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Effects of BOSU® ball balance training on balance ability and proprioception in adults with ankle instability

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Abstract

Background/Objectives*: Lower limb muscle strength training and balance training are effective in improving and preventing ankle instability. In the present study, we aimed to investigate the effects of balance training with a BOSU® Ball on balance ability and proprioception in adults with ankle instability.*

Methods/Statistical analysis*: Twenty-six adults in their twenties with ankle instability were selected and randomly assigned to either the BOSU® Ball exercise group (BBG; n=13) or the Thera-band exercise group (TBG; n=13). The intervention was carried out three times a week for four weeks, for a total of twelve times. Proprioception and balance ability tests were performed before and after the intervention.*

Findings*: Proprioception significantly decreased for the BBG ($p<0.05$). Proprioception significantly decreased for the TBG ($p<0.05$). Forward-backward distance, right-left distance, and total distance significantly increased for the BBG ($p<0.05$). Total distance significantly increased for the TBG ($p<0.05$).*

Improvements/Applications*: The findings of this study suggest that performing balance training on the BOSU® Ball improves the proprioception and balance ability of the ankle joint.*

Keywords: *BOSU® Ball, Thera-band training, Balance training, Balance ability, Proprioception*

1. INTRODUCTION

Ankle sprains are one of the most prevalent injuries that occur in physically active individuals. Previous history of an ankle sprain is the most common factor associated with the occurrence of ankle sprains[1,2].

Anandacoomarasamy and Barnsley (2005) reported that between 32 and 74% of people who sustained an ankle sprain had symptoms, such as the ankle giving way, swelling, pain, and anxiety[3]. Moreover, Yeung et al. (1994) observed that 73% of athletes have recurrent ankle sprains, of whom 59% have severe disabilities and residual symptoms that impact their athletic performance[4]. Repeated ankle injuries lead to weakness of the lower leg muscles and cause a reduced sense of stability. These complex factors give rise to ankle instability, which in turn results in reinjury[5]. In addition, musculoskeletal system injuries are known to impair joint proprioception, which contributes to an increased risk of recurrent injuries[6]. The associated proprioceptors provide sensory feedback necessary for controlling movement patterns; therefore, joint proprioception is considered essential for proper biomechanics and joint stability[7]. A weakness of leg muscles is the most important contributing factor to repeated ankle sprains. Reinjury of the ankle can be prevented when muscle strength and proprioception around the ankle joint maintain normal function.

Balance exercise programs are frequently used for improving proprioception, and many of these exercise protocols include the use of an unstable surface, such as the BOSU® Ball[8, 9]. In a study by Anguish and Sandrey (2018), subjects with chronic ankle instability who performed balance training three times a week for four weeks showed improvements in their balance ability and joint position sense[10]. Docherty et al. (1998) reported that subjects with functional ankle instability who performed strength training three times a week for six weeks showed improvement in their joint position sense[11]. Thus, muscle and balance training of the legs appears to be effective in improving ankle instability and preventing reinjury.

However, there is a lack of research on combined exercise programs that take these factors into consideration. Therefore, in this study, we aimed to investigate the effects of balance training with the BOSU® Ball on balance ability and proprioception in adults with ankle instability.

2. Materials And Methods

2.1. *Subjects*

The subjects of this study were 26 students in their twenties at N University, located in Cheonan. The subjects were randomly assigned to either the BOSU® Ball exercise group (BBG; n=13) or the Thera-band exercise group (TBG; n=13). Inclusion criteria for the subjects were as follows: (1) those with a score of 25 points or less on the Cumberland Ankle Instability Tool (CAIT), a measuring tool for ankle instability; (2) those with ankle instability only on one side, either the right or left ankle; (3) those with no history of an ankle joint fracture; (4) those without neurological or orthopedic problems that affect leg and ankle movements; (5) those with no history of ankle joint surgery[12-15]. All subjects were informed of the purpose of the present study before they voluntarily signed a consent form. General characteristics of the subjects are presented in Table 1.

