurement between time points. Both sides of the body were measured. Average CSAs of the iliacus and psoas muscles were taken from consecutive slices starting at the iliac crest until the point where these two muscles fused. Average CSAs of the iliopsoas and sartorius muscles were measured from consecutive slices spanning the femoral head of the hip joint. The average muscle CSA of gluteus
minimus was measured from three consecutive slices starting at the apex of the sacrum while gluteus medius muscle CSA was measured from three consecutive slices starting at the base of the sacrum. Measurements were performed blinded to subject identification, time point and group allocation. Intra-rater reliability of CSA measurement for each muscle was high (ICC$_{1,1}$ ranging from 0.97 to 0.99; 95% CI 0.81-0.99; SEM 0.3cm$^2$), based on a sample of 10 subjects from the current study.

IBM SPSS Statistics (version 22, IBM Corp, Armonk, NY) was used for statistical analysis with a significance level set at 0.05. Gluteus medius CSA measurements were not possible at one time point due to truncated images for 2 participants. SPSS was used to estimate four data points using the series mean function (0.2% of total data set). Preliminary analyses were conducted to investigate differences in age, height, weight and distribution of players with and without LBP between the Intervention and Wait-list Control groups at baseline.

Linear mixed models were used to examine the effect of intervention on individual hip muscle size in players with and without LBP. Fixed factors of ‘Time’, ‘Group’ (Intervention (Group 1 and 2 combined) or Wait-list Control (Group 3)), and ‘LBP’ (no LBP or current LBP) and up to a 3-way interaction between these factors were fitted for each muscle with an autoregressive first order covariance structure. Intervention Groups 1 and 2 were combined for the analysis as previous research indicated no additional benefit of a prolonged intervention for trunk and hip muscles. All cases (n=46) were assessed.

**Results**

The mean age, height and weight for the 46 players were 22.8 (SD 3.5) years, 187.9 (SD 6.0) cm and 88.3 (SD 6.6) kg. The mean age, height and weight of players in each group were as follows: 22.6 (3.3) years, 188.1 (5.4) cm, 88.3 (7.1) kg in the Intervention group and 23.1 (3.9) years, 187.4 (7.5) cm, 88.2 (5.6) kg in the Wait-list Control group. At baseline, there were no significant differences for age, height and weight between groups (all p > 0.63). Thirty-three players did not have LBP (23 in Intervention group, 10 in Wait-list Control
group) and 13 players had current LBP (9 in Intervention group, 4 in Wait-list Control group).

Fisher’s exact test indicated no significant difference in the distribution of players with or without LBP across the 2 groups at baseline (p = 0.62).

There was a significant interaction effect of ‘Time’ and ‘Group’ for the iliopsoas (F = 3.65, p = 0.03), sartorius (F = 4.22 , p = 0.02), and gluteus medius (F = 4.13, p = 0.02) muscles. From Time 1 to Time 2, post hoc comparisons indicated a significant increase in iliopsoas, sartorius and gluteus medius muscle size for the Intervention group (all p < 0.05) with no significant change in size for the Wait-list Control group (all p > 0.05) (Figure 2 c, d, e). No significant interaction effects were found for the iliacus (F = 0.27, p =0.76), psoas (F = 0.64 , p = 0.53) and gluteus minimus (F = 0.77 , p = 0.47) muscles (Figure 2 a, b, f). In the follow-up period for the Intervention group (Time 2 to Time 3), the increase in iliopsoas, sartorius and gluteus medius muscle size was maintained (all p < 0.01) (Figure 2 c, d, e).

A significant interaction effect between ‘Time’, ‘Group’ and ‘LBP’ was found for the sartorius (F = 2.50, p = 0.03) and gluteus medius (F = 2.85, p = 0.02) muscles only. For players with current LBP in the Intervention group, sartorius and gluteus medius muscle size significantly increased for those who received motor control training (all p < 0.05, Table 1). For players with current LBP in the Wait-list Control group, the sartorius muscle significantly decreased in size from Time 1 to Time 2 (p < 0.05, Table 1) while no significant change in size occurred for the gluteus medius muscle (p > 0.05). In the follow-up period for the Intervention group (Time 2 to Time 3), the increase in sartorius and gluteus medius muscle size was maintained for players with current LBP (all p < 0.01).

