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Original Article

Relationships among lumbar hip motion angle, perceptual awareness, and low back pain in young adults

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Abstract. [Purpose] We aimed to examine the relationships among low back pain, lumbar-hip motion angle, and lumbar perceptual awareness in young adults to improve the treatment of low back pain. [Participants and Methods] Data were collected from 36 university students with low back pain. The items included for evaluation were the low back pain intensity (Numeric Rating Scale), disability due to low back pain (Oswestry Low Back Pain Disability Index), lumbar spine and hip motion angles in test movements, and perceptual awareness (Fremantle Back Awareness Questionnaire). The test movements employed included trunk forward bending, trunk back bending, and prone hip extension. The motion angles of the lumbar spine and hip joints were measured using a wearable sensor. [Results] The Numeric Rating Scale was not correlated with the lumbar hip motion angle and perceptual awareness. The Oswestry Low Back Pain Disability Index was correlated with lumbar hip motion angles, at the beginning of trunk forward bending and at maximum trunk backward bending, and with perceptual awareness. [Conclusion] There are relationships among disabilities due to low back pain, lumbar hip motion angles, and perceptual awareness in each test movement; however, they vary depending on the type and angle of the test movement conducted.
Key words: Low back pain, Motion angle, Perceptual awareness

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INTRODUCTION

The prevalence of low back pain is high worldwide, and it is considered a socioeconomic problem as well as an obstacle in the lives of individuals[1, 2)]. Several researchers have examined the kinematic characteristics of the lumbar spine in individuals with low back pain in order to develop appropriate treatments for low back pain[3–5)]. The hip joint is known to have a close relationship with the lumbar region, and they complement each other's functions, which are recognized as the lumbopelvic and pelvifemoral rhythms[6, 7)]. When the range of motion of the lumbar spine is reduced, the hip joint moves in a compensatory manner; conversely, when the range of motion of the hip joint is reduced, the lumbar joint moves significantly to secure the overall movement angle and distribute the stretching load associated with the motion. If this load distribution fails and the capacity is exceeded due to excessive load bias to one side, it can result in hip joint labral injury and lumbar damage[8, 9)]. Panjabi et al.[10, 11)] discussed the neutral zone, the position of least resistance to movement, and showed that an injury-induced increase in the range of the neutral zone is associated with pain. Therefore, it is necessary to focus not only on the final range of motion of the movement task, but also on the difference in the functional contribution of the hip and lumbar region during the movement. A variety of movement tests are used to evaluate the motion of the lumbar spine and hip joints[12–14)]. However, there is insufficient consensus on the relationship between the results of these movement tests and low back pain. In addition,

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perceptual awareness has recently been focused on as a factor other than the kinematics related to pain[15, 16]; it is known that those with intractable pain have abnormalities in body image and body perception[15, 16]. Wand et al.[17] assessed the perceptual awareness of patients with chronic low back pain and reported different results in individuals with and without low back pain. The Fremantle Back Awareness Questionnaire (FreBAQ) is a 9-item questionnaire developed by Wand et al.[17] to assess the perceptual awareness of the lumbar spine. The items numbered 1–3 are referred to as neglect-like symptoms; items 4–5 are referred to as the proprioceptive sense; and items 6–9 are referred to as body image-related indicators[18]. A Japanese version of the FreBAQ has also been prepared and its validity has been demonstrated[18]. Although perceptual awareness is thought to be closely related not only to pain but also motor control, there is insufficient evidence to establish any clear relationships among perceptual awareness, low back pain, and lumbar and hip motion. Therefore, the purpose of this study was to evaluate relationships among low back pain, lumbar spine and hip motion angles, and lumbar perceptual awareness in each movement test to provide better treatment for low back pain.

PARTICIPANTS AND METHODS

The study used a cross-sectional observational study design. The participants were university students who were willing to participate in the study. A total of 36 students (13 males, 23 females) participated in the study. The inclusion criteria were as follows: 1) participants who had low back pain (localized below the costal margin and above the inferior gluteal folds[19]) for more than 3 months at the time of measurement, 2) participants who did not have typical physical functional disabilities such as paralysis or arthropathy, 3) participants who did not experience any pain that interfered with daily life other than that in the lumbar region, and 4) participants who had not undergone surgery that affected the movement of the lumbar spine or hip joint such as lumbar fusion surgery or artificial hip joint. To calculate the sample size, G*Power v.3.1. was used with an effect size of 0.4, an alpha value of 0.05, and a power value of 0.8. The recruitment was closed once the required sample size exceeded the anticipated dropouts.