Table 1: General features of the research subjects

Variables	BBG (M±SD)	TBG (M±SD)	*p*
Age [yr]	22.69±2.93	22.69±3.40	.24
Height [㎝]	173.61±7.02	172.69±5.43	.31
Weight [㎏]	75.54±11.15	74.21±8.29	.14
SMM [㎏]	23.45±10.13	26.36±13.08	.17
BFM [㎏]	26.49±10.61	27.48±9.19	.28
BMI [㎏/㎡]	24.98±2.46	24.89±2.83	.22

BBG: BOSU® Ball exercise group, TBG: Thera-band exercise group,
SMM: Skeletal muscle mass, BFM: Body fat mass, BMI: Body mass index

2.2. *Interventions*

In the present study, the intervention was carried out three times a week for four weeks, for a total of twelve times. Proprioception and balance ability tests were performed before and after the four-week intervention. The BBG performed muscle training with balance training, while the TBG only performed muscle training. Only the leg with ankle instability was used to perform the exercises. A modified Cruza-Diaz et al. (2015) exercise

program was used for the balance training using the BOSU® Ball[16]. Four movements, single-limb stance with eyes open on the BOSU® Ball, single-limb stance with eyes closed on the BOSU® Ball, single-limb hop on the BOSU® Ball, and double-limb step-up and step-down on the BOSU® Ball, were performed according to the established program. Here, we refer to four types of movement errors from McKeon et al. (2008), with modifications as appropriate for our intervention, to give subjects guidance on the movements. The errors were as follows[17]: (1) subject touching the opposite leg, (2) excessive trunk motion (>30° lateral flexion), (3) removal of arms crossed at the chest during exercise; (4) raised foot touching the ground. The exercise program of the BBG consisted of five minutes of warm-up, twenty minutes of muscle training, twenty minutes of balance training, and five minutes of cool-down, taking a total of approximately fifty minutes. A modified Kaminski et al. (2003) exercise program was used for the strength training using the Thera band (USA, green) [18]. The Thera-band was doubled over to form two layers and secured behind a pole. One end of the band was secured to the foot with the band stretched to 70% of its resting length. The subjects performed 4 types of movements, inversion, eversion, dorsiflexion, and plantar flexion, according to an established program. Here, the subjects were instructed to concentrate on the ankle exercise in a seated position, with the knee extended. The exercise program of the TBG consisted of five minutes of warm-up, forty minutes of muscle training, and five minutes of cool-down, taking a total of approximately fifty minutes. Detailed descriptions of the balance and muscle training program are shown in Table 2.

Table 2: BOSU® Ball and Thera-band training protocol

Session		Exercise	Sets
Warm-up		Lower limb stretching	5 min.
Main	Balance training	1. Open your eyes and keep your arms crossed over your chest on BOSU® Ball for 60 sec 2. Close your eyes and keep single leg standing for 30 sec with your arms crossed over your chest on BOSU® Ball 3. Open your eyes and jumping on BOSU® Ball for 30 sec with single leg 4. Open your eyes, jumping from the ground to BOSU® Ball, and go back to the ground (30 times)	· BBG: -Balance training 2 set (20 min) -Thera-band training 2 set (20 min) · TBG: -Thera-band training 4 set (40 min) · 30 sec break between each exercise · 60 sec between sets
	Thera-band training	1. Ankle dorsiflexion using Thera-band (20 times) 2. Ankle Plantarflexion using Thera-band (20 times) 3. Ankle inversion using Thera-band (20 times) 4. Ankle eversion using Thera-band (20 times)	
Cool-down		Lower limb stretching	5 min.

BBG: BOSU® Ball exercise group, TBG: Thera-band exercise group

2.3. *Measurements*

2.3.1. Balance ability

In this study, balance ability was measured using the HUR BT4 (HURLABS, Tampere, Finland). To measure balance ability, the limits of stability (LOS) test was used. Subjects were instructed to take off their shoes and step on the device, keeping their heels 2 cm apart with each foot pointed 15° outward and both hands naturally resting on their pants. The subjects performed maximal voluntary leaning in four directions, forward, backward, left, and right, for eight seconds while standing in an upright position without taking both feet off the balance platform. From this, the maximum leaning angle for each direction was extracted[19].

2.3.2 Proprioception

Proprioception was measured using the Dualer IQ (JTECH Medical, USA) digital inclinometer. The proprioception of the ankle joint was assessed by joint position sense in dorsiflexion and plantar flexion. We adapted the assessment methods used in previous studies for this current study[20-21]. To perform the joint position sense test, patients lay down barefoot in the supine position with their leg placed on the platform so that their knee joint was bent 90° and their hip joint was bent 110-120°. The subjects were blindfolded to eliminate visual information. Here, the leg with the ankle instability was assessed. The target positions and angles for the joint position sense test were 15° of dorsiflexion and 30° of plantar flexion. Prior to the start of the test, the subjects were instructed to maintain the target position and angle provided by the investigator for ten seconds and concentrate. This was repeated three times. Then, the subjects were instructed to move their ankle on their own to position their ankle to the target angle and say ‘stop’ when they thought it was at the target position. Here, the angle of this position was measured, and the measurements were taken three times. The measured values were used to calculate the difference between the target angle set by the investigator and the subject’s actual target angle. The mean value was used for the analysis.

