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ORIGINAL RESEARCH

Effect of two different exercises on balance, pain and ankle motor function in male college students with chronic ankle instability

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Abstract

Strength and proprioceptive exercise are known to be representative exercise methods used in patients with chronic ankle instability (CAI) and they are effective in restoring ankle stability and body balance, which gets reduced by repetitive ankle sprains. But, there is a lack of data comparing the effects of strengthening or proprioceptive exercise rehabilitation program for CAI patients. The purpose of this study is to investigate the effect of a 4-week exercise program on ankle range of motion (ROM), static/dynamic balance, and drop landing in college students with CAI. The subjects of this study were 21 male college students who had the Cumberland ankle instability tool (CAIT) questionnaire scores of 24 or less, and they were divided into three groups; the non-treated group (NTG), the traditional strength exercise group (SEG) and the proprioceptive exercise group (PEG). The exercise rehabilitation program was applied 3 times a week for 4 weeks. To examine the difference between groups, CAIT, visual analogue scale (VAS), body composition, ankle ROM, one-leg standing with eyes closed and Y-balance test (YBT) as well as center of pressure (COP) 95% confidence ellipse area during drop landing were measured before and after the exercise intervention. CAIT scores and static balance were significantly increased in the PEG compared to the NTG and the SEG, and ankle dorsiflexion ROM and Y-balance were significantly increased in the SEG and the PEG compared to the NTG. In addition, pain, ankle inversion ROM, and COP 95% confidence ellipse area were significantly reduced in the SEG and the PEG compared to the NTG. The proprioceptive exercise program is thought to be effective therapeutic approach on improving the symptoms of CAI patients.

Keywords

Chronic ankle instability; Male students; Strengthening exercise; Proprioceptive exercise; Range of motion

1. Introduction

As interest in quality of life and health has increased, the number of modern people participating in leisure and sports has rapidly increased [1]. This rise in sports participation showed a positive correlation with the rate of sports injuries [2]. According to previous studies, it is understood that lower extremity injuries occur most frequently in sports situations, and among lower extremity injuries, ankle sprains are the second more common after knee injuries [3]. Ankle sprain refers to a condition where the lateral ligaments supporting the ankle get damaged due to sudden inversion and internal rotation of the ankle [4]. Although an ankle sprain is recognized as a minor injury, 74% of patients with ankle sprains develop chronic ankle instability (CAI) owing to repetitive ankle sprains [5, 6].

CAI has been known to result in the complex interaction of various functional deficits and mechanical insufficiencies, which cause repeated re-injury to the same joint and other ankle issues [7]. According to the epidemiological study, the prevalence of CAI is 25%, and the prevalence of CAI with a history of ankle sprains is 46% in 15- and 32-years old participants [8]. Therefore, for functional improvement of patients with CAI, exercise rehabilitation programs including ankle mobility training, muscle strengthening exercise around the ankle, proprioception, and agility enhancing exercises are essential [9].

In a recent study, exercise interventions for improving motor function in patients with CAI consisted of balance training, multimodal rehabilitation, joint mobilization, resistive training, soft-tissue mobilization, passive calf stretching, and the therapeutic effect of exercise has been demonstrated [10].

Ankle strengthening exercises program is mainly performed on the tibialis anterior and gastrocnemius muscles to improve ankle stability [11]. Strengthening exercise using elastic band is frequently applied during the exercise rehabilitation period for patients with CAI, which has been known to be an effective therapeutic exercise to improve muscle strength, muscular endurance and body balance [12–15].

Proprioceptive exercise is also one of the representative exercise methods used in CAI rehabilitation and it is effective in restoring ankle stability and body balance, which gets reduced by repetitive ankle sprains [16]. Many previous studies have reported various exercises using various auxiliary tools such as balance board and BOSU ball [17, 18]. Balance exercise performed on unstable ground is effective in improving proprioceptive function, ankle dorsiflexion and plantar flexion range of motion (ROM) damaged by ankle sprains [19]. According to a study by Kwon [20], it is reported that muscle strength and proprioceptive exercises for the ankle are important to improve ankle instability as proprioception affects both static and dynamic stability. However, a study by Surakhamhaeng *et al.* [21] reported that the 6-week balance exercise program did not cause any improvement in CAI balance. In addition, Alahmari *et al.* [22] reported that combined muscular strength exercise with balance exercise did not have a positive effect on strength and static/dynamic balance improvement.

