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Comparison of Differences in Kinetics of Elderly Women at Risk of Falling during Lumbar Stabilization Exercise per Obstacle Height

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***Abstract*—This study was performed to identify the kinetic and kinematic effects of the lumbar stabilization exercise on obstacle gait(5.2cm,15.2cm) among elderly women at risk of falls. The study subjects were 32 women aged 65 and over with a risk of falls identified by the Tinetti test. They were randomly allocated into 2 groups: the experimental group and the control group, and the lumbar stabilization exercise program was given to the experimental group for 12 weeks. The chi-square test and t-test were used to test homogeneity and compare baseline results of kinetic measurements on obstacle gait between the experimental and control groups. To identify the effects of the lumbar stabilization exercise program among study subjects, repeated measures of analysis of variance (ANOVA) were performed. Regarding kinetic variables, the knee joint angle of the propulsion foot significantly increased when overcoming a 5.2cm obstacle. When overcoming a 15.2cm obstacle, the obstacle overcoming speed and the knee joint angles of the support and propulsion feet significantly increased. However, the shortest vertical distance between the support and propulsion feet was reduced considerably. Our findings suggest that lumbar stabilization exercises could be a promising therapeutic exercise method for fall prevention and management in elderly women at risk of falling, providing reassurance about the effectiveness of our study's findings and the potential benefits for the elderly and other patients requiring trunk stability.**

***Keywords*— Obstacles; elderly women; falling risk; kinetics; lumbar stabilization exercise.**

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I. INTRODUCTION

A fall is an injury caused by falling to a low position due to a sudden change in posture [1]. Elderly people have decreased cadence and stride length to compensate for reduced walking balance and stability; the basal surface increases and walking speed decreases [2]. In other words, as aging progresses, the ability to control balance decreases, and the ability to propel the body forward decreases, increasing the risk of falling while walking [3]. In particular, falls are caused by obstacles such as thresholds, sidewalk blocks, and safety barriers in parking lots. It occurs frequently [3], [4].

Elderly people who have experienced a fall experience a vicious cycle in which their activity level decreases, and they develop psychological problems such as depression and anxiety due to fear of falling again, which limits their physical function and social activities, lowering their health-related quality of life and increasing the risk of falling. It is repeated [5], [6]. In particular, elderly women are exposed to a more severe risk of fractures due to falls than elderly men due to osteoporosis and joint abnormalities due to lack of estrogen after menopause [7].

It is estimated that approximately 6.26 million elderly people will suffer from falls worldwide by 2050, and as a result, elderly healthcare costs are expected to increase rapidly [8]. Accordingly, the need for intervention to prevent falls, a major threat to the health of the elderly, has emerged, and many developed countries have recently developed and implemented fall prevention programs for the elderly [9].

As interventions related to fall prevention, complex programs such as exercise, education, and environmental management have been developed [10], [11], [12], and among these, exercise has a positive effect on improving the body's ability to maintain balance by improving muscle strength, flexibility, and balance. It is most widely used as a fall prevention program [13].

Lumbar stabilization exercise simultaneously activates the transversus abdominis and multifidus muscles innervated by the cerebral hemisphere to restore muscle and movement control ability, thereby increasing postural stability, improving balance ability, and promoting normal exercise patterns by promoting gait patterns. It is exercise [14]. In addition, it is more effective than mobilization exercises in terms of efficiency in increasing the strength of trunk muscles, and by adopting a method that contributes to lumbar stability and posture control with tonic or postural muscles, it reduces the risk of accidents during exercise rather than existing muscle function strengthening methods. It has advantages [15], [16]. It also has the benefit of having fewer restrictions on location, time, and cost. In particular, when combined with a Swiss ball, it stimulates proprioceptors more strongly, improving the sense of balance and maintenance ability, thereby improving physical function [17].

Until recently, most of the research on lumbar stabilization exercises was conducted as treatment and research to reduce pain in patients with back pain, herniated discs, and stroke patients, and studies related to walking with obstacles [18], [20]. Research has been conducted on general elderly women through structured exercise, Tai Chi Chuan, multicomponent exercise, and aquatic exercise [21], [22], [23], [24], [25], but it is insufficient to quantitatively prove that lumbar stabilization exercise is an effective exercise program to prevent falls. Research on the effectiveness of postural balance in avoiding falls in at-risk elderly women is rare.

