Effects of Neuro-feedback Training on Balance and Ankle Instability in Patients with Anterior Talofibular Ligament Rupture

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Abstract

Background/Objectives: Anterior talofibular ligament rupture is difficult to heal, and ankle sprains can lead to chronic ankle instability; therefore, we studied the effects of neuro-feedback training on anterior talofibular ligament rupture.

Methods/Statistical analysis: We selected 20 patients and divided them into two groups: a control group and a neuro-feedback group (n = 10 each). The neuro-feedback group underwent neuro-feedback training for 20 minutes while the control group meditated for 20 minutes. Both groups participated in an ankle rehabilitation program for 30 minutes, thrice a week for eight weeks. Data analysis was performed using the Statistical Package for the Social Sciences (version 21.0), and the significance level was set at 0.05.

Findings: We used the numerical rating scale (NRS), foot pressure (Zebris FDM-system), one-leg standing test (OLST), timed up and go (TUG), and Cumberland ankle instability tool (CAIT) to compare the differences between the control and training groups. In both groups, the pain decreased with time. In the training group, there were significant differences in the NRS, foot pressure, OLST, TUG, CAIT, and CAIT measurements before and after the experiment. Furthermore, there were significant differences in the NRS, foot pressure, balance, and CAIT values between the groups.

Improvements/Applications: Our study demonstrated the effects of neuro-feedback training in patients with ankle ligament rupture. Neuro-feedback training program is effective in reducing pain, improving balance, and improving ankle instability in patients with anterior talofibular ligament rupture.

Keywords**:** Anterior talofibular ligament rupture, Neuro-feedback training, Ankle instability, talofibular ligament, Balance

1. Introduction

Approximately 77% of sports-related injuries occur mainly in the lower extremities, and the ankle and knee joints are the most commonly injured areas in sportspersons [1] [2]. Injuries of the ankle joints account for more than 85% of inversion sprains, and 70-80% of the inversion sprains occur in anterior talofibular ligaments [3]. Furthermore, damage to the ankle lateral ligament causes chronic instability of the ankle joint, increasing the risk of additional injury [2]. Chronic ankle instability causes continuous pain and swelling due to frequent injury of the ligaments supporting the ankle joint [4]. Following this, the proprioceptive ability and postural control ability are lowered, which increases the ankle whirl and causes muscle weakness [5]. Recently, the modified Brostrom operation (MBO) method has shown positive results [6]. The advantage of MBO is that the anatomical structure is less damaged and the function of the ankle and talus bone joint is preserved, which is advantageous for postoperative rehabilitation with fewer side effects and complications [7]. Postoperative ankle lateral instability results in increased pain, decreased muscle strength, decreased proprioceptive sensation, and reduced balance [8]. In order to maximize ankle recovery postoperatively, rehabilitation programs should be implemented as early as possible, and ankle rehabilitation programs should include methods that increase muscle strength and range of motion, reduce pain, and improve endurance and balance [9]. Neuro-feedback training has been shown to be an easy, consistent, and time saving method in neurological patients to reduce imbalance and body shaking [10]. It is also reported to be effective for dynamic balance not only in the case of poor balance ability, such as in the elderly, but also in the case of athletes [11]. There are various interventions for ankle injury, and early intervention is important, but it is difficult for all patients with ankle injury to participate in active rehabilitation programs immediately after ankle surgery. Especially in the elderly and complicated cases, early rehabilitation is difficult; therefore, there is a need for a safe and comfortable treatment method for ankle joint problems. This study was conducted to investigate the relationship between balance and ankle instability using neuro-feedback and ankle rehabilitation program in patients who underwent MBO for anterior talofibular ligament rupture.

2. Materials and Methods

The study was conducted for eight weeks from June 2019, with the approval of the Institutional Review Board. Twenty patients who had undergone MBO for lateral anterior talofibular ligament rupture after four weeks were selected and equally randomized to the neuro-feedback (NGF) and control groups. Four patients were excluded from this study. Finally, data were collected and analyzed for the two groups: the NGF group (n = 8) and the control group (n = 8). The general characteristics of the participants are shown in Table 1. The procedure of the study is as follows[Figure 1].

