

Relationship Between Lumbar Region Stability and Lower Extremity Motor Function in Community-Dwelling Elderly Individuals

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Abstract

This study aimed to determine the relationship between lumbar region stability and lower extremity motor function in community-dwelling elderly individuals. The study included 10 community-dwelling elderly individuals (male, 1; females, 9; age: 79.3±7.0 years). The lumbar region extension angle during prone hip extension movement was measured as an index of lumbar region stability, and the Short Physical Performance Battery (SPPB), which comprehensively evaluates lower extremity motor function, was measured using three items: normal walking speed, tandem position, and five-repetition sit-to-stand test as an index of lower extremity motor function. For the measurement of the lumbar region extension angle, inertial sensors were installed at three locations: the right thigh, lumbosacral vertebral transition, and thoracolumbar vertebral transition. Lumbar region extension angle was defined as the difference in the tilt angle between the inertial sensors at the lumbosacral vertebral transition and thoracolumbar vertebral transition during prone hip extension movement. The lumbar region extension angle was calculated at a 10° tilt of the inertial sensor of the right thigh and at the maximum tilt angle. As a result, there was a negative correlation between the lumbar region extension angle at a 10° tilt of the inertial sensor of the right thigh and SPPB scores. On the other hand, there was no correlation between the lumbar region extension angle at the maximum tilt angle of the inertial sensor of the right thigh and SPPB scores. In conclusion, lumbar region stability in the middle of lower extremity movement is associated with lower extremity motor function in community-dwelling elderly individuals..

Keywords: Community-dwelling elderly individuals; Lumbar region stability; Lower extremity motor function; Short Physical Performance Battery.

INTRODUCTION

Elderly individuals experience deterioration of lower extremity motor function, such as the walking speed, standing balance ability, and lower extremity muscle strength with an increase in age [1, 2]. This deterioration in lower extremity motor function is associated with falls [3] and has a significant impact on the socio-economy, including increased medical costs due to bedridden patients after falls [4]. Therefore, it

is a socioeconomically important issue to establish a strategy to improve the lower extremity motor function in the elderly individuals. Lower extremity motor function is related to trunk function [5, 6], and in particular, lumbar region stability is closely related to lower extremity motor function [5-7]. Lumbar region stability is the foundation for efficient limb movement [6, 7]; additionally, it has been reported that reduced lumbar region stability affects reduced

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lower extremity motor function in athletes and patients with cerebrovascular disorders [8, 9]. The lumbar muscle groups are important for maintaining lumbar region stability [10]. Moreover, it has been reported that the lumbar muscle groups of the elderly individuals exhibit muscle weakness with an increase in age, similar to that of the lower extremity muscle groups [11, 12]. In addition to age-related muscle weakness, it has also been reported that muscle activity in the lumbar muscle groups that precede limb movement is delayed [13]. Therefore, it is presumed that deterioration in lower extremity motor function in the elderly individuals may not be due to only age-related lower limb muscle weakness [14], but also the difficulty in exerting lower extremity muscle strength due to deterioration in the lumbar region stability, which is the foundation of movement. Therefore, it is expected that lower extremity motor function may be impaired in the elderly individuals due to decreased lumbar region stability, as in athletes and patients with cerebrovascular disorders; however, the relationship between lumbar region stability and lower extremity motor function has not been clarified.

Therefore, the purpose of this study is to clarify the relationship between lumbar region stability and lower extremity motor function in community-dwelling elderly individuals. The results of this study will help us to plan methods to improve the lower extremity motor function of community-dwelling elderly individuals.

MATERIALS AND METHODS

Study Design and Participants

The study design was a cross-sectional study. The participants were 10 community-dwelling elderly individuals, who participated in a health exercise class in Nanto City (male, 1; females, 9; age: 79.3 ± 7.0 years, height: 149.0 ± 4.1 cm, weight: 51.6 ± 8.5 kg). The participants were those who were able to walk independently without a walking aid, had no specific orthopedic diseases of the lumbar or hip joints, and had no obvious limitation of the hip joint range of motion (hip flexion angle: $107.5 \pm 5.4^\circ$, hip extension angle: $10.5 \pm 1.6^\circ$). As an ethical consideration, this study was conducted with sufficient explanation and written consent from the participants. In addition, this study was conducted with the approval of the ethics committee of Nanto Visiting Nurse Station (approval number: 2020.NHS.09).

