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LUMBOPELVIC MOTOR CONTROL AND LOW BACK PAIN IN ELITE SOCCER PLAYERS: A CROSS-SECTIONAL STUDY

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Keywords: Soccer player; low back pain; motor control impairment; lumbopelvic

Abstract

This study aimed to investigate the relationship between the history of low back pain and quality of lumbopelvic motor control in soccer players. Forty-three male elite soccer players (mean age, 18.2 ± 1.4 years) filled in questionnaires related to low back pain and attended a session to assess lumbopelvic motor control by means of five tests (the bent knee fall out test, the knee lift abdominal test, the sitting knee extension test, the waiter's bow and the transversus abdominis test). A physiotherapist, blinded to the medical history of the participants, scored (0 = failed, 1 = correct) the performance of the players for each of the tests resulting in a lumbopelvic motor control score ranging from 0 to 5. Forty-seven per cent of the soccer players reported a disabling low back pain episode lasting at least two consecutive days in the previous year. These players scored worse lumbopelvic motor control than players without a history of low back pain (lumbopelvic motor control score of 1.8 vs. 3.3, $P < 0.01$). The between-groups difference was particularly marked for the bent knee fall out test, the knee lift abdominal test and the transversus abdominis test ($P < 0.01$). In conclusion, most soccer players with

a history of low back pain had an altered lumbopelvic motor control. Further research should examine whether lumbopelvic motor control is etiologically involved in low back pain episodes in soccer players.

Introduction

Soccer is the most popular sport in the world and is played by men and women, children and adults with different levels of ability (Junge & Dvorak, 2004; Stolen, Chamari, Castagna, & Wisloff, 2005). Soccer involves various tasks such as short sprints, kicking a ball with either foot, pivoting, sudden starts and stops and heading the ball and occasionally throwing it with two hands above the head. In addition, the game frequently involves physical contact with opponents including intentional pushing and side-to-side cutting (Gregory, Batt, & Kerslake, 2004).

At the elite level, the high volume of training combined with the frequent match plays is a potential risk factor for injury. The incidence of injuries during competitive match play is approximately 19.8 to 35.5 per 1000 match hours (Junge & Dvorak, 2004; Schmikli, de Vries, Inklaar, & Backx, 2011; Walden, Hagglund, & Ekstrand, 2005). Most acute soccer injuries are in the lower extremities (Schmikli et al., 2011; Walden et al., 2005). However, trunk and groin injuries are also frequent with an annual frequency of 6–18% (Arnason et al., 2004; Hölmich, Larsen, Krogsgaard, & Gluud, 2010; Paajanen, Ristolainen, Turunen, & Kujala, 2011; Schmidt-Olsen, Jorgensen, Kaalund, & Sorensen, 1991; Schmikli et al., 2011; Walden et al., 2005). Furthermore, in a 13-year follow-up study, low back pain is reported in 53% of players (Lundin, Hellstrom, Nilsson, & Sward, 2001).

Controversies exist regarding the cause of low back pain. High compressive and repetitive loads, fatigue, weakness and low flexibility of trunk muscle are possible contributing factors in the development of low back pain and predictors for first-time occurrence of low back injuries (Evans, Refshauge, Adams, & Aliprandi, 2005). Trunk muscles strength imbalance remains a controversial risk factor for low back pain (Andersson, Sward, & Thorstensson, 1988; Lee et al., 1999). Maus et al. (2010) compared the trunk muscles strength of soccer players with and without low back pain. They failed to show an influence of the performance of the trunk musculature on the incidence of low back pain in soccer players. According to several authors, attention should be paid to motor control rather than strength impairments (Hodges & Richardson, 1998; Jull & Richardson, 2000). Indeed, several studies have reported that poor control of the trunk predisposes athletes to sports injuries of the spine and lower extremity (Cholewicki et al., 2005; Myer, Chu, Brent, & Hewett, 2008; Zazulak, Cholewicki, & Reeves, 2008; Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007). Stability of the lumbopelvic region depends on the integrity of passive structures and on an appropriate dynamic neuromuscular control (Panjabi, 2003). Among trunk muscles, transversus abdominis and multifidus play an important role in controlling the stability of the spine and pelvis (Hides, Stanton, Mendis, Gildea, & Sexton, 2012). These muscles activate before initiation of the limb movement (Hodges & Richardson, 1997). Various methods have been used to assess the possible dysfunctions of the neuromuscular system with regard to proprioception and lumbopelvic motor control. Imaging techniques [real-time ultrasound imaging (Hides, Richardson, & Hodges, 2004; Hides et al., 2010), magnetic resonance imaging (Hides et al., 2004, 2012, 2010), computerised tomography (Danneels, Vanderstraeten, Cambier, Witvrouw, & De Cuyper, 2000)] and electromyography (Hodges & Richardson, 1997, 1998) have been used to study

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impairments of the multifidus and transversus abdominis muscles in athletes and participants with low back pain. However, as electromyography is not available in most clinical practices, field tests have been developed to assess lumbopelvic motor control. They test the ability to control and reposition the lumbopelvic complex when challenged in different directions (Luomajoki, Kool, de Bruin, & Airaksinen, 2007; Roussel et al., 2009).

As low back pain is a common injury reported in soccer players and deficits in lumbopelvic motor control have been shown in patients with low back pain, it appears particularly relevant to: (1) assess lumbopelvic motor control in elite soccer players by means of a field test battery, and (2) determine whether there is a lumbopelvic motor control difference between players with and without a history of low back pain.