Accordingly, this study selected elderly women at risk of falling as research subjects through the Tinetti stability test [26] and conducted a 12-week lumbar stabilization exercise program. Then, the bathroom threshold (5.2 cm) and the road where falls most frequently occur were selected. This study evaluated changes in measurable kinematic characteristics when walking over obstacles at the chin (15.2 cm) to suggest the feasibility of lumbar stabilization exercises as an efficient therapeutic method for preventing and managing falls in elderly women.

II. Materials and Method

A. Subject

The subjects of this study were elderly women between the ages of 65 and 80 who understood the contents of this study and agreed to participate among elderly women at senior centers located in Districts D and N of G Metropolitan City. Study subjects are those who have no visual or hearing problems and can walk independently, those who do not have neurological problems such as damage to the central nervous system or vestibular system, those who do not have orthopedic issues such as fractures or severe osteoarthritis, those who have no experience of falling, and those who have Tinetti The mobility test was conducted on elderly women with scores between 19 and 24.

Forty-seven research subjects were selected and assigned to 25 experimental groups and 22 control groups. Excluding two elderly women who experienced falls during the research process (experimental group) and two who did not take measurements (control group), 43 people participated until the final experiment. Eleven people (7 in the experimental group, 4 in the control group) who could not be measured due to a marker falling off during measurement or noise in electromyography analysis were eliminated, and a total of 32 people (16 in the experimental group and 16 in the control group) were selected for analysis.

B. Exercise program

In this study, the lumbar stabilization exercise program proposed by Mahmood (2022) and Norris (1995) was applied to the experimental group [27], [28]. The exercise consisted of 10 minutes of warm-up, 40 minutes of main exercise, and 10 minutes of cool-down. The first six weeks were performed on the floor, and the remaining six weeks were performed on a Swiss ball. A researcher and a physical therapist conducted the exercise program.

The warm-up and cool-down exercises included lower extremity-centered stretching for 10 minutes each, and the main exercise included bridge exercise 1, bridge exercise 2, a footbridge exercise on one leg, a side support exercise, arm raising in a four-legged position, and leg lifting in a four-legged position. A total of 7 exercises were performed, such as lifting the opposite arm and leg in a quadruped position for 10 seconds each for three sets.

C. Procedure

We filmed obstacle walking movements using six infrared cameras (Motion Master200, Visol, USA) to collect video data. The infrared camera, which can obtain 3D position coordinates at the same time as shooting, was used to shoot with an exposure time of 1/500 second and a camera speed of 200 frames per second (200Hz).

For infrared tracking, the marker was attached using double-sided tape, and the attachment sites were the left and right Anterior Superior Iliac Spine (ASIS), Posterior Superior Iliac Spine (PSIS), and the center point of the left and right femur. (mid-thigh), left and right lateral epicondyle left and right medial epicondyle, left and right mid shank, left and right lateral malleolus, left and right These were the medial malleolus, the left and right heels, and the tips of the left and right big toes. Two ground reaction force devices (AMTIORG-6, AMTI, USA) were used to collect ground reaction force data while walking, and ground reaction force data was collected at 2000 Hz.

There are two obstacle heights: 5.2cm and 15.2cm. It was set to height, and the size was 60cm wide and 10cm wide. It was installed between two ground reaction machines. As a kinematic variable, obstacle overcoming speed was calculated by dividing the horizontal distance from the moment the propulsion foot leaves the ground before overcoming the obstacle to the section where the heel touches the ground again after overcoming the obstacle by the time taken, and the vertical shortest distance was calculated to overcome the obstacle. The vertical distance between the height of the obstacle before and the forefoot of the propulsion foot (shortest vertical distance of the propulsion foot) and the vertical distance between the height of the obstacle and the forefoot of the support foot after overcoming the obstacle (shortest vertical distance of the support foot) were measured. The knee joint angle is the point where the vertical position of the forefoot of the driving foot matches the height of the obstacle before overcoming the obstacle (knee joint angle of the driving foot), and the point where the vertical position of the forefoot of the supporting foot matches the height of the obstacle after overcoming the obstacle (knee joint of the supporting foot) The angle of the knee joint was measured.

