The effects of ratio in the multifidus muscle thickness according to various angle of mediolateral ramp during double stance

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Abstract. [Purpose] This study was conducted to predict the risks of standing on mediolateral ramps by identifying the ratios of the multifidus muscles on the two sides of the spine when standing postures are maintained on mediolateral ramps of diverse angles. [Subjects and Methods] The study was conducted with 15 healthy adult males. All subjects participated voluntarily. Mediolateral ramps at five angles (0°, 5°, 10°, 15°, and 20°) were used. Ultrasoundography was used to determine the thicknesses of the multifidus muscles under individual conditions. [Results] The ratio of the left/right multifidus muscles showed statistically significant differences as the angle of the mediolateral ramp increased. Post-hoc test results showed that the use of the two multifidus muscles was asymmetric on mediolateral ramps at angles equal to or larger than 10°. [Conclusion] The asymmetric use of the multifidus muscles began on a mediolateral ramp at an angle of 10°, suggesting that subjects with instability in body control might have risk factors such as falls on mediolateral ramps with angles equal to or larger than 10°. Therefore, caregivers must be attentive and/or assist patients and older adults when they are walking on ramps at angles of approximately 10° and up in their daily lives.

Key words: Mediolateral ramp, Multifidus muscle, Ultrasonography

INTRODUCTION

The multifidus muscles on the spine are among the important muscles that maintain the stability of the spine and pelvis1). In the spine neutral position, the contraction of the multifidus muscles on the two sides increases the spine stability and prevents lumbar instability and low back pain2). In particular, they provide greater amounts of stability in the L4/L5 segments, where lumbar instability appears the most frequently3). The proximal stability provided by the multifidus muscles affects the motility of the limbs, which are distal parts4). That is, asymmetric and abnormal contractions of the multifidus muscles affect low back pain and body balance5).

Balance and stability in the body are secured through the complex processes of diverse structures of the body. Strategies for restoring balance and securing stability include the ankle joint strategy, hip joint strategy, and integration strategy. Among these, the integration strategy is used for most external agitations6). The use of the integration strategy requires the cooperative actions of the body segments and the trunk, and the stability of the trunk should be secured for the cooperative movements of the limbs7).

External factors affecting the body’s balance are very diverse due to the development of society. Among the external factors, ramps are a facility for the simultaneous vertical and horizontal movements of walking. To ensure safe walks and the use of facilities via ramps, the angles of ramps have been determined by the Act on Guarantee of Promotion of Convenience of Persons with Disabilities, the Aged, Pregnant Women, etc. in South Korea. Studies on ramps have been continuously...
conducted with respect to ascending and descending slopes to fit the purpose of the use of the ramps. Movements using ramps are very complex due to defects and weakness in the anatomical structures of the lower limbs \(^9\). In addition, ramp gaits can secure stability only when the movements of the knee, hip, and ankle joints are changed to be more diverse compared to movements on flat ground \(^9\). Therefore, if the body lacks the ability to adapt to changes in the ground such as ramps, the risk of falls is high due to lack of stability \(^9\). As such, the environments of ramps increase the risk of falls in cases where physical movements are deficient, such as in older adults and people with disabilities. However, most studies on ramps have been limited to the analysis of body movements on ascending and descending ramps, and studies on environments where people cross the ascending and descending ramps, such as where people cross roadways, are quite insufficient due to changes in social environments.

Therefore, this study was conducted to identify changes in the multifidus muscles while body balance is maintained on mediolateral ramps rather than ascending and descending ramps. This study used mediolateral ramp environments with diverse angles and analyzed the left/right balance of the multifidus muscles, which play an important role in trunk stability when walking on an angled ramp, to provide basic data that informs the field about the risks of increasing mediolateral ramp angles.

**SUBJECTS AND METHODS**

This study was conducted with 15 healthy adult males in their 20s, who voluntarily agreed to participate in the study. All the subjects were right-sided, had no neurological or musculoskeletal disorders, heard sufficient explanations of the purpose of the study, and understood the explanations. To enhance the reliability of the muscle thicknesses measured through ultrasonography, subjects that corresponded to body mass indexes (BMI) that ranged from 18.5 to 24.9 were selected to ensure the homogeneity of the soft tissues \(^11\). The mean age of the study subjects was 22.8 years, the mean height was 171.36 cm, and the mean body weight was 67.4 kg. We declare that the abovementioned manuscript was approved by Ethics Committee of Kyungsung University according to approval number KSU-17-04-004 and that an Informed Consent Form was signed by the participants.

Ultrasound imaging equipment (MyLabTMSix, ESAOTE Europe BV, Netherlands) was used to measure the thicknesses of the multifidus muscles. The multifidus muscles were measured by a proficient expert who had knowledge of the anatomical locations and functions of the multifidus muscles to minimize inter-examiner errors due to muscle locations and applied pressure. The researchers used a convex probe (3.5–5 MHz) to acquire standardized ultrasound images and obtained the clearest images by locating the anatomical position of the muscles between the L4/L5 spinous processes \(^12\). The thicknesses of the multifidus muscles were identified from the acquired images using NIH Image J software (version 1.44 for Windows). The measurements were conducted three times on each subject for each ramp angle condition, the average value was calculated, and the thickness ratios of the left and right multifidus muscles were used as statistics. The thickness ratios of the left/right multifidus muscles were calculated using the following equation.

