東京有明医療大学雑誌　Vol. 13：1－8，2021

原著論文

Changes in sagittal spinal alignment and comparison of deep trunk muscles contraction rate in low back pain of male high school soccer players

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Abstract：Background：In spinal alignment, the posture cannot be maintained only by the bones and ligaments, and trunk rigidity is maintained by the presence of the surrounding trunk muscles. However, there are no reports of spinal alignment and trunk muscles in male high school soccer players.
Purpose：In this study, we focused on spinal alignment and deep trunk muscles, to clarify the mechanism of low back pain（LBP）in male high school soccer players. Methods : The participants were 90 male high school soccer players. The presence of LBP was evaluated using a questionnaire. We assigned the participants into two groups : the non-LBP group（n = 58）and the LBP group（n = 32）.
Results：Comparing the upright position with spinal alignment, a correlation was found between thoracic kyphotic angle（TKA）and lumbar lordosis angle（LLA）and between LLA and sacral inclination angle（SIA）in the non-LBP group. Conversely, in the LBP group, a correlation was found only between LLA and SIA, and no correlation was found between TKA and LLA. With regard to spinal alignment using the amount of change in the forward and backward bending positions, a correlation was found between LLA and SIA in the non-LBP group. By contrast, in the LBP group, a correlation was found between TKA and LLA, but no correlation was found between LLA and SIA. In addition, compared with the deep trunk muscles, the lumbar multifidus（LM）muscle contraction rate was lower in the LBP group than in the non-LBP group.
Conclusion：This study suggests that changes in spinal alignment and decreased LM contraction rate may be involved in LBP in male high school soccer players.

key words：spinal alignment, Spinal Mouse, ultrasonographic imaging, lumbar multifidus muscle, transversus abdominis muscle

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抄録：背景：姿勢は骨や靭帯のみでは維持することができず，体幹周囲の筋によって体幹の剛性が維持される．しかし，高校男子サッカー選手の脊柱アライメントと体幹深層筋についての関連性は明らかにされていない．
目的：本研究では，脊柱アライメントおよび体幹深層筋に着目し，高校男子サッカー選手の腰痛（LBP）のメカニズムを明らかにすることを目的とした．
方法：対象は高校男子サッカー選手90名とした．腰痛はアンケートを用いて評価した．アンケートの結果から対象をnon-LBP群（n=58）とLBP群（n=32）に分類した．
結果：立位時の脊柱アライメントの相関関係について，non-LBP群では胸椎後弯角（TKA）と腰椎前弯角（LLA）の間，LLAと仙骨傾斜角（SIA）の間に相関関係が認められた．一方でLBP群では，LLAとSIAのみ相関関係が認められ，TKAとLLAの間に相関関係を認めなかった．立位から前屈位への変化量（U–F）と立位から後屈位への変化量（U–B）を用いた脊柱アライメントの相関関係について，non-LBP群ではLLAとSIAの間に相関関係が認められた．一方でLBP群ではTKAとLLAの間に相関関係を認めたが，LLAとSIAの間に相関関係を認めなかった．体幹深層筋の比較において腰部多裂筋（LM）の収縮率は，non-LBP群に比べLBP群で有意に低値を示した．
結論：本研究では，脊柱アライメントの変化とLM収縮率の低下が高校男子サッカー選手のLBPに関与している可能性が示唆された．

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Introduction

Soccer is a sport that frequently injures players [1, 2], and many of players experience low back pain (LBP). Focusing on young soccer players, Loose et al. [3] investigated the incidence and prevalence of injuries at five skill levels, elite junior players had a significantly higher incidence of overuse complaints (7.4 in 1,000-h football exposure), with the lower back, thigh, and groin mostly affected by trauma. In addition, Shah et al. [4] investigated the lower back symptoms of adolescent soccer players. Fractures resulted in the longest absence from training (median, 149 days), followed by bone type injuries (pain from a bony structure without definite radiological evidence of a fracture; median, 15.5 days) and soft tissue injuries (median, 13 days). Furthermore, the incidence of injuries per 1000 h has been reported to escalate with increasing age. Thus, young soccer players often have LBP that require, taking a break from practice and games, and the incidence of LBP increases as they get older. Therefore, it is necessary to prevent LBP in young soccer players.