Considering these findings, the effects of strengthening exercise or proprioceptive exercise for patients with CAI remains controversial, and it is not clear which type of exercise is most effective for patients with CAI. Our hypothesis was that a separate exercise program, rather than a combined exercise, can improve gait pattern and quality of life by improving pain and functional recovery in patients with CAI as much as a typical concurrent strength and balance exercise. Therefore, the purpose of this study was to investigate which proprioceptive exercise or muscular strength exercise is more effective in improving ankle dorsiflexion and plantar flexion ROM, static/dynamic balance, and motor functions in college students with CAI.

2. Materials and Methods

2.1 Participants

Eighty-three male college students participated in the Cumberland ankle instability tool (CAIT) questionnaire. Among these, 21 adult males with a score of $<$24, no history of orthopedic surgery other than CAI, two sprains in the same ankle in the last 6 months, and predictable and uncontrollable excessive inversion of the rear foot during walking or running were selected. Sixty-two males with a CAI score $>$25 (n = 20), history of orthopedic surgery (n = 15), and personal reasons (n = 27) were excluded. Before beginning the study, all participants were provided a detailed explanation of this study and submitted their written informed consent to the researchers. All participants were randomly divided into 3 groups; a non-treated group (NTG, n = 7), a traditional strength exercise group (SEG, n = 7), and a proprioceptive exercise group (PEG, n = 7) (Table 1).

2.2 Exercise program

The strength exercise and proprioceptive exercise programs were conducted for 30 minutes a day and three times a week for 4 weeks, and other exercises were limited during the experimental period. Based on the exercise program suggested in the functional improvement study of patients with CAI [13, 23], the strength exercise program was reconstructed as a resistance exercise method using a light intensity elastic band and the proprioceptive exercise program was reconstructed as an unstable exercise method using a BOSU ball (Table 2).

2.3 Cumberland ankle instability questionnaire and visual analogue scale test

The Cumberland ankle instability tool (CAIT), a self-reported questionnaire, is the "gold standard" method used in identifying individuals with ankle instability, and its reliability and validity for evaluating CAI has been proven [24, 25]. If the questionnaire score was $<$24 of the 30 points, it was considerable as a CAI. The visual analogue scale (VAS) suggested by Cole *et al.* [26] was used to indicate the pain level of the affected ankle during daily life before and after the exercise rehabilitation program with a questionnaire divided into a scale from 1 (no pain at all) to 10 (excruciating pain). VAS scores of 1 to 2 refer to intervals representing "annoying pain". The CAIT and VAS scores were evaluated before and after the exercise rehabilitation. The CAIT and VAS questionnaires were translated into Korean for internal consistency and tested using subjective self-report measures.

2.4 Body composition and range of motion measurement

The height of participants was measured using an automatic height scale (DS-103M, Dong San jenic, Seoul, Korea) and the body weight and BMI were measured using a body composition analyzer (Inbody 720, Biospace, Seoul, Korea) applied with bioelectrical impedance analysis. A ROM was measured using a goniometer (Baseline, Aurora, IL, USA) by active motion. For measurement of the ROM for plantar flexion and dorsiflexion, the midline of the lateral malleolus and head of the fibula were set as the reference axis of the goniometer, and the fifth metatarsal bone was set as the moving axis. For measurement of the ROM for inversion and eversion, the midline of the tibial tuberosity and talocrural joint was set as the reference axis of the goniometer, and the second metatarsal bone was set as the moving axis.

2.5 Static and dynamic balance measurement

A stopwatch (CASIO, OST-30W, Tokyo, Japan) was used to measure one-leg standing with eyes closed. After standing on both feet, one leg was lifted up to the waist by bending the knee 90° and both arms were stretched to the side while standing on one leg. The score was recorded as the maximal posture maintenance time in unit of 0.1 second, twice in total of the ipsilateral ankle [27]. The Y-balance test (YBT) was measured using a Y-balance measuring tool (Y-balance Test Kit, Functional Movement Systems, Inc., Chatham, VA, USA). In this measurement, the participant extended the measuring tool to the maximum in the anterior, posteromedial, and posterolateral directions using the ipsilateral leg. Measurements were recorded in units of 1 cm, with three trials totaling the ipsilateral ankle [28].

TABLE 1. Characteristics of participants.

