Can Motor Control Training Lower the Risk of Injury for Professional Football Players?

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ABSTRACT

HIDES, J. A., and W. R. STANTON. Can Motor Control Training Lower the Risk of Injury for Professional Football Players? Med. Sci. Sports Exerc., Vol. 46, No. 4, pp. 762–768, 2014. Purpose: Among injuries reported by the Australian Football League (AFL), lower limb injuries have shown the highest incidence and prevalence rates. Deficits in the muscles of the lumbopelvic region, such as a smaller size of multifidus (MF) muscle, have been related to the occurrence of lower limb injuries in the preseason in AFL players. Motor control training programs have been effective in restoring the size and control of the MF muscle, but the relationship between motor control training and occurrence of injuries has not been extensively examined. Methods: This pre- and postintervention trial was delivered during the playing season as a panel design with three groups. The motor control program involved voluntary contractions of the MF, transversus abdominis, and pelvic floor muscles while receiving feedback from ultrasound imaging and progressed into a functional rehabilitation program. Assessments of muscle size and function were performed using magnetic resonance imaging and included the measurement of cross-sectional areas of MF, psoas, and quadratus lumborum muscles and the change in trunk cross-sectional area due to voluntarily contracting the transversus abdominis muscle. Injury data were obtained from club records. Informed consent was obtained from all study participants. Results: A smaller size of the MF muscle (odds ratio [OR] = 2.38) or quadratus lumborum muscle (OR = 2.17) was predictive of lower limb injury in the playing season. At the time point when one group of players had not received the intervention (n = 14), comparisons were made with the combined groups who had received the intervention (n = 32). The risk of sustaining a severe injury was lower for those players who received the motor control intervention (OR = 0.09). Conclusion: Although there are many factors associated with injuries in AFL, motor control training may provide a useful addition to strategies aimed at reducing lower limb injuries. Key Words: AUSTRALIAN FOOTBALL LEAGUE, LOW BACK REHABILITATION, MAGNETIC RESONANCE IMAGING, ULTRASOUND IMAGING

Football is a physically demanding sport, particularly at the professional level of all codes. Players require high levels of aerobic fitness as well as speed, explosive strength, and agility (6,9). Through the playing season, the high physical demands of competition and high levels of physical contact result in performance fatigue and injury (10,22). During the 10 Australian Football League (AFL) playing seasons from 2001 to 2010, injuries grouped as “hip, groin, and thigh” (HGT) have consistently had the highest incidence, prevalence, and recurrence rate of all injury groups (25). Efforts to reduce the injury rates have focused on changes in the AFL’s rules of the game, examination of environmental factors such as the playing surface, and player preparation and training regimes. It would be useful to identify more of the risk factors for these common injuries to support the design of prevention strategies.

In elite sport, as well as everyday function, the stability of the lumbopelvic region involves both good dynamic neuromuscular control and intact passive structures (31). One muscle that has been shown to contribute to localized control of segments of the lumbar spine and control the lumbar lordosis is the lumbar multifidus (MF) (1,30). This muscle therefore plays a crucial role in force distribution from the lower limbs. A longitudinal study showed that a decrease in the cross-sectional area (CSA) of the MF muscle can be a response to playing AFL football, which is a flexor dominant sport (17). The transversus abdominis (TrA) muscle also plays an important role in force distribution within the kinetic chain through its effects on the sacroiliac joint, where it has been shown to contribute to force closure and stiffening of the joint (26,28). Research has indicated that fatigue of the abdominal muscles may contribute to hamstring injuries among rugby union players (7), and a delay in activation of the TrA muscle has been associated with long-standing groin pain experienced by AFL players (4).

