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Effect of proprioceptive exercise on static/dynamic balance, pain and motor functions in college students with chronic ankle instability

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GRADUATE SCHOOL

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<Abstract>

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The purpose of this study is to investigate the effect of a 4-week proprioceptive exercise program on ankle range of motion (ROM), static/dynamic balance, power and motor functions in college students with chronic ankle instability (CAI). The subjects of this study were 21 adult males who had the Cumberland ankle instability tool (CAIT) questionnaire scores of 24 or less, and they had no orthopedic history in the past 6 months, as well as no clinical problems in exercise performance. The selected subjects were classified into a non-treated group (NTG), a traditional strength exercise group (SEG), and a proprioceptive exercise group (PEG) by a random assignment method. The subjects in the SEG performed a strength training program using an elastic band, and the subjects in the PEG applied a proprioceptive exercise program using BOSU ball 3 times a week for 4 weeks. To examine the difference between groups, CAIT, visual analogue scale (VAS), body composition, ankle ROM, one leg standing with eyes closed, Y-balance test (YBT), vertical jump test, ground reaction force and center of pressure (COP)-related variables were measured before and after the exercise intervention. For measurement

data, the mean and standard deviation of each variable were calculated using the SPSS for windows (Version 22.0) statistical program. Two-way repeated measures ANOVA was performed to verify the difference between groups and periods, and one-way ANOVA analysis was performed to compare the differences between groups. For post-hoc verification, the Tukey method was used, and the statistical significance level of all analyzes was set to $p<0.05$, and the following results were obtained. CAIT scores and static balance were significantly increased in PEG compared to NTG and SEG, and ankle dorsiflexion ROM and Y-balance were significantly increased in SEG and PEG compared to NTG. In addition, the vertical jump and Y-balance were significantly increased in PEG compared to NTG, and pain, ankle inversion ROM, and COP 95% confidence ellipse area were significantly reduced in SEG and PEG compared to NTG. Summarizing the above results, we found that 4-week proprioceptive exercise in patient with CAI showed improvement in CAIT scores, pain, balance, ROM, power and ankle stability. Therefore, the proprioceptive exercise program is thought to be effective therapeutic approach on improving the symptoms of CAI.

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I. Introduction

1. Research significance

Standard of living of Korean people has raised due to an increase in their income levels, therefore, the number of people enjoying leisure life has increased. The participation of people in sports for improving the quality of life and health is also continuously increasing (Kim, 2019). Sport is an activity in which individuals or teams compete against physical abilities such as speed, agility, power, flexibility, endurance, and balance according to certain rules. However, it is reported that as the layperson's participation in sports increases, the incidence of sports injuries also increases (Lee et al., 2012).

According to a previous study, among the body parts where sports injuries occur, lower extremity injuries were the most frequent (77%). Among the 1234 participants who experienced lower extremity injuries, knee injury was most frequent (606/1234) followed by ankle sprain (374/1234) (Francis et al., 2019). Ankle sprain refers to a condition where the lateral ligaments supporting the ankle get damaged due to sudden inversion and lateral rotation or torsion of the ankle (Puffer, 2001). Moreover, among all ankle sprains, those due to inversion are most frequent (85%). Although an ankle sprain is recognized as a minor injury, approximately 26% recover within 7 days, and 74% develop chronic ankle instability (CAI) and experience repeated ankle sprains (Anandacoomarasamy & Barnsley, 2005; Powden et al., 2017).

CAI is known to affect both functional and mechanical insufficiency and with persistent ankle sprains, these insufficiencies cause ankle instability or repeated re-injury to the same joint (Delahunt et al., 2010). Mechanical insufficiency of the ankle includes changes in joint synovial fluid, degenerative changes, pathological relaxation of surrounding tissues, and limitation of joint movement (Hertel, 2002). Therefore, ankle mobility training, muscle strengthening exercise around the ankle, proprioception, and agility enhancing exercise for ankle stability are required during treatment and rehabilitation (Karagiannakis et al., 2020).

Ankle strengthening exercises are mainly performed on tibialis anterior and gastrocnemius muscles, which are the agonists involved in ankle sprains. They are known to improve ankle stability through normalization of ankle mobility and stabilization of the surrounding tissues due to muscle strengthening (Ahn et al., 2020). Recently, as more people are doing home training owing to the temporal, spatial, and social constraints of modern world, research on strength exercises using elastic bands among home training methods has increased. Strength exercise using elastic bands is cost-effective and space efficient. It is frequently used during CAI rehabilitation and is effective in improving muscle strength and muscular endurance (Ahern et al., 2021; Cain et al., 2020). In these exercises, it is relatively easy to set the exercise intensity and direction compared to other resistance exercises. They are effective in balancing the body by increasing the range of motion (ROM) of joint using an elastic band and controlling the muscle activity (Feger et al., 2021; Kim, 2020).

Proprioceptive exercise, along with resistance exercise, is one of the representative exercise methods used in CAI rehabilitation and is effective in restoring ankle stability and body balance, which gets reduced by repetitive ankle sprains (Alghadir et al., 2020). A proprioceptor plays a role in sending sensory information from tissues such as muscles, tendons, ligaments, and joints to the central nervous system. It is an important organ for the muscles and joints to function properly while performing day-to-day activities and sports. Many studies have reported exercises using various auxiliary tools such as balance board, BOSU ball, and balance cushion. It is seen that balance exercise performed on unstable ground is effective in improving proprioception, ankle dorsiflexion, and plantar flexion damaged by ankle sprain (Lazarou et al., 2018). ROM of ankle joint is also closely related to body balance. In a study comparing the effects of 6 weeks of strength training using an elastic band and proprioceptive exercise program on CAI balance, both programs showed significant differences in isokinetic muscle strength (30°/sec, 120°/sec) and Y-balance test (Wang et al., 2021). Furthermore, Cain et al. (2017) reported that 4 weeks of proprioceptive exercise program using BAPS improved ankle stability and dynamic balance by reducing postural stability, increase in sensory receptors, and delay in muscle onset of CAI. According to a study by Kwon (2018), it is reported that muscle strength and proprioceptive exercises for the ankle are important to improve ankle instability as proprioception affects both static and dynamic stability.

However, another study by Surakhamhaeng et al. (2020) reported that the 6-week balance exercise program did not cause any improvement in CAI balance. Also Alahmari et al. (2021) reported that combined exercise did not have a positive effect on strength and static/dynamic balance improvement. There is a lack of data comparing the effects of each exercise program on people with CAI in Korea.

Thus, further research is needed to confirm the effect of the proprioceptive and strength exercise for CAI rehabilitation.

2. Research purpose

The purpose of this study was to investigate the effect of 4-week proprioceptive and strength exercise programs (strength training using elastic band and proprioceptive exercise program using BOSU) on ankle range of motion, static/dynamic balance, power and motor functions of CAI college students.

3. Research hypothesis

The research hypothesis of this study was:

Depending on the exercise program method,

1) there may be differences in the static/dynamic balance.

2) there may be differences in the range of motion of the ankle joint.

3) there may be differences in the maximum ground reaction force.

4) there may be differences in the center of pressure upon landing.

5) there may be differences in the lower extremity muscle power.

6) there may be differences in the pain perception.

4. Research limitations

The following are some limitations of this study:

1) The duration of disease (chronic ankle instability) of the participants was not identical.

2) It was not possible to completely control the degree of exercise program performance of the measurement target.

3) The psychological factors of the participants could not be controlled.

4) Diet and sleep time of participants were not equally controlled.

5. Operational definitions

The operational definitions used in this study are as follows:

1) Chronic ankle instability

It refers to a state in which mechanical and functional ankle instability exist together due to repeated injury to the ankle ligament without complete recovery (Anandacoomarasamy & Barnsley, 2005; Delahunt et al., 2010).

2) Mechanical ankle instability

It refers to a condition where the tissues that make up the anatomical structures such as bones and ligaments of the ankle are displaced beyond the normal range in the joint.

3) Functional ankle instability

It refers to a condition where the functioning of ankle is affected during activities due to an unstable state.

4) Range of motion

It refers to the maximum range of motion that the joint can move by the muscles around ankle or external force.

5) Proprioceptive exercise

It refers to an exercise that is used to control balance on an unstable support surface. It is an effective in increasing the muscle fiber mobilization rate, muscle nerve action, and stability around the complex joints.

II. Literacture review

1. Anatomical structure of the ankle joint

The talocrural joint is a hinge joint composed of the tibia, fibula, and talus in contact with each other. It also consists of the ankle, subtalar, transverse tarsal and tarsometatarsal joints. The ankle and subtalar joints form the ankle joint complex, which is involved in the movement in sagittal, coronal, and horizontal planes. Among the bones that make up the ankle joint, the tibia is the second largest bone in the human body after the femur, and there is a medial malleolus in the distal part. The fibula is located lateral to the tibia, providing space for muscles to attach and stability to the ankle joint, and there is a lateral malleolus in the distal part. In addition, since the fibula descends more towards the ankle than the tibia, the range of motion (ROM) of the inversion is greater than that of the inversion, and the incidence of damage due to the inversion is also high (Morrison & Kaminski, 2007). The talus is the second largest bone in the ankle joint and is located above the calcaneous, which serves to redistribute the load on the foot in three directions.

Representative ligaments involved in ankle movement consist of the anterior tibiotalar, tibionavicular, and tibiocalcaneal ligaments located on the medial side, and the deltoid, anterior and posterior talofibular ligaments and calcaneofibular ligament located on the outside. The medial collateral ligament is stronger than the lateral and can withstand stronger external tension. However, due to inversion, the lateral collateral ligament suffers the most damage during ankle sprains, mainly to the peroneus longus/brevis, the calcaneofibular, and the anterior talofibular ligaments (Simpson et al., 2019).

2. Ankle range of motion

The ankle joint ROM refers to the maximum ROM that a joint can move by the muscles around the ankle or external force. It is divided into the passive range of motion (PROM), which is entirely due to the external force, and the active range of motion (AROM), which is due to the active contraction of the muscles around the joint.

In the sagittal plane, dorsiflexion and plantar flexion about the transverse axis transversing the medial malleolus and lateral malleolus occur in the ankle joint; however, in the coronal plane, inversion and eversion about the sagittal axis transversing the center of the ankle occur. The normal ROM for plantar flexion is 50°, and for dorsiflexion is 20° (A.A.O.S., 1991). Chronic ankle instability (CAI) reduces the functioning of the muscles around the ankle and the ankle ligaments due to repetitive ankle sprains. Since most ankle sprains are caused by inversion, the functions of flexor muscles such as the tibialis anterior deteriorate and the ROM of plantar flexion decreases. The normal joint ROM of the inversion is 40°, and for eversion is 20°. Inversion and abduction mainly occur in the subtalar joint, and injuries of peroneus longus and peroneus brevis occur during ankle sprains, such that in people with CAI, the movement of inversion exceeds the normal ROM (Simpson et al., 2019).

The joint ROM is affected by muscle contraction according to the body movement, tendon and ligament tension and joint angle change, muscle atrophy and soft tissue rupture due to injury, and joint structure. The ROM of the human body increases with the use of joint. Generally, the younger the age, the larger the ROM, and women show a greater ROM than men (Adrian & Cooper, 1989). However, soft tissue damage due to continuous use of the joint, decreased muscle function, and decreased water in the synovial sac due to aging are the causes of the reduction in the ROM of the joint.

3. Chronic ankle instability

CAI refers to a condition in which ankle muscle function, joint range of motion, proprioceptive sensation and stability decrease, and pain is experienced due to repetitive sprains caused in the absence of treatment and exercise rehabilitation after experiencing an initial ankle sprain (Puffer, 2001). In CAI, mechanical and functional insufficiencies exist together due to continuous damage to the ankle, and few studies have reported cases showing repeated re-injuries to a specific joint due to such insufficiencies (Delahunt et al., 2010). Factors such as changes in the joint synovial fluid, degenerative changes, pathological relaxation of the surrounding tissues, and limitation of joint motion exist in mechanical insufficiency of the ankle (Hertel, 2006). To evaluate mechanical insufficiency, an anterior drawer test and evaluation measures such as the talar tilt test are used (Hubbard et al., 2004). Functional defects include factors such as muscle damage, postural control, proprioceptive sensory damage, neuromuscular control (Hertel, 2002), and muscle and nerve tissue around the ankle, including ligaments, which are damaged due to sprains resulting in neuromuscular defects. Such damage affects the sensory receptor function, which leads to a decrease in proprioceptive sensation involved in the movement of joints of the human body. To recover from the defect caused by such an ankle injury; ankle mobility training, muscle strengthening exercise around the ankle, proprioception and agility enhancing exercise for ankle stability are required during treatment and rehabilitation (Karagiannakis et al., 2020).

4. Proprioceptive exercise

Proprioception is a sense that controls muscles and senses joint positions to perform all body movements during physical activity (Konczak et al., 2009).

Proprioceptive sense receives various sensory information such as joint position, force, and weight from sensory organs such as muscle spindle, Golgi tendon organ (GTO), and joint receptors through the central nervous system (Lephart et al., 1997). Among these, the conscious level information is transmitted to the cerebral cortex by mechanoreceptors, which provides information to the motor senses according to the body's static or dynamic state. Moreover, information at the unconscious level is transmitted to the afferent to the cerebellum and is involved in the coordination of the human body (Kisner et al., 2017).

Proprioceptors and joint and ligament receptors provide information to maintain a sense of balance by recognizing the adaptive state of each body part, including the speed of movement during physical activity. The muscle spindle plays a role in detecting changes in muscle length, and GTO plays a role in confirming changes in muscle tension (Oliver et al., 2021).

The proprioceptive exercise that can improve the function of the muscle spindle and GTO is performed using various tools, and the representative exercises include the BOSU and the SWISS ball. The conservative ball exercise is an exercise performed on an unstable support surface, and is reported to be effective in improving muscle strength by increasing the nerve action of the muscle, stability of the complex joint, and the mobilization rate of muscle fibers (Lee, 2011). The SWISS ball exercise is reported to improve proprioception by stimulating the sense of sight and balance (Sung et al., 2003).

