Archives of Physical Health and Sports Medicine

ISSN: 2639-1805

Volume 3, Issue 2, 2020, PP: 24-32

The Motor Control Ability of the Lumbar Region and Hip Joint are Related to the Direction of the Hip Movement Test in Older People

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Abstract

This study aimed to clarify whether the motion ratio and the motor control ability of lumbar region and hip joint are specific to the direction of movement in healthy older people. Fourteen healthy older people were included in the study. The motion ratio and motor control ability of the lumbar and hip joint during hip extension and external and internal rotations were measured in the prone position using a wearable sensor, and the relationship between each movement was investigated. As a result, both the lumbar and hip joint motion ratio and the motor control ability were positively correlated between the sagittal plane component of hip extension and the horizontal plane component of hip external rotation. There were negatively correlated in the horizontal plane component of hip extension and the horizontal plane component of hip external rotation. There was no correlation between them during the internal rotation of the hip joint and any other movement. With regard to the hip movement test, there is an association between hip extension and external rotation. Because each movement relates differently to other movements, movement tests should be selected based on the characteristics of the movement.

Key words: *lumbar region, hip joint, movement test, motor control ability, older people.*

Introduction

Low back pain is one of the top risk factors leading to disability worldwide [1], and the decrease in activity associated with the progression of low back pain in older individuals is recognized as an important factor leading to the need for care [2]. Therefore, evaluation and management for the prevention and improvement of low back pain in older individuals is important. Movement of the lumbar region and hip joint is accompanied by movement of the pelvis, and their close relationship is known as lumbopelvic rhythm [3, 4] and pelvifemoral rhythm [5]. Disruption of lumbopelvic and pelvifemoral rhythm is regarded as a hip-spine syndrome. The normal functioning of the lumbar region and hip joint prevents one of them from being overloaded; therefore, many studies have focused on the motion ratio of the lumbar region and hip joint [6, 7]. Sahrmann et al. [8] described that the hip joint is generally less mobile than the lumbar region, resulting in the emergence of over-movement in the lumbar region, which leads to microtrauma and micro instability in the lumbar region. In fact, it has been reported that lumbar movement appears earlier, and lumbar motion is greater than that of the hip joint during limb movements in those with a history of low back pain compared to those without a history of low back pain [9, 10]. It has also been reported that people with low back pain have a poor ability to modify abnormal movements in the lumbar region [11], and people with low back pain have been described to have problems with motor control of the lumbar region. Therefore, motor control of the lumbar region is considered to be an important factor in the prevention and improvement of low back pain. In addition, Sahrmann et al [8] have proposed that repetition and continuous loading in a particular direction can produce directional tendency(DT).

It has been suggested that the presence of DT in the lumbar region may increase the frequency of excessive motion in the lumbar region and lead to an increase in stress in the lumbar tissues associated with excessive motion [9]. There have been many studies on movement tests using lower extremity movements as an assessment of DT and motor control as it relates to the lumbar region [12, 13] and Van et al have reported that movement tests regionssociated with lower extremity and trunk movements performed on a daily basis [14]. Regarding low back pain, the relationship between low back pain and the ability to control lumbar movement during supine hip extension [15, 16] and external rotation [9] has been reported, which suggests the utility of movement tests using hip movement. It is assumed that many muscles related to the lumbar region and the pelvic girdle, such as the abdominal muscles and the back muscles, cooperate with each other to control the motion of the lumbar region during hip movements. However, there are few reports that investigate whether the motor control ability of the lumbar region during hip movement is direction-specific or not. In particular, older people may have long term DT and movement with more emphasis on DT. In addition, excessive load on the lumbar region may lead to irreversible changes with aging. Therefore, basic information on lumbar movements in older people is important to prevent and improve low back pain.

Therefore, this study aimed to clarify whether the lumbar hip ratio (LHR) and motor control ability (MCA) are specific to the direction of the hip movement test in healthy older people.