Measurement of Lumbar Region Stability and Lower Extremity Motor Function

The lumbar region extension angle during the hip extension movement test in the prone position was used as an index of lumbar region stability. Additionally, the Short Physical Performance Battery (SPPB) was used as an index of lower extremity motor function [15, 16]. Tests using hip extension movement test in the prone position have been used to assess lumbar region stability and movement patterns [17-19]. Inertial motion sensors (TSND151, ATR-Promotions, Sagara, Japan) and receiving software (Sensor Controller, ATR-Promotions, Sagara, Japan) were used to measure the lumbar region extension angle. The inertial motion sensors were placed at three locations: the right thigh (posterior surface of the thigh at the midpoint of the sciatic tuberosity and popliteal fossa), lumbosacral vertebral transition (top edge of the sensor placed at the upper edge of the first sacrum vertebra), and thoracolumbar vertebral transition (top edge of the sensor placed at the upper edge of the first lumbar vertebra) (Fig. 1a). The settings of the receiving software were as follows: the acceleration range of the sensor was ± 8 G, angular velocity range was ± 1.000 dps, and sampling interval was 10 ms. As a measurement procedure, the participants performed the right hip extension movement to the final position of hip extension in an automatic movement for 3 s. In this case, the participants were held in the final position for 3 s (Fig. 1b). The measurement was conducted once, and the hip extension movement test was practiced once before the measurement. For data analysis, the lumbar region extension angle was defined as the difference between the sensor tilt angle at the thoracolumbar vertebral transition and the sensor tilt angle at the lumbosacral vertebral transition. Subsequently, the lumbar region extension angles of the right thigh at the inertial sensor 10° (10° tilt) and maximum tilt angle (maximum tilt) were calculated, respectively.

SPPB, which is used as an index of lower extremity motor function, is an evaluation battery consisting of three items: normal walking speed as an assessment of walking ability, time to hold different standing postures as an assessment of standing balance ability, and the five-repetition sit-to-stand test as an assessment of lower extremity muscle strength, and is used to reflect the lower extremity motor function of the elderly individuals [15]. Each of these three evaluation items

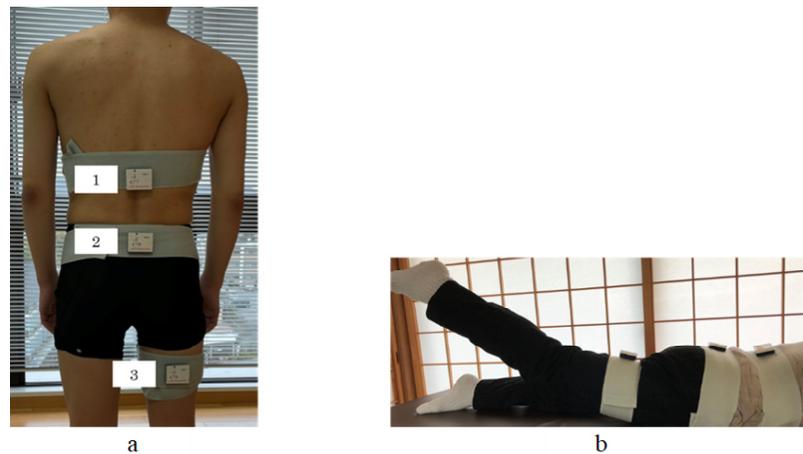


Figure 1. Location of the inertial sensor (a) and hip extension movement test (b); a-1: The top edge of the sensor is placed at the top edge of the first lumbar vertebra; a-2: The top edge of the sensor is placed at the top edge of the first sacral vertebra; a-3: Midpoint of the sciatic tuberosity and popliteal fossa;

b: Maximum hip extension movement

was graded on a scale of 0 to 4 points [15], and those with a higher total score meant that they had superior lower extremity motor function. The measurement method of SPPB in this study was based on the method of Makizako et al. [16], and the normal walking speed, holding time of the tandem position, and five-repetition sit-to-stand test were measured. For the measurement of normal walking speed, a walking path was set up with a measurement section of 2.4 m (8 ft) and a 2-m reserve path at both ends of the measurement section. The participants were instructed to walk on the walking path at their normal walking speed, and their walking speed was measured twice. The tandem position was defined as a standing position with the heel of any side in contact with the foot tip with the eyes open [16]. The measurement of the holding time of the tandem position was performed once. One practice session was conducted before the holding of the tandem position. In the five-repetition sit-to-stand test, the participants sat on a 45-cm-high table and folded both upper extremities in front of the chest as the starting posture. The participant was instructed to repeat five consecutive rising movements as quickly as possible, and the time required from the start of the movement to the full standing position after the completion of the five rising movements was measured. The five-repetition sit-to-stand test was performed once. When the knee joint was not in full extension or seated in the standing position, the measurement was repeated. All measurements were performed without the use of walking aids, such as canes or walkers. For the data