Methods

PARTICIPANTS

Male elite soccer players, from three clubs of the Belgian Pro League and Belgian Second Division, were recruited to participate in this study in the middle of the soccer season.

The exclusion criteria were: aged under 17 years or over 30 years, female soccer players, playing as goalkeeper, previous history of low back surgery, and the history of serious injury or operative treatment which could interfere with normal soccer training or competing at the time of the study.

Prior to participation, the purpose and procedure associated with the study were explained in detail to the participants and their parents (for participants under 18 years of age). The research protocol was approved by the Hospital and Faculty Ethics Committee of Liege University Hospital Centre, Belgium (Ref. number B707201318621).

PROCEDURE

A cross-sectional design was used to evaluate differences in test results between soccer players with and without a history of low back pain. Lumbopelvic motor control and questionnaire assessments were completed in the designated fitness room of each soccer club.

All participants were asked to fill in several questionnaires. A general questionnaire was used to collect demographic information (age, weight, height and dominant lower limb) as well as information regarding sport practice (number of years in high-performance sport, hours of training per week, number of weekly training sessions and playing position on the field). The presence and sites of musculoskeletal disorders were assessed by means of the French version of the NORDIC questionnaire (Descatha et al., 2007). The following anatomical sites were studied: neck, upper back, lower back, hip/thigh, knee/lower leg and ankle/foot. An injury was defined as any physical complaint that is the result of participating in football training or a football match, leading to a player being unable to fully participate in future football training or match play. The NORDIC questionnaire comprised of three questions regarding musculoskeletal pain including annual and 7 days prevalence of symptoms, and

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annual prevention from normal training or competing. We also included the following questions from the NORDIC questionnaire:

– Have you ever experienced low back pain?

– How many days during the past 12 months have you had low back pain?

– Have you been examined or treated for low back pain by a physician, physical therapist, chiropractor or other health personnel as an outpatient during the previous 12 months?

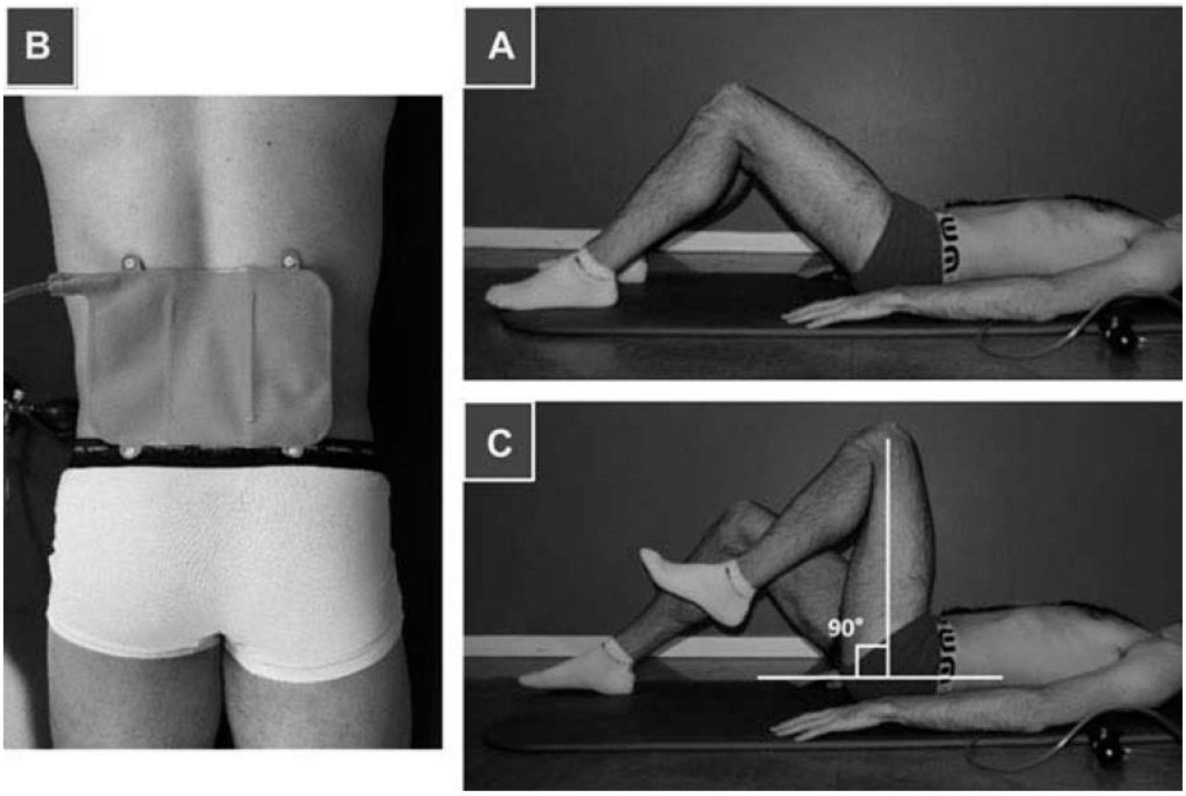
A recent study showed that the NORDIC questionnaire is a valid instrument for identifying participants with chronic or recurring low back pain (Takekawa, Gonçalves, Moriguchi, Coury, & Sato, 2015). Moreover, for participants reporting low back pain at the time of testing, a 0–10 visual analogue scale (VAS) was used to score present low back pain intensity.

