

Effects of Elastic Band Exercise Using Proprioceptive Neuromuscular Facilitation on Strength and Dynamic Balance of Adults with Ankle Instability

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ABSTRACT

The purpose of this study was to assess the effects of proprioceptive neuromuscular facilitation (PNF) with elastic band exercise on strength and dynamic balance in ankle instability. A total of 19 subjects with ankle instability. Subjects were randomly divided into ST(Stretching group, n=10) and STPNF(Stretching with Proprioceptive Neuromuscular Facilitation group, n=10). Two groups measured strength dynamic balance. The differences in ankle muscle strength and balance ability between pre- and post-intervention were analyzed using paired t-test and independent t-test. In the within-group pre-post comparison, STPNF showed significant increase in muscle strength at RPF30°, LPF30°, and RPF90°. In the between-groups comparison, significant difference in muscle strength was found at RPF30°, LPF30°, LDF30°, RDF90°, LPF90°, and LDF90° ($p<0.05$). In the within-group pre-post comparison of dynamic balance, STPNF showed significant increase in leftward and rightward ($p<0.05$). In the between-groups comparison, significant difference in rightward balance was found ($p<0.05$). The results from this study indicated that PNF with elastic band have improved the strength and balance in ankle instability.

Keywords: PNF, Elastic band, strength, Balance, Ankle instability

Introduction

The ankle joint plays an important role in controlling leg movement during sports activities that require running and jumping, as well as for walking and supporting body weight. Recently, more and more people are spending more time on sports and leisure, which has resulted in increased number of ankle injuries¹⁾. Ankle instability, which is usually accompanied by a feeling of the ankle giving way during activities of daily living or reinjury of ankle sprain due to lack of stability in the ankle, negatively affects muscle reflex, muscle strength, motor sense, and postural stability to cause decline in physical balance ability and proprioception²⁾. Lack of stability in the ankle joint appears when there is a problem in controlling postural balance and when there

is a recurrence of ankle sprain³⁾, while it may also occur from lack of proprioceptive function and postural reflex altered by tissues surrounding the ankle⁴⁾.

Balance refers to the ability to maintain the center of the body on the supporting surface with minimal postural sway⁵⁾. Numerous studies have reported on improving balancing through training musculoskeletal factors, such as muscle tone, muscle strength, endurance, and joint flexibility or stability, as well as training of neurological factors, such as visual, auditory, vestibular, and proprioceptive senses. The ability to control balance may be lost due to impairment of these factors⁶⁾. Among these, muscle strength plays a role in maintaining body alignment when standing or sitting, and in particular, weakened leg muscle strength can cause unstable posture. Therefore, effective muscle strengthening exercise strategies are needed to maintain balance⁷⁾.

A study by Hess and Woollacott⁸⁾ reported that functional balance ability can be improved through high-intensity muscle strength training. In a study by Rosa et al.⁹⁾ on changes in balance control ability after

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inducing muscle fatigue near knee and ankle joints of healthy elderly subjects, the results showed that muscle fatigue reduced balance control ability. These results indicated the need for muscle strength training on muscle near specific joints to improve balance ability. Balance control is achieved by musculoskeletal movement and control based on processing of visual, equilibrium, and proprioceptive cues by the central nervous system, where a major cause of ankle injury is impairment of proprioception¹⁰. Niam et al.¹¹ reported that subjects with damaged proprioception suffered leg injuries due to impaired proprioceptive functions associated with ankle stability and expression of muscle strength, while LePhart et al.¹² reported that proprioception exercise is an effective form of exercise for preventing and rehabilitating ankle injury. As mentioned, proprioception exercise has been reported to be associated with change in irritability of the leg by increasing the ability to control muscle nerves¹³.

Elastic bands activate only the target muscle and has less force applied to the joints that weight-bearing exercise, and thus, they offer the advantage of reduced shock during exercise even when motions are performed at various angles¹⁴. Brill et al.¹⁵ reported that resistance exercise using elastic bands can provide the necessary effect for rehabilitation exercise after an injury, health management, muscle strengthening, and stability of flexibility for wide range of age groups, and when elastic band exercise was applied to healthy subjects, the results showed 10~27% improvement in muscle strength, stability, and basic physical fitness.

There have been many previous studies on using proprioceptive neuromuscular facilitation (PNF) pattern exercise with elastic bands, but there are not many previous studies on its effect on the ankle muscle strength and dynamic balance. Moreover, while there have been studies that applied exercise on healthy adults or stroke patients, studies on adults with ankle instability are lacking.

