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The Effects of Muscle Strengthening of the Ankle Joints on Postural Sway

The purpose of this study to identified the effect of muscle strengthening of ankle joints on postural sway. The subjects of this study were 29 healthy adults aged between 20 and 30 years(male 18, female 11). All subjects received ankle muscle strengthening exercise for 3 times, 3 sessions, 30 minutes per week over 4weeks period. The measured item of muscle strength, postural sway. Data collected from all subjects the result were as follows. The ankle strength showed significant increase($p<.05$). One leg stand test with eye close increase in static balance($p<.05$), left-right sway distance and anterior-posterior sway distance with eye open and close in static balance($p<.05$). The result findings show that strength of the ankle joint muscles is a factor which affects postural sway and the ankle joints are important in static balance.

Key words: *Ankle Joint; Muscle Strength; Static Balance; Postural Sway*

Ho Jung An[a], Min Soo Kang[b], Yong Nam Park[c]

[a]Dongnam Health College, Suwon. [b]Dr Choi' s Pain & Rehap Clinic, Ansan. [c]Daewon University College, Jecheon, Korea

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Address for correspondence
Yong Nam Park, PT, MS
599 Shinwol-dong Jecheon-si Chungbuk, Korea.
Tel : 82-33-563-1103
E-mail : till87@hanmail.net

INTRODUCTION

Postural balance refers to the process of adjustment for maintaining the center of gravity of the body against the base of support while a person is stationary or moves(1). Postural balance is classified into dynamic balance and static balance. Dynamic balance means balance when a person moves on the base of support or moves the human due to external stimuli. Static balance is an ability to stand on the base of support without swaying(2) and to maintain a posture when the body does not move by placing the center of gravity within the base of support.

In order to stably maintain an upright standing position, anterior-posterior stability, medial-lateral stability, and multi-directional stability are required. Exercise strategies to maintain such stability are divided into ankle joint, hip joint, and foot hold strategies(3). Ankle joint strategy is a strategy used when sway for balance is small and the base of support is stable. Movement made from ankle joint strategy transfers to the proximal area, contributing to postural stability maintenance(4). It is in particular a strategy necessary to maintain balance in a static condition. The hip and ankle joints play an important role in balance adjustment for physical stability and loss of balance sense is related to the weakening of muscle strength of the ankle joints(5). When muscle performance of the ankles, which plays a crucial part in balance adjustment for physical stability is lacking, it affects balance(6, 7) and increases the risk of a fall. Diverse studies have observed that muscle strength of the ankle joints is an important factor in balance adjustment and emphasized the importance of muscle strength of the ankle joints in order to maintain static balance.

Accordingly, this study aims to examine the effects of ankle joint muscle strength on their postural sway in a static state after increasing muscle strength of the ankle joints of normal adults, subjects of this study, through an exercise to muscle strength of the ankle joints.

METHODS

Subjects

The subjects of this study were 29 healthy adults aged between 20 and 30 years(male 18, female 11). The subjects were those who listened to the purpose and methods of this study and consented to participate in this study. The exclusion criteria for selection of the subjects are as follows.

- The subject who do not have musculoskeletal or neuromuscular disabilities
- The subject who have no limit in range of motion of the lower extremities
- The subject who did not undergo traumatic injury to or a surgical operation of the ankle joints for the recent six months

General characteristics of the subjects such as age, height, and weight are as follows Table 1.

Table 1. General characteristics of subjects

Classification	Mean±SD
Age(year)	23.86±1.21
Height(cm)	168.29±7.3
Weight(kg)	63.14±8.6

Study Procedures

In order to examine the effects of ankle muscle strength on static balance of the subjects, all the subjects performed exercise to enhance muscle strength of the ankle joints. Exercise to improve muscle strength-dorsiflexion, plantar flexion, inversion, and eversion-was conducted using Theraband (Hygenic Corporation, U.S.A). The subjects conducted the exercise three times per week for 30 minutes per each time for four weeks.

Prior to and after the exercise, ankle joint muscle strength and static balance of all the subjects were measured using a manual muscle tester. The squeeze of the right and the left hands was tested and only the muscle of the ankle joint on the side whose squeeze was stronger was measured. With regard to static balance, the subjects received one leg stand test, and their anterior-posterior sway distance, medial-lateral sway distance, and sway frequency were measured using a global postural system(GPS) while standing for 30 seconds for each posture with both the eyes closed and open.

Exercise to Improve Muscle Strength

As an exercise to strengthen muscle strength of the ankle joints, the subjects conducted a warm up exercise(5 minutes), an exercise to improve muscle strength(20 minutes), and a cool down exercise(5 minutes). For the warm up exercise, the subjects lightly stretched body parts in the order of the neck, the shoulders, the wrists, the elbows, the waist, the hip joints, the knees, and the ankles and then drew a large circle in a row, walking slowly or in one spot.