Prospective studies that have investigated the neuromuscular control of the trunk have shown that deficits in this area can predict lower limb injuries (32,33). Zazulak et al. (32) showed that increased trunk displacement in response to
sudden trunk force release (factors related to lumbopelvic stability) was predictive of knee, ligament, and anterior cruciate ligament injuries in female athletes. The rationale for this was that the 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. In addition, a recent study of elite AFL players, which examined the size of trunk muscles at the start of preseason training using magnetic resonance imaging (MRI), showed that players who incurred relatively more severe HGT injuries had a significantly smaller CSA of the MF muscle before the injury compared with players with no HGT injury (13). Baseline CSA of the MF muscles at the L5 vertebral level predicted HGT injuries in 83.3% of cases.

There is evidence that motor control retraining can increase MF muscle size and improve the ability to draw in the abdominal wall in athletes. This result has recently been demonstrated with elite cricketers (18,20) and elite AFL players (19). In the study of AFL players, the availability of players for competition games was used to examine the effect of the change in MF muscle morphology on injuries. The motor control training program used was associated with an increase in availability for games (19).

The previous study of AFL players (19) did not investigate the severity of the injuries, and further investigation is required to quantify the effect of motor control training. The objectives of this study were to confirm that the predictive relationship of muscle measurements and relatively severe injuries reported for the preseason (13) was also evident in the playing season and to examine if a motor control training program could reduce the incidence of lower limb injuries incurred by elite AFL players during a playing season.

METHODS

Sample. The participants in the study were the entire training squad of 46 elite players from a club in the national AFL. The mean ± SD values of the players’ age, height, and body mass were 22.8 ± 3.5 yr, 187.9 ± 6.0 cm, and 88.3 ± 6.6 kg, respectively. The study was approved by the Medical Research Ethics Committee, University of Queensland. Informed consent was obtained from all study participants.

Intervention design. Players were involved in a 22-wk playing season through autumn and winter. Their routine training included a Pilates exercise program that was not part of the intervention. The Pilates program (combination of a floor and reformer program focused on trunk muscle training) was delivered by a qualified Pilates instructor and performed twice weekly for 30 min duration from the start of the preseason training period and throughout the playing season. Most players performed their Pilates program in groups (floor exercises). Once the intervention period commenced, the players in the group receiving the intervention program ceased the Pilates program for the duration of that period. Once players completed their motor control training, they resumed their Pilates sessions.

The intervention trial was delivered in three blocks, each of 7- or 8-wk duration (see Table 1). It was a requirement of the football club that all players received the intervention during the playing season. Therefore, a single-blinded panel design was used in which group 3 acted as a wait-list control group for groups 1 and 2. Group 3 received the intervention during the last 7 wk of the competition games. A complete randomization of the 46 players into one of the three intervention groups was performed by a person independent of the study using a computer-generated sequence of random numbers. There were no participants lost to follow-up or excluded from the trial.

Motor control intervention program. The program was delivered on site by experienced physiotherapists with expertise in motor control training and the use of ultrasound imaging. Each physiotherapist was trained in the specific intervention protocol that was used in this study (15,27) so that the program was delivered in a consistent manner between therapists. The motor control training program, shown to be effective for treatment of low back pain (11), has been described in detail in our previous article (19). In summary, players were trained to voluntarily contract the MF and deep abdominal muscles with the aid of feedback from ultrasound imaging (19). These exercises were commenced in non-weight-bearing positions, with players then progressed to training in upright functional positions, with a focus on maintaining correct spinal alignment (15,27). The feedback of spinal position was provided using ultrasound imaging while players used the weight bar during activities such as upright rows and dead lifts, with an aim of developing good awareness and control of spinal position. Thera-Band exercise bands (The Hygenic Corporation, Akron, OH) were used to add resistance to the exercises described earlier. The endurance of the trunk muscles was also enhanced by training using a Bodyblade (Hymanson Inc., Marina Del Rey, CA). Exercises were performed in sitting and semisquat positions and during one and two leg squats. Participants were also instructed to maintain good spinal alignment in the weights room and to maintain good postural alignment in their daily life. Intervention sessions were given individually for each player, and the program consisted of two 30-min sessions per week.

MRI procedure. Assessments of muscle size and function were conducted in a hospital setting at the start of block.