**Discussion**

A main finding of this study was that the motor control training program was commensurate with an increase in iliopsoas, sartorius and gluteus medius muscle size. This effect may be explained by the functional role of these hip muscles and the types of exercises used in the
motor control training program. Hip flexor muscles such as the iliopsoas and sartorius muscles play an important role in functional tasks that involve hip flexion such as walking or kicking\textsuperscript{22, 23}. In addition to hip abduction, the gluteus medius muscle is an important stabilizer of the hip and pelvis in single leg stance\textsuperscript{24}. The types of exercises employed in the motor control program involved facilitation of voluntary control of the lumbopelvic muscles, initially in non-weightbearing positions and then progressing to functional weightbearing positions such as single leg stance or squats and in dynamic tasks such as single leg hopping and kicking\textsuperscript{19}. In the program, there was a focus on good postural alignment, adopting a diaphragmatic breathing pattern, dissociation of trunk movement from hip movement and optimal trunk, pelvic and lower limb alignment when load was added in functional sports specific positions. The functional weightbearing positions used for training would have required the use of hip muscles, such as the iliopsoas, sartorius, and gluteus medius muscles, that are responsible for the control of alignment and joint stability in the hip and pelvic region as well as normal hip function\textsuperscript{23-25}. This may explain the observed increase in size of these specific hip muscles in the Intervention group. This finding is similar to previous research, which also found that motor control training increased the size of the piriformis muscle\textsuperscript{15}, a hip external rotator that is important in the control of pelvic stability and lower limb alignment in weightbearing positions\textsuperscript{26}.

Motor control training did not result in a change in iliacus, psoas and gluteus minimus muscle size. The iliacus and psoas muscles are proposed to contribute to stability of the lumbar spine, pelvis and hip joint\textsuperscript{27}. Similar to the rotator cuff muscles of the shoulder, the iliacus and psoas muscles are proposed to contribute to stability of the femoral head in the acetabulum through the muscle belly and tendon of the iliopsoas muscle as it crosses the anterior hip joint\textsuperscript{25}. In the current study, an increase in size of the iliopsoas muscle at the hip joint was found but no change in size of the iliacus and psoas muscles with intervention. This finding may indicate that the motor control training targeted the functional role of this muscle complex at the hip joint rather than across the lumbar spine and pelvis. In addition to hip
abduction, the gluteus minimus muscle is a deep hip muscle proposed to primarily control the
femoral head in the acetabulum\textsuperscript{24}. Considering the weightbearing positions used in the motor
control training program, it is surprising that this muscle did not respond to the intervention.
Perhaps specific exercises targeted to its functional role are required for an increase in
the gluteus minimus muscle size.

The motor control training program has previously been used to treat patients and elite
athletes with LBP and has resulted in improved size and function of the trunk muscles\textsuperscript{7, 8, 19}
and increased size of the piriformis muscle\textsuperscript{15}. Similarly, in the current study, the motor
control training program was found to be associated with an increase in size of the sartorius
and gluteus medius muscles for football players with current LBP. A decrease in the size of
the sartorius muscle was also found in players with current LBP who did not receive the
intervention during the season. This finding of decreased hip flexor (sartorius) muscle size is
similar to previous research which has found piriformis muscle atrophy in football players
with LBP\textsuperscript{15}. This suggests that, despite the high levels of activity that these elite football
players undertake, the presence of LBP may inhibit specific hip muscles, resulting in muscle
atrophy. As the motor control training program improved hip muscle size in players with LBP,
this suggests that the effects of LBP on hip muscle size can be mitigated by use of this
intervention.

The motor control training program could be incorporated into rehabilitation or training
programs for football players with and without low back pain to target muscles of the trunk
and hip simultaneously. Considering the physically demanding sports specific skills involved
in playing football, optimal function of the lumbo-pelvic region would be important for these
athletes. The motor control training approach has also been shown to be beneficial in injury
prevention with increased availability for games demonstrated for those players who received
motor control training\textsuperscript{19, 28}. This beneficial effect on availability for games was thought to be
due to improved trunk control. However, considering the effect of motor control training on
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hip muscle size, the increased availability for playing games, may also be due to the effect of the intervention on other muscles of the lower limb kinetic chain.

A limitation of the current study is its small sample size, which involved one professional football club. Another limitation is that all hip muscles could not be measured in the current study. Future research could investigate the effect of motor control training on a larger sample of athletes and investigate other hip muscles such as the adductor and extensor muscles.

Conclusion

The motor control training program was associated with an increase in iliopsoas, sartorius and gluteus medius muscle size in elite Australian football players. Due to the functional components of the training program that encourage optimal trunk, pelvic and lower limb alignment when load is added in functional weight bearing positions, motor control training programs may benefit more muscles in the kinetic chain than trunk muscles alone. For players with current LBP, the motor control training program mitigated sartorius muscle atrophy and improved gluteus medius muscle size. These findings may help in the management of LBP in elite football players.