5. Strength exercise

Strength exercise induces an increase in the number of intramuscular capillaries and the development of muscle fibers. It plays an important role in improving the function of the muscles and ligaments around the ankle damaged and weakened by CAI (Luan et al., 2021). Recently, due to the COVID-19 pandemic, the number of people practicing home training has increased, and among various strength training methods, an exercise method using an elastic band is in the spotlight. Previous studies have reported improvements in ankle flexibility and stability, walking ability, and neuromuscular function demonstrating CAI improvement using the elastic band exercise (Orange et al., 2019; Guillot et al., 2019).

The elastic band is divided into various colors according to the strength during exercise, and the tension for each color differs by about 20-30%. Even with the same color band, the resistance varies according to the lengthened length. Elastic bands are generally safer than the devices used for resistance exercise; they are easy to use regardless of gender and are portable and cheap compared to other exercise devices. These advantages increase access to strength training for beginners and increase exercise continuity.

Moreover, when strength training using an elastic band is continued for a long period of time, an increase in grip strength and improvement of proprioceptive sensation occur in addition to an improvement in the muscle strength due to the action of pulling a band whose angle is not fixed by hand (Chen et al., 2019). Therefore, elastic band exercise is one of the methods mainly used in CAI's rehabilitation exercise program, and is reported to improve muscle strength, and increase ROM and ankle stability (Hall et al., 2018).

III. Materials and methods

1. Participants

This study was approved by the Jeju National University Institutional Review Board (JJNU-IRB-2021-049), and a total of 83 college students enrolled at J University in J city participated in the Cumberland ankle instability tool (CAIT) questionnaire. Among these, 21 adult males with a score of <24, no history of orthopedic surgery other than chronic ankle instability in the last 6 months, and no clinical problems in exercise performance were selected. After explaining the purpose and signing the consent form, seven people each were enrolled in a non-treated group (NTG), a traditional strength exercise group (SEG), and a proprioceptive exercise group (PEG) by random assignment. The participants in the strength training group underwent a training program using an elastic band at 7 to 8 intensity of OMNI perceived exertion scale for resistance exercise (OMNI-RES), three times a week for 4 weeks. The receptive sensory exercise program was commenced three times a week for 4 weeks with a rating of perceived exertion (RPE) of 12-14 intensity. <Table 1> shows the physical characteristics of the participants in this study.

Table 1. Characteristics of participants (Mean±SD)

Group / Variables	NTG (n=7)	SEG (n=7)	PEG (n=7)
Age (yrs)	21.71±2.21	22.71±3.64	22.71±2.14
Height (cm)	173.81±6.11	170.03±2.79	173.60±3.57
Weight (kg)	73.79±12.73	79.72±11.44	75.86±9.74
BMI (kg/m^2)	24.28±2.98	27.51±3.39	25.12±2.56
FFM (kg)	56.27±11.41	59.38±6.49	57.47±6.72
% Fat (%)	22.46±4.05	26.08±4.97	20.48±5.30

BMI, Body Mass Index; FFM, Fat-free Mass; % Fat, body fat percentage; yrs, years; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group.

2. Study design

This study was conducted on 21 adult males (score of <24) among 83 students who understood the purpose and procedure of the study and gave their consent for the CAIT questionnaire. Each subject was divided into NTG, SEG, and PEG. After pre-measurement, the SEG and PEG groups underwent strength training and proprioceptive exercise programs, respectively, for 4 weeks. The purpose of this study was to identify the effect of differences in exercise programs on each variable by observing changes in the ankle joint range of motion, pain level, balance, and motor functions before and after exercise in all participants. The overall experimental design of this study is shown in <Figure 1>.

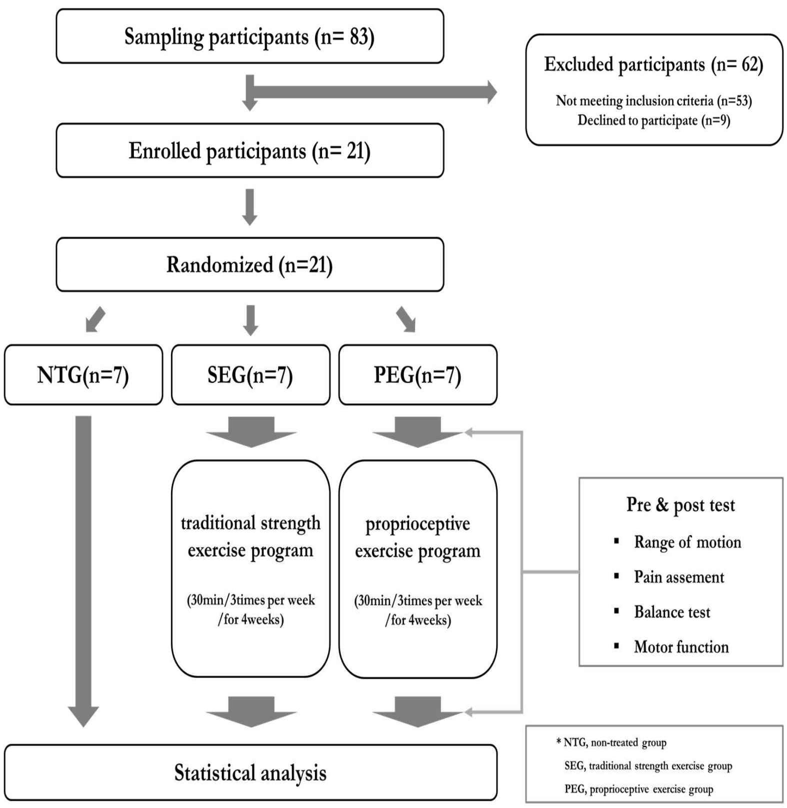

Figure 1. Study design

3. Design of exercise program

In this study, proprioceptive and strength exercise programs were implemented for 4 weeks to improve symptoms of CAI university students. A warm-up through dynamic stretching and a cool-down through static stretching were performed for 5 minutes each.

1) Traditional strength exercise program

The strength exercise program in this study was conducted for 30 minutes a day and three times a week for 4 weeks. Based on the study of Cain et al. (2020), it was reconstructed as a resistance exercise method using a yellow elastic band. For strength training, concentric and eccentric contraction were performed for 1 second each, and plantar/dorsiflexion, in/eversion, knee flexion/extension, and leg abduction were performed using an elastic band. The rest time between sets was set to 20 seconds and the rest time between sets was set to 1 minute. Furthermore, the exercise intensity was performed by setting the OMNI-RES score of 7-8, which is a slightly difficult level. The strength exercise program was conducted as shown in <Table 2> and <Figure 2>.

Table 2. Strength exercise program with elastic band

Contents of exercise	Reps	Rest	Set	Frequency	Intensity
Plantar flexion	10reps	20sec	3sets /1min rest between sets	3days/week for 4weeks	OMNI 7~8
Dorsiflexion					
Inversion					
Eversion					
Knee extension					
Knee flexion					
Abduction					

Reps, repetitions; sec, seconds

a. Plantar flexion

b. Dorsiflexion

c. Inversion

d. Eversion

e. Knee extension

f. Knee flexion

g. Abduction

Figure 2. The posture of traditional strength exercise program with elastic band

2) Proprioceptive exercise program

The proprioceptive exercise program in this study was conducted for 30 minutes a day and three times a week for 4 weeks. Based on a study by Cain et al. (2020), it was reconstructed as an unstable exercise method using a BOSU ball. For proprioceptive exercises, squat, plantar/dorsiflexion, step back lunge, one-leg balance backward, one-leg balance forward, one-leg adduction/abduction, and single leg deadlift were performed using a BOSU ball. The rest period within the set was set to 20 seconds and between the sets to 1 minute. In addition, the exercise intensity was performed by setting the RPE score of 12-14, which is a slightly difficult level. The proprioceptive exercise program was conducted as shown in <Table 3> and <Figure 3>.

Table 3. Proprioceptive exercise program with BOSU ball

Contents of exercise	Reps	Rest	Set	Frequency	Intensity
Squat	10reps	20sec	3sets /1min rest between sets	3days/week for 4weeks	RPE 12~14
Plantar/dorsiflexion	10reps				
Step back lunge	10reps				
One-leg balance backward	20sec				
One-leg balance forward	20sec				
Ad/abduction	10reps				
Single leg deadlift	10reps				

Reps, repetitions; sec, seconds; RPE, rate of perceived exertion

a. Squat

b. Plantar/dorsiflexion

c. Step back lunge

d. One-leg balance backward

e. One-leg balance forward

f. Ad/abduction

g. Single leg deadlift

Figure 3. The posture of proprioceptive exercise program with BOSU ball

4. Tools and Measurements

1) Cumberland ankle instability tool

The Korean Cumberland ankle instability tool (CAIT-K) questionnaire was used to evaluate CAI. If the questionnaire score was <24 of 30 points, it was evaluated as CAI. The format of this questionnaire was translated from the data presented in the study by Hiller et al. (2006), and consisted of nine categories and 41 questions. CAIT-K has shown excellent test-retest reliability based on high intra-class correlation coefficient (ICC2,1=0.94) along with construct validity and internal consistency (Cronbach's α=0.89) (Ko et al., 2015) <Appendix 1>.

2) Visual analogue scale

In this study, to evaluate the pain level of CAI, the visual analogue scale (VAS) suggested by Cole et al. (1994) was used to indicate the pain level of the affected ankle before and after the exercise program on a questionnaire divided on a scale of 1-10.

3) Body composition

The height of participants was measured using an automatic height scale (DS-103M, Dong San jenic, Seoul, Korea) and the body weight (kg) and BMI were measured using a body composition analyzer (Inbody 720, Seoul, KOREA) applied with bioelectrical impedance analysis. To minimize the error during measurement and increase the reliability of the results, the fasting state was maintained for 12 hours before the measurement, and subjects were allowed to measure in the same environmental conditions.

4) Range of motion

The ankle range of motion (ROM) was measured using a goniometer (Baseline, USA). During the measurement, the participants were laid down on the ceiling, both knees were straightened, and the heels of the feet were turned outwards to the ground so that there was no discomfort in movement. For the accuracy of the measurements before and after the exercise, the measurements were taken by the same person, and the average value was calculated by measuring each part. The measurement posture is shown in <Figure 4>.

(1) Plantar flexion/dorsiflexion

For measurement of the ROM for plantar flexion and dorsiflexion, the midline of the lateral malleolus and head of fibula was set as the reference axis of the goniometer, and the fifth metatarsal bone was set as the moving axis. The maximum value was presented after a total of two measurements. The normal ROM of plantar flexion was 50° and of dorsiflexion was 20°.

(2) Inversion/eversion

The ROM of inversion and eversion was measured twice after setting the line connecting the middle of the tibial tuberosity and the talocrural joint as the reference axis of the goniometer and the second metatarsal bone as the moving axis. The measured values were calculated. The normal ROM of the inner turn was 40° and of the outer turn was 20°.

a. Plantar flexion

b. Dorsiflexion

c. Inversion

d. Eversion

Figure 4. The posture of range of motion measurements

5) Static/dynamic balance

(1) One leg standing with eyes closed

A stopwatch (CASIO, OST-30W) was used to measure one-leg standing with eyes closed. After standing on both feet, one leg was bent at 90° and both arms were outstretched to the side while standing on one leg. From the moment when the eyes were closed with arms and leg was raised to the moment when the holding leg falls to the floor or the lifted foot left the measurement space, it was recorded and presented. Measurement was performed twice in total, and 0.1 second was recorded as a unit of measurement.

(2) Y-balance test

The Y-balance test (YBT) was measured using a Y-balance measuring tool (Y-balance Test Kit, Functional Movement Systems, Inc., USA). Before measurement, the participant was explained about the Y-balance test and then was asked to practice three times. In this measurement, the participant extended the measuring tool to the maximum in the anterior, posteromedial, and posterolateral directions using his legs. This movement was measured thrice in each direction and the sum of the measured values was then divided by the length of the leg. At this time, if the foot supporting the ground fell, if the outstretched foot supported the floor for balance or could not return to the starting position, it was considered a failure and the measurements were repeated.

6) Motor function

(1) Vertical jump

The vertical jump was measured using a device (DW 771A, KOREA) to calculate the height in proportion to the flight time while jumping. During the measurement, the participants momentarily bent their knees while stretching their feet to shoulder width on the jumping platform and then they jumped vertically as high as possible to measure the flight time (Choi, 2011). Double motion was not allowed during jumping, and the rest time between the jumps was limited to 1 minute. The maximum value was recorded and presented after a total of two measurements.

(2) Ground reaction force

To measure the ground reaction force (GRF), a 30 cm high box was placed 20 cm from the GRF meter, and after putting more than half of the affected foot on the end of the box, one knee was bent 90 degrees and both arms were stretched to the side to take a ready position. The body was then tilted forward along with the supervisor's signal to perform a drop landing using the affected leg above the GRF meter (Cho et al., 2012; Niu et al, 2011). Before the main measurement, this movement was practiced approximately 5 times, and after drop landing, a stable posture was maintained for 3 seconds. Moreover, the experiment was conducted with barefoot to avoid data errors due to the material and shape of the shoes.

A GRF meter (AMTI-OR6-7, AMTI, USA) was used to measure the movement of the center of pressure and the GRF per participant's body weight during drop landing. The variables of the GRFs generated based on the time when the affected foot landed on the ground during a drop landing, were presented at a sampling rate of 2000 Hz. The GRF was standardized by dividing the absolute value (impact peak, N) of the vertical GRF measured by setting the vertical axis as the Z axis and the body mass of each participant to quantify the measured value.

$$\textit{Relative value of peak vertical GRF} = \textit{Peak VGRF/body weight(N/bw)}$$

For the length and velocity of the center of pressure (COP), the amount of change in COPx and COPy was analyzed by setting the X axis as the front, rear axes as the left, and the Y axis as the right axes. The COP 95% confidence ellipse area was analyzed by analyzing the square area created during ground contact when the posture was maintained after landing (Hyun & Ryu, 2015).

$$\int_{t1}^{t2} \Delta COPx \cdot \Delta COPy$$

For measurement, three successful landing motions were recorded, and the most stable motion was selected and used for analysis (Park and Jeon, 2018).