<table>
<thead>
<tr>
<th>No. Players</th>
<th>Preintervention</th>
<th>Time 1 (7 wk)</th>
<th>Time 2 (8 wk)</th>
<th>Time 3 (7 wk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (n = 17)</td>
<td>Pilates</td>
<td>Motor control training</td>
<td>Motor control training (advanced)</td>
<td>Pilates</td>
</tr>
<tr>
<td>Group 2 (n = 15)</td>
<td>Pilates</td>
<td>Pilates</td>
<td>Motor control training</td>
<td>Pilates</td>
</tr>
<tr>
<td>Group 3 (n = 14)</td>
<td>Pilates</td>
<td>Pilates</td>
<td>Motor control training</td>
<td>Pilates</td>
</tr>
</tbody>
</table>

TABLE 1. Intervention design.
1 (time 1), at the end of block 2 (time 2), and then at the end of block 3 (time 3) using a 1.5-T Siemens Sonata MR system (Siemens AG, Munich, Germany). Participants were screened by a medical practitioner for contraindications to MRI. The MRI operators were blinded to patient history and group allocation.

While in the MRI machine, participants were positioned in a supine position with their hips and knees resting on a foam wedge. Standard instructions were given on how to draw in the abdominal wall. A relaxed abdominal wall was verified by palpation and observation of the breathing pattern. Instructions were given on performing the muscle test for the TrA muscle, with subjects asked to gently draw in the abdominal wall without moving the spine. These instructions were provided by a physical therapist who was blinded to patient histories and group allocation. The subjects were allowed to practice the abdominal muscle contraction, with the instructor’s hand placed under the subject’s lumbar spine. If the pelvis or spine moved into posterior tilt or flexion, indicating contraction of the oblique abdominal or rectus abdominis muscles, the subjects received the instructions once again (not to move the spine) and had one more practice. This was to ensure that the subjects fully understood the instructions before they performed the muscle test. The CSA of the deep musculofascial system was measured first at rest and then in the contracted state. A True FISP (fast imaging with steady state precession) sequence using 14 × 7 mm contiguous slices centered on L3–L4 disc was used for static images of muscle size. For the measurement of abdominal muscle function, a cine sequence of one 7-mm slice was taken during a contraction at a frame rate of 500 ms for 7 s. Rest images were performed in a breath hold at midexpiration. Contraction images were commenced after vocal initiation of the contraction by the operator. The cine series was commenced before the initiation of a contraction to ensure complete temporal coverage of the drawing-in maneuver.

Images from the MRI were stored and measured at a later time on a laptop computer. Image visualization and measurements were conducted using ImageJ version 1.36 b (National Institutes of Health, Bethesda, MD; http://rsb.info.nih.gov/ij/). The MF, the quadratus lumborum (QL), and the psoas (PS) trunk muscles were measured (Figs. 1A, 1B, and 1C, respectively). The MF muscle was imaged bilaterally at the L5 vertebral level (16). The QL and the PS muscles were measured where their CSAs are greatest (L3/L4 and L4/L5 vertebral levels, respectively) (14). Measurements of the abdominal muscles included CSA of the trunk at rest and on contraction (Fig. 1D and 1E, respectively). Measurements of study data were deidentified to ensure the researchers were
blinded to group allocation and presenting symptoms. Reliability statistics for measuring these lumbopelvic muscles have been previously reported (12,16).

**Injury data records.** Injury data were obtained from records collected by the AFL club staff from the start of the preseason to the end of the playing season period (late November to late August). An injury was defined as a condition resulting from playing or training that prevented a player from playing the next game (25). Each recorded injury was diagnosed by team medical staff who advised on a player’s ability to train or play matches. Clearance to resume playing was given when the team physiotherapist and strength and conditioning coach agreed that the player was not at risk of further injury. This was based on a clinical assessment of the player’s ability to perform the skill requirements of training sessions and physical test parameters included in their rehabilitation program (e.g., running at a certain speed).

