



Original Article

Effects of balance training by knee joint motions on muscle activity in adult men with functional ankle instability

SEUNG-MIN NAM, PT, MS¹⁾, WON-BOK KIM, MD, PhD^{1)*}, CHANG-KYO YUN, PT, MSc¹⁾

¹⁾ Department of Physical Therapy, College of Rehabilitation Science, Graduate School, Daegu University: 201 Jilyang, Gyeongsan-si, Kyeongbuk 712-714, Republic of Korea

Abstract. [Purpose] This study examined the effects of balance training by applying knee joint movements on muscle activity in male adults with functional ankle instability. [Subjects and Methods] 28 adults with functional ankle instability, divided randomly into an experimental group, which performed balance training by applying knee joint movements for 20 minutes and ankle joint exercises for 10 minutes, and a control group, which performed ankle joint exercise for 30 minutes. Exercises were completed three times a week for 8 weeks. Electromyographic values of the tibialis anterior, peroneus longus, peroneus brevis, and the lateral gastrocnemius muscles were obtained to compare and analyze muscle activity before and after the experiments in each group. [Results] The experimental group had significant increases in muscle activity in the tibialis anterior, peroneus longus, and lateral gastrocnemius muscles, while muscle activity in the peroneus brevis increased without significance. The control group had significant increases in muscle activity in the tibialis anterior and peroneus longus, while muscle activity in the peroneus brevis and lateral gastrocnemius muscles increased without significance. [Conclusion] In conclusion, balance training by applying knee joint movements can be recommended as a treatment method for patients with functional ankle instability.

Key words: Functional ankle instability, Balance training

(This article was submitted Jan. 5, 2016, and was accepted Feb. 6, 2016)

INTRODUCTION

Modernly, more and more people participate in sport activities for leisure, leading to an increase in sport-related injuries. The most frequently damaged area in the body is a lower extremity, accounting for approximately 77% of all injuries. More specifically, damage to the knee joints accounts for 21% of injuries, and that to the ankle joints accounts for 18% of injuries¹⁾. In particular, ankle sprain is one of the main causes of the impediment of activity, and 20–40% of patients with sprained ankles progress into having chronic ankle instability, which causes pain and instability in ankle joints, thereby causing reinjury of the ankle sprain²⁾.

Ankle instability can lead to pain, weakened muscle strength, decreased proprioception, balance difficulties, and the impediment of activities. Thus, balance training, proprioceptive-stimulation training, muscle-strengthening exercises, and manual therapy are used to increase the stability of ankle joints^{3, 4)}. Among these treatments, balance training is a widely used method that can improve posture control and proprioception and increase the stability of ankle joints^{3, 5, 6)}. In this study, balance training with knee joint movements was used rather than balance training alone. Balance training increases the stability of ankle joints, and a previous study reported that controlling ankle joints through knee joint flexion can not only absorb the impact of the ankle joints appropriately, but knee joints can also strategically compensate for weakened muscle strength and ankle instability^{7, 8)}. Furthermore, patients are easily upset by balance training due to its monotony and may quit

*Corresponding author. Won-bok Kim (E-mail: ak090700@gmail.com)

©2016 The Society of Physical Therapy Science. Published by IPEC Inc.

This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (by-nc-nd) License <<http://creativecommons.org/licenses/by-nc-nd/4.0/>>.

the training sooner than planned; however, patients using a balance-training apparatus to apply knee joint movements can watch the monitor while exercising, thereby achieving active exercise with a will to move, and they are more easily able to overcome feelings of monotony⁹⁾.

Therefore, this study aimed to determine the effects of balance training by applying knee joint movements on muscle activity in the ankle joints of male adults with ankle instability while inducing sudden inversion of ankle joints.

SUBJECTS AND METHODS

This study selected 28 adult male subjects between 19 and 30 years of age who had functional ankle instability determined by the Cumberland Ankle Instability Tool (Table 1). The selection criteria were as follows: men in their 20s who had experienced an ankle sprain at least once, those who felt giving way in their ankle joints, those with a Cumberland Ankle Instability Toolscore below 24 points, and those who could support their body weight fully while conducting the tasks in this study. The exclusion criteria were as follows: those with no other particular diseases than ankle instability, those who had experienced ankle joint surgery in the past, and those who felt pain in their ankles while performing daily activities.