Changes in spinal alignment related to LBP have been reported to increase lumbar lordosis and decrease lumbar spine mobility, suggesting that changes in spinal alignment are significantly involved in LBP [5]. Regarding the relationship between spinal alignment and pelvic tilt, Kobayashi stated in a 12-year cohort study of 100 patients that the sacral angle was the determining factor for lumbar lordosis [6]. It has been reported that the sacral superior surface and lumbar lordosis are highly related [7－9]. However, the relationship of spinal alignment is evaluated only in the standing position and not in the forward or backward bending position.

Stabilization of the lumbar region is reported to be achieved by increasing the contractility of the abdominal and lumbar muscles[10]. However, subjects with LBP showed reduced transverse abdominal (TrA)[11] and lumbar multifidus (LM) muscle contraction rates[12]. Richardson et al. suggested that the TrA and LM are the main stabilizing mechanisms of the lumbar spine segment and minimize the compressive force on the spinal structure[13]. This suggests that contraction of the TrA and LM is important for postural control, and spinal alignment is closely related to the deep trunk muscles such as the TrA and LM. However, there have been few reports to date on spinal alignment and the contraction rate of deep trunk muscles.

As a hypothesis, changes in spinal alignment in LBP are recognized, considering the influence of the TrA and LM contraction rates. Therefore, in this study, we aimed to clarify the mechanism of LBP in high school soccer players by focusing on the changes in spinal alignment and the contraction rates of the deep trunk muscles.

Materials and Methods

This cross-sectional study was conducted in 2019, in accordance with the principles of the Helsinki Declaration, after receiving approval from the Ethical Review Board (no. 260) of Tokyo Ariake University of Medical Sciences, the participants of the study were asked in advance to conduct the research. The purpose and contents were explained, and written informed consent was obtained from all participants and parents.

Participants

The participants were 116 male high school soccer players aged 15-18 years old. We recruited one soccer team at the national tournament level in Japan. All soccer players regularly spent a total of approximately 2 h in soccer training for 6 days/week.

A questionnaire survey was conducted to investigate the demographic characteristics and medical history. The participants' demographic characteristics (i.e., height and weight) were determined. Body mass index was calculated as body weight (kg) divided by the square of height (m^2).

Information on age and years of sporting experience was obtained using questionnaires. Moreover, all the participants were asked about their experiences of LBP within a year (yes or no). LBP in this study was defined as "pain between the lowermost rib and lower buttock, that the lasts for 24 hours or more"[11]. The exclusion criteria were as follows : participants who experienced LBP more than a year ago and those who could not participate in some measurements due to injury to other body parts. All the participants were divided into two groups : the non-LBP group (n = 58) and the LBP group (n = 32). As the LBP group was comprised of participants with LBP episodes in the previous a year, some had no pain at the time of measurement.

Measurement of sagittal spinal alignment

Sagittal spinal alignment was measured using Spinal Mouse (Idiag AG, Volketswil, Switzerland) in the following three positions (Fig. 1) : (1) upright, (2) forward bending, and (3) backward bending. The measurement range was from the seventh cervical vertebra (C7) to the third sacral vertebra (S3), and the Spinal Mouse was applied to the C7 spinous process and moved cephalocaudally. The measurement parameters of sagittal spinal alignment were the thoracic kyphotic angle (TKA), lumbar lordosis angle (LLA), and sacral inclination angle (SIA). The measured values based on the upright position (UP) were positive for the kyphosis angle, negative for the lordosis angle, and for SIA, the forward tilt was positive, and the backward tilt was negative.

The values used for statistics were the angles of the UP, the amount of change from the UP to forward bending (U-F), and the amount of change from UP to backward bending (U-B). The reliability of Spinal Mouse is guaranteed[14]. In this study, each participant was evaluated by the same examiner (RT) in a single session.