For plantar flexion, the subjects stretched the legs and performed plantar flexion with the ankle against the theraband and maintained the posture for 30 seconds. For dorsiflexion, the subjects performed dorsiflexion with the ankle against the theraband and maintained the posture for 30 seconds. For inversion and eversion, the subjects sat and stretched the legs and then bent one knee and stretched the other knee. An assistant helped the subjects' calf area fixed. The subjects performed inversion and eversion after fixing the band on the end of the foot. They repeated the exercise after maintaining the posture for one second at the height. All the exercises were applied to the bilateral ankle joints for three sessions with 10 times as one session. After one session was finished, they took a rest for two minutes. The strength of the theraband was adjusted to be suitable for the subjects' muscle strength. All the exercises were applied to the bilateral ankle joints(8).

For the cool down exercise, the subjects stretched the upper and lower extremities and the trunk. The stretching exercise focused on the muscles of the lower extremities in particular.

Measurement Method and Tool

Muscle measurement

Muscle strength was measured using a manual muscle tester(MMT, lafayette, U.S.A). In all tests, measurement was taken while the subjects took a posture against the center of gravity.

To measure muscle strength during dorsiflexion, the subjects took a sitting position and resistance was applied to the movement from the metatasal bone of the foot. To measure muscle strength during plantar flexion, the subjects took a prone position and resistance was applied to the sole. To measure muscle strength during inversion, the subjects stretched the legs and took a side-lying position and then resistance was applied from the medial metatarsal

bone. To measure muscle strength during eversion, the subjects took a side-lying position and resistance was applied from the lateral metatarsal bone(7). The manual muscle tester was attached on the area where resistance was applied. The average of measurements taken three times was considered a measured value. The unit was kg.

Balance measurement

To measure static balance, one leg standing test was conducted and the GPS was used.

The one leg standing test is used as a clinical measurement item aimed at evaluating static balance (10). In the test, static balance is measured while the subjects stand and bring together both feet and then raise and maintain one leg. In this state, the time until the subjects touched the foot on the ground or opened the eyes was measured. First, measurement was taken with the subjects opening their eyes. Then after a 10 minutes rest, measurement was taken again with their eyes closed. Measurement was taken three times and the average value was assumed as a measured value. The unit was second.

The GPS is a balance performance monitor produced by Chinesport, Italia. The subjects stand up on a movable board with both feet and their movement to maintain balance is sensed by the sensor of the board and the result is shown on the computer screen in the form of numerical values and graphs [Fig 1]. Measurement was taken after the subjects stood on the board with the eyes open. After a 10 minute rest, measurement was taken again with the subjects' eyes closed. The subjects maintained the posture under each condition for 30 seconds.

Measurement items included anterior-posterior sway distance, left-right sway distance, and the number of anterior-posterior and left-right sways. Sway distance signifies distance of the subjects' movement of the center of gravity backward and forward and to left and right in a standing position in order to maintain static balance. The unit is mm.

Sway frequency refers to the number of the subjects' swaying for one second in order to maintain static balance. If the number of sways for one second is equal to N, the sway frequency is 1/N and its unit is Hz. Therefore, the smaller the sway distance is and the larger the number of sways, the better the subjects' static balance is.

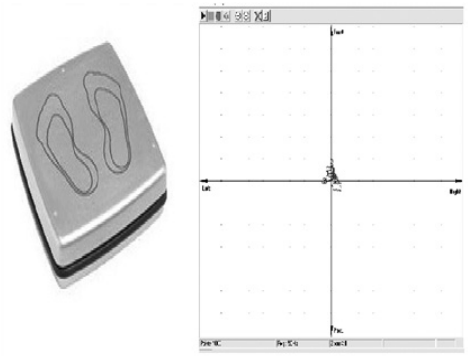

Fig. 1. GPS footboard and graph on the screen

Data Analysis

Statistical analyses were performed using SPSS version 14 for Windows(SPSS Institute Korea, Seoul, Korea) and the results are presented as Mean±SD. In order to analyze the changes in muscle strength and one leg stand, postural sway between the pre- and post-test, the paired t-test was used for the changes within each group Statistical significance was accepted for values of as $p<.05$.

RESULTS

Changes in Muscle Strength after Exercise Compared to Prior to Exercise

Muscle strength during dorsiflexion, plantar flexion, inversion, and eversion statistically significantly increased after the ankle joint exercise relative to prior to the exercise($p<.05$)〈Table 2〉.

Table 2. Comparison of ankle muscle strength (kg)

	pre	post	t	p
DF	21.81±4.25	23.04±3.75	-2.977	.025*
PF	22.17±3.72	24.74±3.46	-3.225	.018*
IV	12.43±3.02	15.56±3.28	-2.491	.047*
EV	11.87±3.18	14.63±2.60	-2.570	.042*

DF: dorsi flexion; PF: plantar flexion; IV: inversion; EV: eversion
*p<.05

Changes in Static Balance after the Exercise Compared to Prior to the Exercise

There was significant improvement in the one leg standing test after the exercise relative to prior to the exercise($p<.05$). Left-right sway distance with the subjects' eyes open did not significantly changed after the exercise compared to prior to the exercise but there was significant change after the exercise relative to prior to the exercise when the subjects closed their eyes($p<.05$). Anterior-posterior sway distance was significantly different between prior to and after the exercise with both the subjects' eyes open and closed($p<.05$). There was no statistically significant difference in left-right sway distance between prior to and after the exercise with the subjects' eyes open. There were positive changes in the number of sways with the subjects' eyes open and closed, which was not statistically significantly different, however 〈Table 3〉.