analysis of SPPB, one measurement of the holding time of the tandem position and five-repetition sit-to-stand test were used as the representative values; additionally, the average of the two measurements of normal walking speed was used as the representative values of the participants. Based on the method used by Makizako et al. [16] to calculate the scores, the normal walking speed and five-repetition sit-to-stand test were scored from 0 to 4 points, and the holding time of the tandem position was scored from 0 to 2 points, and the score for each evaluation item and the total score of the three evaluation items (maximum 10 points) were calculated.

Statistical Analysis

The statistical analysis was performed using EZR (Easy R, Saitama Medical Center, Jichi Medical University, Saitama, Japan) [20]. The Spearman's rank correlation coefficient was used to analyze the relationship between the lumbar region extension angle and SPPB scores. The significance level was set at 5%.

RESULTS

The lumbar region extension angle during the hip extension movement test and the scores and total scores of each evaluation item in the SPPB are shown in Table 1. The correlation coefficients between the lumbar region extension angle during the hip extension movement test and the scores of each evaluation item and the total score in the SPPB are shown in Table 2. There were no significant correlations between the

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lumbar region extension angle at a 10° tilt and the five-repetition sit-to-stand test scores; however, there were significant negative correlations between the lumbar region extension angle and normal walking speed, holding time of the tandem position, and the SPPB total score (rs=-0.68, p=0.02; rs=-0.72, p=0.01; rs=-0.77, p=0.01). There was no significant correlation between the lumbar region extension angle at maximum tilt and all the SPPB assessment items and total score.

Table 1. Lumbar region extension angle on the hip extension movement test and SPPB scores

Lumbar region extension angle at a 10° tilt (°)	2.0 (1.6-2.7)
Lumbar region extension angle at maximum tilt (°)	5.0 (2.5-9.0)
Normal walking speed score (points)	3.0 (1.3-3.0)
Holding time of the tandem position scores (points)	2.0 (1.3-2.0)
Five-repetition sit-to-stand test scores (points)	1.0 (1.0-2.0)
SPPB Total Score (points)	6.0 (4.0-7.8)

Values are expressed as median (interquartile range).

SPPB: Short Physical Performance Battery

Table 2. Correlation coefficient between the lumbar region extension angle and SPPB Score in hip extension movement test

	Lumbar region extension angle at a 10° tilt (°)	Lumbar region extension angle at maximum tilt (°)
Normal walking speed score (points)	-0.68*	-0.17
Holding time of the tandem position scores (points)	-0.72*	-0.11
Five-repetition sit-to-stand test scores (points)	-0.49	0.31
SPPB Total Score (points)	-0.77*	-0.03

SPPB: Short Physical Performance Battery

* Significant correlation (p < 0.05)

DISCUSSION

This study examined the relationship between lumbar region stability and lower extremity motor function in community-dwelling elderly individuals. The results of this study showed a negative correlation between the lumbar region extension angle at a 10° tilt and the normal walking speed, holding time of the tandem position, and total score in the SPPB. Therefore, it is suggested that a decrease in lumbar region stability in the middle of lower extremity movement may affect the lower extremity motor function in the elderly individuals. In this study, there was no correlation between the lumbar region extension angle at maximum tilt and the SPPB scores; however, there was a correlation between the lumbar region extension angle at a 10° tilt and the SPPB scores. Therefore, the present results suggest that the lumbar region

movement angle in the middle of lower extremity movement is more related to lower extremity motor function than the lumbar region movement angle in the final of lower extremity movement in terms of lumbar region stability. Panjabi [21] proposed that lumbar region stability is important not only in the elastic zone near the end of the range of motion, but also in the neutral zone (the region where physiological intervertebral movement occurs with a slight load). In particular, it has been reported that active control by muscles is largely involved in stability in the neutral zone [22]. In addition, it has been reported that excessive lumbar region movement occurs in the elderly individuals from the early stage of trunk and lower extremity movement compared to the young individuals [23]. Therefore, active control of the lumbar neutral zone, which is the movement of the lumbar region in the middle of lower extremity movement,