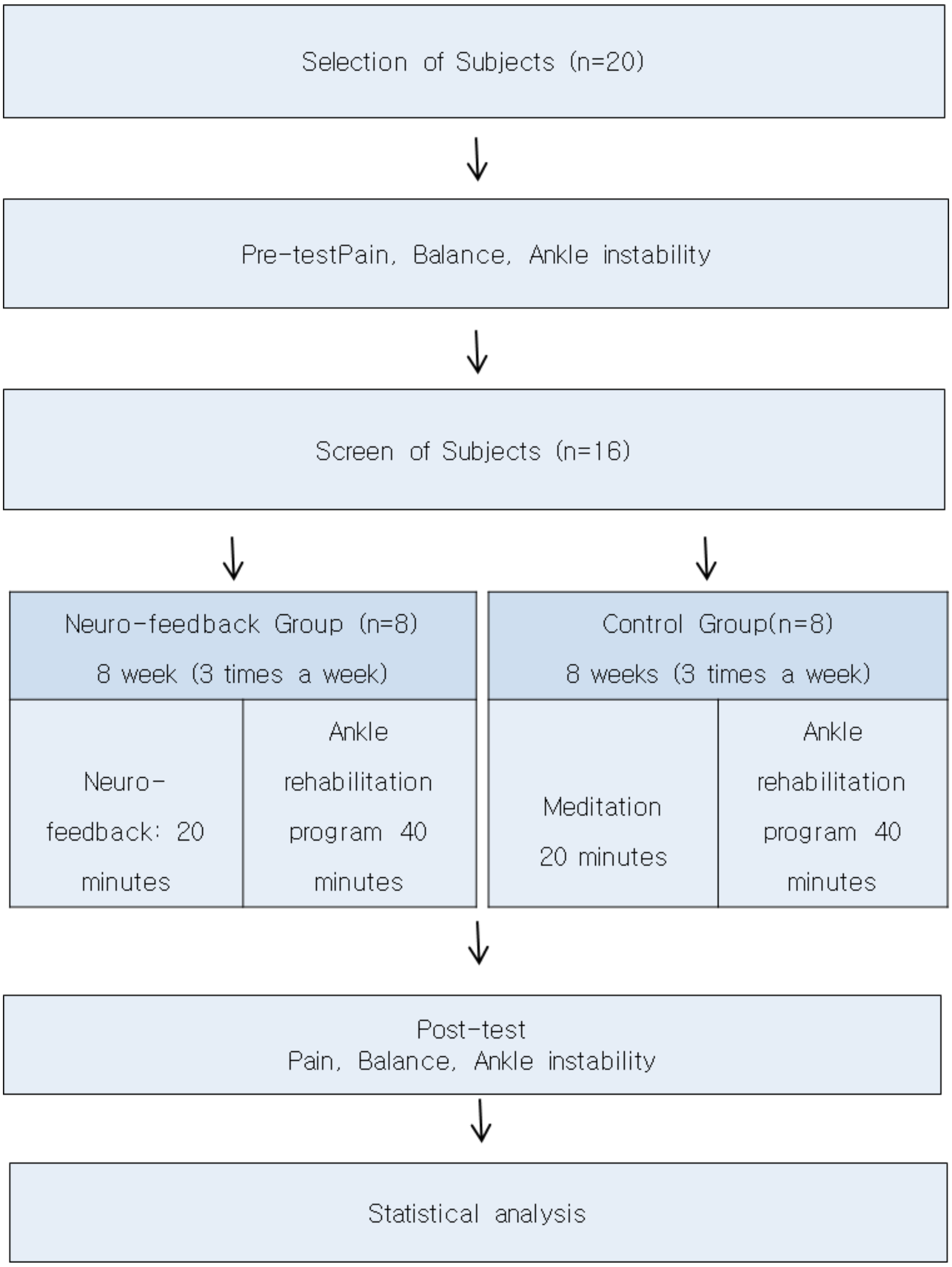

Figure 1. Schematic diagram of the study framework

Table 1. Comparison of the general characteristics of the patient (age, height and weight)