The purpose and methods of the study were explained to the participants orally and in writing. Additionally, written consent for “free participation” was obtained from them before the study was conducted. This research has been approved by the Ethics Committee of the authors’ affiliated institutions (Approval No. 20-09).

The items measured include the intensity of low back pain, degree of disability due to low back pain, perceptual awareness of the low back, and motion angle of the lumbar spine and hip joint during each movement test. The numeric rating scale (NRS) was used for the intensity of low back pain and the Oswestry low back pain disability index (ODI) was used for the degree of disability due to low back pain. The Japanese version of the FreBAQ was used to assess the perceptual awareness of the lumbar region[18]. The motion angles of the lumbar spine and hip joints in the sagittal plane of each test were measured using similar methods from a previous study[20]; small sensors (TSND151®, ATR-Promotions, Sagara, Japan) and a receiving software (ARMS®, ATR-Promotions) were used with the sensors attached to the thoracolumbar transition, lumbosacral transition, and right thigh. The thoracolumbar transition sensor was placed in the midline of the first lumbar vertebra, the lumbosacral transition sensor was placed in the midline of the upper sacrum, and the thigh sensor was placed at the center of the posterior thigh (Fig. 1). The sensors were pre-marked and sufficiently fixed with elastic tape or elastic bands to prevent them from changing location. The sensor settings were as follows: ± 8 G for acceleration range, ± 1.000 dps for angular rate range, 100 Hz for sampling frequency, and 1 time for average number of samples. The measurement tasks performed by the participants were trunk forward bending (TFB), trunk back bending (TBB), and prone hip extension (PHE) (Fig. 2). TFB and TBB both started in the resting position (standing position with lower limbs shoulder-width apart) for 5 seconds, which were both subsequently followed by automatically moving to the final position in the next 5 seconds according to a pacing set by a metronome at 60 BPM. The participants were requested to perform the TFB movement using the instruction, “Please bend forward” from the standing position and with the upper limbs freely hanging down; on the other hand, the participants were requested to perform TBB using the instruction, “Please deflect your body backward” from the standing position and with the upper limbs folded in front of the chest[21]. Meanwhile, the PHE started with the patient lying in the prone position on the treatment bed, which was followed by the participant being instructed to “lift the lower limb” for 5 seconds according to the same metronome at 60 BPM[20]. Measurements were performed three times for each task, and the calculated average values were used. The motion angle of the lumbar spine was measured as the difference in the tilt angle between the sensor placed at the thoracolumbar transition and the sensor located at the lumbosacral transition; additionally, the motion angle of the hip joint was measured as the difference in the tilt angle between the sensor placed at the lumbosacral transition and the sensor located at the thigh. For the values obtained from the sensors, positive values were defined as flexion and negative values as extension. For TFB, analysis was possible up to a sensor tilt angle of 60° at the thoracolumbar transition; however, 22 participants were unable to perform movements beyond 60°. Therefore, the data for every 10° in the range of 10° to 60° (e.g., 10° forward bending) as well as the maximum position (maximal position) recorded were used for the availability of data for all participants. For the same reason, the TBB used data from the sensor at located the thoracolumbar transition at a 10° tilt and at the maximum position, and the PHE used data from the sensor located at the thigh at a 10° tilt and at the maximum position. The difference between the motion angles of the hip joint and lumbar spine (ADLH; hip motion angle−lumbar motion angle) was calculated from the obtained motion angles of the lumbar spine and hip joint.

SPSS, version 27 (IBM SPSS Statistics, Japan IBM, Tokyo, Japan) was used for statistical analysis. Relationships among the NRS, ODI, and the lumbar and hip motion angles in each movement test were examined by calculating Pearson's product rate correlation coefficient. The significance level was set at 0.05; all values were expressed as mean ± standard deviation.

RESULTS

The general characteristics and the NRS, ODI, and FREBAQ scores of the participants are shown in Table 1. Table 2 shows the motion angles of the lumbar spine and hip joints; additionally, Table 3 shows the correlation coefficients of NRS, ODI, FreBAQ, and the motion angles of the lumbar spine and hip joints. Although NRS was not significantly correlated with the ODI, FreBAQ score, and the lumbar and hip motion angles; a significant positive correlation was observed between the ODI and FreBAQ score. A negative correlation was also found between the ODI and lumbar motion angle of 10° to 40° of TFB. Additionally, a positive correlation was found between ODI and the hip motion angle and ADLH of 10° and 40° of TFB. ODI was also positively correlated with the lumbar motion angle at maximum TFB, but ADLH was negatively correlated with ODI. Finally, FreBAQ was positively correlated with the lumbar motion angle in TFB, but negatively correlated with ADLH in TFB.