Accordingly, the present study applied elastic band exercise using PNF lower extremity pattern on adults with ankle instability to measure muscle strength by isokinetic knee exercise test and to assess balance ability. The objective was to determine the effects of this exercise on ankle muscle strength and balance ability through proprioceptive improvement.

Materials and Method

Subjects: The participants in the present study consisted of 19 students with ankle instability who were enrolled in “N” College in Cheonan. To obtain reliable statistical significance, the participants were divided into two groups: 10 in the control group and 9 in the experimental group [Table 1]. Ankle instability was defined as having Cumberland ankle instability tool (CAIT) score of ≤ 24 points. The selection criteria were set as those who experienced pain due to an ankle sprain in the past 3 months and those who have no difficulty walking during the experiment. Those with psychological problems in understanding the treatment protocol, those showing psychiatric signs, and those who are pregnant were excluded from the experiment. The study purpose and the methods were explained to all participants, who provided written informed consent as defined by the Declaration of Helsinki before participating:

Table 1: General characteristics of participants

Variable	ST (n = 10)	STPNF (n = 9)
	Mean \pm SD	Mean \pm SD
Age (yrs)	21.22 \pm 1.474	20.80 \pm 1.720
Height (cm)	163.27 \pm 6.298	168.88 \pm 8.522
Weight (kg)	62.26 \pm 9.400	65.22 \pm 12.999

ST: Stretching group, STPNF: Stretching with Proprioceptive Neuromuscular Facilitation group

Measurement Tools: The present study used a body composition analyzer (Inbody720, Korea) to measure the physical characteristics of the subjects; a professional balance assessment and training system (BT4, Finland) to measure balance ability; and a functional rehabilitation exercise equipment (PRIMUS RS, USA) for isokinetic test on the ankles.

Procedures

- 1. Elastic Band:** Elastic bands need to be used according to one's own ability to allow efficient and effective exercise. The strength of the elastic band can be adjusted according to the color and the length and position by which it is held. The elastic band was selected based on the maximum resistance corresponding to the color representing 10 maximum repetitions, after which, the Rating of Perceived Exertion (RPE) designed by Brog¹⁶

was used to select the band with 15-16 RPE that the participant felt was difficult (Borg 1982:377-81).

- 2. Exercise Program:** Warm-up exercise consisted of 10 minutes of stretching each joint and dynamic ankle stretching. Dynamic ankle stretching, which was performed on an inclined plate, consisted of maintaining plantar flexion for 10 s; returning to the neutral position and resting for 5 s; maintaining plantar flexion again for 10 s; and returning to the original position. Four repetitions of motions comprised one set and a total of 10 sets were

performed. For the main exercise, one set consisted of exercises listed from a) to d) in Figure 1. Each time the position and pattern was changed, 1 min of rest was given. The exercise program consisted of 3 sets per session; 3 sessions per week; for a total of 6 weeks. For cool-down exercise, the same stretching used for warm-up exercise was performed for 5 min. The exercise with elastic bands using PNF lower extremity patterns of sprinter and skater proposed by Dietz¹⁷⁾ was performed by adults with ankle instability [Table 2]

Table 2: Exercise program protocol

Group	Position	Pattern	Program	Intensity
Warm-up	Standing		Stretching & Dynamic Stretching	10min
Main Exercise	Standing Quadruped	Sprinter	Knee Ex, Hip Ext-Ab-IR, Ankle DR-In Knee Flx, Hip Flx-Ad-ER, Ankle PF-Ev	Left/Right 1min 1set, 1min rest/ between sets
		Skater	Knee Ex, Hip Ext-Ad-ER, Ankle DR-Ev Knee Flx, Hip Flx-Ab-IR, Ankle PF-In	
Cool-down	Standing		Stretching	5min

Ab=abduction, Ad=adduction, Ex=Extension, Flx=Flexion, IR=Internal Rotation, ER=External Rotation, PF=Plantar flexion, DR=Dorsi Flexion, In=Inversion, Ev=Eversion

- 3. Isokinetic ankle muscle strength test:** For the measurements, each participant placed the ankle on the measurement plate in neutral position while wearing shoes. The hip joint was flexed by 70° and the knees were flexed 10° and 70° to assume a position that would allow smooth range of motion in the ankles. To minimize errors and movement between foot and shoe and between shoe and measurement plate, a strap was used to firmly fix it. After providing detailed explanation about the testing procedure to the participant, auditory cue was used to draw out maximum muscle strength. Muscle strength during plantar flexion and dorsiflexion was measured, 3 times each at angular velocity of 30°/sec for maximum muscle strength and at 90°/sec for motor test in angular velocity and muscle strength required during motion with fast joint movement, such as running and jumping. The mean value of maximum muscle strength for motion of each group was derived.