Materials and Methods

Participants

The participants were 14 older people [3 males (age: 74.7±5.9 years, height 162.4±5.6 cm, weight 63.4±8.7kg) and 11 females (age: 72.7±3.9 years, height 151.3±3.8 cm, weight 50.5±3.4kg]. The participants were independent enough to participate in the study by themselves. The exclusion criterion were participants with dementia, those who either did not fully understand the purpose and methodology of the study, were certified as requiring nursing care, complained of severe pain that interfered with daily life, had any physical disabilities such as cerebrovascular disease and/or rheumatoid arthritis or whose range of motion of hip joint extension was less than 0°. After explaining the purpose and methodology of the study verbally and in writing, those who agreed to provide written consent to participate in the study "voluntarily" were considered.

This study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Kyototachibana University (approval number: 19-30).

Measurement of LHR and MCA During Hip Extension and Rotation Movement

Based on our previous studies [17], LHR and MCA of the lumbar region and hip joint during hip extension and rotation movements were measured using a wearable sensor (TSND151, ATR-Promotions, Sagara, Japan) and receiving software (Sensor Controller, ATR-Promotions, Sagara, Japan). The wearable sensors were attached to the pelvis and right femoral region. The pelvic sensor was attached to the center of the sacrum, where the upper edge of the sensor was at the line connecting the superior posterior iliac spine on both sides. The femoral sensor was attached to the posterior surface of the femoral region, midway between the sciatic tubercle and fossa poplitea. The wearable sensor settings regions follows, the acceleration range was ±8 G, the angular velocity range was ±1.000 dps, the sampling interval was 10 ms, and the average number of samples taken was 1. The tilt angles in the sagittal and horizontal planes of the sacrum and femoral region during hip extension and rotation movements were measured. Hip extension was an active movement, and the starting position of the hip extension was in the prone position with hip extension, abduction, and rotation at 0°. Subsequently, the patients were instructed to perform the right hip extension movement with the knee joint extended from the starting position. Hip rotation was also an active movement, and the starting position of the hip rotation was in the prone position with hip extension, abduction, and rotation at 0° and right knee flexion at 90°. Subsequently, the participants were instructed to perform the right hip external or internal rotations movement from the starting position. Each movement was performed twice, first Natural movement (NM) and then Modified movement (MM), in which the participants were instructed to reduce the movement of the pelvis (lumbar) by themselves. For hip extension movement, the values at the time when the femoral wearable sensor was tilted 10° in the direction of hip extension on the sagittal and the horizontal plane (10° tilt) and at the maximum tilt (maximum tilt) were used. For hip rotation movement, the values at the time when the femoral wearable sensor was tilted 10° in the direction of hip external or internal rotation on the horizontal plane (10° tilt) and at the maximum tilt (maximum tilt) were used. For these values, the pelvis tilt angle was defined as the lumbar motion angle, and the difference between the femur tilt angle and the pelvis tilt angle was defined as the hip joint motion angle. The LHR and MCA were calculated from the motion angles of the sagittal and horizontal components of hip extension movement and the horizontal component of hip rotation movement. LHR was calculated as the ratio of lumbar to hip motion angle (lumbar motion angle / hip motion angle), and MCA was calculated as the ratio of NM and MM change in LHR (MM / NM).