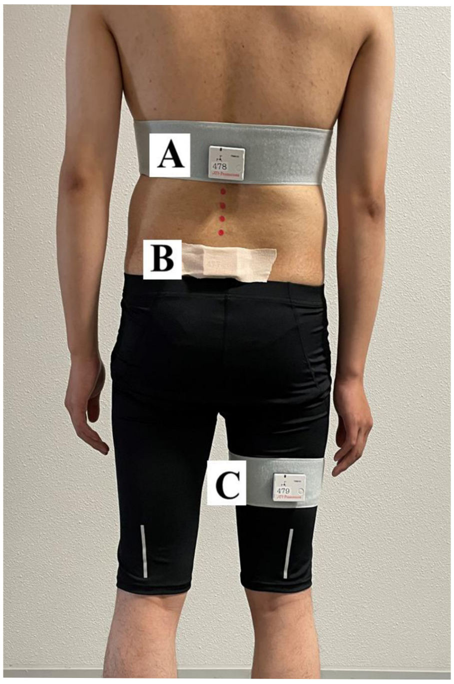

Fig. 1. Placement of wearable sensors: A) thoracolumbar transition, B) lumbosacral transition, and C) right thigh.

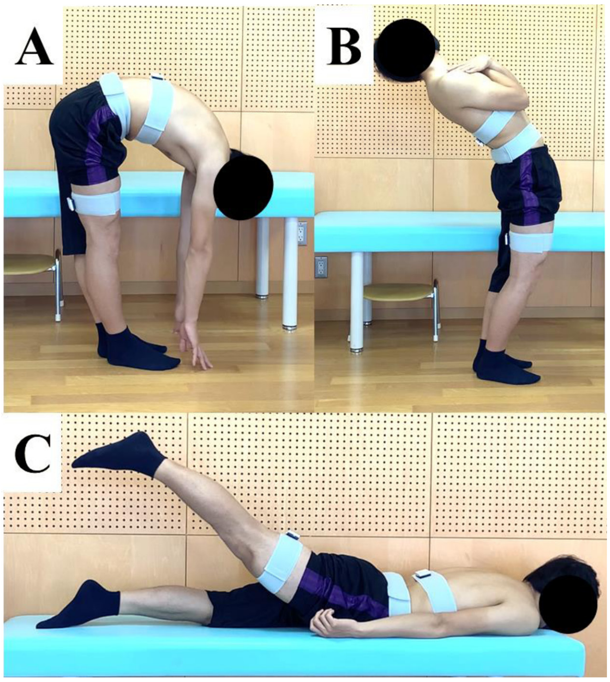

Fig. 2. Clinical movement tests conducted: A) trunk forward bending, B) trunk backward bending, C) prone hip extension.

Table 1. General characteristics, the NRS, ODI, and FreBAQ scores of the participants

Gender, n (%)	Male, 13 (36.1)
	Female, 23 (63.9)
Age (years)	20.0 ± 1.1
Height (cm)	164.4 ± 8.6
Weight (kg)	57.8 ± 11.1
BMI (kg/m^2)	21.2 ± 2.6
NRS (scores)	2.4 ± 1.2
ODI (scores)	4.5 ± 2.9
FreBAQ (scores)	2.7 ± 3.2

Mean ± SD.
BMI: body mass index, NRS: Numeric Rating Scale; ODI: Oswestry low back pain disability index; FreBAQ: Fremantle Back Awareness Questionnaire.