Afterwards, participants were submitted to five lumbopelvic motor control field tests. The order of the tests was randomly assigned to avoid order effects.

– The knee lift abdominal test and the bent knee fall out test were performed in supine position and based on the pressure changes monitored with the pressure biofeedback unit (Chattanooga Ltd Hixson, USA).

For the knee lift abdominal test, the participant was positioned in a crook lying position (the knees flexed at 90°), the arms relaxed beside the body (Figure 1A). The pressure biofeedback unit was placed horizontally under the spine of the participant, with the lower edge at the level of the posterior superior iliac spines (Figure 1B).

Figure 1. (A) Start position for the knee lift abdominal test (KLAT). (B) Position of the pressure biofeedback unit. (C) Test movement for the KLAT.



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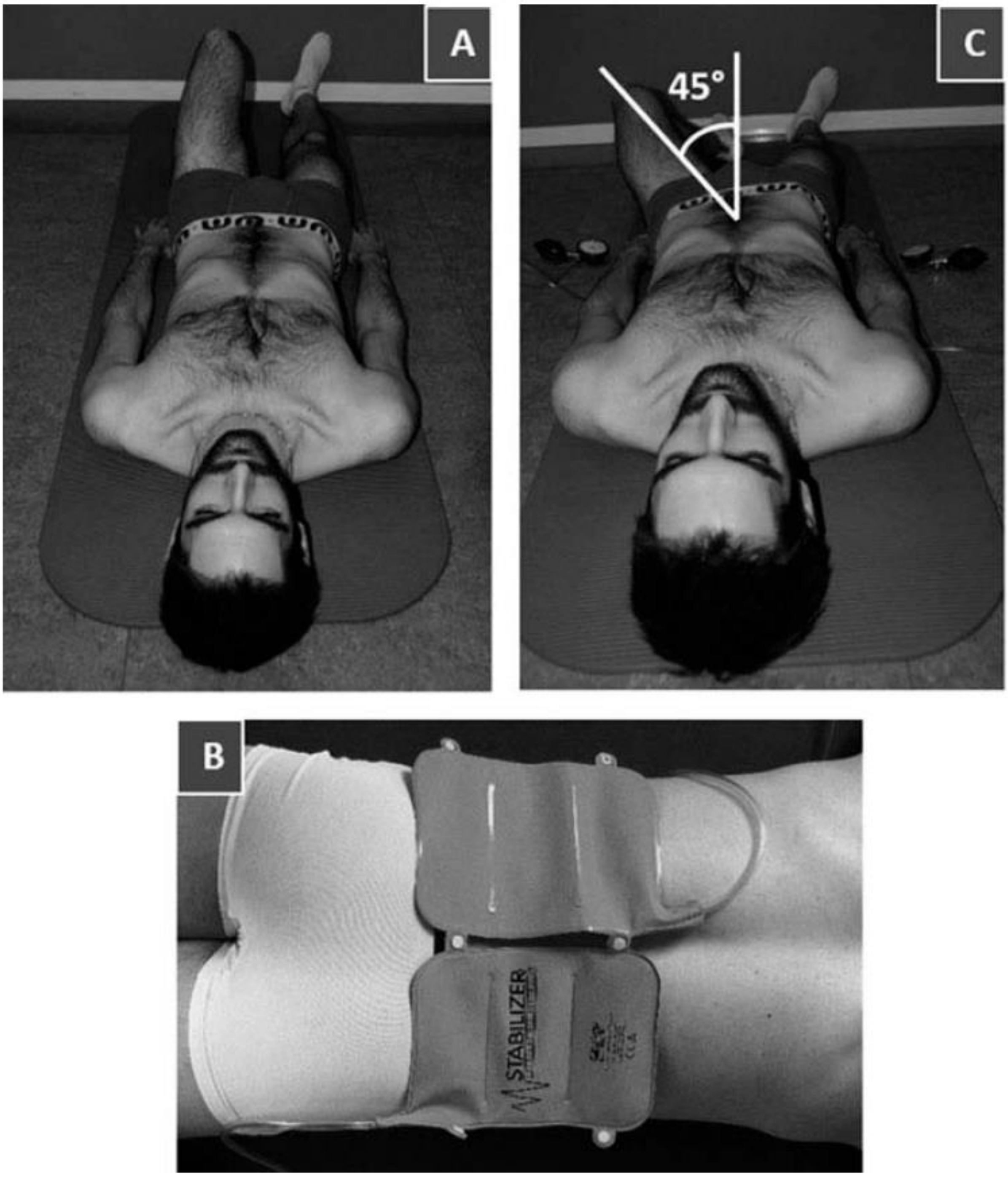
For the bent knee fall out test, the participant was supine with one hip flexed, the knee flexed at 120° and the foot resting on the floor. The other leg was extended and the arms relaxed beside the body (Figure 2A). Two pressure biofeedback units were positioned vertically under the lumbar spine with the lower edge 2 cm caudal of the posterior superior iliac spine (Figure 2B).

Figure 2. (A) Start position for the bent knee fall out (BKFO) test. (B) Position of the pressure biofeedback units. (C) Test movement for the BKFO.