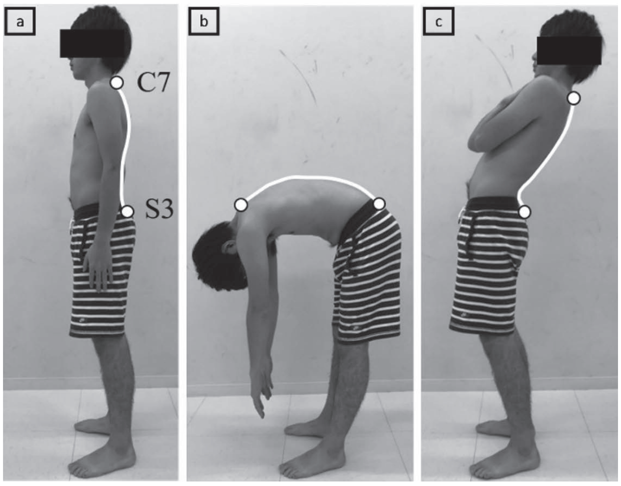

Fig. 1. Sagittal spinal alignment: (a) upright position, (b) forward bending, and (c) backward bending

Measurement of deep trunk muscles

The deep trunk muscles were measured by one examiner using an ultrasonic imaging device (LOGIQe ; GE Healthcare), a linear probe, and B mode. The visualization conditions were a frequency of 8 MHz, a depth of 50 mm, and a focus of 20 mm. The deep trunk muscles were measured in the TrA and LM. The contraction rate was calculated by measuring the muscle thickness of each muscle during relaxation and contraction. The contraction rate was calculated using the formula "(contraction − rest) / rest × 100"[15]. It has been reported that the measurement reliabilities of the TrA[16] and LM[17] are high. In addition, the TrA and LM were visualized and measured by the same operator.

Measurement of the TrA

The TrA was measured in a supine position, and the upper limbs were crossed in the anterior chest with the hips and knees flexed. The imaging method was the center of the rib margin and the iliac crest on the anterior axillary line, and the probe was placed so that it was

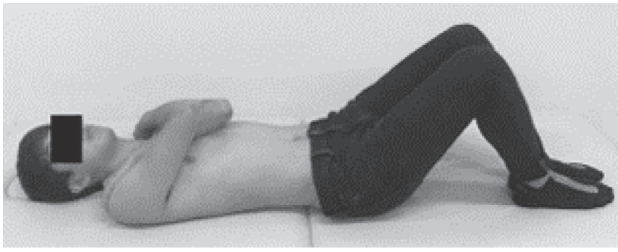

Fig 2. Abdominal draw-in maneuver (ADIM). Contraction of the transverse abdominal muscle was measured using ADIM

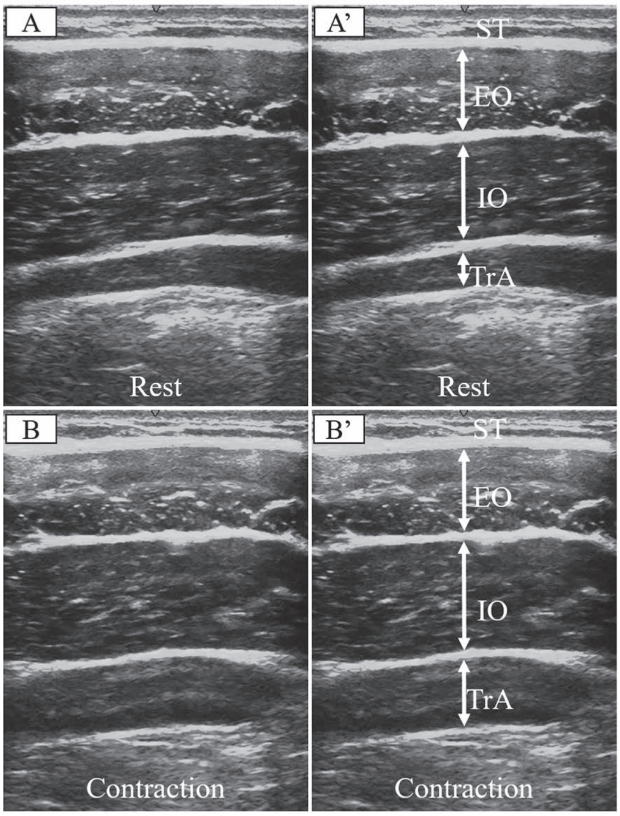

Fig 3. Ultrasonographic image of the lateral abdominal muscles. Figure A is an ultrasonographic image during relaxation, and Figure B is an image during contraction. ST, soft tissue; EO, external oblique muscle; IO, internal oblique muscle; TrA, transverse abdominal muscle