- 4. Balance ability:** Dynamic balance was tested using the limit of stability test method. As drawn on the balance plate, the heels were placed with the center point of the plate at the center and spread apart by 2 cm. The feet were pointed

outward at an angle of 15° and the hands were placed naturally on the side of the pants. The participant was instructed to bend the body as much as possible in the direction indicated by the test (order or forward, backward, left, and right). Here, the participant was instructed to keep both feet on the ground, and if the feet came off the ground, the test was re-started. Dynamic balance in all four directions was measured by the maximum inclination angle.

Statistical Analysis: SPSS version 20.0 for Windows was used for data processing. General characteristics were presented as mean and standard deviation. For the characteristics of the study, normal distribution was tested using Kolomgorov-Smirnov test (K-S test). Pre- and post-intervention differences in isokinetic ankle muscle strength and balance ability of each group were analyzed using paired t-test and independent t-test. Statistical significance level was set to $\alpha = 0.05$.

Result and Discussion

Ankle Muscle Strength: In the within-group pre-post comparison of ankle muscle strength, ST showed no significant difference in all muscles [Table 3].

Meanwhile, STPNF showed significant increase at RPF30°, LPF30°, and RPF90° (p<.05). In the between-group pre-post comparison, significant differences were found at RPF30°, LPF30°, LDF30°, RDF90°, LPF90°, and LDF90° (p<.05) [Table 4]

Kim et al. ¹⁸⁾ reported that exercise with elastic band using PNF pattern significantly increased isokinetic knee muscle strength of softball players, while Lim ¹⁹⁾ reported

that application of leg stretching, muscle strengthening, proprioception, and muscle endurance exercise program showed significant difference in dorsiflexion at ankle angular velocity of 30°/sec in patients with chronic ankle instability. PNF exercise not only provides visual and auditory information, but it also stimulates all senses that humans can use to activate and strengthen the neuromuscular system. Consequently, combining elastic band and PNF pattern resulted in increased muscle ²⁰⁾.

Table 3: Within-group pre-post comparison of isokinetic muscle strength

Variables	ST (n = 10)		p	STPNF (n = 9)		p
	pre(M ± SD)	post(M ± SD)		pre(M ± SD)	post(M ± SD)	
RPF30°	162.30 ± 61.02	143.10 ± 73.57	0.54	147.44 ± 48.48	206.11 ± 93.40	0.02*
RDF30°	92.50 ± 44.78	86.30 ± 52.50	0.61	66.00 ± 46.25	43.56 ± 24.66	0.31
LPF30°	171.70 ± 84.48	163.00 ± 84.39	0.47	180.11 ± 89.50	233.56 ± 80.87	0.00*
LDF30°	67.20 ± 53.37	70.40 ± 39.99	0.63	71.78 ± 29.63	68.22 ± 35.86	0.72
RPF90°	123.00 ± 76.85	141.00 ± 81.78	0.20	128.89 ± 52.19	163.33 ± 67.32	0.02*
RDF90°	48.80 ± 52.73	52.80 ± 41.70	0.23	47.00 ± 26.64	55.89 ± 40.37	0.58
LPF90°	151.10 ± 80.56	128.60 ± 68.97	0.21	135.67 ± 67.10	176.78 ± 91.35	0.12
LDF90°	53.40 ± 47.05	46.90 ± 33.61	0.28	46.22 ± 17.56	52.44 ± 41.23	0.73

ST: Stretching, STPNF: Stretching + Proprioceptive Neuromuscular Facilitation, RPF: Right Plantar Flexion, RDF: Right Dorsi Flexion, LPF: Left Plantar Flexion, LDF: Left Dorsi Flexion, *p<0.05

Table 4: Between-groups pre-post comparison of isokinetic muscle strength

Variables	ST (n = 10)	STPNF (n = 9)	p
	post-pre (M ± SD)	post-pre (M ± SD)	
RPF30°	-19.20 ± 94.84	58.67 ± 58.15	.05*
RDF30°	-31.20 ± 49.35	-22.44 ± 61.90	0.74
LPF30°	-8.70 ± 36.88	53.44 ± 37.62	0.00*
LDF30°	-38.80 ± 28.47	-3.56 ± 28.47	0.02*
RPF90°	18.00 ± 40.79	34.44 ± 37.24	0.37
RDF90°	-33.00 ± 34.76	8.89 ± 45.99	0.04*
LPF90°	-22.50 ± 52.56	41.11 ± 71.73	0.04*
LDF90°	-52.50 ± 33.65	6.22 ± 51.72	0.01*