The measure of injury severity used in the study was based on the availability of players for weekly competition games. This information was extracted from club records of whether squad members were available for selection or unavailable because of injury for the 22 games of the playing season. The choice of the number of games missed used to define a severe injury was determined as part of the analysis, described in the next section. The injuries coded as severe were all lower limb injuries.

**Statistical analysis.** Assessment was conducted with all 46 players in the squad, resulting in a complete data set for analysis. The Statistical Package for the Social Sciences (version 16; www.spss.com) was used for data analysis, with a level of statistical significance set at \( P < 0.05 \). Baseline differences in the intervention groups for the muscle measurements, demographic factors, and history of recent injury were examined by analysis of variance and chi-square analysis.

Binomial logistic regression analysis was used to assess the predictive effect of lumbopelvic muscle size, side-to-side asymmetry, and the motor control intervention on the occurrence of injury during the competition playing season. Odds ratios produced with this procedure were used to estimate the level of injury risk. A sensitivity analysis was used to select the cutoff value of number of games missed (\( n = 2 \)) that defined a relatively more severe injury. This was based on players being unavailable for two or more consecutive weeks of the 22 wk of the season (\( n = 23 \)) or recurrence of the injury within 4 wk (\( n = 1 \)). Alternative models were based on an injury coding of one or more games missed and three or more games missed. All models provided the same pattern of results and selection of two or more games missed was based on the criteria of maximizing the variance explained by the model (\( r^2 \)), maximizing the sensitivity and specificity of the model, and the consideration of a balanced design (similar numbers of participants in each injury group).

For the logistic regression analysis, injury group was the binomial outcome measure coded as less than two games missed (\( n = 22 \)) versus two or more games missed (\( n = 24 \)) due to injury. The predictor variables in the model were age, height, occurrence of an injury in the preseason, CSA of the trunk contraction (rest minus contracted) measured in square centimeters, average CSA across vertebral sides for the PS, QL, and MF muscles measured in square centimeters, and intervention group (coded as intervention or control at the end of time 2). For the analysis of muscle asymmetry, a similar model was used, replacing average CSA of the PS, QL, and MF muscles with absolute percentage change in muscle CSA across the vertebral body, calculated as \((\text{right side} - \text{left side}) / \text{right side} \times 100\). The body mass variable of was not included in the model due to the extent of co-linearity with height (\( r = 0.75 \)).

**RESULTS**

During the competition season, 34 players (73.9%) incurred an injury that resulted in them missing a game, and 12 players (26.1%) were available for all games in the season. Most of the players also had an injury in the preseason leading up to the start of competition games (67.4%), and 21 players (45.7%) had an injury in the preseason as well as an injury in the playing season.

During the playing season, there were 44 injury events, with seven players (15.2%) incurring multiple injuries. Most of the injury events occurred in the hip, groin, and thigh regions (12 hamstring, 11 quadriceps, and 3 groin injuries), followed by joints (4 knee, 4 ankle, and 1 foot injuries), and then lower limb (3 Achilles, 1 calf, and 1 patella tendon injuries). Only four of the injuries were above the hip, which consisted of a shoulder injury (one game missed), finger injury (three games missed), and two back injuries, unspecified as upper or lower back (one game missed). The case with a finger injury also missed two games because of a quadriceps injury and was therefore included in the more severe injury group. Therefore, the group of 24 players who missed two or more games all had injuries in the lower part of the kinetic chain.

Initial analysis of baseline intervention group differences indicated no statistically significant effect for any of the measurements used in the logistic regression (all \( P > 0.35 \)). Results of the logistic regression analysis of baseline measures that predict the risk of injury during the playing season are shown in Table 2. The odds of an injury were higher for taller players and higher for those with smaller MF muscles or smaller QL muscles, but the odds of an injury were lower for those who received the motor control intervention. The odds ratios indicate that the risk of an injury that results in two or more games missed were 1.25 times higher for a 1-cm increase in height, 2.17 higher for a 1-cm² decrease in QL size, 2.38 higher for a 1-cm² decrease in MF size, and 0.09 lower for those who had performed the motor control intervention by time 2.