All of the subjects understood the purpose of this study and gave their written consent before participating, according to the ethical standards of the Helsinki Declaration. Ethical approval was obtained by the local university or hospital research ethics boards.

In this study, subjects were divided into an experimental balance-training group, to which knee joint movements were applied, and an exercise control group, which conducted muscle stretching and muscle strengthening exercises. Examination was conducted prior to intervention, and a post-examination was conducted after eight weeks of intervention.

For the balance trainer, a Bal Pro (Man & Tel Co., Korea) was used, and knee joint movements were applied. The balance trainer consists of a screen, a pressure sensor that can sense the horizontal movements of weight loads on the foothold, a tilt sensor that can perceive the angle of the knee joint, and a main body containing programs to process the information perceived by the tilt sensor. The pressure sensor at the foothold can sense the body weight centers of patients to help them move horizontally using a finger-shaped cursor on the screen during the game as the body weight is moved to the right or left. A tilt sensor detects the angle of flexion and extension of the knee joints. For example, when the knees are bent, a cursor is raised, and when the knees are extended, a cursor descends, thereby performing training to touch various fruits arranged randomly on a tree on the screen. Training difficulty consists of seven levels, which can be adjusted with the size of the finger-shaped cursor, size of the fruits, and number of fruits. As the finger-shaped cursor on the screen and size of the fruits become smaller and the number of fruits increases, the level of difficulty of the training also increases^{10, 11)}.

The balance training was conducted three times a week for 8 weeks. Each exercise timespan was 30 minutes. Out of the 30 minutes, 20 minutes were allocated for balance training, while 10 minutes were allocated for exercise treatment of the ankle joints. The intensity of the ankle joint exercise treatment was adjusted gradually in accordance with the patient's condition. The control group applied stretching and muscle-strengthening exercises. The exercise was conducted three times a week for 8 weeks, and the intensity was adjusted gradually according to the patient's condition.

For examination, a trap door was employed to analyze the ankle injuries kinematically. The trap door was a foothold designed specifically to induce sudden ankle joint inversion, similar to a lateral ankle joint strain. Once a patient stood on the trap door with bare feet, a rope connected to the vertical supports at both sides was pulled, and the trap door opened, thereby inducing sudden inversion of ankle joints. Since the patients could detect when the trap door would open, visual and auditory information was blocked¹²⁾. The sudden ankle joint inversion using the trap door was conducted three times with the dominant foot before and after the training. The trap door was custom manufactured.

The electrodes were attached to four muscles that play a role in providing stability of ankle joints: the tibialis anterior, peroneus longus, peroneus brevis, and lateral gastrocnemius. The electrodes were attached to the dominant foot. To obtain a mean value of the muscle activity, three repeated measured amplitudes were averaged and converted into a root-mean-square value for comparison and analysis. The surface electromyography was used to generalize the collected data. It standardized measured values on the basis of the maximal voluntary isometric contraction (MVIC) or reference voluntary contraction. In this study, MVIC was used for standardization, considering that the subjects were active adults. The reference value of MVIC was represented as a ratio of the mean values of the activity measured for 2 seconds from the muscle activity start time when inducing the inversion of ankle joints¹³⁾. Three measurements were performed, and the mean value was used in the calculation.

Data analyses were performed using the SPSS program version 20.0. The Kolmogorov-Smirnov test was used to test for normality. To identify the changes in each parameter between before and after training of the two groups, a paired t-test was used. Statistical significance was accepted for values with $p < 0.05$.