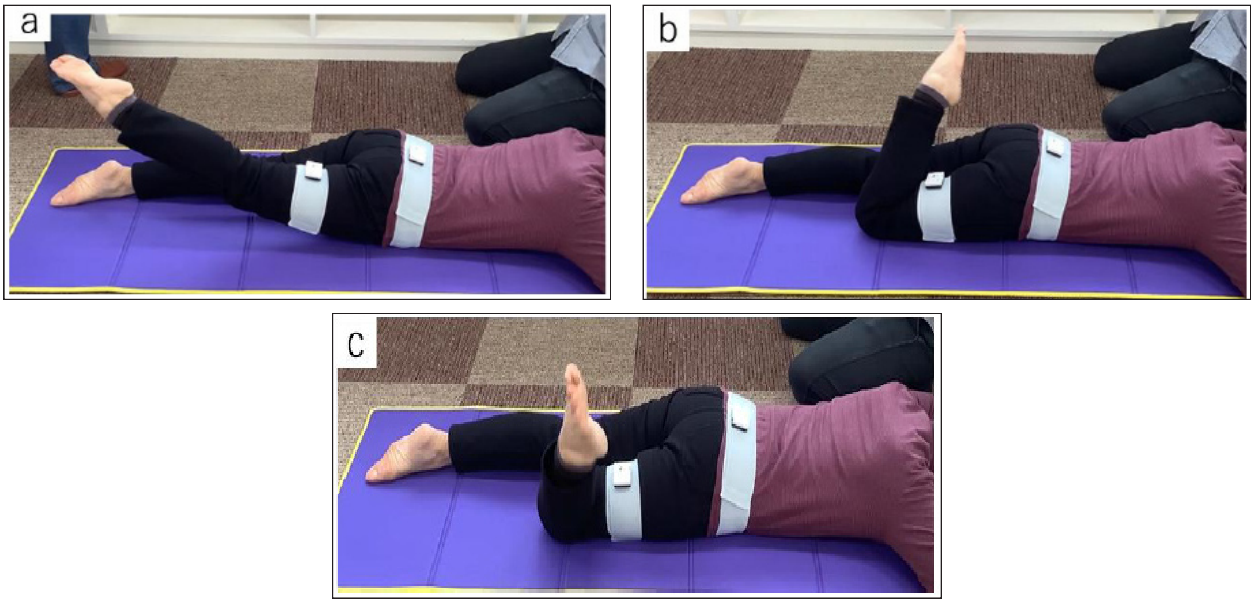

Figure 1. *Measurement of lumbar region and hip joint movement during hip movement using a wearable sensor. a, hip extension; b, hip external rotation; c, hip internal rotation*

Statistical Analysis

All statistical analyses were carried out using SPSS, version 24 (IBM SPSS Statistics, Japan IBM, Tokyo, Japan). For comparison of the LHR and MCA between NM and MM, the paired t-test was used after confirmation of normality by the Shapiro-Wilk test. For the relationships between LHR and MCA for each movement, Pearson's correlation coefficient was applied. Values of $p < 0.05$ were considered significant., and all values are presented as the mean ± standard error.

Results

The Lumbar Hip Ratio (LHR) During Hip Movement

Table 1 shows the motion ratio of lumbar region and hip joint during hip extension and rotation. The NM was significantly larger than MM at the maximum tilt of the femur in the sagittal plane component of hip extension movement (p=0.01). However, other movements were not significantly different. Table 2 shows the correlation coefficients between lumbar and hip motion ratios during hip extension and rotation. At the maximum tilt, the LHR of hip external rotation had a significant positive correlation with that of sagittal component of hip extension in NM (p<0.01, r=0.78). In the MM, there was a significant positive correlation between the LHRs of hip external rotation and sagittal component of hip extension (p<0.01, r=0.69). There was a significant negative correlation between the LHRs hip external rotation and the horizontal component of hip extension (p<0.01, r=-0.90). There was no significant correlation between the LHR of internal rotation and external rotation of the hip joint. Only the LHR of sagittal component of hip extension was positively correlated with that of external hip rotation in MM (p<0.01, r=0.89). There was no significant correlation between LHRs of hip extension and hip external rotation in NM or between the LHRs of internal rotation and external rotation of the hip joint.

Table 1. *Lumbar and hip joint movement ratio (lumbar / hip joint) during hip extension / hip rotation task*

		Maximum Tilt	10° Tilt
EX (Sagittal plane)	**Natural movement**	5.6±1.3	1.2±0.3
	Modified movement	1.3±0.3	1.0±0.6
	95% confidence interval	1.2~7.3*	-0.8~1.1
EX (Horizontal plane)	**Natural movement**	1.0±0.5	0.3±0.1
	Modified movement	-1.9±2.9	0.3±0.2
	95% confidence interval	-3.3~9.2	-0.5~0.5
ER	**Natural movement**	0.4±0.1	0.3±0.1
	Modified movement	0.6±0.1	0.5±0.1
	95% confidence interval	-0.4~0.1	-0.3~0.1
IR	**Natural movement**	1.1±0.3	0.4±0.1
	Modified movement	1.0±0.6	5.4±4.8
	95% confidence interval	-0.8~1.1	-15.3~5.3

Data are presented as the mean± standard error or minimum and maximum values with 95% confidence interval. EX, hip joint extension; ER, hip joint external rotation; IR, hip joint internal rotation.