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may be insufficient in the elderly due to muscle weakness or delayed muscle activity in the lumbar region; additionally, the lumbar region movement angle in the middle of lower extremity movement may be more involved in the lumbar region stability in lower extremity movement function. In terms of the relationship between the lumbar region extension angle at a 10° tilt, which is the lumbar movement angle in the middle of lower extremity movement, and each item of the SPPB, which is an index of lower extremity movement function, there was no correlation between the lumbar region extension angle at a 10° tilt and five-repetition sit-to-stand test; however, there was a negative correlation between the normal walking speed and the holding time of the tandem position. In the relationship between the lumbar region extension angle at a 10° tilt and normal walking speed, the psoas major muscle [11], which experiences the most age-related muscle atrophy among the lumbar and lower extremity muscle groups in the elderly individuals, has been reported to be associated with walking speed [24]. Furthermore, it has been reported that the psoas major muscle, which influences walking ability, is also related to lumbar region stability [25]. Therefore, it is possible that a decrease in the range of swing of the lower extremity as well as lumbar region instability may have occurred in the elderly individuals due to muscle weakness of the psoas major muscle due to an increase in age, and a negative correlation may have been observed between the lumbar region extension angle at a 10° tilt and the normal walking speed. Furthermore, in the relationship between the lumbar region extension angle at a 10° tilt and the holding time of the tandem position, although the elderly individuals have a lower ability to control posture mainly at the ankle joint and posture control by hip and trunk movements is dominant [26], the holding of the tandem position requires complex control at the ankle joint for posture maintenance due to the characteristic stance of the tandem position with the feet in front and behind [27]. Therefore, it is possible that the elderly individuals maintained their posture by postural control with excessive movement of the lumbar region during holding of the tandem position, resulting in a negative correlation between the lumbar region extension angle at a 10° tilt and the holding time of the tandem position scores. On the other hand, regarding the lack of correlation between the lumbar region extension angle at a 10° tilt and

the five-repetition sit-to-stand test scores, Bohannon et al. [28] reported that knee joint extension muscle strength was the most relevant factor in the five-repetition sit-to-stand test. However, hip extension muscle strength, which is closely related to lumbar region movement [29], has been reported not to be associated with the time of the five-repetition sit-to-stand test [30]. Therefore, the effect of lumbar and hip movements on the time of five-repetition sit-to-stand test was small; additionally, the lumbar region extension angle at a 10° tilt was not related to the five-repetition sit-to-stand test scores. In terms of lumbar stability in elderly people, Miyachi et al. [31] reported that conscious control of lumbar region movement at the start of lower extremity movement stabilizes lumbar region movement in the middle of lower extremity movement. Therefore, the results of this study suggest that it is necessary to focus the lumbar region stability in the middle of lower extremity movement, such as training the lower extremities while the lumbar region is stable, in order to evaluate and treat the deterioration of lower extremity motor function in the elderly individuals.

The first limitation of this study is the number of participants; there were only 10 participants in this study. Therefore, it is necessary to increase the number of participants in the future to examine the relationship between lumbar region stability and lower extremity motor function in community-dwelling elderly individuals. Second, in this study, we could not clarify the causal relationship between low lower extremity motor function due to low lumbar region stability or low lumbar region stability due to low lower extremity motor function. Therefore, it is necessary to verify this causal relationship in the future. Third, this study did not actually measure the lumbar region movement in each SPPB test. Therefore, it is necessary to verify the relationship between the lumbar region movement angle during each SPPB test and the lumbar region movement angle during hip extension movement in the prone position, which is an index of lumbar region stability. Finally, this study was only a cross-sectional study. Therefore, it is necessary to conduct a longitudinal study to verify whether training of the lower extremities while stabilizing the lumbar region in the middle of lower extremity movement improves the lower extremity movement function in community-dwelling elderly individuals.

CONCLUSIONS

The study aimed to determine the relationship between lumbar region stability and lower extremity motor function in community-dwelling elderly individuals. The results showed that lumbar region stability was associated with lower extremity motor function. Therefore, it is necessary to focus on the lumbar region stability in addition to the lower extremities exercise in community-dwelling elderly individuals to evaluate and treat the deterioration of lower extremity motor function in community-dwelling elderly individuals.

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