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Effect of Jumping Exercise on Supporting Surface on Ankle Muscle Thickness, Proprioception and Balance in Adults with Functional Ankle Instability

Background: Functional ankle instability (FAI) indicating a decrease in muscle strength, proprioception, neuromuscular control, balance and postural control function.

Objective: To investigate the effect of jumping exercise on the supporting surface on the ankle muscle thickness, proprioceptive sensation, and balance in adults with FAI.

Design: Randomized Controlled Trial.

Methods: Twenty young people with FAI were randomly assigned to the unstable supporting surface jump group (N=10) and the stable supporting surface jump group (N=10). The intervention was conducted three times a week for eight weeks, and for 30 minutes per session. Trampoline was used as an unstable support surface and the stable support surface was carried out on a regular floor. The thickness of the tibialis anterior muscle and medial gastrocnemius muscle was measured by ultrasonography, and the proprioception of dorsiflexion and plantarflexion was measured using an electrogoniometer. The dynamic balance was also measured with a balance meter.

Results: The the muscle thickness of the medial gastrocnemius muscle was significantly higher in the stable supporting surface jump group than in the unstable supporting surface jump group (p<.05). Furthermore, the plantar flexion proprioception and dynamic balance were significantly improved in the unstable supporting surface jump group than in the stable supporting surface jump group in the intergroup comparison (p<.05).

Conclusions: The conclusion has been reached in this study that the jumping exercise on the unstable supporting surface could be a more effective in improving FAI than the regular surface.

Key words: *Jumping exercise, Muscle thickness, Proprioceptive, Balance, Functional ankle instability*

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INTRODUCTION

Chronic ankle instability (CAI), an important issue in orthopedics, is characterized by discomfort when performing repetitive physical activities [1]. CAI can be classified into mechanical ankle instability caused by abnormalities in anatomical structures and cartilage, on the one hand, and functional ankle instability (FAI) indicating a decrease in muscle strength, proprioception, neuromuscular control, balance and postural control function [2].

Balance can be divided into static balance that can stand on a fixed support surface and dynamic balance that moves on its own when motion occurs on the support surface or when stimulation occurs from outside [3, 4]. In order to maintain balance, ankle-joint strategies, among other strategies, are essential [5]. The ankle joint strategy is controlled by alternating contractions of the tibialis anterior muscle and medial gastrocnemius muscle and requires sufficient muscle strength [6]. The ankle controls the small sway of the body that is related to balance ability.

Proprioception plays an important role in maintaining the stability of the ankle joint [8]. The proprioceptive senses include kinesthetic sensation, joint position sensation, and sensation of force [9].

Recently, several intervention methods for rehabilitation of FAI have been proposed, including using taping, step, visual feedback, and unstable supporting surface [10-13]. However, recent study have shown that the intervention period is short. Also studied involving only one gender or long intervention period have had few measurement variables. Among these methods, trampoline as an unstable supporting surface movement has been reported to reduce the impact force on the ankle and prevent injuries [14]. The trampoline exercise is effective in inducing motivation by stimulating participants' interest. Movements that can be performed on a trampoline can enhance physical factors, such as trunk stability, muscular coordination reactions, range of joint movements, and spatial orientation [15]. The trampoline is a rehabilitation method that can stimulate proprioception and enhance a person's ability to balance [16].

Therefore, in the present study, we aimed to investigate the effects of jumping on the trampoline and regular floor on the ankle muscle thickness, proprioception, and balance of FAI, and to obtain clinical data for ankle instability rehabilitation exercise.

METHODS

Subjects

This study was conducted on sample of a total of 20 adults with FAI, which is less than 24 out of 30 points in a Cumberland Ankle Instability Tool (CAIT) survey at N University in Gwangju. The criteria for selection were a person with a CAIT score of 24 or less. Additionally, individuals with ankle pain, ankle surgery experience, nervous system disease, and those currently exercising regularly were excluded. A total of 20 participants were randomly assigned to the unstable supporting surface jump (USSJ) group (N=10) and the stable supporting surface jump (SSSJ) groups (N=10) using the Excel function program 17). All participants were informed about the purpose and method of this study before participating in the study. This study was conducted with the approval of research institution Bioethics Committee of Nambu University (IRB 1041478-2018-HR-029).

Materials and outcome measures

Functional Ankle Instability

The CAIT is an ankle instability evaluation tool developed by [18] the questionnaire consists of 9 questions, and 25 or more of the 30 total points are normal, while 24 or less indicate FAI. CAIT has high reliability (ICC (2,1) = .96) [19].

Supporting Surface Type

In this study, Trampoline (Korea, Joysports) was used as an unstable support (Figure 1). The stable support surface was carried out on a regular floor.