Table 2. Motion angle of the lumbar spine and hip joint

Movement	Angle	Lumbar spine (°)	Hip joint (°)	ADLH (°)
TFB (n=36)	10°	5.2 ± 2.3	5.1 ± 2.2	−0.1 ± 4.3
	20°	10.2 ± 3.5	11.9 ± 3.6	1.7 ± 6.9
	30°	15.5 ± 4.7	18.4 ± 4.9	2.9 ± 9.4
	40°	21.0 ± 5.8	24.3 ± 6.0	3.3 ± 11.6
	50°	26.5 ± 6.7	30.0 ± 6.9	3.5 ± 13.3
	60°	31.9 ± 7.3	35.6 ± 7.6	3.6 ± 14.6
	Max	53.9 ± 8.9	65.4 ± 14.7	11.5 ± 17.0
TBB (n=36)	10°	−7.8 ± 2.8	−4.9 ± 2.3	2.9 ± 4.5
	Max	−19.5 ± 7.8	−12.5 ± 5.4	7.0 ± 9.1
PHE (n=36)	10°	−2.8 ± 3.0	−10.4 ± 1.8	−7.5 ± 4.6
	Max	−12.5 ± 5.4	−25.7 ± 3.8	−13.1 ± 6.2

Mean ± SD.
TFB: trunk forward bending; TBB: trunk backward bending; PHE: prone hip extension; NRS: Numeric Rating Scale; ODI: Oswestry low back pain disability index; FreBAQ: Fremantle Back Awareness Questionnaire; ADLH: angular difference between the lumbar spine and hip joint.

DISCUSSION

This study examined relationships among intensity of low back pain, degree of disability due to low back pain, the lumbar spine and hip motion angles in each movement test, and lumbar perceptual awareness. The results of this study clarify relationships observed among low back pain, lumbar spine and hip motion, and perceptual awareness, and could help in formulating an assessment and treatment plan for low back pain.

Although the results showed that the motion angles of the lumbar spine and hip joints were not related to intensity of low back pain, they were related to disability caused by low back pain. However, it is reported that various factors, such as psychosocial and neurophysiological factors, are involved in the mechanism of low back pain in addition to mechanical load[22]. Therefore, it is difficult to interpret the intensity of low back pain solely based on kinematic factors. Parks et al.[23] found no relationship between ODI and lumbar range of motion during TFB and were skeptical about the implications of using lumbar range of motion measurements for assessments. In the results of the present study, similar to their study, there were no associations observed with ODI in the final position of TFB; however, the results showed that ODI was associated with the initial phase of TFB.

It is widely accepted that pain can cause changes in control[24]; moreover, it is not unnatural that reduced movement of the lumbar spine can lead to disability, as seen in the present results. Therefore, the results of this study may provide a basis for therapists to intervene from a kinesiological perspective, emphasizing disability rather than pain intensity as the outcome. In addition, in the present results, disability was more pronounced in those who had lesser lumbar movement and more hip movement from the beginning to the middle of TFB. Porter et al.[25] reported that the contribution of the lumbar spine decreased in comparison to the hip in the early phase of TFB in individuals with low back pain, and the present results were consistent with those of previous studies. The contribution of the lumbar spine is larger than that of the hip joint in the early phase of movement with respect to trunk movement[26]. In addition, Leinonen et al.[27] reported that muscle activity was different in the early and late stages of TFB, exhibiting that patients with and without low back pain had different muscle activity patterns. Therefore, in the early phase of the TFB, there is a change in control that reduces lumbar motion associated with low back pain; additionally, the treatment of this change may be an important aspect of resolving the problem in the direction of flexion. On the other hand, ODI was larger in those with a smaller lumbar motion angle at the maximum position of TFB. The range of motion of TBB was smaller than that of TFB, suggesting that in daily life, activities related to lumbar extension, such as walking, are more common than those related to the final range of lumbar flexion. In addition, the reason only the lumbar spine had ODI and FreBAQ in TBB may be that TBB can be compensated using knee joint flexion in conjunction with the hip joint. Since the knee joint motion was not specified or measured in this study, further validation is needed in future studies.

FreBAQ was not correlated with NRS, but was correlated with ODI. Wand et al.[28] found that the NRS and FreBAQ scores were correlated in pregnant women with low back pain and that the body image disturbance was associated with pain. However, in the present study, there was no correlation observed with intensity of low back pain, but only with disability. The reason for this may be that the study by Wand et al.[28] targeted pregnant women, whose body image and other body perceptions differ from those of university students. However, the fact that FreBAQ was associated with ODI may indicate that an improvement in perceptual awareness can lead to an improvement in disability. Notably, FreBAQ scores were correlated with the lumbar and hip motion angles during TFB. The motor control adjusts the output based on the sensory informa-