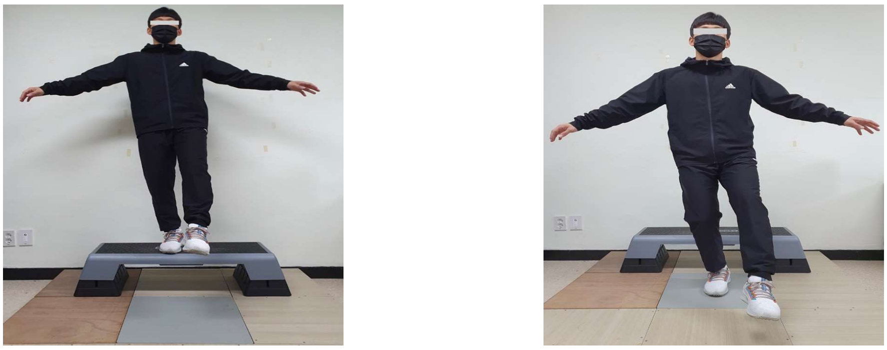

Figure 5. The posture of drop landing

5. Statistical analysis

For the measurement data obtained in this study, the mean and standard deviation of each variable were calculated through group descriptive statistics using the SPSS for windows (Version 22.0) statistical program. The detailed method is as follows. Two-way repeated measures ANOVA was performed to verify the effect of interaction between groups and periods of strength training and proprioceptive exercise. To compare the differences between the groups before and after the experiment, one-way ANOVA was performed, and the differences between the groups were confirmed through the Tukey post-hoc test. The statistical significance level was set to $p<0.05$.

IV. Results

1) Cumberland ankle instability tool

The descriptive statistics on the results of CAIT in this study are presented, and the results of one-way ANOVA are shown in <Table 4> to find out the differences between groups by period. <Table 5> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was a significant difference in the interaction effect according to the group and measurement period (F=7.160, p=.005), and there was a significant difference between the groups (F=6.859, p=.006], a significant difference was also observed between the measurement periods (F=20.901, p=.001). As a result of performing one-way ANOVA to compare the differences between groups, significant differences were found post hoc (p=.001), and PEG was significantly higher than NTG and SEG.

Table 4. The result of descriptive statistics and one-way ANOVA of CAIT by measurement trials (score)

Group	Pre	Post	Total
NTG[a]	16.43±5.10	15.86±4.06	16.14±4.44
SEG[b]	13.86±4.56	19.00±3.65	16.43±4.78
PEG[c]	19.14±2.04	25.14±2.85	22.14±3.92
Total	16.48±4.50	20.00±5.20	18.24±0.43
F	2.882	12.343	-
p	.082	.001	-
Tukey	-	a,b<c	-

Mean±Standard Deviation.
CAIT, cumberland ankle instability tool; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 5. The result of two-way repeated measures ANOVA for CAIT

Variable	SS	df	MS	F	p	η^2	β
Between Subject							
Group	320.762	2	160.381	6.859	.006	.433	.870
Error	420.857	18	23.381	-	-	-	-
Within Subject							
Period	130.381	2	130.381	20.901	.001	.537	.991
Group×Period	89.333	2	44.667	7.160	.005	.443	.885
Error	112.268	18	6.238	-	-	-	-

CAIT, cumberland ankle instability tool

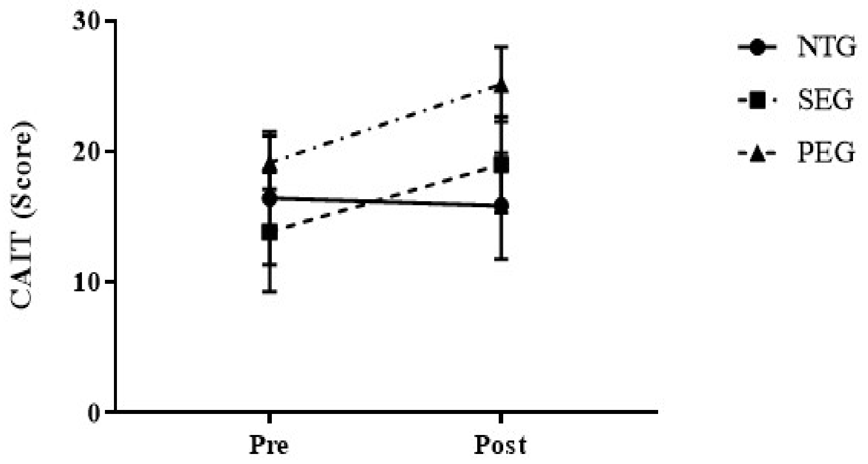

Figure 6. Comparison of cumberland ankle instability tool. CAIT, cumberland ankle instability tool; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

2) Visual analogue scale

The descriptive statistics on the results of VAS in this study are presented, and the results of one-way ANOVA are shown in <Table 6> to find out the differences between groups by period. <Table 7> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was a significant difference in the interaction effect according to the group and measurement period (F=5.727, p=.012), there was no significant difference between the groups (F=.824, p=.455), but there was a significant difference between the measurement periods (F=22.091, p=.001). As a result of performing one-way ANOVA to compare the differences between groups, significant differences were found post hoc (p=.007), and SEG and PEG were significantly lower than NTG.

Table 6. The result of descriptive statistics and one-way ANOVA of VAS by measurement trials (score)

Group	Pre	Post	Total
NTG[a]	1.29±0.49	1.29±0.76	1.29±0.61
SEG[b]	1.71±1.10	0.29±0.49	1.00±1.11
PEG[c]	1.43±0.97	0.29±0.49	0.86±0.96
Total	1.48±0.87	0.62±0.74	1.05±0.25
F	1.800	6.682	-
p	.194	.007	-
Tukey	-	b,c<a	-

Mean±Standard Deviation.
VAS, visual analogue scale; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 7. The result of two-way repeated measures ANOVA for VAS score

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	1.333	2	.667	.824	.455	.084	.169
Error	14.571	18	.810	-	-	-	-
Within Subject							
Period	7.714	1	7.714	22.091	.001	.551	.993
Group×Period	4.000	2	2.000	5.727	.012	.389	.801
Error	6.286	18	.349	-	-	-	-

VAS, visual analogue scale

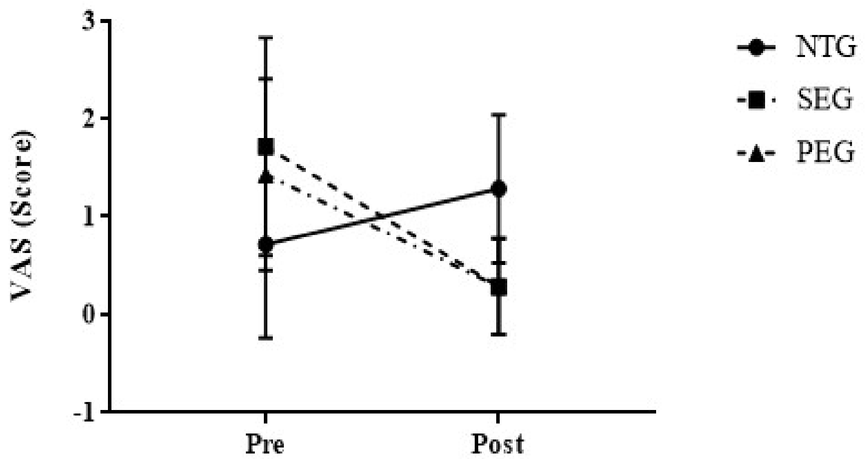

Figure 7. Comparison of visual analogue scale. VAS, visual analogue scale; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

3) Range of motion

① Plantar flexion

The descriptive statistics on the results of plantar flexion in this study are presented, and the results of one-way ANOVA are shown in <Table 8> to find out the differences between groups by period. <Table 9> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of performing two-way repeated measures ANOVA, there was no significant difference in the interaction effect according to the group and measurement period (F=.120, p=.888), there was no significant difference between the groups (F= 2.640, p=.099), and also there was no significant difference between measurement periods (F=.165, p=.689). As a result of performing one-way ANOVA to compare the differences between groups, there was no significant difference after the intervention (p=.303).

Table 8. The result of descriptive statistics and one-way ANOVA of ROM of plantar flexion by measurement trials (°)

Group	Pre	Post	Total
NTG[a]	46.16±5.56	44.84±7.35	45.50±6.30
SEG[b]	43.23±5.75	42.17±4.55	42.70±5.01
PEG[c]	39.47±6.99	39.91±5.03	39.69±5.86
Total	42.95±6.46	42.31±5.85	42.63±0.65
F	2.088	1.278	-
p	.153	.303	-

Mean±Standard Deviation.
ROM, range of motion; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 9. The result of two-way repeated measures ANOVA for ROM of plantar flexion

Variable	SS	df	MS	F	p	η^2	β
Between Subject							
Group	236.160	2	118.080	2.640	.099	.227	.457
Error	805.074	18	44.726	-	-	-	-
Within Subject							
Period	4.339	1	4.339	.165	.689	.009	.067
Group×Period	6.304	2	3.152	.120	.888	.013	.066
Error	472.891	18	26.272	-	-	-	-

ROM, range of motion

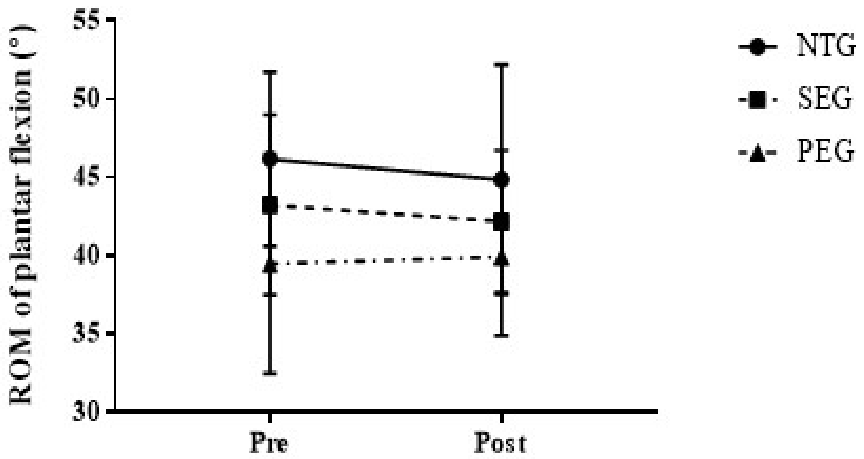

Figure 8. Comparison of ROM of plantar flexion. ROM, range of motion; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

② Dorsiflexion

The descriptive statistics on the results of dorsiflexion in this study are presented, and the results of one-way ANOVA are shown in <Table 10> to find out the differences between groups by period. <Table 11> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was no significant difference in the interaction effect according to the group and measurement period (F=1.675, p=.215), but there was a significant difference between the groups (F=5.642, p=.013), and also there was a significant difference between the measurement periods (F=9.429, p=.007). As a result of performing one-way ANOVA to compare the differences between groups, significant differences were found post hoc (p=.010), and SEG and PEG were significantly higher than NTG.

Table 10. The result of descriptive statistics and one-way ANOVA of ROM of dorsiflexion by measurement trials (°)

Group	Pre	Post	Total
NTG[a]	7.96±2.91	8.36±3.26	8.17±2.98
SEG[b]	8.61±2.24	12.46±2.81	10.54±3.15
PEG[c]	9.31±2.72	13.23±2.23	11.27±3.14
Total	8.63±2.57	11.36±3.43	9.99±0.10
F	.463	6.047	-
p	.637	.010	-
Tukey	-	a<b,c	-

Mean±Standard Deviation.
ROM, range of motion; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 11. The result of two-way repeated measures ANOVA for ROM of dorsiflexion

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	73.459	2	36.729	5.642	.013	.385	11.284
Error	117.184	18	6.510	-	-	-	-
Within Subject							
Period	78.174	1	78.174	9.429	.007	.344	.827
Group×Period	27.781	2	13.891	1.675	.215	.157	.306
Error	149.230	18	8.291	-	-	-	-

ROM, range of motion

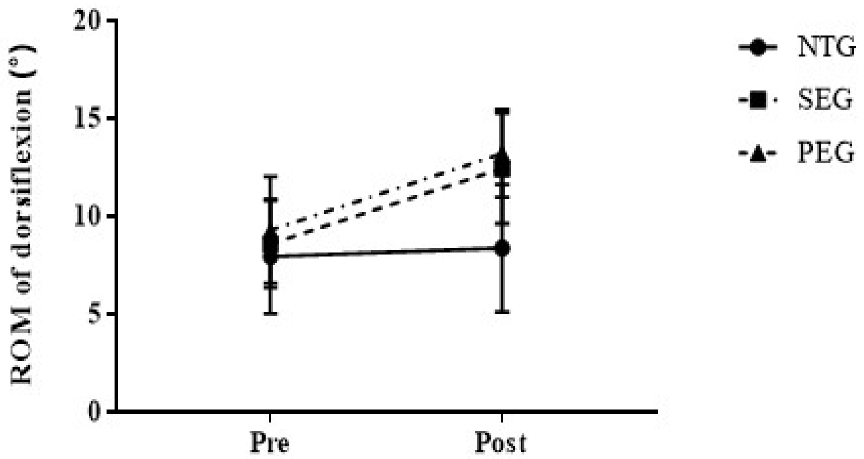

Figure 9. Comparison of ROM of dorsiflexion. ROM, range of motion; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

③ Inversion

The descriptive statistics on the results of inversion in this study are presented, and the results of one-way ANOVA are shown in <Table 12> to find out the differences between groups by period. <Table 13> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was a significant difference in the interaction effect according to the group and measurement period (F=5.579, p=.013), and there was a significant difference between the groups (F=5.782, p=.011), a significant difference was also observed between the measurement periods (F=7.651, p=.013). As a result of performing one-way ANOVA to compare the differences between groups, significant differences were found post hoc (p=.002), and SEG and PEG were significantly lower than NTG.