* Significant differences between Natural movement and Modified movement ($p < 0.05$).

Table 2. *Correlation coefficient of lumbar hip ratio (lumbar angle / hip joint angle) during hip extension / hip rotation task*

		Natural movement		Modified movement	
		ER	IR	ER	IR
Maximum Tilt	EX (Sagittal plane)	0.78*	0.28	0.69*	-0.32
	EX (Horizontal plane)	-0.01	-0.14	-0.90*	0.10
	ER	-	0.38	-	-0.04
10° Tilt	EX (Sagittal plane)	0.16	-0.07	0.89*	-0.06
	EX (Horizontal plane)	-0.12	-0.43	0.50	-0.04
	ER	-	-0.35	-	-0.07

EX, hip joint extension; ER, hip joint external rotation; IR, hip joint internal rotation.

* Significant correlation ($p < 0.05$)

The Motor Control Ability (MCA) During Hip Movement

Table 3 shows the motor control ability of the lumbar region during hip extension and rotation, and table 4 shows the correlation coefficients between each movement.

At maximum tilt, there was a significant positive correlation between MCAs of hip external rotation and the sagittal component of hip extension ($p<0.01$, $r=0.90$). There was a significant negative correlation between MCAs of hip external rotation and the horizontal plane component of hip extension ($p<0.01$, $r=-0.90$). There was no significant correlation between MCAs of hip internal rotation and hip extension/ external rotation or between MCAs of all movements at a 10° tilt.

Table 3. *Motor control ability (Modified movement / Natural movement) during hip extension / hip rotation task.*

	Maximum Tilt	10° Tilt
EX (Sagittal plane)	0.5±0.2	0.5±1.2
EX (Horizontal plane)	-3.3±4.5	-1.4±1.3
ER	1.5±0.3	2.7±0.8
IR	0.7±0.2	6.8±5.4

Data are presented as the mean± standard error. EX, hip joint extension; ER, hip joint external rotation; IR, hip joint internal rotation.

Table 4. *Correlation coefficient of motor control ability during hip extension / hip rotation task*

		ER	IR
Maximum Tilt	**EX(Sagittal plane)**	0.90*	0.37
	EX(Horizontal plane)	-0.90*	-0.47
	ER	-	0.37
10° Tilt	**EX(Sagittal plane)**	0.17	-0.04
	EX(Horizontal plane)	0.52	-0.07
	ER	-	0.09

EX; Hip extension, ER; Hip external rotation, IR; Hip internal rotation.

* Significant correlation ($p < 0.05$).

Discussion

This study was conducted to determine whether the motion ratio and the motor control ability of the lumbar region and hip joint are related to the direction of the hip movement test in healthy older people. The results of this study provides a basis for selecting a movement test to formulate a lumbar movement strategy and evaluate the motor control of older people with low back pain and other conditions and helps in the motor control training of the lumbar region and hip joint.