Fig 4. Arm elevation. Contraction of the lumbar multifidus muscle was measured using arm elevation

orthogonal to the anterior axillary line[18]. Measurements at rest were taken at the end of the rest exhalation. The measurement during contraction was performed using the abdominal draw-in maneuver (ADIM)[19], and three deep breaths were taken, a contraction of 5 s was performed during the third exhalation, and images were taken when the muscle was maximally bulged (Fig. 2). Before the measurement, all the participants were trained on ADIM once or twice before imaging (Fig. 3). The TrA thickness was calculated using the image analysis software Image J (National Institutes of Health, Bethesda, Maryland, USA).

Measurement of the LM

The LM was measured in a prone position, and a pillow was inserted in the abdomen. Both upper limbs were hung from the bedside. The center of the probe was placed 2 cm outside the spinous process, and the long axis was used to visualize the thickness of the LM between L4 and L5 [20]. The rest of the measurements were taken at rest on the bed. Arm elevation was used as the contraction method, and LM contractions on the opposite side of the listed upper limbs were imaged (e.g., the LM of the left lumbar region was imaged when raising the right upper limb)[21] (Fig. 4). Arm elevation was performed with 90° flexion of the elbow joint and 120° external displacement of the shoulder joint as the starting limb position, and the upper limb was raised with a 1-kg weight held in the hand. From the obtained images, the bone landmarks of the LM thickness were the facet joints, and the distance from the subcutaneous tissue to the facet joints was measured as the LM thickness (Fig. 5). The LM thickness was calculated

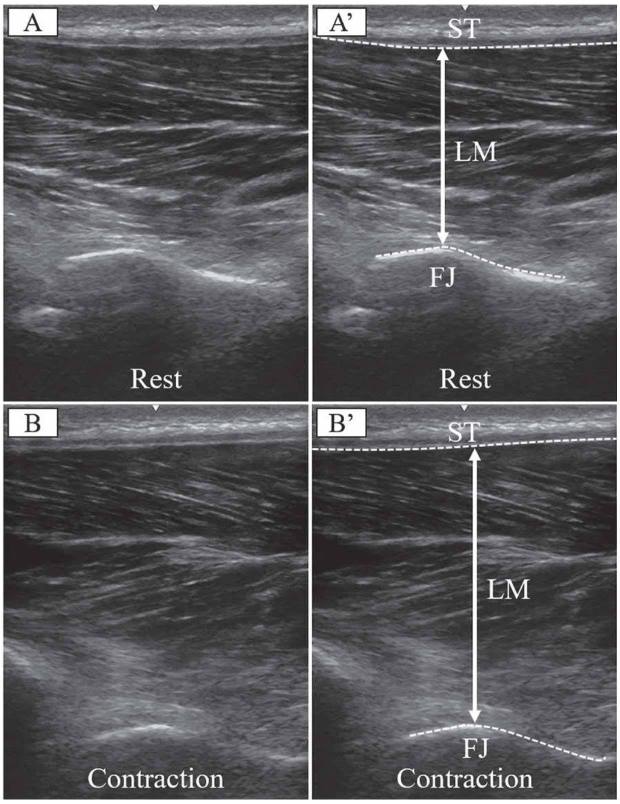

Fig 5. Ultrasonographic image of the lumbar multifidus muscle. Figure A is an ultrasonographic image during relaxation, and Figure B is an image during contraction. ST, subcutaneous tissue; LM, lumbar multifidus muscle; FJ, facet joint

using the image analysis software Image J.

Data analysis

IBM SPSS version 23.0 (IBM, Armonk, NY, USA) was used for all statistical analyses. The normality test was performed using the Shapiro-Wilk test. The Pearson correlation coefficient was used to determine the correlation of spinal alignment. In addition, unpaired t tests were performed for spinal alignment and comparison of deep trunk muscles. A significance level of $< 5\%$ was considered statistically significant.

Results

The physical characteristics of the athletes are shown in Table 1. The body weight of the LBP group was significantly higher than that of the non-LBP group.