Variables	Group			F	p
	NTG (n = 7)	SEG (n = 7)	PEG (n = 7)		
Age (yrs)	21.7 ± 2.2	22.7 ± 3.6	22.7 ± 2.1	0.115	0.893
Height (cm)	173.8 ± 6.1	170.0 ± 2.7	173.6 ± 3.5	0.439	0.663
Weight (kg)	73.7 ± 12.7	79.7 ± 11.4	75.8 ± 9.7	0.227	0.803
BMI (kg/m^2)	24.2 ± 2.9	27.5 ± 3.3	25.1 ± 2.5	1.235	0.355
FFM (kg)	56.2 ± 11.4	59.3 ± 6.4	57.4 ± 6.7	0.108	0.898
% Fat (%)	22.4 ± 4.0	26.0 ± 4.9	20.4 ± 5.3	1.474	0.301

All data represents mean ± standard deviation. BMI, Body Mass Index; FFM, Fat-free Mass; % Fat, body fat percentage; yrs, years; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group.

TABLE 2. Strength and proprioceptive exercise program.

Type of exercise	Contents of exercise	Reps	Rest	Sets	Frequency	Intensity
Strength exercise						
	Plantar flexion					
	Dorsiflexion					
	Inversion					
	Eversion	10 reps	20 s	3 sets/1 min rest between sets	3 days/week for 4 weeks	OMNI-RES 7∼8
	Knee extension					
	Knee flexion					
	Abduction					
Proprioceptive exercise						
	Squat	10 reps				
	Plantar/dorsiflexion	10 reps				
	Step back lunge	10 reps				
	One-leg balance backward	20 s	20 s	3 sets/1 min rest between sets	3 days/week for 4 weeks	RPE 12∼14
	One-leg balance forward	20 s				
	Ad/abduction	10 reps				
	Single leg deadlift	10 reps				

Reps, repetitions; s, seconds; Ad, adduction; OMNI-RES, OMNI resistance exercise scale; RPE, rating of perceived exertion.

2.6 Ground reaction force measurement

To measure the ground reaction force (GRF), a 30 cm high box was placed 20 cm away from the force plate (AMTI-OR6-7, AMTI, Watertown, MA, USA), after which more than half of the affected foot was placed on the end of the box, one knee was bent 90° and both arms were stretched to the side to take a ready position. Then, using the affected leg over the GRF meter, a drop landing was performed at the supervisor's signal in the barefoot conditions [29, 30]. The experiment was conducted barefoot to avoid data errors. The variable of the GRF generated based on the time when the affected foot landed on the ground during drop landing was presented at a sampling rate of 2000 Hz. The center of pressure (COP) 95% confidence ellipse area was analyzed by determining the square area created during ground contact when the posture was maintained after landing [31]. Three successful landing motions were recorded, and the most stable motion was selected and used for analysis [32].

2.7 Statistical analysis

The mean and standard deviation of each variable were calculated through group descriptive statistics using SPSS for Windows (Version 22.0; SPSS, Inc., Chicago, IL, USA). Two-way repeated measures analysis of variance (ANOVA) was performed to verify the effect of the interaction between groups and periods of strength training and proprioceptive exercise. The differences between the groups were confirmed using Tukey post-hoc test, and the statistical significance level was

TABLE 3. Changes in ankle instability and pain.

Variable	Group	Pre	Post		F	p	Tukey
CAIT (score)							
	NTG[a]	16.4 ± 5.1	15.8 ± 4.0	Period	20.901	0.001	
	SEG[b]	13.8 ± 4.5	19.0 ± 3.6	Group	6.859	0.006	a,b < c
	PEG[c]	19.1 ± 2.0	25.1 ± 2.8	Period × Group	7.160	0.005	
VAS (score)							
	NTG[a]	1.2 ± 0.4	1.2 ± 0.7	Period	22.091	0.001	
	SEG[b]	1.7 ± 1.1	0.2 ± 0.4	Group	0.824	0.455	b,c < a
	PEG[c]	1.4 ± 0.9	0.2 ± 0.4	Period × Group	5.727	0.012	

All data represents mean ± standard deviation. CAIT, Cumberland ankle instability; VAS, visual analogue scale; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group.

set at $p < 0.05$.

3. Results

3.1 Changes in stability and pain scores of the ipsilateral ankle

The descriptive statistics of the CAIT and VAS scores in this study are presented in Table 3. The CAIT score (F = 2.882, p = 0.082) at baseline was not significantly different among the groups, but there was a significant difference in the interaction effect according to the group and period (p = 0.005). PEG was significantly higher for the CAIT score than for these NTG and SEG scores. In addition, the VAS pain score showed a significant difference in the interaction effect according to the group and period (p = 0.012), and PEG and SEG had significantly lower VAS pain scores than NTG.

3.2 Change in ROM of ipsilateral ankle

The descriptive statistics of the ROM results of this study are presented in Table 4. In ankle dorsiflexion (p = 0.015) and inversion (p = 0.013) ROM, there was a significant difference in the interaction effect according to the group and measurement period. In dorsiflexion ROM, SEG and PEG were significantly higher compared to those in NTG, and ankle inversion ROM represented a significant decrease in SEG and PEG compared to those in NTG.