Before starting the tests, the pressure biofeedback unit was inflated to 40 mmHg (baseline pressure) (Jull, Richardson, Toppenberg, Comerford, & Bui, 1993); then, the participants were asked to inhale

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and exhale twice, followed by a readjustment of the pressure (40 mmHg). The participants were instructed to maintain a neutral spine position (preventing spinal movement) during the following trials. For each test, three familiarisation trials preceded the test trial.

For the knee lift abdominal test, the participant was instructed to raise slowly the leg to 90° hip flexion (in approximately 4 to 6 s) with a flexed knee, keeping the pelvis and lumbar spine stable (Figure 1C). For the bent knee fall out test, the participant had to lower out slowly the bent leg to 45° of abduction/lateral rotation (in approximately 4 to 6 s), while keeping the foot on the floor beside the straight leg and the pelvis and lumbar spine stable (Figure 2C). Participants were blinded to the pressure monitor during the tests. The maximal pressure deviation was recorded and used for further analyses. For the bent knee fall out test, the pressure was recorded with the pressure biofeedback unit on the ipsilateral side of that of the bent knee. A change in the pressure level equal to or lower than 8 mmHg (either up or down) was recorded as successful completion. Reliability of the pressure recording during these tests was acceptable (Monnier, Heuer, Norman, & Äng, 2012; Roussel et al., 2009).

– The waiter's bow and the sitting knee extension test were executed respectively in an upright standing (Figure 3A) and in an upright sitting (Figure 4A) neutral (i.e. in the mid-range between anterior and posterior pelvic tilt) position. The tests were scored with visual inspection. Three familiarisation trials preceded the test trial.

Figure 3. (A) Start position for the waiter's bow. (B) Test movement: the participant was instructed to bend forwards from the hips to approximately 50°, keeping the lumbar spine in neutral position.

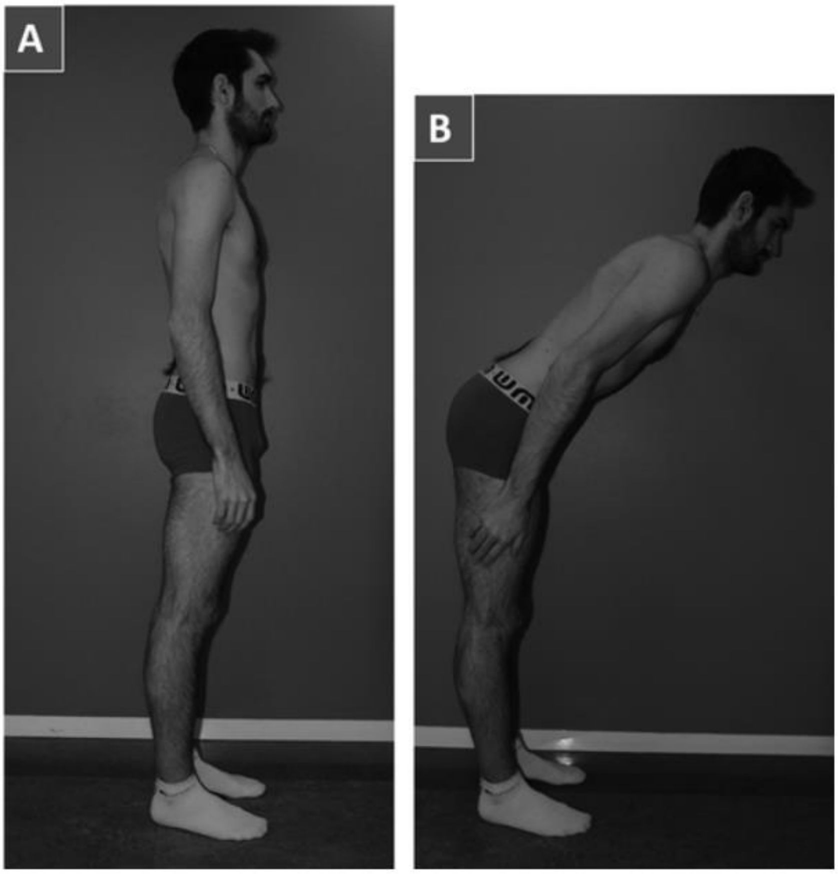

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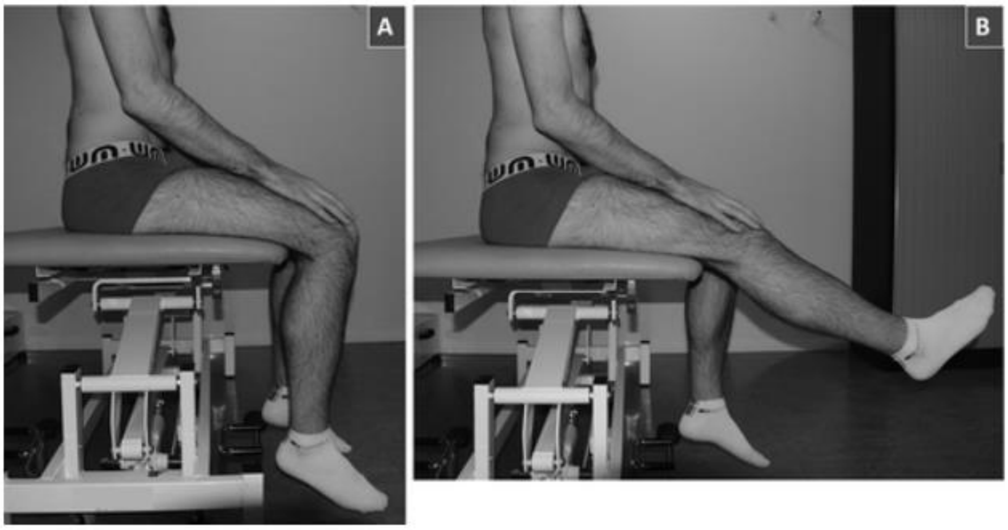
Figure 4. (A) Start position for the sitting knee extension test. (B) Test movement: the participant was instructed to remain in a neutral position of the lumbar spine, while extending the knee.