The model was effective in predicting the players who did or did not incur an injury (\( r^2 = 0.51 \)). In particular, the
measure of sensitivity indicates that the model correctly identified 19 (79.2%) of the 24 cases who missed two or more games because of injury. The measure of specificity shows that 17 (77.3%) of the 22 cases who did not incur an injury were also correctly identified. Analysis of muscle asymmetry indicated that differences in muscle measurement across vertebral side were not related to injury in the playing season (P > 0.05). The muscle measurements for the two injury groups are shown in Table 3.

Evidence of a possible mechanism of effect for muscle size in relation to injury was also sought. The interrelationship between injury, muscle size, and the effect of the intervention was examined in a post hoc logistic regression model by replacing the variable of the “intervention group” with the interaction terms for “group” and “change in the size” of MF and QL from time 1 to time 2. The results showed a relationship between intervention and the change in MF size as a predictor of players who did not incur a severe lower limb injury (P = 0.055) but no such relationship for QL size (P = 0.501).

**DISCUSSION**

Muscle size as a predictor of injury. Results of the current study showed that among the trunk muscles assessed (MF, PS, and QL), the CSA of the MF and QL muscles predicted injuries in the AFL playing season. For the MF, this finding supported the results of a prior study that assessed the CSA of the MF muscle size at the lumbosacral junction was predictive of relatively more severe lower limb injuries. No relationship was found for size or asymmetry of the PS muscles or for the ability to contract the TrA muscle through “drawing in” of the abdominal wall. With respect to the QL muscle, analysis of the association between increased asymmetry of the QL muscle with more severe HGT injuries in the previous study produced a P value of 0.092 (13). The possibility of the QL muscle being associated with lower limb injury could be related to its proposed role in the control of spinal buckling (23). In a review article (3), it is reported that when there is a lack of lumbopelvic control, muscles such as QL increase activity to compensate.

**TABLE 2. Logistic regression results of variables related to the occurrence of an injury resulting in two or more games missed.**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Chi-square</th>
<th>P</th>
<th>Odds Ratio</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr (older)</td>
<td>0.93</td>
<td>0.335</td>
<td>0.89</td>
<td>0.70–1.13</td>
</tr>
<tr>
<td>Height, cm (taller)</td>
<td>5.50</td>
<td>0.019</td>
<td>1.25</td>
<td>1.04–1.50</td>
</tr>
<tr>
<td>Preseason injury (yes)</td>
<td>0.03</td>
<td>0.859</td>
<td>1.16</td>
<td>0.22–6.20</td>
</tr>
<tr>
<td>Trunk contraction, cm² (smaller)</td>
<td>0.00</td>
<td>0.984</td>
<td>1.00</td>
<td>0.93–1.06</td>
</tr>
<tr>
<td>QL size, cm² (smaller)</td>
<td>6.12</td>
<td>0.013</td>
<td>2.17</td>
<td>1.18–4.00</td>
</tr>
<tr>
<td>PS size, cm² (smaller)</td>
<td>0.22</td>
<td>0.636</td>
<td>1.10</td>
<td>0.76–1.59</td>
</tr>
<tr>
<td>Multifidus size, cm² (smaller)</td>
<td>5.56</td>
<td>0.018</td>
<td>2.38</td>
<td>1.16–5.00</td>
</tr>
<tr>
<td>Intervention (yes)</td>
<td>5.67</td>
<td>0.017</td>
<td>0.09</td>
<td>0.02–0.65</td>
</tr>
</tbody>
</table>

*For each variable, the odds ratio refers to the category in brackets.*

Results of the current study showed that the model correctly identified 79.2% of cases who missed two or more games due to injury and 77.3% who did not incur an injury were also correctly identified. The implication of these findings is that the measurement of muscle size could be used as a screening tool in Australian Football, and possibly other football codes.