Table 12. The result of descriptive statistics and one-way ANOVA of ROM of inversion by measurement trials (°)

Group	Pre	Post	Total
NTG[a]	40.19±2.95	42.10±4.69	34.56±10.33
SEG[b]	40.06±3.36	35.61±4.61	29.83±6.90
PEG[c]	39.20±3.03	33.30±2.30	24.86±5.90
Total	39.81±2.99	37.01±5.40	29.75±2.32
F	.206	9.000	-
p	.815	.002	-
Tukey	-	b,c<a	-

Mean±Standard Deviation.
ROM, range of motion; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 13. The result of two-way repeated measures ANOVA for ROM of inversion

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	174.495	2	87.247	5.782	.011	.391	.805
Error	271.591	18	15.088	-	-	-	-
Within Subject							
Period	82.881	1	82.881	7.651	.013	.298	.744
Group×Period	120.866	2	60.433	5.579	.013	.383	.790
Error	194.983	18	10.832	-	-	-	-

ROM, range of motion

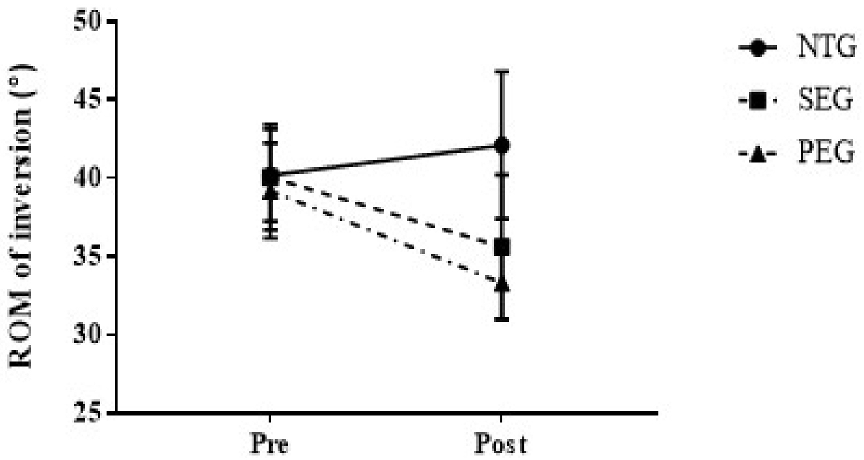

Figure 10. Comparison of ROM of inversion. ROM, range of motion; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

④ Eversion

The descriptive statistics on the results of eversion in this study are presented, and the results of one-way ANOVA are shown in <Table 14> to find out the differences between groups by period. <Table 15> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was no significant difference in the interaction effect according to the group and measurement period (F=.258, p=.775), and there was no significant difference between the groups (F=1.780, p=.197), a significant difference was not observed between the measurement periods (F=2.847, p=.109). As a result of performing one-way ANOVA to compare the differences between groups, there was no significant difference after the intervention (p=.199).

Table 14. The result of descriptive statistics and one-way ANOVA of ROM of eversion by measurement trials (°)

Group	Pre	Post	Total
NTG[a]	13.53±2.72	14.66±2.61	14.09±2.67
SEG[b]	12.96±2.32	15.10±2.42	14.03±2.54
PEG[c]	11.80±3.60	12.59±2.96	12.19±3.19
Total	12.76±2.90	14.11±2.77	13.44±0.35
F	.620	1.766	-
p	.549	.199	-

Mean±Standard Deviation.
ROM, range of motion; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 15. The result of two-way repeated measures ANOVA for ROM of eversion

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	32.592	2	16.296	1.780	.197	.165	.323
Error	164.787	18	9.155	-	-	-	-
Within Subject							
Period	19.204	1	19.204	2.847	.109	.137	.359
Group×Period	3.486	2	1.743	.258	.775	.028	.085
Error	121.410	18	6.745	-	-	-	-

ROM, range of motion

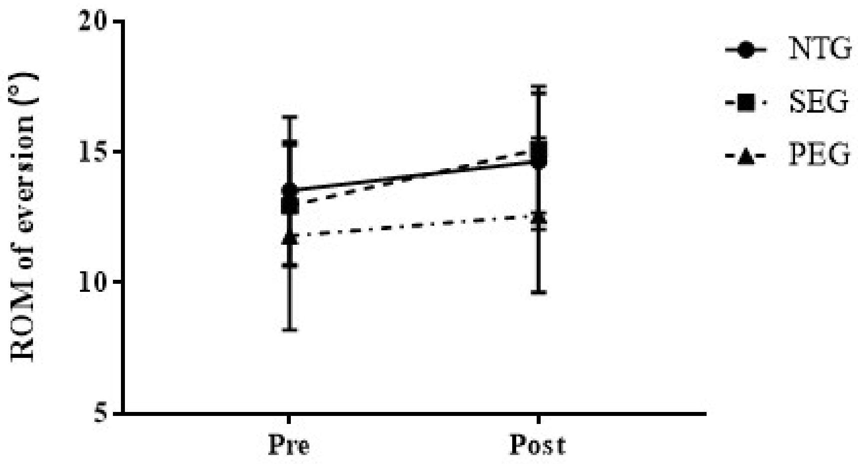

Figure 11. Comparison of ROM of eversion. ROM, range of motion; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

4) One leg standing with eyes closed

The descriptive statistics on the results of one leg standing with eyes closed in this study are presented, and the results of one-way ANOVA are shown in <Table 16> to find out the differences between groups by period. <Table 17> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was a significant difference in the interaction effect according to the group and measurement period (F=13.572, p=.001), and there was a significant difference between the groups (F=5.369, p=.015), a significant difference was also observed between the measurement periods (F=11.768, p=.003). As a result of performing one-way ANOVA to compare the differences between groups, significant differences were found post hoc (p=.001), and PEG was significantly higher than NTG and SEG.

Table 16. The result of descriptive statistics and one-way ANOVA of one leg standing with eyes closed by measurement trials (sec)

Group	Pre	Post	Total
NTG[a]	18.42±4.43	13.05±8.44	15.74±7.05
SEG[b]	15.15±10.33	21.27±4.99	18.21±8.41
PEG[c]	15.66±5.28	34.12±5.91	24.89±10.99
Total	16.41±6.96	22.82±10.87	19.61±2.00
F	.422	18.068	-
p	.662	.001	-
Tukey	-	a,b<c	-

Mean±Standard Deviation.
NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 17. The result of two-way repeated measures ANOVA for one leg standing with eyes closed

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	627.752	2	313.876	5.369	.015	.3744	.773
Error	1052.200	18	58.456	-	-	-	-
Within Subject							
Period	431.105	1	431.105	11.768	.003	.395	.900
Group×Period	994.324	2	497.162	13.572	.001	.601	.993
Error	659.386	18	36.633	-	-	-	-

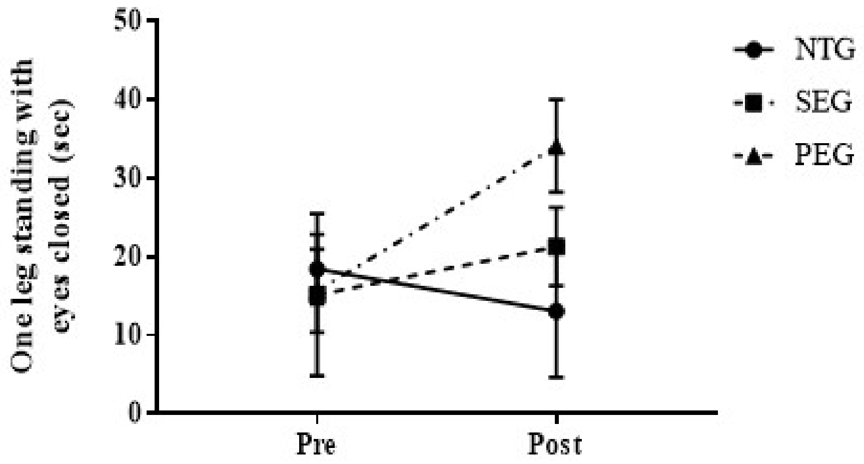

Figure 12. Comparison of one leg standing with eyes closed. NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

5) Y-balance test

① Left leg anterior

The descriptive statistics on the results of left leg anterior in this study are presented, and the results of one-way ANOVA are shown in <Table 18> to find out the differences between groups by period. <Table 19> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was a significant difference in the interaction effect according to the group and measurement period (F=9.066, p=.002), there was no significant difference between the groups (F=.451, p=.644), and also there was no significant difference between the measurement periods (F=3.695, p=.071). As a result of performing one-way ANOVA to compare the differences between groups, significant differences were found post hoc (p=.045), and PEG was significantly higher than NTG.

Table 18. The result of descriptive statistics and one-way ANOVA of left leg anterior of YBT by measurement trials (%LL)

Group	Pre	Post	Total
NTG[a]	71.15±4.94	68.31±5.76	70.23±5.53
SEG[b]	71.03±8.30	73.53±5.84	72.28±7.02
PEG[c]	68.82±2.91	76.57±5.60	72.69±5.87
Total	70.67±5.71	72.80±6.46	71.74±0.78
F	.591	3.709	-
p	.564	.045	-
Tukey	-	a<c	-

Mean±Standard Deviation.

YBT, Y-balance test; %LL, percentage of limb length; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 19. The result of two-way repeated measures ANOVA for left leg anterior of YBT

Variable	SS	df	MS	F	p	η^2	β
Between Subject							
Group	48.598	2	24.299	.451	.644	.048	.112
Error	969.041	18	53.836	-	-	-	-
Within Subject							
Period	47.978	1	47.978	3.695	.071	.170	.444
Group×Period	235.463	2	117.731	9.066	.002	.502	.947
Error	233.741	18	12.986	-	-	-	-

YBT, Y-balance test

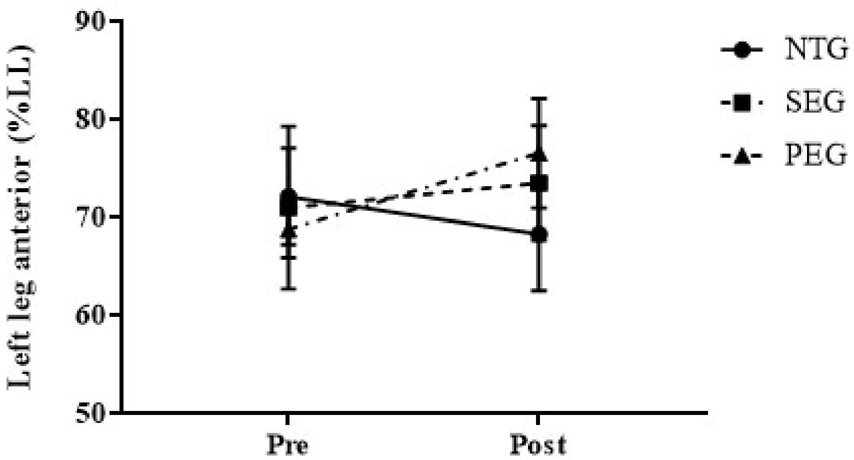

Figure 13. Comparison of left leg anterior. %LL, percentage of limb length; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

② Left leg posteromedial

The descriptive statistics on the results of left leg posteromedial in this study are presented, and the results of one-way ANOVA are shown in <Table 20> to find out the differences between groups by period. <Table 21> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was a significant difference in the interaction effect according to the group and measurement period (F=14.325, p=.001), but there was no significant difference between the groups (F=.373, p=.694), and there was a significant difference between the measurement periods (F=7.271, p=.015). As a result of performing one-way ANOVA to compare the differences between groups, there was no significant difference after the intervention (p=.050).

Table 20. The result of descriptive statistics and one-way ANOVA of left leg posteromedial of YBT by measurement trials (%LL)

Group	Pre	Post	Total
NTG[a]	91.99±11.34	83.70±11.05	87.85±11.58
SEG[b]	86.75±9.39	97.16±11.89	91.95±11.63
PEG[c]	83.97±5.33	95.63±7.57	89.80±8.73
Total	87.57±9.23	92.16±11.59	89.87±1.66
F	1.423	3.553	-
p	.267	.050	-

Mean±Standard Deviation.

YBT, Y-balance test; %LL, percentage of limb length; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 21. The result of two-way repeated measures ANOVA for left leg posteromedial of YBT

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	118.105	2	59.053	.373	.694	.040	.101
Error	2846.486	18	158.138	-	-	-	-
Within Subject							
Period	221.854	2	221.854	7.271	.015	.288	.723
Group×Period	874.232	2	437.116	14.325	.001	.614	.995
Error	549.245	18	30.514	-	-	-	-

YBT, Y-balance test

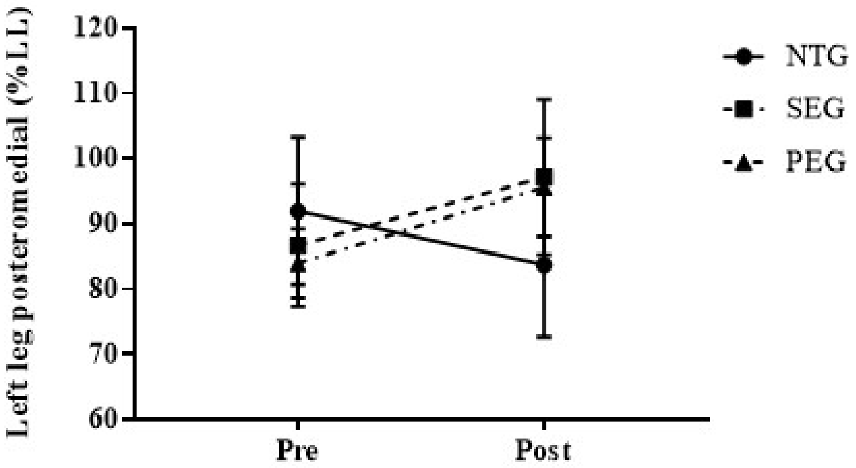

Figure 14. Comparison of left leg posteromedial. %LL, percentage of limb length; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

③ Left leg posterolateral

The descriptive statistics on the results of left leg posterolateral in this study are presented, and the results of one-way ANOVA are shown in <Table 22> to find out the differences between groups by period. <Table 23> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was a significant difference in the interaction effect according to the group and measurement period (F=11.447, p=.001), but there was no significant difference between the groups (F=2.616, p=.101), and also there was no significant difference between the measurement periods (F=2.083, p=.166). As a result of performing one-way ANOVA to compare the differences between groups, significant differences were found post hoc (p=.003), and SEG and PEG were significantly higher than NTG.