2.4. Statistical analyses

Data normality was determined using the Shapiro–Wilk test. The general characteristics of the subjects and the homogeneity test of the pre-measured dependent variables of each group were performed by one-way ANOVA. Paired t-test was performed to compare intra-group dependent variables, and inter-group dependent variables were compared by independent t-test. All variables were expressed as mean ± SD. The significance level was set to α=0.05. All statistical analyses were performed with the SPSS (version 20.0).

3. RESULTS AND DISCUSSION

Table 3: Comparisons proprioception and balance ability between before and after intervention

variables	BBG		*p*	TBG		*p*	*Bp*
	pre (M±SD)	post (M±SD)		pre (M±SD)	post (M±SD)		
DF	5.35±3.95	2.18±1.52	0.03*	5.86±3.12	3.50±2.98	0.06	0.64
PF	5.21±2.76	2.62±1.48	0.00*	5.20±2.62	3.57±1.33	0.04*	0.33
F+B	10.26±1.75	12.40±.93	0.03*	10.11±1.20	10.65±.93	0.19	0.23

R+L	15.11±2.27	16.89±1.12	0.04*	14.82±2.09	15.41±2.46	0.17	0.12
T	25.37±3.58	28.03±1.86	0.01*	24.93±2.62	26.05±3.11	0.10	0.04*

*p<.05, BP: Between group p value, BBG: BOSU® Ball exercise group, TBG: Thera-band exercise group, F-B: Forward-backward distance, R-L: Right-left distance, T: total distance, DF: dorsiflexion, PF: Plantar flexion

3.1. Proprioception

Dorsiflexion and plantar flexion angle errors significantly decreased in the BBG from pre- to post-intervention in Table 3 ($p<0.05$). In the TBG, dorsiflexion angle error was not significantly different before and after the intervention, while the plantar flexion angle error significantly decreased from pre- to post-intervention in Table 3 ($p<0.05$). There were no significant differences between the pre- and post-intervention angle errors for both dorsiflexion and plantar flexion between BBG and TBG.

The results of the present study are similar to the findings of previous studies, which showed balance exercises on unstable surfaces are effective in improving proprioception. Therefore, we believe that these results are due to changes in the stimulation sensitivity with respect to neuromuscular control of the joints and muscles brought about by the proprioception exercise[22, 23]. Moreover, it appears that prolonged stretching of the surrounding tissue in response to sudden changes in the position of the ankle joint stimulated proprioceptors, leading to increased proprioception[24, 25].

3.2. Balance ability

Forward-backward distance, right-left distance, and total distance significantly increased for the BBG from pre- to post-intervention in Table 3 ($p<0.05$). There were no significant differences between the pre- and post-intervention measures for the forward-backward distance, right-left distance, and total distance in the TBG. While comparisons between the two groups of the pre- and post-intervention measures for the forward-backward and right-left distances revealed no significant differences, a significant difference in total distance was found in Table 3 ($p<0.05$).

Cuğ et al. (2016) reported that a four-week balance training program consisting of exercises on a BOSU® ball improved postural control and ankle muscle strength in healthy young adults in their twenties[26]. Strøm et al. (2016) observed muscle activity in 90 healthy subjects during single-legged exercise on an Airex® mat, BOSU® Ball, wobble board, and floor. They found that balancing on a BOSU® Ball and wobble board resulted in the highest muscle activity[27]. No significant difference in balance was found in the TBG, in which the Thera-band provided static resistance to the muscles, whereas proprioception and balance ability significantly increased in the BBG, in which muscles were stimulated by dynamic movements. We believe these results were due to the unstable nature of the BOSU® Ball, which led to a greater amount of movement and muscle activity in the ankle joint[28].

This study had several limitations. This study assessed the proprioception and balance related to only the ankle. The level of change should also be measured using more diverse assessment methods, such as actual gait assessments or assessments related to daily life, in subsequent studies. Future research should address this limitation and determine the various factors that affect balance ability and proprioception. Additionally, we

believe that research should be conducted on potential strategies for enhancing balance and proprioception.

4. CONCLUSION

This study aimed to investigate the effects balance and strength training on a BOSU® ball had on balance ability and proprioception in adults with ankle instability. The results showed significant improvements in proprioception of the ankle joint in the BBG and TBG. A significant increase in balance ability was only found in the BBG. In conclusion, we found that performing a four-week balance training on the BOSU® ball resulted in improvements in the proprioception and balance ability of the ankle joint in subjects with ankle instability.

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