For the waiter's bow, the participant was instructed to perform a 50° trunk flexion at the hips (without movement of the lumbar spine) (Figure 3B) (Luomajoki et al., 2007). The test was successful (waiter's bow score = 1) when the investigator observed that the stabilising muscles of the trunk activated isometrically and managed to keep the spine in neutral position, while the participant bent forwards.

For the sitting knee extension test, the participant was instructed to remain in a neutral position of the lumbar spine, while extending the knee to minus 10° extension or within the available range of motion (ROM) (Figure 4B) (Enoch, Kjaer, Elkjaer, Remvig, & Juul-Kristensen, 2011). The test was successful (sitting knee extension test score = 1) when the investigator observed that the stabilising muscles of the trunk activated isometrically to keep the spine in neutral position, while the participant extended the knee.

Previous studies showed that reliability of both tests (waiter's bow and sitting knee extension test) was acceptable (Luomajoki et al., 2007; Roussel et al., 2009).

– The ability to contract the transversus abdominis muscle was assessed by observation and manual palpation, according to the protocol described by Richardson, Jull, Hodges, and Hides (1999). The participant was positioned in a crook lying position (the knees bent at 90°), the arms relaxed beside the body. The examiner placed her thumbs approximately 2 cm medially and inferiorly to the anterior superior iliac spines (Hides et al., 2004). The participant was asked to draw in the abdominal wall again for 10 s without spinal movement. The results of three aspects of the clinical test were recorded (presence of spinal movement, presence of bulging of the abdominal wall, inability to contract the transversus abdominis and to maintain the contraction for 10 s) and used to score the test. If the investigator observed that 1, 2 or 3 elements were present, the test was failed (score = 0). The test was successful (score = 1) when the contraction was maintained for 10 s, without spinal movement and in the absence of bulging of the abdominal wall. Costa et al. reported sufficient reliability for assessing transversus abdominis recruitment by manual palpation (Costa, Costa Lda, Cancado, Oliveira Wde, & Ferreira, 2006).

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A single physiotherapist, blinded to the medical history questionnaires, scored (0 or 1) the performance of all the players on the five tests, resulting in an original lumbopelvic motor control score ranging from 0 (failed at all tests) to 5 (maximal score). The examiner participated in a 2 years postgraduate manual therapy specialization program including a 3-day course for the assessment and treatment of motor control dysfunctions and had 7 years of clinical and research experience in the field of manual therapy. Moreover, she was trained in performing the tests under supervision of a manual therapist.

STATISTICAL ANALYSIS

Statistical analysis was performed with Statistica version 8.0 (StatSoftInc, Paris, France). Results are expressed as means ± SD. A Shapiro–Wilk test was used to ensure the data did not differ substantially from a Gaussian distribution. In the case of normally distributed variables (height, BMI, duration of soccer practice, knee lift abdominal test pressure variation and bent knee fall out test pressure variation), the independent samples Student's t-test was used to compare the soccer players with a history of low back pain with the players without low back pain. If the Shapiro–Wilk test revealed that a variable was not normally distributed, then the non-parametric Mann–Whitney test was used (for age, weight, soccer activity and lumbopelvic motor control score) to compare the soccer players with a history of low back pain with the players without low back pain.

The Fisher's exact test was used to compare categorical data (knee lift abdominal test, bent knee fall out test, waiter's bow, sitting knee extension test and transversus abdominis test) between the participants with and without low back pain. The significance level was set at 0.05.

The number of positive tests in the two groups was compared; the between-group differences were analysed by the effect size (ES) *d.* The ES (*d*) is the difference of the means divided by the mean standard deviation of the groups. ES with $d < 0.2$ is considered to be small, $d > 0.5$ as moderate and $d > 0.8$ as large.

The sample size was estimated using power-based sample size calculations (power of 0.80 and α of 0.05). The planned sample size was estimated at 17 participants per group. The calculations were based on a study assessing lumbopelvic motor control in healthy participants and patients with low back pain (Roussel et al., Citation2009). We anticipated that approximately half of the soccer players would have experienced low back pain in the year before the study and that differences between healthy and low back pain participants would be 2.5 mmHg. In order to account for possible drop out, 43 soccer players from three clubs of the Belgian Pro League and Belgian Second Division were recruited.

Results

Forty-three male soccer players (mean age, 18.2 ± 1.4 years) completed the study. Thirty-four players (79.1%) were right footed. Twenty players (46.5%) (named LBP group) reported at least one disabling (preventing the player from training or taking part in competition) episode of low back pain lasting more than two consecutive days in the previous year (range 2–45 days). At the time of the testing, all

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players in the LBP group were continued to train and compete. Ten of these players (23%) reported low back pain in the last 7 days. The mean pain VAS score (range 0–10) of participants in the LBP group at the time of testing was 1.8 ± 2.2 (range 0.0–6.0).