Table 22. The result of descriptive statistics and one-way ANOVA of left leg posterolateral of YBT by measurement trials (%LL)

Group	Pre	Post	Total
NTG[a]	91.00±5.50	90.92±5.95	94.96±6.92
SEG[b]	98.99±6.03	105.40±6.39	102.19±6.83
PEG[c]	92.57±9.94	100.87±7.77	96.72±9.259
Total	96.85±7.70	99.06±8.91	97.96±1.57
F	1.748	8.435	-
p	.202	.003	-
Tukey	-	a<b,c	-

Mean±Standard Deviation
YBT, Y-balance test; %LL, percentage of limb length; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 23. The result of two-way repeated measures ANOVA for left leg posterolateral of YBT

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	398.135	2	199.067	2.616	.101	.225	.454
Error	1369.474	18	76.082	-	-	-	-
Within Subject							
Period	51.154	1	51.154	2.083	.166	.104	.277
Group×Period	562.185	2	281.093	11.447	.001	.560	.982
Error	442.014	18	24.556	-	-	-	-

YBT, Y-balance test

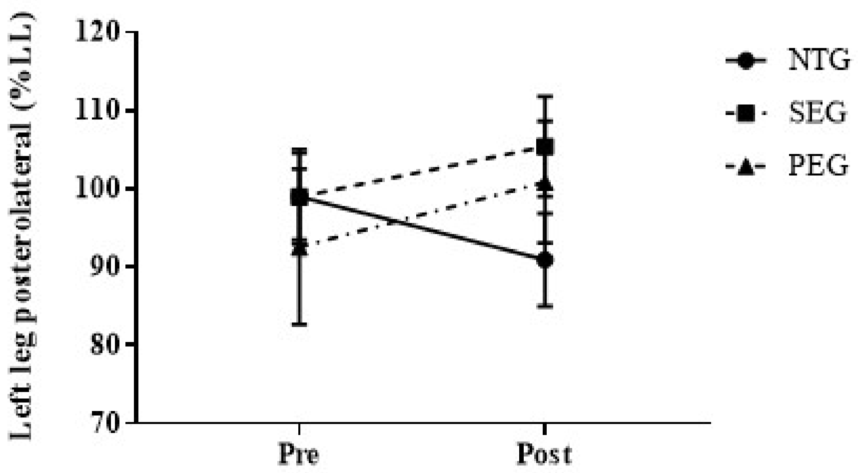

Figure 15. Comparison of left leg posterolateral. %LL, percentage of limb length; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

④ Right leg anterior

The descriptive statistics on the results of right leg anterior in this study are presented, and the results of one-way ANOVA are shown in <Table 24> to find out the differences between groups by period. <Table 25> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was a significant difference in the interaction effect according to the group and measurement period (F=10.049, p=.001), but there was no significant difference between the groups (F=.774, p=.476), and there was a significant difference between the measurement periods (F=9.951, p=.005). As a result of performing one-way ANOVA to compare the differences between groups, there was no significant difference after the intervention (p=.772).

Table 24. The result of descriptive statistics and one-way ANOVA of right leg anterior of YBT by measurement trials (%LL)

Group	Pre	Post	Total
NTG[a]	75.45±4.12	73.33±6.46	74.39±5.32
SEG[b]	73.10±10.01	75.88±8.52	74.49±9.05
PEG[c]	66.50±4.14	75.10±4.74	70.79±6.18
Total	71.68±7.44	74.77±6.50	73.23±1.95
F	3.372	.262	-
p	.057	.772	-

Mean±Standard Deviation

YBT, Y-balance test; %LL, percentage of limb length; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 25. The result of two-way repeated measures ANOVA for right leg anterior of YBT

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	124.327	2	62.164	.774	.476	.079	.161
Error	1445.851	18	80.325	-	-	-	-
Within Subject							
Period	99.780	1	99.780	9.951	.005	.356	.847
Group×Period	201.539	2	100.770	10.049	.001	.528	.966
Error	180.492	18	10.027	-	-	-	-

YBT, Y-balance test

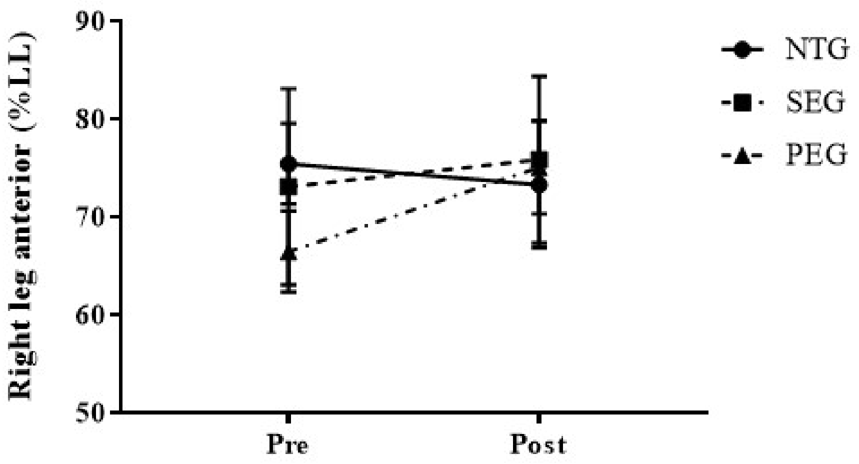

Figure 16. Comparison of right leg anterior. %LL, percentage of limb length; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

⑤ Right leg posteromedial

The descriptive statistics on the results of right leg posteromedial in this study are presented, and the results of one-way ANOVA are shown in <Table 26> to find out the differences between groups by period. <Table 27> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was a significant difference in the interaction effect according to the group and measurement period (F=17.237, p=.001), but there was no significant difference between the groups (F=.415, p=.667), and also there was no significant difference between the measurement periods (F=1.425, p=.248). As a result of performing one-way ANOVA to compare the differences between groups, significant differences were found post hoc (p=.016), and PEG was significantly higher than NTG.

Table 26. The result of descriptive statistics and one-way ANOVA of right leg posteromedial of YBT by measurement trials (%LL)

Group	Pre	Post	Total
NTG[a]	93.09±6.68	83.86±10.15	88.48±9.54
SEG[b]	87.09±10.04	98.25±8.22	92.67±10.54
PEG[c]	84.21±8.15	93.39±6.67	88.80±8.60
Total	88.13±8.83	91.83±10.10	89.98±0.97
F	1.423	5.226	-
p	.267	.016	-
Tukey	-	a<c	-

Mean±Standard Deviation

YBT, Y-balance test; %LL, percentage of limb length; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 27. The result of two-way repeated measures ANOVA for right leg posteromedial of YBT

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	104.953	2	52.476	.415	.667	.044	.107
Error	2278.654	18	126.592	-	-	-	-
Within Subject							
Period	54.384	1	54.384	1.425	.248	.073	.205
Group×Period	1315.245	2	657.623	17.237	.001	.657	.999
Error	686.735	18	38.152	-	-	-	-

YBT, Y-balance test

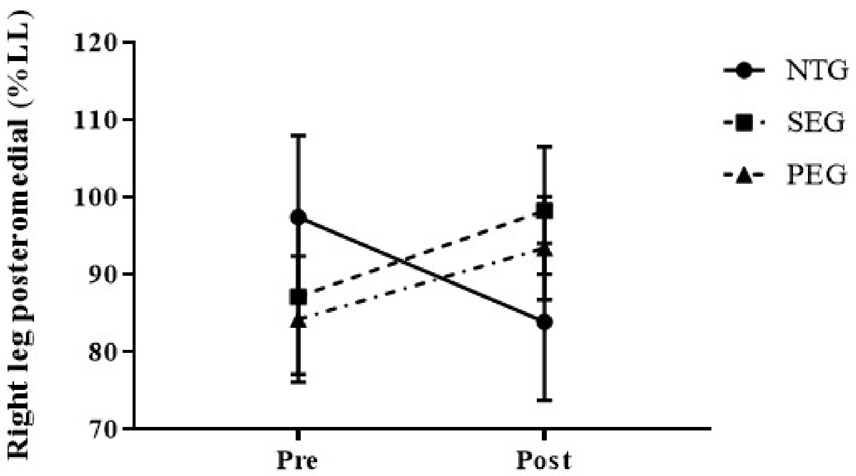

Figure 17. Comparison of right leg posteromedial. %LL, percentage of limb length; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

⑥ Right leg posterolateral

The descriptive statistics on the results of right leg posterolateral in this study are presented, and the results of one-way ANOVA are shown in <Table 28> to find out the differences between groups by period. <Table 29> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was a significant difference in the interaction effect according to the group and measurement period (F=16.547, p=.001), but there was no significant difference between the groups (F=1.679, p=.214), and also there was no significant difference between the measurement periods (F=2.082, p=.166). As a result of performing one-way ANOVA to compare the differences between groups, significant differences were found post hoc (p=.001), and SEG and PEG were significantly higher than NTG.

Table 28. The result of descriptive statistics and one-way ANOVA of right leg posterolateral of YBT by measurement trials (%LL)

Group	Pre	Post	Total
NTG[a]	100.81±8.09	88.57±7.07	94.69±9.67
SEG[b]	96.09±3.56	105.83±7.46	100.96±7.55
PEG[c]	92.02±10.59	102.43±7.66	97.22±10.39
Total	96.31±8.40	98.94±10.38	97.62±1.48
F	2.135	10.686	-
p	.147	.001	-
Tukey	-	a<b,c	-

Mean±Standard Deviation

YBT, Y-balance test; %LL, percentage of limb length; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 29. The result of two-way repeated measures ANOVA for right leg posterolateral of YBT

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	278.894	2	139.447	1.679	.214	.157	.307
Error	1494.929	18	83.052	-	-	-	-
Within Subject							
Period	73.096	1	73.096	2.082	.166	.104	.277
Group×Period	1161.811	2	580.906	16.547	.001	.648	.998
Error	631.907	18	35.106	-	-	-	-

YBT, Y-balance test

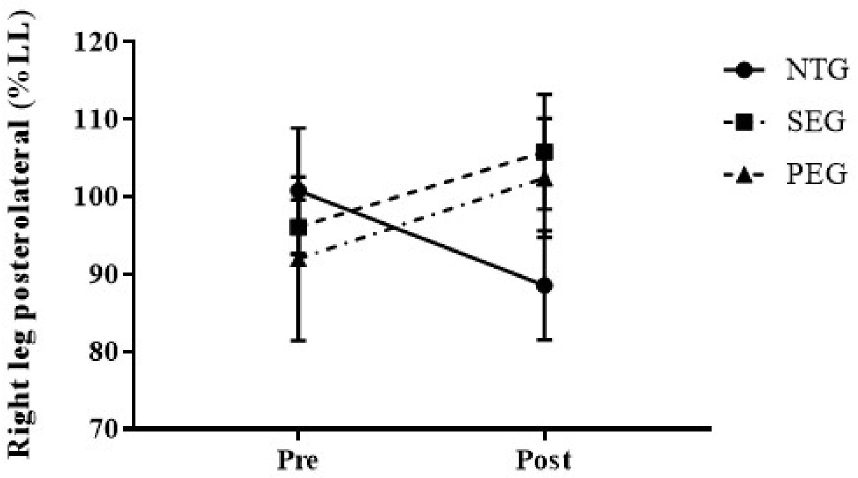

Figure 18. Comparison of right leg posterolateral. %LL, percentage of limb length; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

6) Vertical jump

The descriptive statistics on the results of vertical jump in this study are presented, and the results of one-way ANOVA are shown in <Table 30> to find out the differences between groups by period. <Table 31> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was a significant difference in the interaction effect according to the group and measurement period (F=19.819, p=.001), but there was no significant difference between the groups (F=1.400, p=.272), and there was a significant difference between the measurement periods (F=16.779, p=.001). As a result of performing one-way ANOVA to compare the differences between groups, significant differences were found post hoc (p=.022), and PEG was significantly higher than NTG.

Table 30. The result of descriptive statistics and one-way ANOVA of vertical jump by measurement trials (cm)

Group	Pre	Post	Total
NTG[a]	44.72±8.08	42.0±5.94	43.36±6.96
SEG[b]	45.29±4.61	49.43±4.47	47.36±4.86
PEG[c]	45.71±6.18	51.43±7.35	48.57±7.17
Total	45.24±6.13	47.62±7.07	46.43±1.27
F	.042	4.745	-
p	.959	.022	-
Tukey	-	a<c	-

Mean±Standard Deviation.
NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 31. The result of two-way repeated measures ANOVA for vertical jump

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	208.429	2	104.214	1.400	.272	.135	.261
Error	1339.857	18	74.437	-	-	-	-
Within Subject							
Period	59.524	1	59.524	16.779	.001	.482	.972
Group×Period	140.619	2	70.310	19.819	.001	.688	1.000
Error	63.857	18	3.548	-	-	-	-

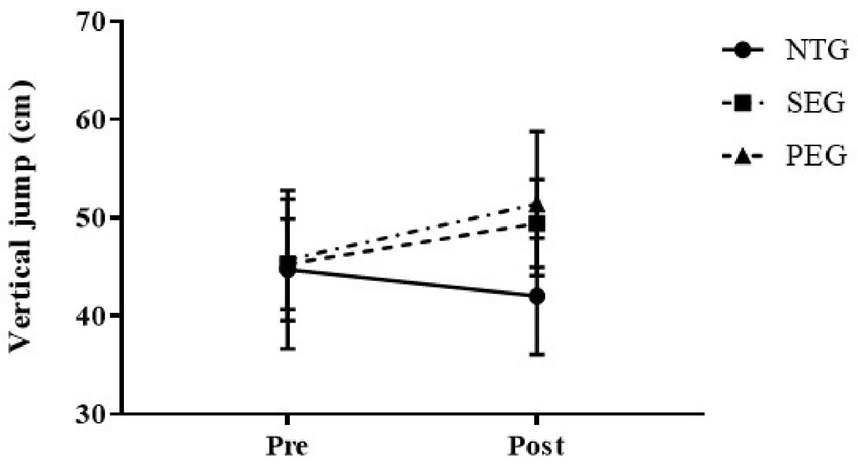

Figure 19. Comparison of vertical jump. NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

7) Ground reaction force

① Absolute value of GRF

The descriptive statistics on the results of the absolute value of GRF in this study are presented, and the results of one-way ANOVA are shown in <Table 32> to find out the differences between groups by period. <Table 33> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was no significant difference in the interaction effect according to the group and measurement period (F=1.724, p=.207), there was no significant difference between the groups (F=2.014, p=.162), and also there was no significant difference between the measurement periods (F=1.392, p=.253). As a result of performing one-way ANOVA to compare the differences between groups, there was no significant difference after the intervention (p=.077).

