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Original Article

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Effects of Progressive Core and Ankle Muscle Strengthening Exercises Using Thera-Band on Body Balance

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Purpose: This study aims to compare the effect on balance during core and ankle muscle strengthening exercises using the Thera-Band.
Methods: 21 healthy college students were recruited. The participants were divided into a core strengthening group (CSG), an ankle strengthening group (ASG), and a non-exercise group (NEG). CSG and ASG were performed twice a week for a total of 4 weeks, and static and dynamic balance were measured before and after the intervention. The static balance were measured as stability index and weight distribution index using Tetrax®. The dynamic balance was measured in each direction by the Y balance test. The Thera-Band intensity was increased after 2 weeks of exercise, and the exercise was subsequently performed.
Results: Participants showed static balance with Tetrax®, a significant difference was noted between normal eye closes and pillow with eye closes in ASG ($p < 0.05$). In the case of dynamic balance with the Y balance test, a significant difference was observed in posterolateral direction (PL) and composite score (CS) between each group for the pre- and post-intervention differences ($p < 0.05$). A significant difference was observed between PL and CS in CSG ($p < 0.05$).
Conclusion: These findings show that the progressive Thera-Band exercise had a positive effect on balance abilities. It was confirmed that core strengthening was effective for dynamic balance, and ankle strengthening was effective for static balance.

Keywords: Core exercise, Ankle, Balance, Y-balance test, Thera-Band

INTRODUCTION

Balance is a complex motor control task that involves the integration of sensory information, neural system processing, and biomechanical factors.[1] Postural stability, called balance, is the ability to control the center of gravity with respect to the base of support,[2] and body stabilization is the ability of the muscles around the lumbar pelvis, the center of the body, to functionally control postural stability during a generally static and dynamic posture.[3] Maintaining balance is an essential factor in improving daily life activities and athletic ability and is also important in preventing injuries.[4] While static stability relates to balance under undisturbed conditions while standing quietly, dynamic stability is balancing or recovering against internal or external disturbances.[5] The body skeleton provides passive mechanical stability in static conditions, whereas in dynamic conditions, the body skeleton can prolong the stabilization time by inhibiting proper postural adjustment.[6]

Factors influencing balance include somatosensory, sensory information and coordination from the visual and vestibular systems, and motor responses that affect joint range of motion and intensity.[7] To improve balance control, studies of various methods, including muscle strength exercise and proprioceptive sensory training using visual feedback and biofeedback, have been conducted.[1] A previouis study on balance training showed little improvement in untrained balance although strong improvement in trained balance.[8] However, the final performance and neuromuscular adaptation obtained through training depend on movements involving external and internal conditions. Due to the evolution of bipedal walking, humans have to control high centers of mass through small supports; therefore, even in static conditions, the central nervous system must apply an appropriate strategy to dynamically control balance.[9]

A Study aimed at forward and backward support displacement and postural responses to unexpected small and slow external disturbances have shown that most individuals reposition COGs primarily by swinging

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with flexible inverted pendulum for ankles with little hip or knee motion. These stereotyped muscle activation patterns were called "ankle joint strategies".[10] Ankle joints play an important role in balancing the human body as a major part of restoration and proprioceptive functions.[11] Ankle muscle injuries, such as traumatic injuries or neuromodulation disorders, can dramatically interfere with the walking ability of various groups. Successfully maintaining dynamic balance is particularly important. Loss of balance can potentially lead to falls and result in long-term injuries that may result in loss of mobility and functional independence.[12] Additionally, lower extremity muscle strength weakening is correlated with functional physical strength weakening, including gait instability, which is reported to also lead to falls.[13,14] Conversely, when responding to larger and faster support displacements, the primary action of most individuals occurs in the hips, which leads to active trunk rotation or the so-called "hip joint strategy".[15] Chrisco et al.[16] reported that muscle cooperation was activated first in the supporter with a small support surface and rapid shaking, followed by thigh muscle activation.