The percentage of players experiencing complaints in the thigh, knee/lower leg and ankle/foot during the previous year was 56%, 23% and 30%, respectively. Descriptive statistics of the two groups are presented in Table 1.

The comparison between players with and without a history of low back pain showed significant differences regarding weight ($P < 0.001$), height ($P < 0.05$) and BMI ($P < 0.01$). In contrast, no differences were observed between the groups in terms of age, hours of soccer practice per week and duration of soccer practice (Table 1).

Table 1. Descriptive statistics of soccer players with and without a history of low back pain in the previous year.

	No LBP (n = 23)		LBP (n = 20)		
	Mean	*SD*	Mean	*SD*	*P*-value
Age (years)	17.8	0.8	18.6	1.8	0.15
Weight (kg)	66.7	5.9	75.2	8.2	0.001
Height (cm)	177.3	5.3	182.2	7.3	0.015
BMI ($kg \cdot m^{-2}$)	21.2	1.3	22.6	1.6	0.003
Soccer activity ($h \cdot wk^{-1}$)	11.5	2.2	13.3	3.0	0.09
Duration of soccer practice (years)	12.3	1.9	12.6	2.5	0.63

Note: LBP, low back pain; *SD*, standard deviation; BMI, body mass index; h, hours; wk, week.

LUMBOPELVIC MOTOR CONTROL ASSESSMENT

The LBP group had a lower lumbopelvic motor control score than players without a history of low back pain (mean of 1.8 vs. 3.3). The ES (*d*) for the difference between the groups was 1.07. The statistical test showed that this was a significant difference ($P = 0.002$). Differences between soccer players with and without a history of low back pain was particularly marked for the bent knee fall out test ($P = 0.004$), the knee lift abdominal test ($P = 0.01$) and the transversus abdominis test ($P = 0.01$). In contrast, no significant differences were found for the sitting knee extension test or the waiter's bow (Table 2).

Regarding pressure biofeedback unit measures, soccer players with a history of low back pain had greater mean pressure variation than players without low back pain both for the knee lift abdominal test and the bent knee fall out test (Table 2).

For the knee lift abdominal test (Figure 5), the majority of the players demonstrated an increase in pressure. Three players without a history of low back pain and one player of the LBP group showed a decrease in pressure. Regarding peak test pressure, 17 players without a history of low back pain kept pressure between 32 and 48 mmHg (successful completion) versus seven players with a history of low back pain.

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Table 2. Motor control assessment in soccer players with and without a history of low back pain in the previous year.

	No LBP (n = 23)		LBP (n = 20)		
	n	%	n	%	P-value
KLAT failed	6	26	13	65	0.010*
BKFO failed	6	26	14	70	0.004*
WB failed	8	35	10	50	0.313
SKET failed	13	56	14	70	0.362
TrA contraction failed	5	22	12	60	0.010*

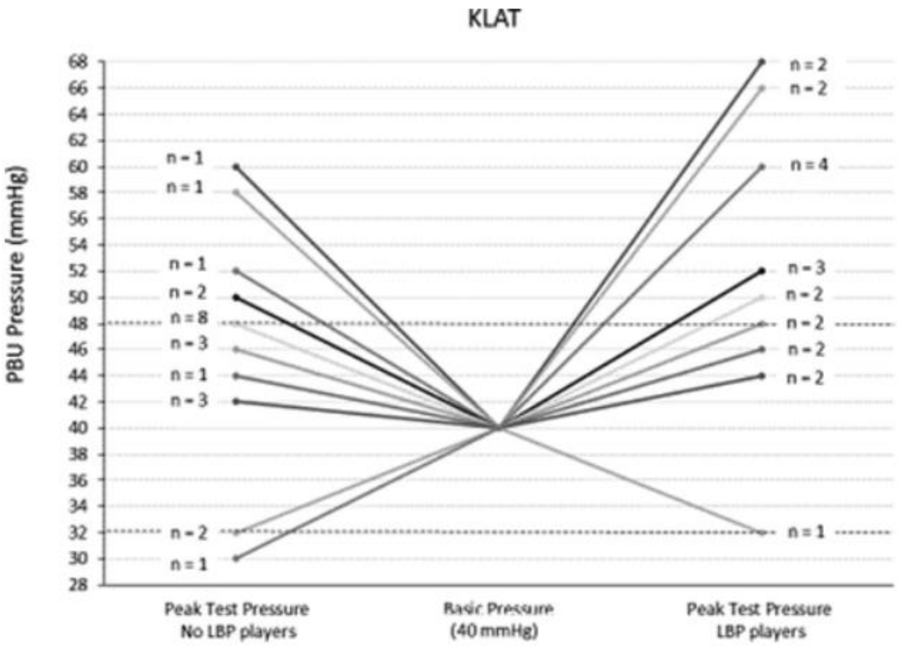
	No LBP (n = 23)		LBP (n = 20)		
	Mean	SD	Mean	SD	P-value
KLAT pressure variation (mmHg)	8.2	4.3	14.4	8.3	0.01*
BKFO pressure variation (mmHg)	6.6	3.6	15.3	8.7	<0.001*

	No LBP (n = 23)		LBP (n = 20)			
	Mean	SD	Mean	SD	P-value	ES
LMC score (0–5)	3.3	1.3	1.8	1.6	0.002*	1.07

Notes: LBP, low back pain; KLAT, knee lift abdominal test; BKFO, bent knee fall out; WB, waiter's bow; SKET, sitting knee extension test; TrA, transversus abdominis; *SD*, standard deviation; LMC, lumbopelvic motor control; ES, effect size.