Table 3. Correlation coefficient for each item

			NRS	ODI	FreBAQ
ODI			0.30	–	–
FreBAQ			0.08	0.51*	–
TFB	10°	Lumbar spine	−0.24	−0.51*	−0.09
		Hip joint	0.15	0.53*	0.14
		ADLH	0.20	0.53*	0.12
	20°	Lumbar spine	−0.23	−0.45*	−0.13
		Hip joint	0.21	0.47*	0.14
		ADLH	0.23	0.47*	0.14
	30°	Lumbar spine	−0.22	−0.40*	−0.15
		Hip joint	0.21	0.41*	0.15
		ADLH	0.22	0.41*	0.15
	40°	Lumbar spine	−0.20	−0.34*	−0.14
		Hip joint	0.21	0.37*	0.15
		ADLH	0.21	0.36*	0.15
	50°	Lumbar spine	−0.18	−0.31	−0.14
		Hip joint	0.20	0.32	0.14
		ADLH	0.19	0.32	0.14
	60°	Lumbar spine	−0.16	−0.28	−0.13
		Hip joint	0.19	0.29	0.13
		ADLH	0.18	0.29	0.13
	Max	Lumbar spine	−0.09	−0.03	0.22
		Hip joint	−0.07	−0.11	0.12
		ADLH	−0.02	−0.08	−0.01
TBB	10°	Lumbar spine	−0.07	0.16	0.42*
		Hip joint	0.04	−0.29	−0.27
		ADLH	0.06	−0.24	−0.39*
	Max	Lumbar spine	0.18	0.48*	0.48*
		Hip joint	−0.04	−0.02	−0.08
		ADLH	−0.17	−0.43*	−0.46*
PHE	10°	Lumbar spine	0.13	0.25	0.23
		Hip joint	−0.08	−0.08	−0.21
		ADLH	−0.11	−0.19	−0.23
	Max	Lumbar spine	0.13	0.28	0.29
		Hip joint	−0.09	0.18	0.07
		ADLH	−0.17	−0.13	−0.21

TFB: trunk forward bending; TBB: trunk backward bending; PHE: prone hip extension; NRS: Numeric Rating Scale; ODI: Oswestry low back pain disability index; FreBAQ: Fremantle Back Awareness Questionnaire; ADLH: angular difference between the lumbar spine and hip joint.
*Statistically significant correlation ($p<0.05$).

tion obtained, and the proprioception, which senses the position and movement of the body, is particularly important[29, 30]. Therefore, it is natural that perceptual awareness is related to the lumbar spine and hip motion angles. However, it is notable that only the direction of trunk extension was related to perceptual awareness. As such, the relationship between the angle of motion and perceptual awareness may vary depending on the direction of motion, the starting point of the motion, the angle, and the limb position, which entail further verification in future investigations.

One of the limitations of this study is that the lumbar spine was analyzed as a single segment. Provided this, it is necessary to verify the results in the future because there may be differences observed among the segments of each vertebra. In this study, the direction of motion was limited to the sagittal plane; however, different results may be obtained in the frontal or horizontal planes. Although the participants of this study were university students with chronic low back pain, there is a possibility that other age groups, especially the older adults, will show different results. Older adults reportedly have decreased lumbar motion and increased hip motion compared with younger adults[31]. In addition, the relationship between the dysfunction caused by low back pain and the movement angle of the lumbar spine and hip joint may be more closely related in older adults than in younger ones; it is expected that the partial impairment will have a greater impact on daily life with age. Furthermore, it is known that aging causes alterations in muscle spindles closely related to proprioception; a decrease in the number of innervated muscle spindles diminishes their sensitivity. A decrease in the integration of sensory information from the brain, neurochemical changes, and other changes in both peripheral as well as central nervous systems result in the functional decline of the proprioceptive system[32]. Therefore, it is possible that younger and older adults show different results in terms of perceptual awareness, but it is unclear whether perceptual awareness in people with low back pain worsens with age or it becomes less susceptible. In our study, many participants had low back pain that was not chronic enough to require medical attention. Therefore, it is necessary to take under consideration the age of the study participants and further localize the sampling in the future.

In conclusion, this study examined the relationships among the intensity of low back pain, degree of disability due to low back pain, the lumbar spine and hip motion angles in select movement tests, and lumbar perceptual awareness. The results showed that disability was related to the angle of motion of the lumbar spine and hip joint, at the beginning of TFB and at the maximum position of TBB, and perceptual awareness. Therefore, relationships exist among disability due to low back pain, the motion angle of the lumbar spine and hip joint, and the perceptual awareness in each movement test; however, they may vary depending on the type and angle of the test.

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Conflict of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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