Table 2 shows the measured values of sagittal spinal alignment. As for the correlation of spinal alignment, in the non-LBP group, there was a correlation between TKA and LLA and LLA and SIA in the UP. In the LBP group, a correlation was found between LLA and SIA

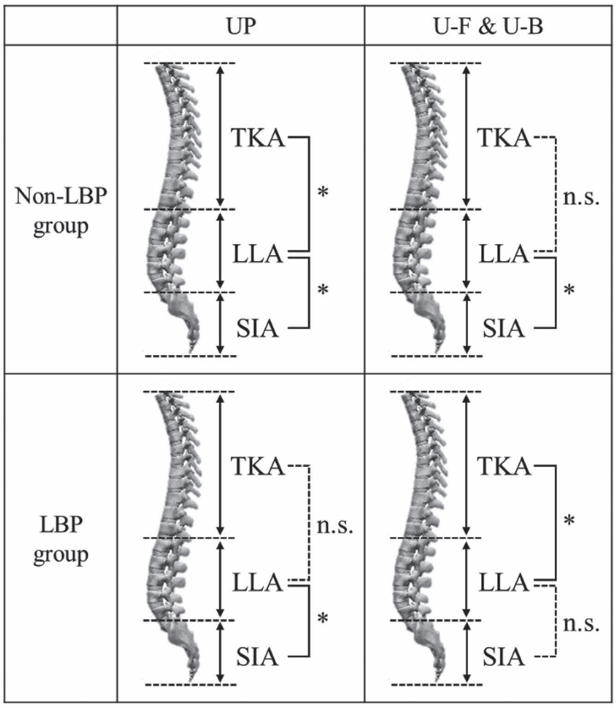

Fig 6. Correlation of each curve angle (TKA, LLA, SIA).

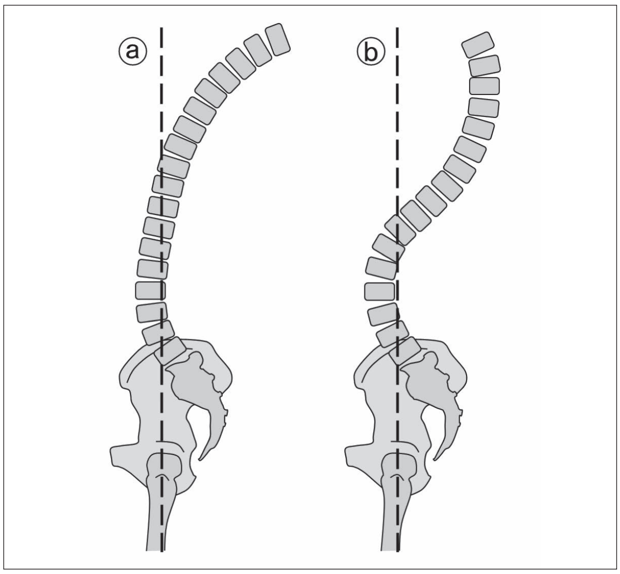

Fig 7. Positional relationship of the spine during trunk backward bending. ⓐ A pattern that allows the thoracic spine to extension. When the lumbar region stabilizes during trunk extension, the lumbar spine and sacrum are maintained to interlock, and the thoracic spine can be extension. ⓑ A pattern that cannot allows the thoracic spine to extension. If the lumbar region is not stable, the lumbar spine is excessively lordosis and the center of gravity is moved backward while leaving the kyphosis of the thoracic spine.

in the UP, but no correlation was found between TKA and LLA. In the non-LBP group, there was a correlation between LLA and SIA in U-F and U-B. Conversely, in the LBP group, there was a correlation between TKA and LLA in U-F and U-B (Table 3, Fig 6). Figure 7 shows a specific example of backward bending position.

Furthermore, the TKA was significantly higher in the LBP group (39.1° ± 6.7°) than in the non-LBP group (34.4° ± 8.1°; $p < 0.01$). Comparing the muscle thickness of the deep trunk muscles, we found that the LM contraction rate on the non-dominant side and the average LM contraction rate were significantly decreased in the LBP group as compared with the non-LBP group (Table 4).