* $P \leq 0.01$.

Figure 5. Pressure biofeedback unit (PBU) pressure (in mmHg) during the knee lift abdominal test (KLAT) for the 23 soccer players without a history of low back pain (no LBP players) and the 20 players with a history of low back pain (LBP players).



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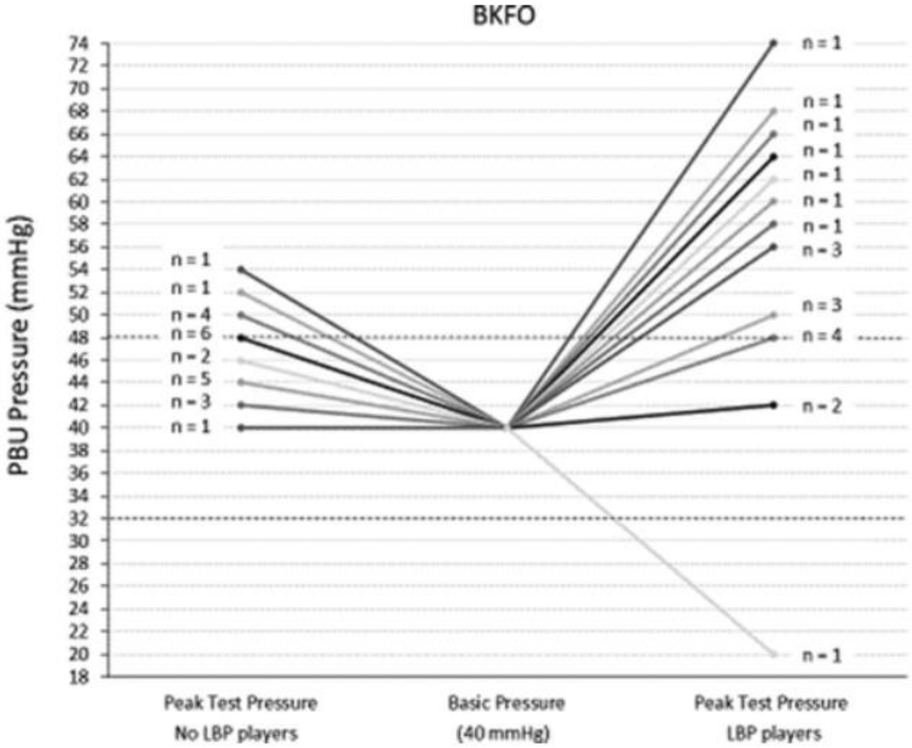
For the bent knee fall out test (Figure 6), the majority of the players also demonstrated an increase in pressure. Only one player with a history of low back pain had a decrease in pressure. Regarding peak test pressure, 17 players without a history of low back pain kept pressure between 32 and 48 mmHg (successful completion) versus 6 players with a history of low back pain.

Figure 6. Pressure biofeedback unit (PBU) pressure (in mmHg) during the bent knee fall out (BKFO) for the 23 soccer players without a history of low back pain (no LBP players) and the 20 players with a history of low back pain (LBP players).



Discussion

The aims of the present study were to assess lumbopelvic motor control in elite soccer players by means of a field test battery, and determine whether there is a lumbopelvic motor control difference between players with and without a history of low back pain. As impaired lumbar motor functions have been associated with low back pain (Hodges & Moseley, 2003), we hypothesized that players with low back pain would show lower performance on the lumbopelvic motor control test battery than players without low back pain.

The results of the present study confirmed that low back pain is common in soccer players and that most soccer players with a history of low back pain have altered motor control of the lumbopelvic region in comparison with players without a history of low back pain. Interestingly, some players without a history of low back pain also failed in some lumbopelvic motor control tests.

In elite soccer players, low back pain is the most common reported overuse injury (Walden et al., 2005). In the present study, 47% of the players suffered from low back pain during the previous year. This finding is higher than the 12-month prevalence rate reported by Çali, Gelecek, and Subasi (2013) who

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found a prevalence of 31% among Turkish male professional players. However, it is lower than the prevalence reported by van Hilst, Hilgersom, Kuilman, Kuijer, and Frings-Dresen (2015) who found that 64% of Netherlands young elite soccer players had low back pain. Although risk factors of low back pain are multi-factorial, delayed trunk muscle reflex responses were identified as a significant predictor of low back injury in athletes (Cholewicki et al., 2005). Trunk muscle provide stability and balance when performing movements with the extremities (Andersson et al., 1988). Therefore, motor control of the trunk and lumbopelvic region is essential during soccer training and competition.