Fig. 1. Unstable supporting surface

Muscle Thickness

To measure the thickness of the ankle muscles, an ultrasonic imaging device AchievoCST (Singapore, V2U Health Care) was used. This device has the frequency modulation range of 6 to 8.5 MHz, and the gain range of 20 to 80. The ultrasound transducer used in the ultrasonic imaging was a 7.5MHz linear transducer, and the gain and dynamic range were fixed and applied in all tests.

The tibialis anterior was placed in a relaxed posture with a towel underneath the knee. At 20% of the distance from the calf bone to the lateral malleolus, the transducer was positioned on the anterior tibial ridge, and the muscle thickness was measured [20]. The calf muscles were allowed to hang their ankle joints at the end of the table in a prone position. The knee was maintained in the extended state, and the muscle belly of the medial gastrocnemius (1/3 position toward the body) was measured [21]. At this time, a sufficient amount of ultrasonic gel was applied to minimize the pressure of the skin, and the transducer was maintained at right angles to the skin so that the measurement was constant. To obtain the correct value, the mean value was derived through three measurements. One minute of rest was given between each test, and all measurements were taken by a skilled physiotherapist. In addition, the same measurements were performed before and after training. To ensure the accuracy of the measurement site, marking with a surgical pen was used.

Proprioception

The error range of the joint position sense was measured by an electrogoniometer (UK, BPM Pathway) to evaluate the proprioception of the ankle joint. We measured the range of error that occurred when each participant in the eyes−invisible state returned to that position after the ankle was placed at an arbitrary angle set by the researcher in the eyes−invisible state. The measurements were performed three times in total, and the mean value across these three measurements was used for further analysis [22].

Balance

In this study, a Biorescue (France, RM INGENIERIE) was used to determine the balance. The dynamic balance test measures the total area of limit of stability.

The method of measurement recognized how to move weight through a monitor located in front of the target and measured the moving area that could move without losing its center of gravity in eight directions: north, northeast, east, southeast, south, southwest, west, and northwest.

Exercise Program

In the unstable supporting jump group (n=10) and the stable supporting surface jump group (n=10), the exercise program (Table 1) was conducted three times a week for eight weeks, and each session lasted for 30 minutes.

Statistical Analysis

All the statistical analyses were performed using IBM SPSS Statistics ver. 21.0 (SPSS Inc., Chicago, IL, USA). The Shapiro−Wilk test was used for the normality test. A paired t−test was used to determine the difference between before and after the intervention in each group, and an independent t−test was used to examine differences between groups. Statistical significance was set at .05.

RESULTS

General Characteristics

Table 2 shows the general characteristics of the study participants.

Muscle Thickness

The changes between before and after exercise in the two groups were statistically significant in the tibialis anterior and the medial gastrocnemius muscle ($p<.05$)(Table 3). In comparison between the groups, there was a significant difference in the medial gastrocnemius muscle after exercise ($p<.05$)(Table 4).

Table 1. Characteristics of subjects

Step	USSJ (n=10)	SSSJ (n=10)	Time (min)
	Program		
Warm up	Whole body stretching		3
Exercise	Two−legged jump		6
	Front and back cross−jump		6
	Both sides Abduction jump		6
	One leg standing		6
Cool down	Whole body stretching		3

USSJ : unstable supporting surface jump
SSSJ : stable supporting surface jump

Table 2. General characteristics

Variable	USSJ	SSSJ	p
Sex (male/female)	3/7	4/6	
Age (years)	21.10±0.73	21.30±1.70	.737
Height (cm)	164.3±5.79	164.6±9.72	.934
Weight (kg)	57.42±8.36	63.64±12.36	.206
CAIT (score)	20.7±5.01	19.1±5.58	.509

Values are means ± standard deviation
USSJ : unstable supporting surface jump
SSSJ : stable supporting surface jump
CAIT : Cumberland Ankle Instability Tool

Proprioception

The changes between before and after exercise in the two groups showed statistically significant differences in dorsiflexion and plantarflexion ($p<.05$)(Table 3). In comparison between the groups, a significant difference in the plantar flexion after exercise was observed ($p<.05$)(Table 4).

Balance

The changes between before and after exercise in the two groups were statistically significant in Limit of Stability ($p<.05$)(Table 3). Comparisons between the groups showed significant differences after exercise ($p<.05$)(Table 4).