For the arms and legs to produce the desired level of force and maintain movement in the same direction, the core muscles must maintain the spinal balance.[17,18] Core muscles are the muscles located in the pelvis of the spine abdomen that provide stability for muscles in the extremities, thereby facilitating movement and functional ability. These muscles are frequently activated when the limbs move, thereby correcting pelvic muscles, increasing the sense of balance, and maintaining stability and motility of the human body.[19] The core is a box-shaped muscle group within the body consisting of the forward abdominal muscles, posterior vertebrae and gluteal muscles, upper diaphragm, and lower pelvic floor muscles and pelvic muscles below.[20] Core muscles provide stabilization to the spinal column, pelvis, and kinetic chain during functional movement.[21]

Lower extremity muscle strength exercise using the Thera-Band is effective in improving muscle strength and balance control ability,[22] and resistance exercise using the Thera-Band improves muscle strength and has a positive effect on improving endurance, balance, gait, and grip strength.[23] Protocols using Thera-Bands for muscle development are established and can be applied to several muscle groups. The progressive 6-week strength training protocol using rubber exercise tubes resulted in improvements in both ankle strength and joint position sensation.[24] Patterson RM et al.[24] showed that the 6-week gradual resistance-Thera-Band exercise increased the strength of dorsal and plantar flexor muscles and inversion and eversion muscles. Moreover, they demonstrated that core muscle exercise with Thera-Band is effective in improving dynamic balance.[25] Resistance exercises using Thera-Band are frequently performed because they are less prone to injury, have constant tension, and can be easily performed by anyone.[26,27] Mainly, Thera-Band can freely control the load intensity, and it is widely used in rehabilitation treatment for muscle strength exercise, sports trauma, and disability since it enables customized training considering the individual's athletic ability.[28] In other words, strength exercise using the resistance of the Thera-Band offers a safe form of resistance; therefore, there is little risk of injury, the cost is low, and it is effective in improving muscle strength.[29]

The ankle and core are essential body parts that maintain stability. However, the previous study investigated only the sense of strength and static balance by ankle and core muscle strengthening using the Thera-Band. Ankle and core strengthening is important for body balance; however, studies on whether strength training exercises using Thera-Band are effective for static and dynamic balance are insufficient. Therefore, this study aims to compare the effects of progressive core and ankle muscle strengthening exercises on balance using Thera-Band and determine an exercise using Thera-Band, which is easy to control load strength and can be used in rehabilitation treatment.

METHODS

1. Subjects

A total of 21 adults in their twenties who were ordinary students attending Asan S University in Chung-nam were included in the study. The participants were selected following satisfaction of the inclusion criteria, received sufficient explanation of the purpose and method of the study, and voluntarily provided written informed consent. The inclusion criteria were as follows: 1) those without stroke, mental illness, or cognitive impairment in the last 2 years, 2) those who without low back pain or orthopedic or neurological disorders in the lower extremities in the last 6 months, 3) those without pain that limits exercise performance, 4) those who were not taking medicines related to muscle strength, 5) those without abnormalities in the vestibular organ, and 6) those who understood the purpose and agreed to participate in the study. The study was conducted following approval from the Bioethics Committee of Sun Moon University (SM-202005-022-1). All participants were randomly assigned to each group, and height and weight were measured using an autonomic BMI-measuring radiometer (BSM370, Korea, 2011). The characteristics of all participants, including sex, age, height, and weight, are presented in Table 1. There was no significant difference among groups in general

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Table 1. General characteristics of participants (n=21)

	Non-exercise group (n=7)	Core strengthening group (n=7)	Ankle strengthening group (n=7)
Sex (%)			
Male	6 (85.7)	2 (28.6)	4 (57.1)
Female	1 (14.3)	5 (71.4)	3 (42.9)
Age (yr)	24.1±3.5	21.1±1.1	22.1±1.4
Height (cm)	170.0±7.3	164.8±7.4	171.6±11.9
Weight (kg)	77.0±17.6	64.3±14.1	70.5±13.8

Mean±SD, All values are presented as mean±standard deviation.

characteristics except for gender (p>0.05).