Practical implications

- Motor control training resulted in an increase in iliopsoas, sartorius and gluteus medius muscle size
- Presence of LBP in football players was associated with specific hip muscle atrophy
- For football players with LBP, assessment and treatment of hip muscles may be indicated.
- Use of the motor control training program could be incorporated into rehabilitation or training programs for football players with or without LBP to improve hip muscle size.
Acknowledgements

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References


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Table 1. Effect of motor control training on hip muscle cross-sectional area (cm$^2$) in the intervention and wait-list control groups for players with and without low back pain$^a$

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Time</th>
<th>Intervention</th>
<th>Wait-list Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No LBP n=23</td>
<td>Current LBP n=9</td>
</tr>
<tr>
<td>Iliacus</td>
<td>Time 1</td>
<td>13.1 (0.5)</td>
<td>11.1 (0.8)</td>
</tr>
<tr>
<td></td>
<td>Time 2</td>
<td>13.2 (0.5)</td>
<td>12.1 (0.8)</td>
</tr>
<tr>
<td></td>
<td>Time 3</td>
<td>11.7 (0.5)</td>
<td>10.9 (0.8)</td>
</tr>
<tr>
<td>Psoas</td>
<td>Time 1</td>
<td>20.2 (0.6)</td>
<td>19.4 (0.9)</td>
</tr>
<tr>
<td></td>
<td>Time 2</td>
<td>19.4 (0.5)</td>
<td>19.2 (0.9)</td>
</tr>
<tr>
<td></td>
<td>Time 3</td>
<td>19.8 (0.6)</td>
<td>19.7 (0.9)</td>
</tr>
<tr>
<td>Iliopsoas</td>
<td>Time 1</td>
<td>13.7 (0.4)</td>
<td>13.9 (0.6)</td>
</tr>
<tr>
<td></td>
<td>Time 2</td>
<td>14.2 (0.4)</td>
<td>14.9 (0.6)</td>
</tr>
<tr>
<td></td>
<td>Time 3</td>
<td>15.2 (0.4)</td>
<td>16.1 (0.6)</td>
</tr>
<tr>
<td>Sartorius</td>
<td>Time 1</td>
<td>3.8 (0.2)</td>
<td>3.5 (0.3)</td>
</tr>
<tr>
<td></td>
<td>Time 2</td>
<td>4.3 (0.2)$\dagger$</td>
<td>4.2 (0.3)$\ddagger$</td>
</tr>
<tr>
<td></td>
<td>Time 3</td>
<td>4.3 (0.2)$\dagger$</td>
<td>4.5 (0.3)$\ddagger$</td>
</tr>
<tr>
<td>Gluteus Medius</td>
<td>Time 1</td>
<td>37.3 (0.9)</td>
<td>35.8 (1.5)</td>
</tr>
<tr>
<td></td>
<td>Time 2</td>
<td>38.5 (0.9)</td>
<td>40.5 (1.4)$\ddagger$</td>
</tr>
<tr>
<td></td>
<td>Time 3</td>
<td>38.7 (0.9)</td>
<td>41.4 (1.5)$\ddagger$</td>
</tr>
<tr>
<td>Gluteus Minimus</td>
<td>Time 1</td>
<td>14.6 (0.4)</td>
<td>14.3 (0.7)</td>
</tr>
<tr>
<td></td>
<td>Time 2</td>
<td>15.4 (0.4)</td>
<td>15.6 (0.7)</td>
</tr>
<tr>
<td></td>
<td>Time 3</td>
<td>16.8 (0.4)</td>
<td>16.9 (0.7)</td>
</tr>
</tbody>
</table>

$^a$Values are marginal means (SE). Intervention group (n = 32) had motor control intervention by Time 2 while the Wait-list Control group (n = 14) had no intervention. $^\star p < 0.05; ^\dagger p < 0.01; ^\ddagger p < 0.001$ indicate significance of difference to Time 1.
Figure legends

Figure 1. Individual muscle boundaries were outlined on MRI slices to measure muscle cross-sectional area for the iliacus (IL), psoas (PS), iliopsoas (ILP), sartorius (SART), gluteus minimus (GMIN) and gluteus medius (GMED) muscles.

Figure 2. Mean hip muscle cross-sectional area in the intervention and wait-list control groups across time. * indicates significant Time x Group effect p<0.05