Although several studies assessed the athlete's ability to stabilise the lumbopelvic region during limb movement (Brophy et al., 2009; Chiaia et al., 2009; Mulhearn & George, 1999; Olivier, Stewart, Olorunju, & McKinon, 2015; Roussel et al., 2013, 2009), the present study is, to our knowledge, the first to report a difference between elite soccer players with or without a recent (last 12 months) disabling low back pain episode. We used an original test battery including five commonly used lumbopelvic motor control tests for which acceptable reliability has been previously demonstrated (Costa et al., 2006; Roussel et al., 2009; Zazulak et al., 2007). Although it is unnatural to keep the spine straight during movements, previous research demonstrated that healthy participants with good trunk stabilisation are able to maintain neutral spine position whilst moving their legs (Jull et al., 1993), and that significant differences are observed between patients with low back pain and healthy participants (Luomajoki et al., 2007). On average, the soccer players with a history of low back pain were less efficient in the different tests than the healthy players. The difference between the groups was significant ($P < 0.01$) and the ES between the groups was large, indicating a large difference in movement control between players with and without a history of low back pain. Using a battery of six lumbopelvic motor control tests (waiter's bow, sitting knee extension test, pelvic tilt, one leg stance, rocking four point kneeling and prone knee bend), Luomajoki, Kool, de Bruin, and Airaksinen (2008) also showed that patients with low back pain had more altered movement control tests than healthy controls. In contrast, lumbopelvic motor control tests could not discriminate between cricket pace bowlers who sustained an injury during the cricket season and those who did not (Olivier et al., 2015). This difference in findings is difficult to interpret due to methodological differences (number and type of lumbopelvic motor control tests used, prospective vs. retrospective injury report). Furthermore, our study compared players with and without a history of low back pain, whereas Olivier et al. (2015) compared bowlers who sustained a lower limb injury and/or low back pain during the cricket season and those who did not. At any rate, low back pain is a multidimensional phenomenon and lumbopelvic motor control alone cannot be expected to explain back pain. However, an original finding of the current study is that our lumbopelvic motor control score, resulting from a battery of five field tests, has the potential to discriminate between soccer players with and without a history of low back pain.

In the present study, two lumbopelvic motor control tests (knee lift abdominal test and bent knee fall out test) were monitored with pressure biofeedback unit. The mean change in pressure obtained for soccer players without a history of low back pain for both knee lift abdominal test (8.2 mmHg) and bent knee fall out test (6.6 mmHg) appears to be close to pressure variations obtained by Olivier et al. (2015) in cricket pace bowlers and by Roussel et al. (2009) in professional dancers. Regarding soccer players with a history of low back pain, mean pressure variation for the bent knee fall out test (15.3 mmHg) appeared higher than the value obtained by Roussel et al. (2013) in dancers with low back pain. In contrast, the mean value for the knee lift abdominal test (14.4 mmHg) in soccer players

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with a history of low back pain is lower than pressure biofeedback unit variation reported in dancers with low back pain (Roussel et al., 2013). Soccer players with a history of low back pain are less efficient to control trunk during rotation movement than dancers.

A large proportion of players with a history of low back pain (73%) were unable to properly contract their transversus abdominis. Similar reduced ability to efficiently contract their transversus abdominis muscle had previously been shown in elite cricketers (Hides et al., 2010) and pre-professional dancers (Roussel et al., 2013) with low back pain in comparison with asymptomatic athletes. In our study, soccer players with a history of low back pain also demonstrated higher pressure deviations on the pressure biofeedback unit during the bent knee fall out test and the knee lift abdominal test. Similar results were observed in pre-professional dancers (Roussel et al., 2013). The role of impaired lumbopelvic motor control in the aetiology of low back pain in soccer players should be further explored. Research should also try to determine whether correcting this dysfunction can reduce the occurrence of low back pain. The cross-sectional design of the present study does not allow for making causative interpretations.

The current study showed that some soccer players without low back pain cannot correctly perform some lumbopelvic motor control tests. This was particularly marked for the waiter's bow and the sitting knee extension test. Although this may suggest that lumbopelvic motor control is impaired in soccer players without a history of low back pain, it could also be due to the frequent lack of hamstring flexibility in soccer players. Indeed, soccer players' flexibility appears to be lower than other team athletes and non-athletes (Dopsaj, 1994; Graham-Smith & Lees, 2002). Several studies showed that decreased hamstring extensibility interferes with lumbar and hip functions (Hamill & Knutzen, 1995; Shin, Shu, Li, Jiang, & Mirka, 2004). Further research should explore the implication of hamstrings flexibility on the result of the waiter's bow and the sitting knee extension test. If our results are confirmed by further studies with larger sample size, it may suggest that the waiter's bow and the sitting knee extension test should be adapted to assess lumbopelvic motor control in soccer players.

This study has some limitations. First, it was conducted on a specific group of participants, i.e. on young elite male soccer players. Therefore, it limits generalisability to other studies. Second, although the sample size in the current study was similar to other studies conducted on elite athletes (Hides et al., 2010; Roussel et al., 2013), it can be considered a small sample. To our knowledge, no previous study used the lumbopelvic motor control test battery using in the present study to assess lumbopelvic motor control in patients with low back pain and healthy controls. Future research is therefore necessary to confirm our results.

In conclusion, low back pain is common in soccer players and an altered motor control of the lumbopelvic region is present in most of the soccer players with a history of low back pain. The original battery of five field tests used in this study had the potential to discriminate between soccer players with and without a history of low back pain. Difference was particularly marked for three out of five lumbopelvic motor control tests (transversus abdominis test, bent knee fall out test and knee lift abdominal test). Interestingly, some players without a history of low back pain also failed some lumbopelvic motor control tests. Further research should try to determine whether impaired lumbopelvic motor control is the origin or the consequence of the low back pain episodes and whether correcting this dysfunction could reduce the occurrence of (new) low back pain episodes in elite soccer players.

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