D. Analysis

All data were analyzed using the SPSS 18.0 program and presented using mean and standard deviation. Repeated measures ANOVA was used to test the differences in changes between groups over time in measurement items to compare the effect of applying the lumbar stabilization exercise program. The significance level was set at α=0.05.

III. Results and Discussion

A. General characteristics of research subjects

There was no statistically significant difference in height and weight between the experimental and control groups (Table 1).

TABLE I

General characteristics of study subjects

	Experimental group	Control group	p-value
Height (㎝)	149.64±6.26	147.78±6.04	0.400
Weight (kg)	54.19±6.04	52.79±7.69	0.571

B. Comparison of kinematic variables when overcoming a 5.2cm obstacle

When the kinematic variables were compared when walking over a 5.2cm obstacle using the lumbar stabilization exercise program, the knee joint angle of the propulsion foot was statistically significantly increased in the experimental and control groups (Table 2).

TABLE II

Comparison of kinematic characteristics of lumbar stabilization exercise program when overcoming a 5.2 ㎝ obstacle

		0 Week	6 Week	12 Week	p-value
Overcoming speed (m/sec)	experiment al group/control group	1.53±0.18 1.58±0.11	1.52±0.57 1.57±0.09	1.55±0.17 1.58±0.10	T: 0.211 G: 0.400 T×G: 0.605
Shortest vertical distance_support foot (㎝)	experiment al group/control group	7.88±1.22 7.83±1.49	7.57±1.41 7.70±1.37	7.23±1.62 7.60±1.45	T: 0.000 G: 0.786 T×G: 0.064
Shortest vertical distance_propulsion foot (㎝)	experiment al group/control group	8.66±1.82 7.89±1.75	8.49±1.78 7.88±1.69	8.42±1.72 7.90±1.81	T: 0.468 G: 0.310 T×G: 0.402
Knee joint angle_supp ort foot (°)	experiment al group/control group	110.49±4.22 111.91±5.45	112.09±3.94 112.50±5.06	112.65±3.98 112.72±4.78	T: 0.000 G: 0.693 T×G: 0.079
Knee joint angle_propulsion foot (°)	experiment al group/control group	109.05±3.67 111.37±4.26	109.60±4.00 111.07±4.6	110.39±4.23 110.66±4.74	T: 0.695 G: 0.358 T×G: 0.038

C. Comparison of Kinematic Variables when Overcoming a 15.2cm Obstacle

As a result of comparing the kinematic variables when walking over a 15.2cm obstacle according to the application of the lumbar stabilization exercise program, the measurement values of the obstacle overcoming speed and knee joint angles of the support and propulsion feet of the experimental and control groups according to the application of the lumbar stabilization exercise were statistically significant. The shortest vertical distance between the support and propulsion feet decreased statistically significantly in the experimental and control groups according to the application of the lumbar stabilization exercise (Table 3).

TABLE III

Comparison of kinematic characteristics of lumbar stabilization exercise program when overcoming a 15.2 ㎝ obstacle

		0 Week	6 Week	12 Week	p-value
Overcoming speed (m/sec)	experiment al group/control group	1.37±0.08 1.37±0.12	1.38±0.09 1.35±0.12	1.41±0.08 1.34±0.13	T: 0.314 G: 0.388 T×G: 0.002
Shortest vertical distance_support foot (㎝)	experimental group/control group	4.17±2.10 4.19±0.88	3.95±2.07 4.19±1.00	3.81±1.97 4.23±1.00	T: 0.088 G: 0.690 T×G: 0.046
Shortest vertical distance_propulsion foot(㎝)	experiment al group/control group	5.84±2.30 5.72±1.38	5.59±2.38 5.66±1.62	5.29±2.37 5.81±1.55	T: 0.054 G: 0.823 T×G: 0.007
Knee joint angle_support foot (°)	experiment al group/control group	98.01±12.10 107.18±8.48	98.87±11.98 107.08±8.21	99.35±11.34 106.83±8.71	T: 0.240 G: 0.029 T×G: 0.042
Knee joint angle_propulsion foot (°)	experiment al group/control group	98.18±12.40 104.66±9.24	98.88±12.69 104.82±9.07	99.56±12.89 104.83±9.26	T: 0.000 G: 0.141 T×G: 0.011

D. Discussion

To maintain health, exercise should be possible in a space with few time and space constraints [29]. Lumbar stabilization exercise maintains the stability of the spinal column and trunk by inducing balance between the spinal flexors and spinal extensors. It improves the balance of the spinal skeletal muscles by reducing the mechanical stress on the spinal structure as much as possible [30] and enhances the balance of the large-scale muscle system. It promotes the mobilization of coordinated motor units with local muscle systems such as the transversus abdominis, diaphragm, and multifidus muscles, balances posture, harmonizes body mobility, improves gait patterns, and promotes standard movement patterns to reduce excessive muscle tension [31], [32].