RESULTS

The measurement result of the MVIC was based on the maximum value of muscle activity measured for 2 seconds when inducing sudden inversion. The muscle activity in the tibialis anterior before and after the exercise by the two groups showed that both the balance-training group and ankle joint exercise group had a significant increase in MVIC when inducing sudden

Table 1. General characteristics of subjects

	BT + AET Group (n=13)	AET Group (n=15)
Age (years)	23.0 ± 2.9	23.7 ± 1.8
Height (cm)	177.4 ± 6.8	174.0 ± 4.0
Weight (kg)	76.1 ± 16.7	66.9 ± 6.4
CAIT (score)	19.6 ± 4.3	21.3 ± 3.2

BT: balance training, AET: ankle exercise treatment, CAIT: Cumberland Ankle Instability Tool

Table 2. Comparison of muscle activity for each group at pre-test and post-test

	Muscle	Pre	Post
BT+AET	TA	24.3 ± 11.0	38.1 ± 21.7*
	PL	48.7 ± 23.4	74.6 ± 25.0*
	PB	19.2 ± 5.9	2.0 ± 6.6
	GAS	52.8 ± 16.6	71.3 ± 25.7*
AET	TA	28.9 ± 16.3	38.3 ± 15.9*
	PL	50.7 ± 21.0	75.7 ± 21.1*
	PB	20.1 ± 9.1	2.0 ± 8.7
	GAS	5.0 ± 27.2	61.8 ± 25.7

* p<0.05.

BT: Balance training, AET: Ankle exercise treatment, TA: tibialis anterior, PL: peroneus longus, PB: peroneus brevis, GAS: gastrocnemius

inversion before and after the exercise (p<0.05) (Table 2). The test results of the MVIC value between the groups when inducing sudden inversion showed no significant difference.

The measurement results of the muscle activity in the peroneus longus showed that both the balance-training and ankle joint exercise groups had a significant increase in the MVIC values when inducing sudden inversion before and after the exercise (p<0.05). However, the test results showed no significant difference between the groups.

The measurement results of the muscle activity in the peroneus brevis showed that neither the balance-training nor ankle joint treatment groups had significant difference in the MVIC values when inducing sudden inversion before and after the exercise (p<0.05). The test results showed no significant difference between the groups.

DISCUSSION

The study results showed that both the balance-training and ankle joint exercise groups had a significant increase in muscle activity in the tibialis anterior and peroneus longus; however, there was no statistically significant difference between the groups. The study result is consistent with previous study results, in which an 8 week ankle joint exercise treatment program was significantly effective in improving the surrounding muscles of ankle joints and the stability of the ankle joint. The current study's findings are also consistent with the results of other studies, in which balance training on unstable footholds increased the muscle activity of the tibialis anterior and peroneus longus significantly¹⁴). In addition, ankle joint exercise treatment increased muscle activity in the tibialis anterior and peroneus longus significantly in this study, which proved the treatment effective once again. This result indicates that balance training by applying knee joint movements stimulates proprioception, thereby increasing sensory nerve signaling from the damaged pressure receptors of the ankle joints, which leads to an increase in the motion control of the surrounding muscles of the ankle joints. The above results indicate that the tibialis anterior and peroneus longus play an important role in preventing recurring ankle strain and in the dynamic stabilization of ankle joints.

Both the balance-training and ankle joint exercise treatment groups had increased muscle activity in the peroneus brevis, but it was not statistically significant. The above result is consistent with the results of another study, which reported that the reflexive contraction of the peroneus brevis was not significantly effective in preventing ankle joint strain¹⁵). Furthermore, it is difficult to record the electrical activities of the peroneus brevis selectively via surface electromyography. Therefore, significant values cannot be obtained.

The balance-training group had statistically increased muscle activity in the lateral gastrocnemius, whereas the ankle joint exercise treatment group had no significant increase in the muscle activity in the lateral gastrocnemius. This is because the gastrocnemius consists of two joint muscles that perform not only plantar flexion in the ankle joints but also knee joint flexion. Thus, balance training with knee joint movements was more effective in increasing the muscle activity of the lateral gastrocnemius than the ankle joint exercise treatment because of the repeated motion of flexion and extension of the knee joints. For patients with functional ankle instability, the functions of all the muscles and joints should be considered, rather than treatment that focuses on individual muscles and joints.

There are three limitations to this study. First, the muscle activity induced by sudden inversion in dynamic situations was not measured. In reality, ankle joint strain occurs frequently in dynamic situations. This study measured muscle activity while inducing sudden inversion in the standing position, which is a static posture. Second, the muscle activity limited to the surrounding muscles of the ankle joints was measured. When sudden postural changes occur, knee joint and hip joint strategies are employed more than ankle joint strategies¹⁶). Thus, future studies should measure the activities of the surrounding

muscles of the knee and hip joints. Third, since our study subjects were limited to male adults only, this study result cannot be generalized to both sexes or across all age groups.