2. Experimental methods

The measurements in this study leveraged the Balanced Capacity Assessment and Training System (Tetrax®, Tetra-ataxiometric posturography, Israel), which is a system capable of simultaneously implementing balanced diagnosis and biofeedback training therapy, and the Y balance test (YBT), which is developed to improve the repeatability of measurements of the Star Excursion Balance Test (SEBT).

In this study, the 21 participants were randomly divided into non-exercise controls, experimental groups to strengthen core muscles, and experimental groups to strengthen ankle muscles, with seven participants per group. The two groups exercised twice a week for 4 weeks, and the participants were allowed 1-minute rest in each set. Regardless of sex, the core strengthening group (CSG) was allocated green and blue Thera-Bands, whereas the ankle strengthening group (ASG) was assigned blue and black Thera-Bands. The strength of the Thera-Band was set at 150% and 170% for core muscle strengthening and ankle muscle strengthening, respectively. All exercises were tested by varying the number of times and the color of the Thera-Band for progressive muscle strengthening. The black band had the strongest tension flowing up by blue and green. Core muscle strengthening increased the number of times from three to four sets using green Thera-Bands over weeks 1–2 and from three to four sets using blue Thera-Bands over weeks 3–4. Ankle muscle strengthening increased the number of times from three to four sets of exercises using blue Thera-Bands over weeks 1–2 and from three to four sets using black Thera-Bands over weeks 3–4. To determine if the participants met the intensity of the motion pursued in this study, a total of 10 steps of motion awareness scale (Rating of Perceived Exerion [RPE] scale, RPE) were used after all exercises. The RPE scale has become a standard method for evaluating perceived forces in exercise testing, training, and rehabilitation and has been validated against objective indications of exercise intensity. It is mainly used in exercise science to monitor exercise intensity and is most often used as a method of quantifying exercise intensity during aerobic trainings.[30] Experiments were conducted by gradually setting the exercise intensity felt by the individual from steps five to seven. As for the number of exercises per set, the number of RPE levels of 5 to 7 intensity was derived through a pilot study.

1) Core muscle strengthening

The CSG included the following exercises: "Thera-Band Abdominal Crunch In Supine," "Thera-Band Abdominal Oblique Crunch In Supine," "Thera-Band Trunk Rotation In Sitting," and "Standing Back Extension" exercises. In the case of "Thera-Band Abdominal Oblique Crunch In Supine" and "Thera-Band Trunk Rotation In Sitting," a total of 60 exercises performed in all four types were defined as one set.

(1) Thera-Band Abdominal Crunch In Supine: after fixing the end of the Thera-Band to the object, the participant lies upright and holds the middle part of the Thera-Band with knees bent. Both arms remain pinned, and the scapulars are lifted off the floor.

(2) Thera-Band Abdominal Oblique Crunch In Supine: after fixing the end of the Thera-Band to the object, the subject lies upright and holds the middle part of the Thera-Band with knees bent. Both arms remain pinned, and the scapulars are lifted off the floor. At this time, the body is bent diagonally toward the left or right side.

(3) Thera-Band Trunk Rotation In Sitting: the participant holds one end of the Thera-Band with both hands while seated in a chair and subsequently rotates the trunk in the opposite direction of the Thera-Band.

(4) Standing Back Extension: the participant is fixed by stepping on the middle of the band in a lunge position with one foot protruding forward. Hold both ends of the band and keep the elbows bent, using the back muscles to denigrate the trunk.

2) Ankle muscle strengthening

The ASG performed the following exercises: "Dorsiflexion," "Plantar Flexion," "Inversion," and "Eversion." In the case of "Inversion" and "Eversion" the examiner assists by fixing the participant's leg to prevent compensation of other joints and muscles during ankle movement. A total of 40 exercises that performed all four types of movements were defined as one set, and three or four sets were performed in consideration of the gradual movement. These exercises were equally performed on both ankles.

(1) Dorsiflexion: in a sitting position with both legs straightened, the

participant wraps the Thera-Band around the metatarsal bones and pulls the foot of the ankle toward the head against the force of the Thera-Band stretched forward.

(2) Plantar Flexion: in a sitting position with both legs straightened, the participant wraps the Thera-Band around the metatarsal bones and pushes the foot of the ankle downward against the force of the stretched Thera-Band.