Table 3. Comparison of muscle thickness, proprioception, balance before and after jump exercise

Variable		Pre	Post	t	p
Tibialis Anterior (cm)	USSJ	1.87±0.13	2.03±0.17	−3.703	.005*
	SSSJ	1.94±0.17	2.10±0.15	−4.781	.001*
Medial Gastrocnemius (cm)	USSJ	1.49±0.24	1.61±0.22	−5.947	.000*
	SSSJ	1.48±0.20	1.69±0.22	−7.651	.000*
Proprioception (Dorsiflexion)(°)	USSJ	3.50±0.67	1.07±0.83	7.692	.000*
	SSSJ	3.64±1.38	1.67±0.82	8.425	.000*
Proprioception (Plantarflexion)(°)	USSJ	3.97±1.20	1.40±0.70	7.733	.000*
	SSSJ	3.61±0.60	2.03±0.43	7.755	.000*
Limit of Stability (cm^2)	USSJ	71.85±19.83	141.58±42.21	−6.550	.000*
	SSSJ	69.99±19.60	105.30±30.80	−4.661	.001*

Values are means ± standard deviation, * $p<.05$
USSJ: unstable supporting surface jump
SSSJ: stable supporting surface jump

Table 4. Comparisons between the groups of muscle thickness, proprioception, balance jump exercises

Variable		USSJ	SSSJ	t	p
Tibialis Anterior (cm)	Pre	1.87±0.13	1.94±0.17	−.960	.350
	Post	2.03±0.17	2.10±0.15	−.899	.381
	Post−Pre	0.17±0.13	0.15±0.10	.271	.790
Medial Gastrocnemius (cm)	Pre	1.49±0.24	1.48±0.20	.080	.937
	Post	1.61±0.22	1.69±0.22	−.811	.428
	Post−Pre	0.11±0.06	0.20±0.08	−2.707	.014*
Proprioception (Dorsiflexion)(°)	Pre	3.50±0.67	3.64±1.38	−.288	.777
	Post	1.07±0.83	1.67±0.82	−1.619	.123
	Post−Pre	−2.43±0.99	−1.97±0.73	−1.170	.257
Proprioception (Plantarflexion)(°)	Pre	3.97±1.20	3.61±0.60	.848	.408
	Post	1.40±0.70	2.03±0.43	−2.416	.027*
	Post−Pre	−2.57±1.05	−1.68±0.78	−2.150	.045*
Limit of Stability (cm^2)	Pre	71.85±19.83	69.99±19.60	.211	.835
	Post	141.58±42.21	105.30±30.80	2.195	.042*
	Post−Pre	65.72±32.30	35.30±23.95	2.397	.028*

Values are means ± standard deviation, * $p<.05$
USSJ: unstable supporting surface jump
SSSJ: stable supporting surface jump

DISCUSSION

In previous studies, the unstable supporting surface exercise was a static movement on the local supporting surface. In this study, trampoline was used as an unstable supporting surface. Therefore, dynamic movement can be performed over a larger area than the previous study, and it is possible to perform whole body movement instead of local ankle movement.

Thickness and size of muscle fiber are factors that affect muscle strength, and muscle thickness is an index of change in muscle strength [23]. The results of the present study demonstrate that, in both USSJ and SSSJ groups, the muscle thickness of the tibialis anterior and the medial gastrocnemius was increased after intervention. Furthermore, stretch-shortening cycle (SSC) is an important neuromuscular function that produces muscle strength [24]. Akasaka [25] reported that the ankle motion was greater in jumping on a stable supporting surface than when jumping on a trampoline. The USSJ group is assisted by the ground elasticity of the trampoline when landing, but does not benefit from ground elasticity in the SSJ group jump. Therefore, as the result of previous studies, it is considered that as the ROM of the ankle increases, the length of the medial gastrocnemius muscle and SCC increases when landing, thus the muscle strength and muscle thickness increase.

Proprioception integrates the important kinematical information input from the joint receptors, the muscle spindle, and the golgi tendon organs and transmits this information them to the central nervous system to induce normal joint movement and to protect the joints from external damage [26]. According to our results, in both the USSJ and SSSJ groups, the error angle between the plantar flexion and the dorsiflexion decreased after intervention. However, in the plantar flexion, the USSJ group showed more decrease in error angle than the SSSJ group. In a study of patients with chronic ankle sprain, Elis and Rosenbaum [27] demonstrated that the stabilization of the joints in the experimental group significantly improved as compared to that in the control group when the participants did balance exercise on the unstable supporting surface for 6 weeks; in addition, the reaction rate was significantly improved too. Therefore, the unstable supporting surface seems to contribute more to the ankle joint proprioceptive sensation than the stable supporting surface.

People with ankle instability usually experience difficulties adjusting the dynamic balance [28]. In the present study, the participants in both USSJ and SSSJ groups showed an increased dynamic balance after intervention. However, dynamic balance increased more in the unstable supporting surface group. Likewise, Nam [12] reported that, after 8 weeks of balanced training, unstable ankle patients showed improvement of limit of stability in the experimental group as compared to the control group.

In the present study, the increase in muscle thickness and proprioception appeared to affect the balance ability, and jumping on the unstable supporting surface, as compared to that on the stable supporting surface, was found to be more effective in the patients with FAI.

CONCLUSION

Overall, suggest that jumping on the unstable supporting surface could be a more effective exercise method for functional ankle instability than jumping on the stable supporting surface.

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