The effect of motor control training on injury events. The results of the current study showed that the rehabilitation approach adopted by the AFL players decreased the occurrence of relatively more severe injuries across the playing season. Using a rehabilitation protocol that involved progression from motor control training to high-load exercise has been shown in prior studies on athletes (18,19) and nonathletes (5) to lead to hypertrophy of the MF muscle. A goal of the program 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 (2). Careful attention to spinal position when load was added and during weight training would explain the documented increases in multifidus muscle size that were reported in this study. With respect to the effect of motor control training on injury events, it is possible that the intervention, which targeted deficits in the neuromuscular control of the lumbopelvic region, allowed improved dynamic trunk control, with safe production, transfer, and control of forces and motion to the distal segments of the kinetic chain (21). Good control of the lumbopelvic area is likely to be required to meet the high demands imposed on AFL players.

**Additional findings.** It has been reported that a previous history of injury is a predictive risk factor for injury in AFL (8). Results of the current study do not support this finding in relation to the occurrence of any other injury in the preseason, which is 4 months leading up to competition games. Another finding was that there was a relationship between the player’s height and the occurrence of an injury, with taller players more likely to be injured during the playing season.

**TABLE 3. Muscle measurements at the start of the playing season.**

<table>
<thead>
<tr>
<th>Predictor variable</th>
<th>Injury Group 1 (-2 Games Missed)</th>
<th>Injury Group 2 (2 or More Games Missed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk contraction (relaxed minus contracted) (cm²)</td>
<td>19.8 ± 3.3</td>
<td>20.5 ± 2.2</td>
</tr>
<tr>
<td>PS CSA (cm²)</td>
<td>24.3 ± 0.6</td>
<td>24.3 ± 0.4</td>
</tr>
<tr>
<td>QL CSA (cm²)</td>
<td>9.0 ± 0.4</td>
<td>8.8 ± 0.3</td>
</tr>
<tr>
<td>Multifidus CSA (cm²)</td>
<td>11.2 ± 0.3</td>
<td>10.8 ± 0.2</td>
</tr>
<tr>
<td>PS asymmetry (absolute % difference)</td>
<td>6.1 ± 1.8</td>
<td>7.9 ± 1.2</td>
</tr>
<tr>
<td>QL asymmetry (absolute % difference)</td>
<td>10.2 ± 2.3</td>
<td>13.0 ± 1.5</td>
</tr>
<tr>
<td>Multifidus asymmetry (absolute % difference)</td>
<td>6.9 ± 1.5</td>
<td>4.9 ± 1.0</td>
</tr>
</tbody>
</table>

Mean values are marginal means, adjusted for age, height, and body mass. Body mass was included in the calculation of means to enable unbiased comparisons with other samples. Asymmetry measures based on percentage differences are not normally distributed.
future predictive measures for injury, such as decreased size of the MF muscles at the start of the playing season (relative to other players of similar age, height, and body mass), may allow the identification of players more at risk for injuries. With this knowledge, appropriate interventions can be undertaken to retrain the motor control of the trunk muscles to decrease the occurrence of lower limb injuries in AFL players.

Limitations and future directions. This study has some limitations, such as the small sample size, which is a characteristic of other studies in this area (13,14,29). Furthermore, as the participants in this study were elite sportsmen, caution is needed in generalizing from these results. Further studies are needed to determine whether these findings apply to amateur players and those participating in other sports.

REFERENCES

11. Future studies of size and asymmetry of muscles such as the QL and MF could be conducted with ultrasound imaging rather than MRI (16). The benefits of using ultrasound include increased accessibility, lower costs, and possibility for more frequent measurements. Investigation of other factors related to MF change, such as physical performance, should also be conducted.

What are the new findings?

- Measurements of trunk muscle size using imaging techniques can predict injury.
- Motor control training effectively reduces injury rates.
- Lumbo pelvic muscle size may allow the identification of players at risk of injury.

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The authors have no conflicts of interest.

The results of the present study do not constitute endorsement by the American College of Sports Medicine.