ST: Stretching, STPNF: Stretching + Proprioceptive Neuromuscular Facilitation, RPF: Right Plantar Flexion, RDF: Right Dorsi Flexion, LPF: Left Plantar Flexion, LDF: Left Dorsi Flexion, *p<0.05

Dynamic Balance: STPNF showed significant increase in leftward balance (p<0.05) and rightward balance (p<0.05) [Table 5]. In the between-groups comparison after the intervention, there was a significant difference in rightward balance (p<.05) [Table 6].

Elastic band exercise can improve muscle strength and hand grip; increase joint range of motion and flexibility; and improve gait ability, postural balance,

and proprioception and sense of equilibrium ²¹⁻²⁵⁾. Kwak et al. ²⁶⁾ reported that applying 12 weeks of elastic band exercise improved flexibility and sense of balance in the elderly, while Topp et al. ²⁷⁾ reported that applying 12 weeks of elastic band exercise improved gait ability and balance ability in the elderly. PNF stimulates proprioceptors to improve control of nerves and muscles and have a positive effect on muscle strength, flexibility,

and balance. Accordingly, greater improvement in dynamic balance was found in the group that performed stretching and PNF than the group that performed stretching alone in the present study ²⁸⁾.

The participants in the present study were limited to adults aged 20-29 years and the sample size was small with only 19 participants. Therefore, it is difficult

to generalize the findings. Moreover, it was difficult to control the lifestyle habits of the participants during the study period, while studies with larger training period than 6 weeks, which is the minimum training period for significant difference in balance, are also needed. Therefore, additional future studies are needed to apply various PNF patterns over a sufficient period with participants in different age groups.

Table 5: Within-group pre-post comparison of dynamic balance

Variables	ST (n = 10)		P	STPNF (n = 9)		P
	pre (M ± SD)	Post (M ± SD)		pre(M ± SD)	post(M ± SD)	
forward	4.42 ± 1.15	4.59 ± .91	0.81*	5.21 ± 1.37	5.52 ± 1.19	0.55
rearward	4.56 ± 1.34	5.09 ± .67	0.17	4.41 ± 1.27	4.61 ± .96	0.74
leftward	5.87 ± .73	6.10 ± .93	0.25*	6.29 ± 1.12	7.11 ± .88	0.04*
rightward	6.15 ± .83	6.52 ± .82	0.27	6.01 ± 1.18	7.31 ± 1.31	0.01*

ST: Stretching, STPNF: Stretching + Proprioceptive Neuromuscular Facilitation, RPF: Right Plantar Flexion, RDF: Right Dorsi Flexion, LPF: Left Plantar Flexion, LDF: Left Dorsi Flexion, *p<0.05

Table 6: Between-groups pre-post comparison of dynamic balance

Variables	ST (n = 10)	STPNF (n = 9)	p
	post-pre (M ± SD)	post- pre(M ± SD)	
forward	0.57 ± .78	0.31 ± 1.49	0.64
rearward	0.53 ± 1.12	0.20 ± 1.77	0.63
leftward	0.72 ± .85	0.82 ± 1.04	0.81
rightward	0.37 ± .99	1.50 ± 1.23	0.03*

ST: Stretching, STPNF: Stretching + Proprioceptive Neuromuscular Facilitation, RPF: Right Plantar Flexion, RDF: Right Dorsi Flexion, LPF: Left Plantar Flexion, LDF: Left Dorsi Flexion, *p<0.05

Conclusion

The present study applied elastic band exercise using PNF lower extremity pattern on adults with ankle instability to observe its effect on ankle muscle strength dynamic balance, based on which, the following conclusions were derived. In the within-group pre-post comparison, STPNF showed significant increase in muscle strength at RPF30°, LPF30°, and RPF90°. In the between-groups comparison, significant differences in muscle strength were found at RPF30°, LPF30°, LDF30°, RDF90°, LPF90°, and LDF90° (p<0.05). In the within-group pre-post comparison of dynamic balance, STPNF showed significant increase in leftward and rightward balance (p<0.05). In the between-groups comparison, significant difference in rightward balance was found (p<0.05). Based on the findings in the study, it is determined that elastic band exercise using PNF lower

extremity pattern can help improve muscle strength of adults with ankle instability. It is believed that in future studies, various types and patterns could be combined to use in other patients.

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