Variable	Age(yr)	Height(cm)	Weight(kg)
NFG(N=8)	28.38±12.76	167.75±9.27	63.88±12.17
CG(N=8)	30.13±19.90	171.13±7.00	71.5±12.62

Value are M±SD. p<.05
NFG : Neuro-feedback Group, CG : Control Group

2.1. *Ankle rehabilitation program*

The NGF group underwent neuro-feedback therapy (Neuro HarmonyS, Panaxtos) and ankle exercise program for 20 minutes and 30 minutes, respectively. The control group performed 20 minutes of meditation and 30 minutes of the ankle exercise program. All participants participated in the program thrice a week for eight weeks and the before and after results of the experiments in each group were compared. In the ankle rehabilitation program, a flexibility program was included to improve the range of motion of the joints for the first two weeks, followed by aerobic exercise, isotonic exercise, and balance exercise for six weeks [Table 2].

Table 2. Ankle rehabilitation program

Exercise		Practical Application			
		ROM Ex 5~6 Wk.	Primary Ex 7~8 Wk.	Regular Ex 9~10 Wk.	Final Ex 11~12 Wk.
Flexibility	Continuous Passive Motion (CPM)	50°~70° × 20'	-	-	-
Aerobic	Stationary Cycle-ergometer	-	10'	10'	10'
	Treadmill Walking	-	10'	10'	10'
Isotonic	Towel Pulling with Toe	10 rep × 2 Set	-	-	-
	Toe Raise	-	12 rep × 2 Set	12 rep × 2 Set	12 rep × 2 Set
	Calf Raise	-	12 rep × 2 Set	15 rep × 2 Set	15 rep × 2 Set
	Elastic Band Exer. (inverstion & Eversion)	-	15 rep × 2 Set	18 rep × 2 Set	20 rep × 2 Set
	Proprioceptive Neuromuscular Stimulation Machine	-	-	12 rep × 2 Set	12 rep × 2 Set
	Vertical Jump with One Leg in mini-Trampoline	-	-	-	12 rep × 2 Set
Balance	Balancing with One Leg	-	1' × 2 Set	1' × 2 Set	-
	Balancing with One Leg in air cushion	-	-	1' × 2 Set	-
	Balancing with One Leg in BOSU	-	-	-	1' × 2 Set
Time of Exercise		30'	40'	50'	50'
Frequency of Exercise		3 days per week			

2.2 Statistical analysis

The data in this study were statistically analyzed using the Statistical Package for the Social Sciences for Windows (version 21.0). The Wilcoxon signed rank test was used for the before and after comparisons, and the Mann-Whitney U-test was used for the comparison between the groups. The statistical significance level was set at 0.05. The effect size was used to determine the magnitude of the relationship between variables or the difference between variables. The association is considered small if the effect size is $r^2 < 0.01$, medium if $0.01 < r^2 < 0.09$, and large if $r^2 > 0.25$ [12][13] [Table 3].

Table 3. Calculation of effect size

Test	ES Index	Effect size		
		Small	Medium	Large
Mann-Whitney U test	$r^2 = \frac{Z^2}{n}$	$r^2<.01$	$.01<r^2<.09$	$.25<r^2$

Z - standardized value for the U-value
n - size value of population
r^2 - the index assumes values from 0 to 1 and multiplied by 100% indicates the percentage of variance in the dependent variable explained by the independent variable