(3) Inversion: in a sitting position with both legs straightened, the participant wraps the Thera-Band around the metatarsal bone and subsequently turns the ankle moving inward against the force of the Thera-Band stretched to one side.

(4) Eversion: in a sitting position with both legs stretched out, the participant wraps the Thera-Band around the metatarsal bone and subsequently turns the ankle moving outward against the force of the Thera-Band stretched to one side

3. Measurements

1) Static balance

Tetrax®, which is a balance ability evaluation and training system, can analyze the interaction and synchronization between each area by measuring the toe and heel of each of the left and right four areas through the measurement and evaluation of balance ability. Furthermore, it is possible to identify various causes of balance impairment. The pressure on the platform is digitally integrated and processed by the computer. The participants were instructed to place their feet side by side on a foot-shaped platform and not to speak or move during the measurement. Four separate plates were used, and the vertical pressures at the distal and proximal ends of both feet were measured. The pressure on each plate was measured, and data were analyzed using the Tetrax® software program. The participants were asked to open and close their eyes on a stable platform (NO; eye open, NC; eye close) and unstable support surface using pillows (PO; eye open with pillow, PC; eye close with pillow), respectively, and the pressure was measured four times. The participant's foot was then placed on the plate in the normal neutral position and was asked to perform it for 32 s.

The stability index (ST) measures the change in weight on the four force plates. The larger the ST, the more unstable is the change in weight, suggesting that changes in the percentage (%) of body weight on the four tread plates frequently occur. The weight distribution index (WDI) is a percentage of the weight distribution on four tread plates based on 25% of the weight being loaded on one tread plate. A larger weight distribution index indicates that the weight distribution is inaccurate, suggesting that the percentage of body weight changes frequently at 25%. Therefore, when the ST value decreases, it is considered that general stability increases, and when the WDI decreases, the ability to distribute weight increases; therefore, a significant difference in balance ability is considered.

2) Dynamic balance

The YBT measures the maximum reach by pushing the target indicator along the pipe. The participants support their weight with one leg on the ground for the starting line in each direction (anterior [ANT], posterior and medial, and posterior and lateral). All the participants were asked to return to their starting position with maximum push and balance of the target indicators in each direction with their hands on the hips, maintaining a standing position on the dominant foot, while not carrying any weight. The measurement direction sequence proceeds as follows: ANT, posterior and medial, and posterior and lateral for the weight-supported feet. The participants were scored on an average of three attempts after practice. All tests were performed barefoot to remove additional balance and stability from the shoes. The maximum reach was normalized (%) by multiplying the reach by 100 and dividing by the leg length (cm). Composite score is the sum of the three directions of reach divided by three times the leg length (cm) and multiplied by 100.

4. Statistical analysis

All statistical analyses were conducted using SPSS statistical software (version 20.0: IBM Corp. Armonk, NY). For the measured data of this study, the normality test exceeded 0.05, so the following non-parametric test was performed. The Kruskal–Wallis test was used to compare and analyze the pre-intervention values, and pre- and post-intervention difference values of the three groups. Post-hoc analysis was subsequently performed using the Bonferroni correction method, which was placed in each of the two groups. All statistical significance levels (p) were set to <0.05.

RESULTS

1. Static balance

The premeasurement results of the static balance ability were as follows: the ST of NO, NC, PO, PC, and the WDI of NO, NC, PO, PC with no significant difference noted among groups ($p>0.05$). In the pre- and post-intervention difference values, a significant difference was noted among the three groups in the ST of NC and PC ($p<0.05$). However, no significant

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Table 2. Static balance comparison measured before and after intervention (n=21)