Table 3. Comparison of static balance

	pre	post	t	p
OLSO(sec)	28.23±4.69	29.61±1.02	1.000	.356
OLSC(sec)	21.23±8.12	27.63±4.97	−3.153	.020*
LRDO(mm)	6.43±4.72	4.66±4.85	2.324	.059
LRDC(mm)	8.15±5.14	8.15±5.14	3.478	.013*
APDO(mm)	11.17±7.65	8.23±6.27	3.478	.014*
APDC(mm)	12.37±5.21	8.53±7.37	2.731	.039*
LRSO(Hz)	5.26±.95	6.84±1.03	−.666	.530
LRSC(Hz)	7.03±1.93	8.86±.90	−.286	.784
APSO(Hz)	5.08±.45	5.58±.60	−.019	.985
APSC(Hz)	5.06±.87	6.69±.61	.953	.377

OLSO: one leg stand test with eye open
OLSC: one leg stand test with eye open
LRDO: left-right sway distance with eye open
LRDC: left-right sway distance with eye close
APDO: ant-post sway distance with eye open
APDC: ant-post sway distance with eye close
LRSO: left-right sway frequency with eye open
LRSC: left-right sway frequency with eye close
APSO: ant-post sway frequency with eye open
APSC: ant-post sway frequency with eye close
*p<.05

DISCUSSION

Static balance maintenance is an important factor for humans who carry out most functional activities while standing, and means an ability to respond to changes, however small the changes may be, by making the whole body muscles action(11). Action of muscles is important for balance maintenance. The maximal force muscles may exert is called muscle strength. When the strength of muscles increases, their functions increase, and therefore increased muscle strength is considered to have positive effect on balance maintenance.

Static balance is mainly maintained by closed-chain exercise and the feet and ankle joints are the first contact areas where the body is connected to the external environment. Therefore, abnormal location of the ankle joints may affect structural chain exercise of the lower extremities and as a result may trigger problems with balance. If muscle strength of the ankle joints is weakened, the ankle joints become unstable and postural sway increases(5), lowering balance ability. In this study, after a four-week exercise to increase strength of the ankle muscles, which plays an important part in balance maintenance, muscle strength during dorsiflexion, plantar flexion, inversion, and eversion significantly increased($p<.05$) and left-right sway distance and anterior-posterior sway distance statistically decreased with both the subjects' eyes closed and open($p<.05$). Minimizing sway of the center of gravity is to maintain good balance(13), and analysis of sway of the center of gravity is a crucial variable to evaluate balance ability and large sway of the center of gravity means that balance is not good(14). The result of the present study-increase in strength of the ankle muscles and decrease in left-right and anterior-posterior sway distance after the exercise-verified that strength of the ankle muscles was a factor with positive influence on static balance.

To maintain balance, input and integration of visual senses, the vestibular system, somatic senses, and proprioceptive senses should be made together(15). Among them, when the function of proprioceptive senses declines, posture adjusting and protective reflex abilities and balance ability to cope with postural sway are likely to decrease(16). According to this study result, there was significant change in the one leg standing test with the subjects' eyes closed after the exercise($p<.05$). The condition under which the subjects closed their eyes was to remove visual input to maintain balance, and in this condition

dependence on the somatic and proprioceptive senses became higher than when the subjects opened their eyes. Therefore, one's balance ability may decline with the eyes closed than with the eyes open and in this study result significant increase in the time to maintain balance with the subjects' eyes closed means that their balance ability improved.

Proprioceptive senses signify kinesthesia and joint position senses, and the weakening of muscles decreases proprioceptive senses which accommodate information on the positions and movements of the musculoskeletal muscles and joints(17). Accordingly, this study result was consistent with a report(18) that increase in muscle strength of the ankles led to improvement in position sense of the joints and increase in muscle strength was effective in maintaining balance.

Balance is an ability to maintain the center of the body within the base of support with minimal sway (19), and is a crucial element for postural maintenance. Therefore increase in the number of sways in order to maintain static balance means that balance ability has decreased. In this study result, although there was no significant difference in the number of left-right and anterior-posterior sways between when the subjects' eyes were closed and when their eyes were opened, the number of sways tended to increase, which suggests that it has a positive meaning in balance ability.

The above findings show that strength of the ankle joint muscles is a factor which affects postural sway and the ankle joints are important in static balance. Additional research to present the minimal number of sways necessary for normal adults to maintain static balance is considered necessary.

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