Table 32. The result of descriptive statistics and one-way ANOVA of absolute value of GRF by measurement trials (*N*)

Group	Pre	Post	Total
NTG[a]	3457.49±551.39	3432.72±1259.03	3445.11±933.86
SEG[b]	3399.47±2956.77	4309.02±1277.20	3854.25±1314.88
PEG[c]	2956.77±868.54	2917.88±539.83	2937.33±695.04
Total	3271.24±927.18	3553.21±1182.64	3412.23±312.63
F	.585	2.962	-
p	.567	.077	-

Mean±Standard Deviation.
N, newton; GRF, ground reaction force; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 33. The result of two-way repeated measures ANOVA for absolute value of GRF

Variable	SS	df	MS	F	p	η^2	β
Between Subject							
Group	5907932.464	2	2953966.232	2.014	.162	.183	.361
Error	26394468.82	18	1466359.379	-	-	-	-
Within Subject							
Period	834774.442	1	834774.442	1.392	.253	.072	.201
Group×Period	2068124.889	2	1034062.445	1.724	.207	.161	.314
Error	10795629.37	18	599757.187	-	-	-	-

GRF, ground reaction force

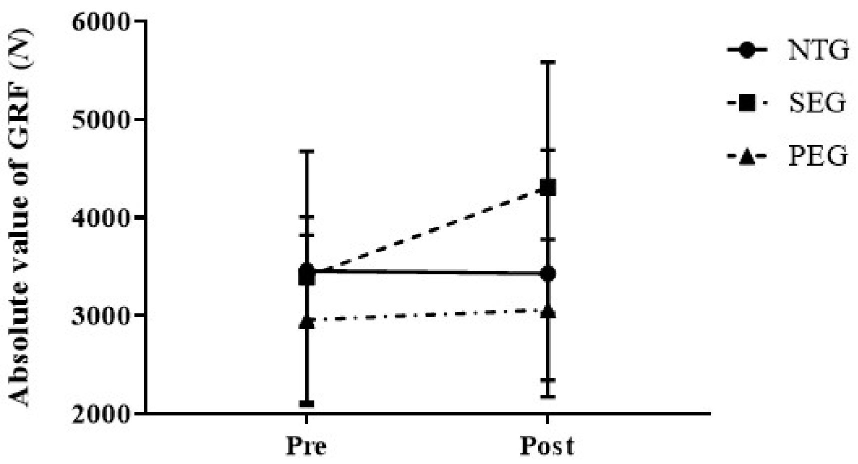

Figure 20. Comparison of absolute value of GRF. GRF, ground reaction force; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

② Relative value of GRF

The descriptive statistics on the results of the relative value of GRF in this study are presented, and the results of one-way ANOVA are shown in <Table 34> to find out the differences between groups by period. <Table 35> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was no significant difference in the interaction effect according to the group and measurement period (F=1.132, p=.344), there was no significant difference between the groups (F=.954, p=.404), and also there was no significant difference between the measurement periods (F=2.053, p=.169). As a result of performing one-way ANOVA to compare the differences between groups, there was no significant difference after the intervention (p=.379).

Table 34. The result of descriptive statistics and one-way ANOVA of relative value of GRF by measurement trials (N/bw)

Group	Pre	Post	Total
NTG[a]	48.33±11.96	49.39±24.33	48.86±18.42
SEG[b]	41.92±13.11	54.63±16.26	48.28±15.65
PEG[c]	39.39±12.26	40.98±10.80	40.18±11.13
Total	43.22±12.43	48.33±18.03	45.77±3.68
F	.959	1.025	-
p	.402	.379	-

Mean±Standard Deviation.

N, newton; bw, bodyweight; GRF, ground reaction force; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 35. The result of two-way repeated measures ANOVA for relative value of GRF

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	658.775	2	329.388	.954	.404	.096	.189
Error	6218.046	18	.356.447	-	-	-	-
Within Subject							
Period	274.838	1	274.838	2.053	.169	.102	.274
Group×Period	303.084	2	151.542	1.132	.344	.112	.218
Error	2409.548	18	133.864	-	-	-	-

GRF, ground reaction force

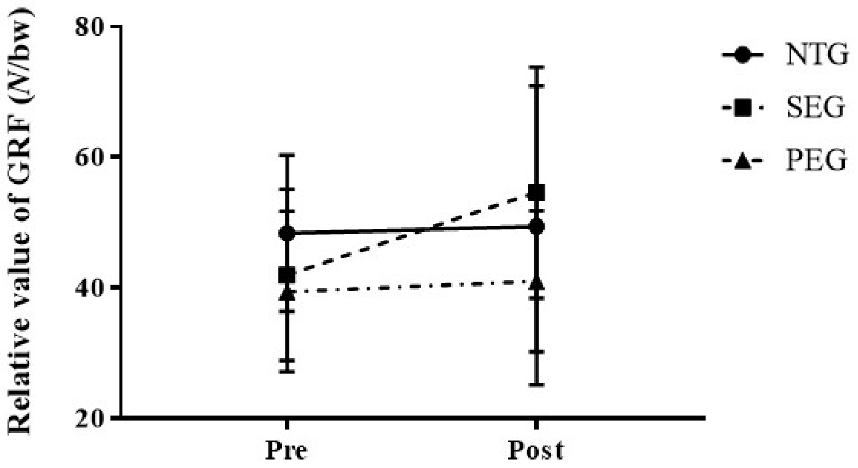

Figure 21. Comparison of relative value of GRF. GRF, ground reaction force; NT, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

③ Length of anterior-posterior COP

The descriptive statistics on the results of length of anterior-posterior COP in this study are presented, and the results of one-way ANOVA are shown in <Table 36> to find out the differences between groups by period. <Table 37> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was no significant difference in the interaction effect according to the group and measurement period (F=.777, p=.474), there was no significant difference between the groups (F=1.892, p=.180), and also there was no significant difference between the measurement periods (F=.452, p=.510). As a result of performing one-way ANOVA to compare the differences between groups, there was no significant difference after the intervention (p=.140).

Table 36. The result of descriptive statistics and one-way ANOVA of length of anterior-posterior COP by measurement trials (cm)

Group	Pre	Post	Total
NTG[a]	123.35±30.49	129.66±55.44	126.51±43.11
SEG[b]	123.01±36.75	115.56±12.08	119.29±26.57
PEG[c]	103.59±18.12	92.72±10.42	98.15±15.28
Total	116.65±29.53	112.65±35.24	114.65±14.0
F	1.030	2.193	-
p	.377	.140	-

Mean±Standard Deviation

COP, center of pressure; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 37. The result of two-way repeated measures ANOVA for length of anterior-posterior COP

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	6078.586	2	3039.293	1.892	.180	.174	.341
Error	28915.715	18	1606.429	-	-	-	-
Within Subject							
Period	168.380	1	168.380	.452	.510	.124	.098
Group×Period	579.183	2	189.591	.777	.474	.079	.162
Error	6706.601	18	372.589	-	-	-	-

COP, center of pressure.

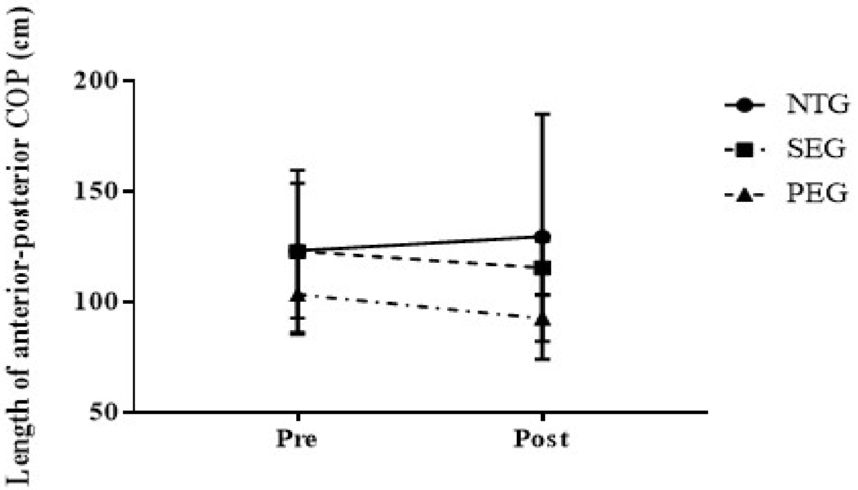

Figure 22. Comparison of length of anterior-posterior COP. COP, center of pressure; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

④ Length of medial-lateral COP

The descriptive statistics on the results of length of medial-lateral COP in this study are presented, and the results of one-way ANOVA are shown in <Table 38> to find out the differences between groups by period. <Table 39> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was no significant difference in the interaction effect according to the group and measurement period (F=.339, p=.717), there was no significant difference between the groups (F=1.460, p=.258), and also there was no significant difference between the measurement periods (F=.786, p=.387). As a result of performing one-way ANOVA to compare the differences between groups, there was no significant difference after the intervention (p=.368).

Table 38. The result of descriptive statistics and one-way ANOVA of length of medial-lateral COP by measurement trials (cm)

Group	Pre	Post	Total
NTG[a]	145.04±34.10	159.56±90.28	152.30±65.99
SEG[b]	127.41±21.74	137.74±19.30	132.58±20.46
PEG[c]	119.36±13.11	117.27±18.87	118.32±15.65
Total	130.60±25.75	138.19±54.56	134.40±27.78
F	2.005	1.058	-
p	.164	.368	-

Mean±Standard Deviation

COP, center of pressure; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 39. The result of two-way repeated measures ANOVA for length of medial-lateral COP

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	8155.296	2	4077.648	1.460	.258	.140	.271
Error	50272.496	18	2792.916	-	-	-	-
Within Subject							
Period	604.251	1	604.251	.786	.387	.042	.134
Group×Period	521.870	2	260.935	.339	.717	.036	.096
Error	13840.879	18	768.938	-	-	-	-

COP, center of pressure

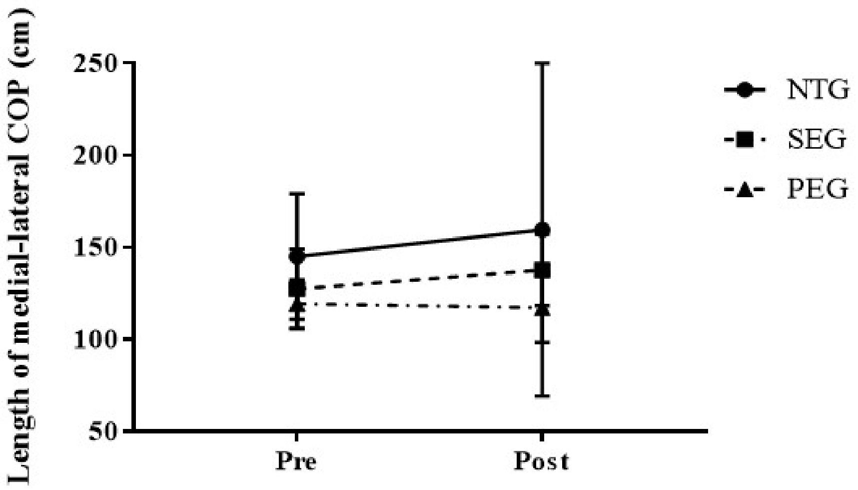

Figure 23. Comparison of length of medial-lateral COP. COP, center of pressure; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

⑤ Total length of COP

The descriptive statistics on the results of total length of COP in this study are presented, and the results of one-way ANOVA are shown in <Table 40> to find out the differences between groups by period. <Table 41> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was no significant difference in the interaction effect according to the group and measurement period (F=.612, p=.553), there was no significant difference between the groups (F=1.652, p=.220), and also there was no significant difference between the measurement periods (F=.081, p=.780). As a result of performing one-way ANOVA to compare the differences between groups, there was no significant difference after the intervention (p=.246).

Table 40. The result of descriptive statistics and one-way ANOVA of total length of COP by measurement trials (cm)

Group	Pre	Post	Total
NTG[a]	211.96±50.73	229.01±112.47	220.49±84.29
SEG[b]	198.85±44.91	200.56±25.00	199.71±34.93
PEG[c]	176.28±20.89	166.11±21.66	171.19±21.12
Total	195.70±41.67	198.56±69.41	197.13±33.21
F	1.361	1.516	-
p	.282	.246	-

Mean±Standard Deviation
COP, center of pressure; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 41. The result of two-way repeated measures ANOVA for total length of COP

Variable	SS	df	MS	F	p	η^2	β
Between Subject							
Group	17149.871	2	8574.935	1.652	.220	.155	.302
Error	93454.140	18	5191.897	-	-	-	-
Within Subject							
Period	85.799	1	85.799	.081	.780	.004	.058
Group×Period	1304.260	2	652.130	.612	.553	.064	.136
Error	19171.014	18	1065.056	-	-	-	-

COP, center of pressure

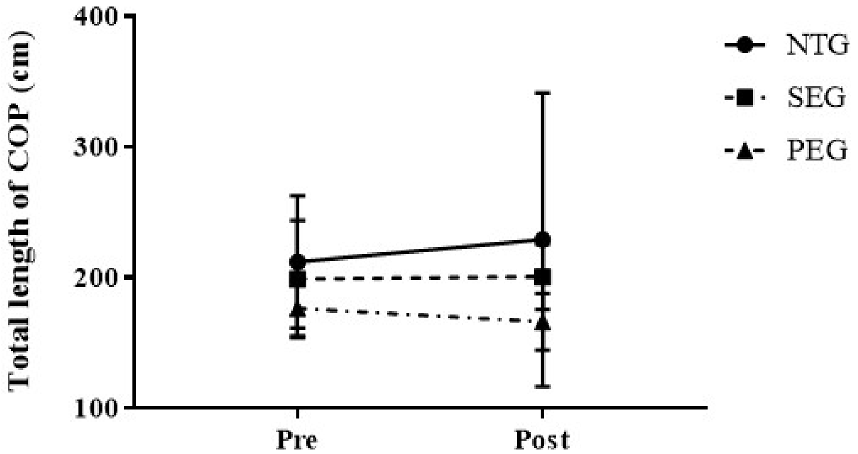

Figure 24. Comparison of total length of COP. COP, center of pressure; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

⑥ Velocity of anterior-posterior COP

The descriptive statistics on the results of velocity of anterior-posterior COP in this study are presented, and the results of one-way ANOVA are shown in <Table 42> to find out the differences between groups by period. <Table 43> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was no significant difference in the interaction effect according to the group and measurement period (F=.777, p=.474), there was no significant difference between the groups (F=1.892, p=.180), and also there was no significant difference between the measurement periods (F=.452, p=.510). As a result of performing one-way ANOVA to compare the differences between groups, there was no significant difference after the intervention (p=.140).