	Position	Group	Mean±SD	F	p	Post-hoc
ST	NO	NEG	-0.14±2.96	0.153	0.667	-
		CSG	0.88±5.12			
		ASG	0.01±2.59			
	NC	NEG	2.10±6.31	3.907	0.032*	ASG<CSG
		CSG	2.17±6.17			ASG<NEG
		ASG	-5.68±5.62			
	PO	NEG	0.46±2.05	1.382	0.228	-
		CSG	0.97±2.67			
		ASG	-1.22±2.94			
	PC	NEG	0.89±2.57	3.466	0.028*	ASG<CSG
		CSG	-2.57±7.05			ASG<NEG
		ASG	-5.67±2.97			
WDI	NO	NEG	0.25±4.11	0.128	0.327	-
		CSG	0.99±1.80			
		ASG	0.73±1.67			
	NC	NEG	0.34±3.67	0.087	0.901	-
		CSG	0.71±2.67			
		ASG	0.02±2.92			
	PO	NEG	1.12±2.43	0.782	0.586	-
		CSG	-0.63±3.88			
		ASG	1.52±3.77			
	PC	NEG	0.54±2.15	0.293	0.780	-
		CSG	-0.03±2.72			
		ASG	-0.49±2.70			

Mean±standard deviation of pre-post differences, ST: Stability Index, WDI: Weight Distribution Index, NO: Normal eye open, NC: Normal eye close, PO: Pillow with eye open, PC: Pillow with close eye, NEG: Non exercise group, CSG: Core strengthening group, ASG: Ankle strengthening group.
*$p<0.05$.

difference was noted among the three groups in the ST of NO and PO postures and all postures of WDI ($p>0.05$)(Table 2). As a result of the post-hoc test, the ST of ASG showed a significant decrease than the CSG for NC. ST of ASG was significantly decreased compared with NEG ($p<0.05$).

2. Dynamic balance

The premeasurement results of YBT were ANT, posteromedial (PM), posterolateral (PL), and composite score (CS) no significant difference among groups ($p>0.05$). Pre-and post-intervention difference values of YBT measurements showed a significant difference among the three groups in PL and CS ($p<0.05$); however, no significant difference was observed among the three groups in ANT and PM ($p>0.05$)(Table 3). As a result of the post-hoc test, the PL and CS values showed a significant increase in the CSG compared to the NEG ($p<0.05$).

Table 3. Dynamic balance comparison measured before and after intervention (n=21)

	Group	Mean ± SD	F	p	Post-hoc
ANT (cm)	NEG	0.70±5.00	1.626	0.382	
	CSG	3.23±3.35			-
	ASG	5.19±5.42			
PM (cm)	NEG	0.26±7.01	2.380	0.094	
	CSG	10.80±9.31			-
	ASG	8.05±11.23			
PL (cm)	NEG	3.71±6.80	3.813	0.032*	CSG>NEG
	CSG	15.25±4.26			
	ASG	11.45±11.23			
CS (%)	NEG	1.07±5.50	4.833	0.014*	CSG>NEG
	CSG	14.53±10.08			
	ASG	7.83±8.06			

Mean±standard deviation of pre-post differences, ANT: Anterior, PM: Posteromedial, PL: Posterolateral, CS: Composite score, NEG: Non exercise group, CSG: Core strengthening group, ASG: Ankle strengthening group.
*$p<0.05$.

DISCUSSION

This study was conducted in 21 healthy adult men and women to compare the effects on dynamic and static balance when progressive core and ankle muscle strengthening exercises were performed using the Thera-Band. To determine the effects of exercise, the study was conducted with the difference value obtained by subtracting the pre-exercise value from the post-exercise measurement after 4 weeks of gradual exercise and before exercise. In this study, Tetrax® (Balance Ability Assessment and Training System Test) showed no significant difference in all postures of WDI, whereas it showed a significant difference in the ST of NC and PC when comparing the difference values between groups before and after exercise. Furthermore, NC and PC showed a significant difference in ASG; however, NEG and CSG did not show a significant difference. In the case of the YBT, a significant difference was noted in PL and CS between each group for the pre- and post-intervention difference; however, no significant difference was observed in the ANT and PM directions. A significant difference was noted between PL and CS in CSG although not in NEG and ASG.