The measurements were performed while the subjects maintained standing postures with both feet on a mediolateral ramps set at five different angles (0°, 5°, 10°, 15°, and 20°). At all ramp angles, the measurements were performed when the subjects were able to maintain the posture without shaking so that they had sufficient time to ensure stability. The standing postures on the ramp were achieved by having the subjects stand with their feet shoulder width apart, with both soles in contact with the ramp, and place the right foot in the lower position of the mediolateral ramp. The ramp was made of aluminum materials and the angles could be adjusted. The postures were performed with bare feet to remove the variable of shoe shapes. Ramp angles were randomly assigned to the subjects and a 2-minute rest time was provided after each condition.

The data were processed using the statistical program SPSS ver. 18.0 (SPSS Inc., Chicago, IL, USA) for Windows. One-way ANOVAs were used to compare the thickness ratios of the left/right multifidus muscles for each ramp angle. Post-hoc tests were conducted using Tukey’s method to identify the statistical difference of each angle. Statistical significance level \(\alpha\) was set to 0.05.

**RESULTS**

The results of the identification of the ratios of the left/right multifidus muscles for each mediolateral ramp angle are as follows. As the angle of the mediolateral ramp changed, the ratios of the left/right multifidus muscles showed statistically significant differences \((p<0.05)\) (Table 1). According to the results of the post-hoc tests, the ratios of the left/right multifidus muscles measured in the standing postures were maintained on the mediolateral slope at 5°, which was not statistically significantly different from those on flat ground. The ratios of the left/right multifidus muscles measured in the standing postures were maintained on the mediolateral slope at 10° (95.04 ± 3.43), which was statistically significantly different compared to those on flat ground and on an angle of 5° \((p=0.05)\) (Table 1). The ratios of the left/right multifidus muscles measured in the standing postures on the mediolateral slope at 15° and 20° showed statistically significant imbalances compared to those on the mediolateral slope at 0°, 5°, and 10° \((p<0.05)\) (Table 1).
TABLE 1. Comparison of both multifidus ratio according to ramp angle

<table>
<thead>
<tr>
<th>Ramp Angle</th>
<th>0° Ramp</th>
<th>5° Ramp</th>
<th>10° Ramp</th>
<th>15° Ramp</th>
<th>20° Ramp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio</td>
<td>100.4 ± 1.6</td>
<td>99.1 ± 2.6</td>
<td>95.0 ± 3.4</td>
<td>87.1 ± 6.3</td>
<td>85.5 ± 6.1</td>
</tr>
</tbody>
</table>

Each value represents the mean ± SD. The values with different superscripts (†, ‡) in the same column are significantly different (p<0.05) by Tukey’s measure. *Statistically significant, p<0.05

DISCUSSION

Due to changes in society, the use of automobiles has been increasing and people use both sides of the road sidewalks and use crosswalks that go across the roadway. Although the Act on Guarantee of Promotion of Convenience of Persons with Disabilities, the Aged, Pregnant Women, etc. provides standards for the environments where people walk, due to changes in age, people are using part of the roadway as a crosswalk and consequently, people are using ramps that are higher than the ramps that have been specified by the law. In addition, people use crosswalks across such ramps. Therefore, this study was conducted to analyze the effects of crosswalk environments on human bodies, thereby studying mediolateral ramps that can prevent falls among older adults and people with disabilities to prepare standards for environments such as crosswalks and ensure stability.

According to the results of this study, standing postures on mediolateral slopes at 5° did not show any statistical difference in the uses of the multifidus muscles on the two sides from standing postures on flat ground, indicating that excessive trunk asymmetry did not occur. However, in the case of standing postures on the mediolateral slope at 10°, the uses of the multifidus muscles on the two sides became asymmetric, indicating that the postures affected the rotation or extension of the trunk. These results were observed at all angles greater than 10° among the angles of the mediolateral slopes used in this study. These results mean that the body changes occur with an angle smaller than the 16° reported to be the angle where ascending/descending ramps affect changes in gait. This means that the risk of mediolateral slopes is higher than that of ascending and descending slopes. In addition, whereas gaits with the same movements on the left and right side of the body are performed on ascending and descending slopes, mediolateral slopes cause asymmetry in which the left and right sides of the body generate different mechanisms. Therefore, the risk of falls can be said to be higher on mediolateral slopes. Among the mechanisms that maintain body balance, the weight shifting strategy adjusts left/right balance and is a more important strategy for patients with cerebral palsy and hemiplegia compared to the anteroposterior balance strategy. Therefore, in the case of patients, although there are risks on ascending and descending slopes, risks on mediolateral slopes can be said to be higher.

According to previous studies, the use of the gluteus medius increases on mediolateral slopes at 15° and this angle affects stability. However, in the present study, which observed the multifidus muscles that directly affect the stability of the trunk and show proactive movements as deep muscles, the multifidus muscles were identified as showing left/right asymmetry at 10°, which is smaller than the 15° slope angle.

Based on the results of this study, the risks of using a mediolateral ramp increase beginning at an angle of 10° and further studies of risks in environments where ramps are crossed, such as crosswalks installed on sloped roads, are necessary. In terms of limitations, since this study was conducted with 15 normal adults, the results may not be safely generalized and since muscles cannot be measured when movements such as gaits are done due to the characteristics of deep muscle measuring equipment, the results cannot be safely identified as results during gaits. More studies on mediolateral ramps should be conducted hereafter with diverse subjects and more detailed angles.

Conflict of interest

There are no conflicts of interest to declare.

Financial disclosure

None.

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