Discussions

From the results of this study, the following findings were obtained. First, regarding sagittal spine alignment, there was a correlation between TKA and LLA, and between LLA and SIA in the UP of the non-LBP group, but a correlation was found only between LLA and SIA in the LBP group. Second, regarding the amount of change in spinal alignment, in the non-LBP, a correlation was found between LLA and SIA in U-F and U-B. In the LBP group, a correlation was found between TKA and LLA. Third, when comparing the contraction rate of the deep trunk muscles between the non-LBP and LBP groups, the LM contraction rate was significantly lower in the LBP group than in the non-LBP group.

The UP in the non-LBP group showed a correlation between TKA and LLA, and between LLA and SIA. The UP in the LBP group showed a correlation between LLA and SIA, but no correlation between TKA and LLA. Raphael et al.[8] and Yin et al.[22] evaluated standing radiographs of the entire spine, reported the relationship between TKA and LLA, and between LLA and SIA. As a result of this study, significant correlations were observed between TKA and LLA, and between LLA and SIA in the UP in the non-LBP group, supporting the results of these studies. However, there was no correlation between TKA and LLA in the LBP group. Feng et al.[23] investigated the morphology and function of the spine in junior high and high school students and found abnormal TKA in 47% of middle school boys and 52.6% of high school boys. Therefore, excessive TKA and lumbar spinal mobility restriction are risk factors for adolescent nonspecific LBP. In the present study, TKA was significantly higher in the LBP group than in the non-LBP group. Therefore, we speculated that the

Table 1. Demographic characteristics of the participants.

Characteristic	non-LBP group (n=58)	LBP group (n=32)	p
Age（years）	16.4（0.7）	16.2（0.8）	0.152
Height（cm）	171.0（5.8）	173.1（4.8）	0.093
Body weight（kg）	61.0（7.2）	64.3（7.8）	0.049*
BMI（kg/m²）	20.8（1.8）	21.4（2.3）	0.154
Soccer experience（years）	9.9（2.1）	9.6（2.3）	0.489

BMI, body mass index ; LBP, low back pain ; P, P value ; *, P<0.05 ; mean（SD）

Table 2. Measurement values of sagittal spine alignment.

Item		non-LBP group (n=58)	LBP group (n=32)
UP	TKA	34.4（ 8.1）	38.7（ 7.1）
(°)	LLA	−21.4（ 7.6）	−23.6（ 8.2）
	SIA	13.6（ 5.3）	13.8（ 5.8）
FB	TKA	58.2（ 7.6）	58.8（ 9.0）
(°)	LLA	33.7（ 8.0）	34.1（ 8.6）
	SIA	66.3（12.5）	65.6（16.6）
BB	TKA	25.2（12.9）	28.0（13.8）
(°)	LLA	−41.8（10.2）	−42.7（ 9.1）
	SIA	−7.6（ 9.0）	−9.0（ 8.4）
U-F	TKA	23.9（10.8）	20.2（10.9）
(°)	LLA	55.1（ 9.0）	57.8（ 7.2）
	SIA	52.8（13.5）	51.8（17.1）
U-B	TKA	−9.1（12.6）	−10.8（13.7）
(°)	LLA	−20.4（ 9.4）	−19.1（ 7.6）
	SIA	−21.2（ 9.0）	−23.0（ 8.3）

UP, upright position ; FB, forward bending ; BB, backward bending ; U-F, Amount of change from upright position to forward bending position ; U-B, Amount of change from upright position to backward bending position ; TKA, thoracic kyphosis angle ; LLA, lumbar lordosis angle ; SIA, sacral inclination angle ; Mean（SD）.

Table 3. Correlation results of sagittal spinal alignment in the non-LBP and LBP groups.

		non-LBP group（n=58）		LBP group（n=32）	
Position	Relation	r	p	r	p
UP	TKA - LLA	−.496	0.001*	−.314	0.080
	LLA - SIA	−.804	0.001*	−.807	0.001*
U-F	TKA - LLA	−.117	0.382	−.366	0.039*
	LLA - SIA	−.469	0.001*	.197	0.279
U-B	TKA - LLA	−.195	0.143	−.399	0.024*
	LLA - SIA	−.478	0.001*	−.321	0.074

UP, upright position ; U-F, Amount of change from upright position to forward bending position ; U-B, Amount of change from upright position to backward bending position ; TKA, thoracic kyphosis angle ; LLA, lumbar lordosis angle ; SIA, sacral inclination angle ; r, correlation co-efficient ; p, p value ; *, p<0.05.