Table 42. The result of descriptive statistics and one-way ANOVA of velocity of anterior-posterior COP by measurement trials (cm/s)

Group	Pre	Post	Total
NTG[a]	12.34±3.05	12.97±5.54	12.65±4.31
SEG[b]	12.30±3.68	11.56±1.21	11.93±2.66
PEG[c]	10.36±1.81	9.27±1.04	9.82±1.53
Total	11.67±2.95	11.26±3.52	11.47±1.40
F	1.030	2.193	-
p	.377	.140	-

Mean±Standard Deviation
COP, center of pressure; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 43. The result of two-way repeated measures ANOVA for velocity of anterior-posterior COP

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	60.786	2	30.393	1.892	.180	.174	.341
Error	289.157	18	16.064	-	-	-	-
Within Subject							
Period	1.684	1	1.684	.452	.510	.024	.098
Group×Period	5.792	2	2.896	.777	.474	.079	.162
Error	67.066	18	3.726	-	-	-	-

COP, center of pressure

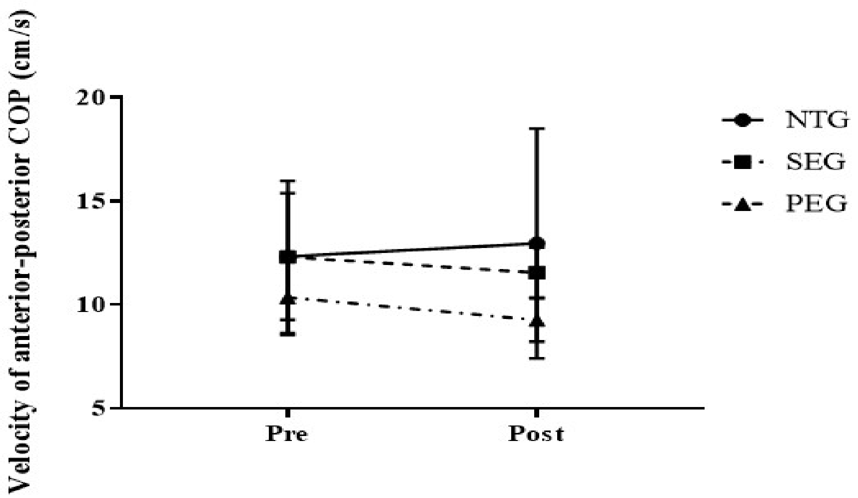

Figure 25. Comparison of velocity of anterior-posterior COP. COP, center of pressure; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

⑦ Velocity of medial-lateral COP

The descriptive statistics on the results of velocity of medial-lateral COP in this study are presented, and the results of one-way ANOVA are shown in <Table 44> to find out the differences between groups by period. <Table 45> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was no significant difference in the interaction effect according to the group and measurement period (F=.339, p=.717), there was no significant difference between the groups (F=1.460, p=.258), and also there was no significant difference between the measurement periods (F=.786, p=.387). As a result of performing one-way ANOVA to compare the differences between groups, there was no significant difference after the intervention (p=.368).

Table 44. The result of descriptive statistics and one-way ANOVA of velocity of medial-lateral COP by measurement trials (cm/s)

Group	Pre	Post	Total
NTG[a]	14.50±3.41	15.96±9.03	15.23±6.60
SEG[b]	12.74±2.17	13.77±1.93	13.26±2.05
PEG[c]	11.94±1.31	11.73±1.89	11.83±1.57
Total	13.06±2.57	13.82±5.46	13.44±2.78
F	2.005	1.058	-
p	.164	.368	-

Mean±Standard Deviation.
COP, center of pressure; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 45. The result of two-way repeated measures ANOVA for velocity of medial-lateral COP

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	81.553	2	40.776	1.460	.258	.140	.271
Error	502.725	18	27.929	-	-	-	-
Within Subject							
Period	6.043	1	6.043	.786	.387	.042	.134
Group×Period	5.219	2	2.609	.339	.717	.036	.096
Error	138.409	18	7.689	-	-	-	-

COP, center of pressure

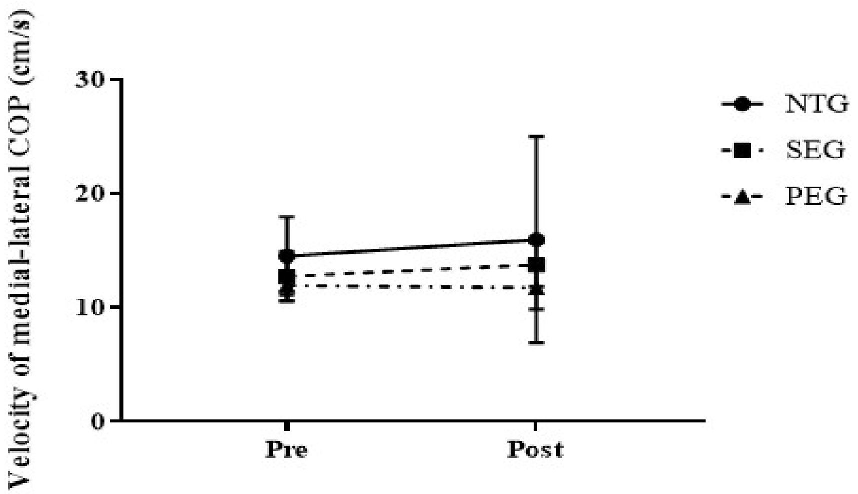

Figure 26. Comparison of velocity of medial-lateral COP. COP, center of pressure; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

⑧ Total velocity of COP

The descriptive statistics on the results of total velocity of COP in this study are presented, and the results of one-way ANOVA are shown in <Table 46> to find out the differences between groups by period. <Table 47> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was no significant difference in the interaction effect according to the group and measurement period (F=.612, p=.553), there was no significant difference between the groups (F=1.652, p=.220), and also there was no significant difference between the measurement periods (F=.081, p=.780). As a result of performing one-way ANOVA to compare the differences between groups, there was no significant difference after the intervention (p=.246).

Table 46. The result of descriptive statistics and one-way ANOVA of total velocity of COP by measurement trials (cm/s)

Group	Pre	Post	Total
NTG[a]	21.20±5.07	22.90±11.25	22.05±8.43
SEG[b]	19.89±4.49	20.06±2.50	19.97±3.49
PEG[c]	17.63±2.09	16.61±2.17	17.12±2.11
Total	19.57±4.17	19.86±6.94	19.71±3.32
F	1.361	1.516	-
p	.282	.246	-

Mean±Standard Deviation.
COP, center of pressure; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 47. The result of two-way repeated measures ANOVA for total velocity of COP

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	171.499	2	85.749	1.652	.220	.155	.302
Error	934.541	18	51.919	-	-	-	-
Within Subject							
Period	.858	1	.858	.081	.780	.004	.058
Group×Period	13.043	2	6.521	.612	.553	.064	.136
Error	191.710	18	10.651	-	-	-	-

COP, center of pressure

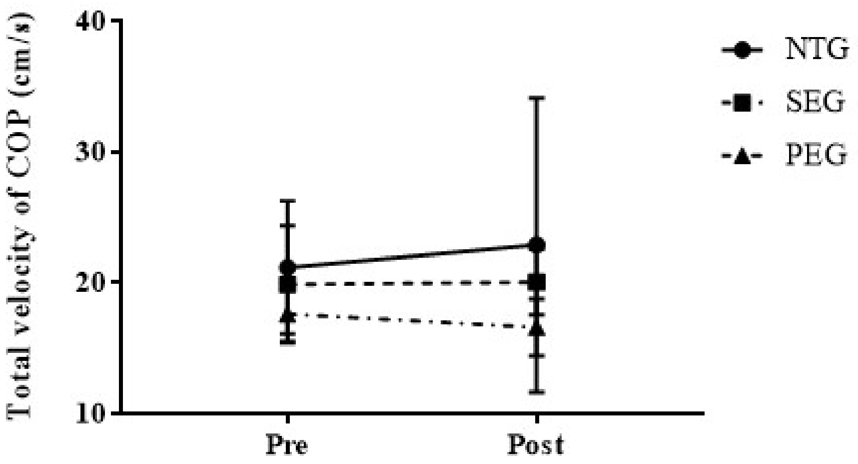

Figure 27. Comparison of total velocity of COP. COP, center of pressure; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

⑧ COP 95% confidence ellipse area

The descriptive statistics on the results of COP 95% confidence ellipse area in this study are presented, and the results of one-way ANOVA are shown in <Table 48> to find out the differences between groups by period. <Table 49> shows the results of the two-way repeated measures ANOVA to examine the interaction between the group and the measurement period.

As a result of two-way repeated measures ANOVA, there was a significant difference in the interaction effect according to the group and measurement period (F=7.767, p=.004), there was a significant difference between the groups (F=3.840, p=.041), and also there was a significant difference between the measurement periods (F=4.839, p=.041). As a result of performing one-way ANOVA to compare the differences between groups, significant differences were found post hoc (p=.001), and SEG and PEG were significantly lower than NTG.

Table 48. The result of descriptive statistics and one-way ANOVA of COP 95% confidence ellipse area by measurement trials (cm^2)

Group	Pre	Post	Total
NTG[a]	47.61±19.92	67.25±11.23	57.43±18.58
SEG[b]	55.03±33.09	32.34±8.12	43.68±25.97
PEG[c]	59.10±19.46	21.65±4.31	40.37±23.68
Total	53.91±24.19	40.41±21.48	47.16±3.79
F	.380	56.731	-
p	.689	.001	-
Tukey	-	b,c<a	-

Mean±Standard Deviation
COP, center of pressure; NTG[a], non-treated group; SEG[b], traditional strength exercise group; PEG[c], proprioceptive exercise group

Table 49. The result of two-way repeated measures ANOVA for COP 95% confidence ellipse area

Variable	SS	df	MS	*F*	*p*	η^2	β
Between Subject							
Group	2290.759	2	1145.379	3.840	.041	.299	.620
Error	5369.658	18	298.314	-	-	-	-
Within Subject							
Period	1914.015	1	1914.015	4.839	.041	.212	.548
Group×Period	6144.906	2	3072.453	7.767	.004	.463	.909
Error	7120.115	18	395.562	-	-	-	-

COP, center of pressure

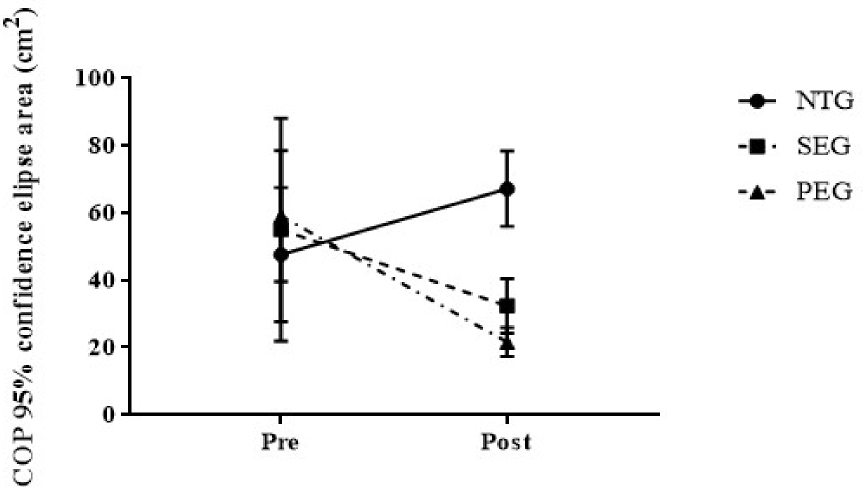

Figure 28. Comparison of COP 95% confidence ellipse area. COP, center of pressure; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group

V. Discussion

In this study, proprioceptive and strength exercise programs for 4 weeks were designed for college students with CAI. The purpose of this study was to investigate the effect of each exercise program on the static and dynamic balance, pain and motor functions in all participants.

CAI is a condition where repetitive sprains occur when a patient does not undergo treatment and exercise rehabilitation after experiencing an initial ankle sprain. Both functional and mechanical insufficiencies of the ankle occur simultaneously. Ankle functional insufficiency includes symptoms such as pain and decreased ankle neuromuscular function, joint ROM, proprioception and stability. Due to these insufficiencies, people with CAI show a change in gait pattern and a decrease in motor performance in day-to-day and sports activities. Tools for evaluating ankle stability, exercise performance, and quality of life due to ankle instability include CAIT, foot and ankle ability measure-activities of daily living, foot and ankle ability measure-sport (FAAM-sport) and foot and ankle disability index. In this study, the ankle instability of CAI college students before and after the exercise was measured by applying the CAIT questionnaire, which is the most used questionnaire for CAI evaluation. A significant difference was noted in the interaction between the group and the time period, and PEG showed a significantly higher value than the other two groups using one-way ANOVA, which was conducted to confirm the difference between the groups during post-mortem measurement. One study has shown that 8 weeks of short-foot exercise and proprioceptive exercise has improved the proprioception deficit and neuromuscular dysfunction (Lee et al., 2019). Furthermore, it was reported that proprioceptive exercise using a wobble board for 4 weeks and a strength exercise program using an elastic band were effective in improving the CAIT score of participants with CAI by activating the impaired postural control and neuromuscular function (Cain et al., 2020). These are in accordance with the results obtained in this study. Therefore, a short-term proprioceptive exercise program of 4 weeks is considered to have a positive effect in improving CAI symptoms by activating postural control and neuromuscular functions that are damaged due to repetitive ankle sprains.