In static balance, the effect difference of balance without external stimuli in the case of a normal person is difficult to determine. However, visual blockages and unstable support surfaces can cause appropriate perturbations for effect differences in static conditions. Additionally, vision recognizes the position of the body in relation to the surrounding environment and plays a key role in stabilizing posture and expected response.[28] When vision is blocked, the other proprioceptive senses of the body are used more; the ankle's proprioception plays a significant role in balance to enable the integration of posture and balance control along with other sensory information. Proprioceptive training, including ankle muscle strengthening exercises, had a positive effect on static balance in healthy individuals.[30] Static balance in ankle joint and lower extremity muscle strength dominated the length and speed of sway in the absence of visual information.[31] The results of the above mentioned study suggest that the ankle strengthening exercises performed in this study had an effect on the improvement of the static balance between the NC and PC through the improvement of proprioception in the posture with an unstable support surface and blindness.

The change in balance ability is attributed to changes in eigen-sensory and neuromuscular regulation, and the decrease in the body sway area implies an improvement in balance ability.[32] ST represents the change in weight (%) on the four tread plates. The decrease in the ST value suggests that the static balance ability is improved due to the reduction in body shaking. Body sway in static balance is closely related to the ankle joint strategy. The ankle joint strategy aims at restoring the center of mass (COM) to a stable position by focusing physical movement around the ankle joint within the acceptable range of the ankle joint. To correct postural shake and position the COM on the foot, proper ankle muscle strength is required.[33,34] Wolfson et al.[33] reported that ankle dorsiflexion plays a significant role because it contributes to the production of reverse motion that stops, lifts the forefoot, and rebalances the body due to unstable movement. Therefore, the results of this study show that ASG was more effective in static balance than CSG and NEG because ankle muscle strengthening improves ankle joint stability and significantly contributes to the ankle joint strategy in the static state.

The core is composed of the lumbar-pelvis-hip complex and is closely related to dynamic balance. Sarvestani et al.[34] reported that improving the muscle strength of the abdominal and lumbar muscles through various core protocols and restoring the axis of the COP to its original position result in an easy dynamic balance of postural shake. The activation of core muscles in limb movements improves postural control and that the body generates rotational torque required around the body through the activation of core muscles and generates limb movements.[35] The results of the previous studies were consistent with those of this study, and it was found that CSG is effective in dynamic balance. Moreover, it can be noted that in dynamic balance, the movement of the limbs adjusts the posture due to core strengthening.

Differences in CS suggest that some exercise effects were noted not only in PL but also in ANT and PM, of which the largest exercise effect was noted in PL Lee et al.[36] reported that the posterior direction of the YBT plays an important role in hip flexion and balanced trunk movement. Hooper et al.[37] showed that YBT performance was decreased in the posterior direction for individuals with LBP although not in the ANT direction, resulting in a further posterior COG compared with the ANT; thus, the core muscle is highly correlated in the posterior case because the posterior COG is relatively far ahead. Therefore, the PL improvement in this study demonstrated that COG is farther back than forward. We believe that a large change in COG has significant differences in improving the balancing capacity of PL through core muscle strengthening.

This study was involved in increasing the dynamic balance of ASG and CSG. Hooper et al.[37] reported that the strengthening of the plantar flexor and invertor muscles is correlated with ANT improvement; among them, the strengthening of the invertor muscle is correlated with PL improvement. In this study, a significant difference was noted in the YBT between CSG and NEG rather than ASG; however, the muscle strength of ASG showed a noticeable effect on the performance improvement of ANT and PL of YBT.

This study has some limitations. First, this study had a small size, and it was difficult to generalize compared with various age groups by conducting a study on healthy men and women in their twenties. Second, it is difficult to control the daily lives of the participants outside the exercise period. Third, this study investigated changes in balance ability through muscle strengthening, but there was no direct evaluation of muscle strength. We thought that scientific consideration was difficult because the muscle strength was not measured for the part where there was no significant change in the PM direction. Therefore, future studies are needed to address these limitations.

This study investigated the effects of core and ankle muscle strengthening exercises on static and dynamic balance through progressive Thera-Band exercises. This study revealed that progressive Thera-Band exercises had a positive effect on core and ankle muscle strengthening. Furthermore, this study confirmed that core strengthening was effective for dynamic balance, and ankle strengthening was effective for static balance.

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