A decrease in muscle strength and mobility due to aging affects the maintenance of balance between the vertebral skeletal muscles and the vertebral skeletal system, making it impossible to maintain normal body alignment [33]. As a result, an imbalance between the left and right skeletal muscles occurs, which reduces balance ability and increases the risk of falls. It can be triggered [34]. A clinical experiment was conducted on the belief that lumbar stabilization exercise, which can restore body alignment by improving the strength and mobility of the spinal skeletal muscles, can secure the spine's stability and improve balance ability.

As a result of measuring the kinematic characteristics according to the lumbar stabilization exercise program, in the experimental group, the speed of overcoming obstacles was significantly faster at 15.2 cm, and the shortest vertical distance was considerably lower on the support and propulsion feet when overcoming a 15.2 cm obstacle. The propulsion leg's knee joint angle significantly increased when overcoming a 5.2cm obstacle. It increased dramatically in both the support leg and the propulsion foot when overcoming a 15.2cm obstacle.

Choi and Yoon [24] conducted water exercise for 12 weeks on elderly women and reported that as the training period increased, the speed of overcoming obstacles tended to increase when overcoming obstacles of 0%, 30%, and 50% of lower limb length. It was partially consistent with this study and with the study by Kim and Yu [23], who reported that the shortest vertical distance value was decreased after underwater exercise. Still, the shortest vertical distance was decreased after gradual strength training to improve lower extremity muscle strength. The results contradicted the study by Lamoureux et al. [35], which reported an increase in body balance. This is because this study's approach of overcoming obstacles by improving body balance ability and the effect of simply increasing lower limb strength were investigated. The research and applied exercise methods were believed to be different, resulting in other results.

In general, to prevent falls when walking over obstacles, it is better to bend the knee significantly when crossing the obstacle to increase the shortest vertical distance [36]. However, if the strength to overcome the obstacle stably is secured, it can be overcome in terms of energy consumption. As in the study by Kim and Yu [23], which reported that it is more efficient to overcome obstacles before exercising, the inefficient movement of lifting the legs excessively to overcome the obstacle safely is prevented by ensuring postural stability through lumbar stabilization exercises. It is believed that the speed of overcoming barriers is increased by bending the knees slightly and reducing the vertical distance to overcome obstacles at a low level.

As a result of the above results, 12 weeks of lumbar stabilization exercise for elderly women at risk of falling improves the function of the transversus abdominis and multifidus muscles that contribute to posture control of the trunk, enhances the ability to maintain body balance and suppresses the elderly's excessive obstacle walking movements, providing accurate and smooth walking. It is thought to have improved the ability to overcome the barriers. In the future, it is believed that lumbar stabilization exercises should be considered an efficient therapeutic method for fall prevention and management in elderly women at risk of falling.

IV. Conclusion

In this study, an experiment was conducted on elderly women at risk of falling to investigate the effect of lumbar stabilization exercise on the kinematics and kinetic variables of these women. In the kinematic variables, the knee joint angle of the propulsion foot significantly increased when overcoming a 5.2 cm obstacle. When overcoming a 15.2cm obstacle, the obstacle overcoming speed and the knee joint angle between the support and propulsion feet significantly increased. The shortest vertical distance between the support and propulsion feet significantly decreased.

Lumbar stabilization exercise applied for 12 weeks to elderly women at risk of falling improved the function of the trunk muscles that contribute to posture control of the trunk, thereby improving the ability to maintain body balance and suppressing excessive obstacle walking movements in elderly women at risk of falling. It was concluded that this improved the ability to overcome the barriers accurately and smoothly. Lumbar stabilization exercises should be considered an efficient therapeutic method for fall prevention and management in elderly women at risk of falling. Future research is needed on not only the elderly but also various patients who require trunk stability.

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