CAI causes damage and weakness of the muscles and soft tissues around the ankle, resulting in repetitive ankle sprains and pain. Ankle pain causes problems such as restriction of movement and deterioration of quality of life while performing day-to-day and sports activities, and a representative method for checking this is VAS (Cole et al., 1994; Green & Heckman, 1994). Therefore, in this study, the degree of pain before and after ankle exercise of college students with CAI were measured using VAS. We noted a significant difference in the interaction between the group and the time period, and SEG and PEG showed significantly lower values than NTG in the one-way ANOVA. In a previous study, balance exercise using a wobble board for 6 weeks activated proprioceptors and joint receptors through balance control on unstable ground (Lazarou et al., 2018). Furthermore, it has been reported that strength training using an elastic band for 6 weeks was effective in reducing pain in adults with CAI by increasing the threshold time through the activation of sensory organs around the ankle and the neuromuscular function damaged by CAI (Hall et al., 2015), consistent with our results. It is seen that strength and proprioceptive exercise programs have a positive effect on pain control and quality of life improvement in adults with CAI.

CAI shows movement beyond the normal ROM in dorsiflexion and inversion due to deterioration of peripheral ligament and muscle functions due to repetitive ankle injury. Moreover, dorsiflexion tends to decrease markedly, affecting the decrease in static and dynamic balance (Gilbreath et al., 2014). Abnormal joint ROM in inversion and dorsiflexion increases the risk of falls due to ankle instability in daily life and causes problems including decreased exercise performance in performing sports activities. In previous studies, ankle ROM was measured to evaluate the mobility of

CAI. In our study, ROM was measured to determine the effect of a 4-week strength training program and a proprioceptive sensory exercise program on the ankle ROM of college students with CAI. A significant difference was observed in the interactions between groups and between periods in dorsiflexion. SEG and PEG showed significantly higher values than NTG in the one-way ANOVA. An interaction between the group and the period was also found in inversion, and SEG and PEG showed significantly lower values than NTG in the one-way ANOVA, which was used to confirm the difference between groups during post-mortem measurement. According to a previous study, strength training and proprioceptive exercise programs stabilized the abnormal ROM of CAI within the normal range by strengthening the function of the muscles around the ankle (A.M.A., 1988). It was also effective in increasing the ROM of dorsiflexion, which was decreased in CAI due to the increased flexibility of the atrophied ankle muscles and ligaments, and the threshold time of the muscle spindle and GTO (Lazarou et al., 2018; Lee et al., 2012). Therefore, such programs show a positive effect in improving the abnormal ROM of patients with CAI.

Weakness of the muscles and ligaments around the ankle caused by repetitive ankle sprains causes a decrease in ankle mobility and proprioception due to a reduced muscle contractility and neuromuscular function, which results in affecting the static/dynamic balance of the human body. This is the main reason of damage caused by the instability of the center of gravity during movements such as walking, changing direction, and landing in while performing daily life and sports activities. In previous studies, various methods including one-leg standing with eyes closed, star excursion balance test, YBT, and dynamic balance evaluation were used to evaluate the balance of CAI (Cain et al., 2017). In this study, we used one-leg standing with eyes closed as a static balance evaluation method for college students with CAI. A significant difference was observed in the interaction between groups and periods while standing with eyes closed. PEG showed a significantly higher value than the other two groups in the one-way ANOVA. According to a previous study, the application of a balance exercise program using a balance exercise tool for 6 weeks was effective in improving static balance by improving the neuromuscular signal transduction and adductor muscle functions weakened due to the muscle weakness in university students with CAI (Alahmari et al., 2021), which is in accordance with our study results. In YBT, significant differences were also found in the interaction between groups and periods in all directions of left and right. PEG showed significantly higher values than NTG in the anterior and posteromedial side of the left leg. Both SEG and PEG were significantly higher than NTG in the posterolateral side of the left and right leg in the one-way ANOVA. A study by Hale et al. (2007) found that strengthening the ankle muscle strength and increasing the sensory receptor threshold through 4 weeks lower extremity strength exercise and proprioceptive exercise programs were effective in improving the dynamic balance of adults with CAI. These results are somewhat similar to those obtained in this study, as we observed that such exercise programs are effective in improving static/dynamic balance in patients with CAI.

Jumping is a movement commonly performed in daily life as well as in sports including basketball, soccer, and volleyball. However, it is also one of the movements that tend to cause sprains in the knee and ankle. The weakness of the ankle muscles and ligaments due to repeated ankle sprains causes problems such as a decrease in an abnormal joint ROM, ankle stability and proprioception. It has been reported that power exercise performance is significantly lower than that of the general population (Holmes & Delahunt, 2009). In previous studies, vertical jump test, drop jump test, and single leg hop test were performed to evaluate the power of CAI. In this study, we measured a power in CAI through the vertical jump test. We noted a significant difference in the interaction between groups and periods in the vertical jump. PEG showed significantly higher values than NTG in the one-way ANOVA. In a study by Yang et al. (2014), dynamic postural control function, ankle mechanoreceptor function improvement, and neuromuscular control were restored in university students with CAI through 8 weeks of balance and combined training with balance and plyometrics. It has been shown that proprioception is effective in improving and increasing counter movement jump. The proprioceptive exercise program improves the jumping ability due to the recovery of damaged sensory receptor function and the increase of postural and neuromuscular control functions in patients with CAI.

CAI is reported to cause a decrease in ankle strength and proprioception because both mechanical and functional defects of the ankle together to cause multiple ankle injuries during landing in sports (Theisen & Day, 2019). Continuous damage caused by movements that occur frequently in daily life can cause greater deterioration of the tissues around the ankle and cause many problems, such as lowering the quality of life. In previous studies, to evaluate ankle instability of CAI, GRF was measured using methods such as gait test, vertical jump, and drop landing (Balasukumaran et al., 2020; Niu et al., 2011; Hyun & Ryu, 2015). In this study, the GRF and COP were measured during drop landing and a significant difference was noted in the interaction between groups and periods in the COP 95% confidence ellipse area. SEG and PEG showed significantly lower values than NTG in one-way ANOVA. In a study by Lee et al. (2021) patients with CAI were asked to perform dynamic lower extremity balance exercise for 4 weeks, and significant differences were found in both the anterior/posterior, left/right velocity, and movement range of the COP. It was observed that 4 weeks of balance exercise led to an increase in proprioceptor and joint receptor threshold and improved sensory function, ankle stability and dynamic postural control function in patients with CAI. However, unlike previous studies, no interaction was found in all variables except for the COP 95% confidence ellipse area and between groups. This reason being the variation between subjects in this study was too large and NTG did not completely control the ankle pain. Therefore, in future studies, the experiment should be performed with precise control on pain even in the group that does not receive treatment.

VI. Conclusion

The purpose of this study was to compare and analyze the effects of proprioceptive exercise programs on balance, pain, and motor functions in college students with CAI, and to suggest an exercise program to improve symptoms of CAI. Accordingly, a 4-week muscle strength and proprioceptive exercise program was designed, and balance, pain, and motor function were compared and analyzed.

The following conclusions were made by analyzing the experimental results in this study:

First, the ankle instability scale score and static balance were significantly increased with PEG than NTG and SEG according to the time before (0 weeks) and after (4 weeks) application of proprioceptive and strength exercise program .

Second, the ROM of plantar flexion and left leg posteromedial, posterolateral, and right leg posterolateral records in YBT were significantly increased with SEG and PEG than NTG according to the time before (0 weeks) and after (4 weeks) application of proprioceptive and strength exercise program.

Third, the vertical jump and left leg anterior and the right leg posteromedial in YBT were significantly increased with PEG than NTG according to the time before (0 weeks) and after (4 weeks) application of the proprioceptive and strength exercise program.

Fourth, the degree of pain, inversion range, and COP 95% confidence ellipse area were significantly decreased with SEG and PEG compared to NTG according to the time before (0 weeks) and after (4 weeks) application of the proprioceptive and strength exercise program.

0Summarizing the results of this study, the application of the proprioceptive exercise program had a positive effect by improving the balance and motor functions of college students with CAI. It can be inferred that the proprioceptive exercise program is necessary to improve the symptoms of CAI by reducing the pain level and COP 95% confidence ellipse area at landing.

However, this study included only male college students, and the differences may be observed with sex and age, therefore, it is necessary to conduct future studies on women and older participants for better results.

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국 문 초 록

고유수용성감각 운동이 만성 발목 불안정성 대학생의 정적/동적 밸런스, 통증 및 운동기능에 미치는 영향

박 영 준

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지도교수 서 태 범

본 연구의 목적은 4주간의 고유수용성감각 운동 프로그램이 만성 발목 불안정성(chronic ankle instability, CAI) 대학생의 발목 가동범위, 정적/동적 밸런스, 통증 및 운동기능에 미치는 영향을 연구하는 데 있다. 본 연구의 대상자는 컴버랜드 발목 불안정성 척도(Cumberland ankle instability tool, CAIT) 설문 점수가 24점 미만이며, 최근 6개월 동안 정형외과적 병력이 없고, 운동수행에 임상적 문제가 없는 성인 남성 21명을 선정하였다. 선정된 대상자는 무선 할당(random assignment)방식에 의해 7명씩 비 처치 집단(non-treated group, NTG), 근력 운동 집단(traditional strength exercise group, SEG), 고유수용성감각 운동 집단(proprioceptive exercise group, PEG)으로 분류하였다. SEG의 대상자는 탄력 밴드를 이용한 근력 운동 프로그램을 주 3회씩 4주간 수행했으며, PEG의 대상자는 BOSU 볼을 이용한 고유수용성감각 운동 프로그램을 주 3회씩 4주간 수행하였다. 운동 프로그램 참여 전과 후에 대상자들에게 CAIT, 통증정도, 신체구성, 발목 관절 가동범위, 눈 감고 외발서기, Y-밸런스 테스트, 수직 높이뛰기, 지면반력 및 압력중심 관련 변인 측정을 실시하였다. 측정 자료는 SPSS for windows (Version 22.0)

통계프로그램을 이용하여 각 변인의 평균(mean)과 표준편차(standard deviation)를 산출하였다. 그룹 과 시기 간에 상호작용 효과 검증은 이원 반복측정 분산분석(two-way repeated measures ANOVA)을 실시하였으며, 그룹 간의 차이를 비교하기 위해 일원배치 분산분석(one-way ANOVA) 분석을 하였다. 사후검증은 Tukey 방법을 사용하였으며, 모든 분석의 통계적 유의수준(p)은 .05로 설정하여 다음과 같은 결과를 얻었다. NTG와 SEG에 비해 PEG에서 CAIT 점수와 정적 밸런스가 유의하게 증가되었으며, NTG에 비해 SEG와 PEG에서 발목 배측굴곡의 관절가동범위와 동적 밸런스가 유의하게 증가하였다. 또한, NTG에 비해 PEG에서 수직 높이뛰기와 동적 밸런스가 유의하게 증가하였고, NTG에 비해 SEG와 PEG에서 통증 정도, 발목 내번의 관절가동범위 및 압력중심 이동범위가 유의한 차이로 감소되었다. 이상의 결과를 종합해 보면 4주간의 고유수용성감각 운동 프로그램은 CAIT 점수, 통증 정도, 밸런스, 발목 관절가동범위, 파워 및 발목 안정성 개선에 효과가 있는 것으로 나타났다. 따라서, 고유수용성감각 운동 프로그램은 CAI 개선에 긍정적인 영향을 미칠 것으로 생각된다. [2)]

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Appendix

	좌	우	점수
1. 다음 중 언제 발목의 통증을 경험합니까?			
전혀 경험하지 않는다.	☐	☐	5
스포츠 활동 중	☐	☐	4
고르지 못한 지면에서 달릴 때	☐	☐	3
고른 지면에서 달릴 때	☐	☐	2
고르지 못한 지면에서 걸을 때	☐	☐	1
고른 지면에서 걸을 때	☐	☐	0
2. 발목의 "불안정한 상태"를 경험합니까?			
전혀 경험하지 않는다.	☐	☐	4
스포츠 활동 중 가끔	☐	☐	3
스포츠 활동 중 자주	☐	☐	2
일상생활 중 가끔	☐	☐	1
일상생활 중 자주	☐	☐	0
3. 스포츠 활동(신체 활동) 중 빠르게(급격히) 방향 전환 시 발목의 "불안정한 상태"를 경험합니까?			
전혀 경험하지 않는다.	☐	☐	3
달릴 때 가끔	☐	☐	2
달릴 때 자주	☐	☐	1
걸을 때	☐	☐	0
4. 계단을 내려갈 때 발목의 "불안정한 상태"를 경험합니까?			
전혀 경험하지 않는다.	☐	☐	3
급히(빠른 속도로) 내려갈 때	☐	☐	2
가끔 느낀다.	☐	☐	1
항상 느낀다.	☐	☐	0
5. 한발서기를 할 때 발목의 "불안정한 상태"를 경험합니까?			
전혀 경험하지 않는다.	☐	☐	2
한 발로 뒷꿈치 들기(까치발)를 할 때	☐	☐	1
한 발로 서 있을 때	☐	☐	0

6. 다음 중 언제 발목의 “불안정한 상태”를 경험합니까?			
전혀 경험하지 않는다.	☐	☐	3
한 발로 좌우 뛰기(사이드 점프)를 할 때	☐	☐	2
한 발로 제자리 뛰기를 할 때	☐	☐	1
양 발을 이용한 점프(버티컬 점프)	☐	☐	0
7. 다음 중 언제 발목의 “불안정한 상태”를 경험합니까?			
전혀 경험하지 않는다.	☐	☐	4
고르지 못한 지면에서 달릴 때	☐	☐	3
고르지 못한 지면에서 가볍게 달릴 때(조깅)	☐	☐	2
고르지 못한 지면에서 걸을 때	☐	☐	1
평편한 표면에서 걸을 때	☐	☐	0
8. 일반적으로, 발목이 돌아가기(뒤틀리기) 시작했을 때 당신 스스로 멈출 수 있습니까?			
항상 즉시 멈출 수 있다.	☐	☐	3
흔히/자주	☐	☐	2
가끔	☐	☐	1
전혀 멈출 수 없다.	☐	☐	0
발목이 돌아가는 것(접지르는 것)을 한 번도 경험하지 못하였다.	☐	☐	3
9. 일반적인 발목이 돌아가기(뒤틀리기)를 경험한 후 당신의 발목은 얼마 후 원래대로 회복이 되었습니까?			
거의 직후/바로	☐	☐	3
24시간 이내	☐	☐	2
1일~2일	☐	☐	1
3일 이상	☐	☐	0
발목이 돌아가는 것(접지르는 것)을 한 번도 경험하지 못하였다.	☐	☐	3
총 점	점	점	

<부록 1> Cumberland ankle instability tool