3. Results and Discussion

In both experimental and control groups, pain decreased over time. Furthermore, the comparison between the groups showed that the NGF group experienced more effective pain relief than the control group ($r^2 > 0.25$) (Table 4). Postoperatively, patients showed decrease in pain suppression control. Neuro-feedback stimulates the activity of pain inhibition regulatory region, stabilizes pain control in the central nervous system, and reduces pain by inhibiting the nervous system pain stimulation [14]. Meditation has a major effect psychologically, such as relieving discomfort and instability, and this could have caused a significant difference in the NGF group. In a previous study using neuro-feedback to improve balance ability, electroencephalogram observations showed significant differences in increasing beta waves, decreasing theta waves, increasing sensorimotor rhythm waves, and decreasing theta waves [15]. Moreover, the effects of neuro-feedback training on athletes as well as the elderly and patients with poor balance reportedly affected the dynamic balance [16]. In this study, experiments were conducted by dividing the participants into static and dynamic balances to determine the change in the overall balance ability. The static balance measured plantar pressure and OLST, and dynamic balance measured TUG. First, foot pressure was compared between the pressure center fluctuation areas of both feet. There was a significant difference between the control group and NGF group before and after the experiment ($p < 0.05$). Particularly, the pressure-centered fluctuations of the experimental and control groups were $r^2 > 0.25$, indicating that the NGF group had more effective results. The OLST and TUG scores were significantly different before and after the experiment in both groups ($p < 0.05$), but there was no significant difference between the groups ($p > 0.05$). However, the NGF group showed a significant effect size, which could be due to neuro-feedback training that positively affected attention, cognitive ability, and self-regulation. The CAIT scores, which indicate ankle instability, showed significant differences before and after the experiment in both groups, as well as between the two groups ($p < 0.05$) [Table 4]. The CAIT evaluates ankle pain, functional performance, anxiety, and stability. Neuro-feedback training increased the sensory rhythm and increased the balance. In the control group, meditation increased alpha and theta waves, and reduced pain and anxiety. Thus, the comprehensively reflecting indicators such as pain, balance, and foot-pressure change in the NGF group may have caused a positive difference in the CAIT effect size of the NGF group.

Table 4. Change of foot pressure

		NFG		CG		r^2	Z^a	p
		Median (interquartile range)	Mean±SD	Median (interquartile range)	Mean±SD			
NRS (score)	pre	3.5(3)	3.88±1.13	3(2.00)	3.25±1.28	.44	-2.661	.01*
	post	.5(0)	.63±.74	1(1.00)	1.50±.76			
	Z^b	-2.585		-2.558				
	p	.01*		.01*				
pressure-centered fluctuations (mm²)	pre	295.5(263.5)	1058.88±1400.55	198.5(78.25)	297.00±339.63	.25	-1.995	.05*
	post	37(21.50)	40.75±29.53	44.5(25.50)	63.88±43.69			
	Z^b	-2.521		-2.240				
	p	.01*		.03*				

OLST(sec)	pre	4.08(2.36)	5.34±3.69	3.58(2.61)	9.27±14.73	.20	-1.785	.08
	post	31.97(14.80)	32.83±18.59	16.53(3.86)	21.45±20.72			
	Z^b	-2.521		-2.521				
	p	.01*		.01*				
TUG (sec)	pre	13.16(12.03)	13.34±1.73	12.06(9.68)	11.92±2.63	.18	-1.680	.11
	post	7.16(6.66)	7.80±2.27	7.26(6.15)	7.76±2.02			
	Z^b	-2.521		-2.521				
	p	.01*		.01*				
CAIT (score)	pre	8.00(6.25)	10.38±4.84	10.00(6.00)	14.38±9.32	.46	-2.698	.01*
	post	26.00(23.00)	25.88±4.55	22.00(15.75)	22.63±6.93			
	Z^b	-2.524		-2.527				
	p	.01*		.01*				

* $p<.05$
Z^a: Mann Whitney U test, Z^b : Wilcoxon signed rank test
r^2 : Effect size
NFG : Neurofeedback Group, CG : Control Group

4. Conclusion

The NGF group that underwent neuro-feedback and ankle rehabilitation program showed effective improvement in pain, balance, and ankle instability as compared to the control group that combined meditation and ankle rehabilitation programs. The neuro-feedback training and ankle rehabilitation program presented in this study are effective in reducing pain, improving balance ability, and improving ankle instability in patients with anterior talofibular ligament rupture. Furthermore, it can be widely used as an exercise program for ankle rehabilitation because of its easy application.

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Conflict of Interest: Sunho Kim and Sangwoong Park are contributed equally this work.

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