The above study results indicated that both the ankle joint exercise treatment and balance training with knee joint movements were effective for functional ankle instability therapy. Furthermore, both improved proprioceptive sensibility and the functional capabilities of the surrounding muscles of the ankle joints, thereby providing a coping mechanism for the unexpected inversion of ankle joints. Therefore, both exercises can be recommended as efficient training methods to prevent the recurrence of ankle joint injury and provide stability to the ankle joints.

ACKNOWLEDGEMENT

This research was supported by the Daegu University Research Grant, 2014.

REFERENCES

- 1) Lynch SA: Assessment of the injured ankle in the athlete. *J Athl Train*, 2002, 37: 406–412. [[Medline](#)]
- 2) Kaminski TW, Hartsell HD: Factors contributing to chronic ankle instability: a strength perspective. *J Athl Train*, 2002, 37: 394–405. [[Medline](#)]
- 3) Mattacola CG, Dwyer MK: Rehabilitation of the ankle after acute sprain or chronic instability. *J Athl Train*, 2002, 37: 413–429. [[Medline](#)]
- 4) Willems T, Witvrouw E, Verstuyft J, et al.: Proprioception and muscle strength in subjects with a history of ankle sprains and chronic instability. *J Athl Train*, 2002, 37: 487–493. [[Medline](#)]
- 5) Arnold BL, De La Motte S, Linens S, et al.: Ankle instability is associated with balance impairments: a meta-analysis. *Med Sci Sports Exerc*, 2009, 41: 1048–1062. [[Medline](#)] [[CrossRef](#)]
- 6) Ross SE, Guskiewicz KM: Effect of coordination training with and without stochastic resonance stimulation on dynamic postural stability of subjects with functional ankle instability and subjects with stable ankles. *Clin J Sport Med*, 2006, 16: 323–328. [[Medline](#)] [[CrossRef](#)]
- 7) Morrison KE, Kaminski TW: Foot characteristics in association with inversion ankle injury. *J Athl Train*, 2007, 42: 135–142. [[Medline](#)]
- 8) Lee DH, Lee SY, Park JS: The effect of fixed ankle and knee joints on postural stability and muscle activity. *J Phys Ther Sci*, 2013, 25: 33–36. [[CrossRef](#)]
- 9) Lai CH, Peng CW, Chen YL, et al.: Effects of interactive video-game based system exercise on the balance of the elderly. *Gait Posture*, 2013, 37: 511–515. [[Medline](#)] [[CrossRef](#)]
- 10) Byun SD, Cho DH, Choi WD, et al.: Effects of the balance control training in chronic hemiplegic stroke patients. *Brain NeuroRehabilitation*, 2012, 5: 32–38. [[CrossRef](#)]
- 11) Jung JC, Goo BO, Lee DH, et al.: Effects of 3D visual feedback exercise on the balance and walking abilities of hemiplegic patients. *J Phys Ther Sci*, 2011, 23: 859–862. [[CrossRef](#)]
- 12) Ty Hopkins J, McLoda T, McCaw S: Muscle activation following sudden ankle inversion during standing and walking. *Eur J Appl Physiol*, 2007, 99: 371–378. [[Medline](#)] [[CrossRef](#)]
- 13) Cordova ML, Jutte LS, Hopkins JT: EMG comparison of selected ankle rehabilitation exercises. *J Sport Rehabil*, 1999, 8: 209–218.
- 14) Forestier N, Toschi P: The effects of an ankle destabilization device on muscular activity while walking. 2005, 26: 464–470.
- 15) Isakov E, Mizrahi J, Solzi P, et al.: Response of the peroneal muscles to sudden inversion of the ankle during standing. *JAB*, 2010, 2: 100–109.
- 16) Aoyama M, Suzuki Y, Onishi J, et al.: Physical and functional factors in activities of daily living that predict falls in community-dwelling older women. *Geriatr Gerontol Int*, 2011, 11: 348–357. [[Medline](#)] [[CrossRef](#)]