Table 4. Results of trunk muscles thickness using ultrasound imaging device.

		non-LBP group (n=58)	LBP group (n=32)	p
EO (%)	Dominantleg	−4.7 (15.5)	−4.8 (15.3)	0.994
	non-dominantleg	−6.9 (13.7)	−8.8 (13.6)	0.537
	Average	−5.8 (12.1)	−6.8 (12.5)	0.726
IO (%)	Dominantleg	31.0 (20.9)	27.0 (25.6)	0.421
	non-dominantleg	29.2 (21.7)	29.9 (22.8)	0.896
	Average	30.1 (18.3)	28.4 (20.3)	0.687
TrA (%)	Dominantleg	103.9 (51.8)	118.6 (74.9)	0.276
	non-dominantleg	93.6 (50.3)	85.4 (50.4)	0.466
	Average	98.7 (41.8)	102.0 (52.6)	0.745
LM (%)	Dominantleg	22.9 (14.2)	18.8 (10.2)	0.153
	non-dominantleg	23.0 (9.9)	18.1 (11.8)	0.041*
	Average	22.9 (10.2)	18.5 (10.2)	0.050*

EO, external oblique muscle ; IO, internal oblique muscle ; TrA, transverse abdominal muscle ; LM, lumbar multifidus muscle ; p, p value ; *, $p<0.05$; Mean (SD).

increase in TKA was one of the factors that did not show a correlation between TKA and LLA in the LBP group, which caused an imbalance in alignment.

Second, regarding the amount of change in spinal alignment, in the non-LBP group, a correlation was found between LLA and SIA in U-F and U-B. In the LBP group, a correlation was found between TKA and LLA. Regarding the relationship between the lumbar spine and pelvis, Kobayashi et al.[6] described that the factor that determines the LLA is the sacral angle, and other studies have reported that the lumbar spine and sacrum are strongly related. In relation to the lumbopelvic region, lumbar lordosis increases with pelvic forward tilt, and lumbar lordosis decreases with pelvic backward tilt. Thus, the change in LLA associated with pelvic movement is a well-known fact and is considered to be a result that supports the relationship between LLA and SIA in all positions in the non-LBP group. However, in the LBP group, no correlation was found between LLA and SIA in U-F and U-B. This is considered to be the state where the link between LLA and SIA is lost. As a result of this study, in comparison with the deep trunk muscle contraction rate, the LM contraction rate of the non-dominant side and the average LM contraction rate were lower in the LBP group than in the non-LBP group. The LM extends the lumbar region when bilaterally contracting and rotating and laterally flexes the lumbar region when unilaterally contracting. Therefore, when the LM contracts, the pelvis forward tilts, and lumbar lordosis increases. In addition, it is reported that the LM acts as a stabilization mechanism of the trunk, and LM is the largest muscle in the lumbosacral transition region and provides the most support at the lumbar level [24]. As the contraction rate of LM decreased in the LBP group, it is considered that the role of the stabilization mechanism of the trunk did not function, and the relationship between the lumbar spine and sacrum was not recognized.

There are some limitations to this study. First, LBP could not be evaluated functionally. In this study, we conducted a questionnaire survey to evaluate LBP. The soccer teams targeted in this study had a large number of players, and the practice time was limited. Therefore, the measurement time per person was short. In addition to the survey, the evaluation of LBP required a more detailed and functional evaluation. In addition, only a single high school was measured in this study, and a larger number of teams must be utilized in the future. Second, this study is not a prospective study. A prospective study is needed to determine whether decreased deep trunk muscle contraction or altered spinal alignment was directly caused by LBP in high school soccer players. However, we hope that our study will provide useful information for improving the health care of high school soccer players.

Conclusions

In this study, we investigated LBP in high school soccer players by focusing on changes in spinal alignment and deep trunk muscle contraction rate. As a result, while LLA and SIA were originally strongly correlated, no correlation was found between LLA and SIA in the LBP group. It was also revealed that the contraction rate of the LM decreased in the LBP group. The stabilization mechanism of lumbar region due to the contraction of LM does not work, it is considered that the movement of the thoracic spine above the lumbar spine is restricted. Therefore, it is important for male high school soccer players to acquire lumbar stability and mobility of each spine.

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

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