The results showed that the LHR of only the sagittal plane component of hip extension motion was significantly higher in NM than in MM. This indicates that modifying the movement of the lumbar region reduced the movement of the lumbar region relative to the hip joint. Conversely, there was no difference between the LHRs of NM and MM in the horizontal component of hip extension and external and internal rotations of the hip joint. Lee et al. [18] reported that the amount of motion in the rotational direction of the lumbar region is less than that in extension and hip motion in the majority of rotational tasks. Therefore, it is assumed that the movement of the lumbar region in the sagittal plane during hip extension movement is larger than that in the horizontal plane, and the amount of change due to the modification was larger in this study as well. Another factor is that movement in the sagittal plane may be easier to control than movement in the horizontal plane. Therefore, it is possible that for persons with lumbar rotational DT, it is necessary to make motor control easier in horizontal rather than in the sagittal plane. The sagittal component of hip extension was positively correlated with hip external rotation at maximum tilt in both NM and MM for both MCA and LHR. Therefore, if there is excessive movement or motor control failure in the lumbar region during hip extension, there is a possibility that excessive movement or motor control failure may also occur during external hip rotation. The LHR of sagittal plane component of hip extension motion was positively correlated with that of hip external rotation at a 10° tilt of MM. This indicates that in hip extension and external rotation, the movements of the lumbar region and hip joint during modification are related to each other throughout their course. In addition, there was a negative correlation between the horizontal plane component of hip extension and hip external rotation at the maximum tilt for both LHR and MCA in MM. The reason might be that the participants attempted to control only the movement in the direction of hip extension and compensated for the angle of femur elevation by the movement in the horizontal plane during hip extension. Therefore, it is necessary to give detailed motion instructions in the horizontal plane as well as the sagittal plane when performing motor control exercises. Stokes et al. [19] reported that increased abdominal pressure increased lumbar stability, but increased stability was not associated with increased specific muscle activity in simulations. Cholewicki et al. [20] also reported that a single muscle does not act on a given load, suggesting the importance of the system as a whole muscle unit. In other words, it is possible that the lumbar stability can be controlled in any direction by the overall action of the muscle unit, rather than direction-dependent control based on the placement of the muscles. However, in the present study, hip internal rotation was not correlated with any movements with respect to LHR and MCA. One of the reasons for this is that the direction of rotation of the pelvis during external hip rotation was in the direction of elevation from the floor. Therefore, the movements of the pelvis were more easily reflected in the external hip rotation rather than in the internal rotation where the pelvis contacts the floor. Consequently, in addition to the possibility that internal hip rotation in the prone position provides independent control of hip extension and external rotation, there is also the possibility that it is less useful as a test of hip and lumbar motor control due to the direction of motion. However, Nelson-Wong et al. [21] examined the prediction of low back pain using the active straight leg raise test, which is a sagittal motion, and the hip abduction test, which is a frontal motion. Moreover, they reported that problems in one plane do not always affect other planes, and the combination of the two tests is more useful than the use of either of the tests. Therefore, it is necessary to examine the usefulness of the internal rotation of the hip joint which is not related to the other movements in the future. The effectiveness of motor control exercises based on DTs has been indicated [22], and it is necessary to select the exercises based on DTs considering the relevance of the results of the study between motor tests.

As a limitation of this study, the present movement test was conducted only in the direction of extension and rotation in the prone position, and measurements in other conditions, such as spinal flexion and other postures including sitting and standing, may give different results. Therefore, it is necessary to investigate the relationship between these other movements. In this study, the participants were healthy older people. Older people with low back pain may show different results. Therefore, it is necessary to investigate LHR and MCA in persons with low back pain to determine the factors and cutoff values associated with low back pain. In this study, the relationship between muscle activity and control of each movement is not clear because the measurement of muscle activity was not performed. Therefore, it is necessary to identify factors related to motor control in the future. In addition, because the patients performed the movement of the lower limb in the prone position, it was assumed that the lumbar region would move from the lower part of the body, and the pelvic movement was interpreted as the movement of the lumbar region. However, it is possible that not only the lumbar but also the thoracic region may have moved. Furthermore, Laird et al. [23] stated that range of motion and LHR generally exhibit day-to-day variability and that this variability needs to be considered when interpreting changes in posture and movement. Therefore, it is also necessary to verify the relationship between each movement while considering the daily variability.

Conclusions

In the present study, there was a correlation between the LHR and MCA for hip extension and external rotation in the prone position, but no such correlation was observed for internal rotation. Because each movement relates differently to other movements, motor tests should be selected based on the characteristics of the movement.

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Citation: **Ryo Miyachi, Junya Miyazaki.** *The Motor Control Ability of the Lumbar Region and Hip Joint are Related to the Direction of the Hip Movement Test in Older People. Archives of Physical Health and Sports Medicine. 2020; 3(2): 24-32.*