3.3 Changes in balance capacity and GRF of ipsilateral ankle

The descriptive statistics of the balance and GRF results of this study are presented in Table 5. There was a significant difference in the interaction effect according to group and measurement period in one-leg standing (p = 0.001), YBT (p = 0.001) and COP 95% confidence ellipse area (p = 0.004). In one-leg standing, PEG was significantly higher than that in NTG and SEG. In the posteromedial direction, PEG was significantly higher compared to the NTG, and in posterolateral of YBT, SEG and PEG were significantly higher compared to NTG. In addition, in the COP 95% confidence ellipse area, PEG was significantly lower compared to NTG.

4. Discussion

CAI is a condition in which repeated sprains occur in the same ankle after experiencing an initial ankle sprain, and patients with CAI suffer from ankle neuromuscular dysfunction accompanied by pain, tenderness and swelling.

In this study, CAIT score were significantly different in the interaction between group and period. Cain *et al.* [13] showed that proprioceptive exercise using a wobble board for 4 weeks and a strength exercise program using an elastic band were effective in increasing the CAIT score of participants with CAI through improving impaired postural control and neuromuscular function. Therefore, a short-term proprioceptive exercise program for 4 weeks is considered to have a positive effect in improving various symptoms including pain and preventing repetitive ankle sprains in patients with CAI.

CAI causes weakness of the muscles and soft tissues around the ankle, resulting in repetitive ankle sprains and pain. CAI with pain leads to ankle dysfunction such as restriction of movement. These dysfunctions can deteriorate quality of life while performing day-to-day and sports activities. Previous studies examining ankle pain in patients with CAI have emphasized the importance of VAS scale [26, 33]. Thus, the present study applied the VAS to examine ankle pain into participants and confirmed that both PEG and SEG significantly decreased the VAS pain scores compared to NTG. Hall *et al.* [34] reported that a resistance band and balance workout for 6 weeks were effective in reducing pain in adults with CAI by activating sensory organs around the ankle and neuromuscular function damaged by CAI. Thus, therapeutic exercise programs, such as strength and proprioceptive exercises, have a positive effect on pain control and quality of life improvement in adults with CAI.

Abnormal changes of ankle dorsiflexion and inversion ROM are the functional problems caused by deterioration of lateral ligaments and ankle muscle weakness in CAI. In particular, it has been suggested that poor static and dynamic balance in patients with CAI is closely associated with limited dorsiflexion ROM in the ipsilateral ankle [35]. In the present study, we investigated ankle dorsiflexion, plantar flexion, inversion, and eversion ROM before and after two types of exercise rehabilitation. PEG and SEG significantly increased dorsiflexion

TABLE 4. Changes in active ROM of the ankle.

Variable	Group	Pre	Post		F	p	Tukey
Plantar flexion (degrees)							
	NTG[a]	46.1 ± 5.5	44.8 ± 7.3	Period	0.165	0.689	
	SEG[b]	43.2 ± 5.7	42.1 ± 4.5	Group	2.640	0.099	
	PEG[c]	39.4 ± 6.9	39.9 ± 5.0	Period × Group	0.120	0.888	
Dorsiflexion (degrees)							
	NTG[a]	7.9 ± 2.9	8.3 ± 3.2	Period	9.429	0.007	
	SEG[b]	8.6 ± 2.2	12.4 ± 2.8	Group	5.642	0.013	a < b,c
	PEG[c]	9.3 ± 2.7	13.2 ± 2.2	Period × Group	5.675	0.015	
Inversion (degrees)							
	NTG[a]	40.1 ± 2.9	42.1 ± 4.6	Period	7.651	0.013	
	SEG[b]	40.0 ± 3.3	35.6 ± 4.6	Group	5.782	0.011	b,c < a
	PEG[c]	39.2 ± 3.0	33.3 ± 2.3	Period × Group	5.579	0.013	
Eversion (degrees)							
	NTG[a]	13.5 ± 2.7	14.6 ± 2.6	Period	2.847	0.109	
	SEG[b]	12.9 ± 2.3	15.1 ± 2.4	Group	1.780	0.197	
	PEG[c]	11.8 ± 3.6	12.5 ± 2.9	Period × Group	0.258	0.775	

All data represents mean ± standard deviation. ROM, range of motion; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group.

TABLE 5. Changes in dynamic balance and GRF of the ipsilateral ankle.

Variable	Group	Pre	Post		F	p	Tukey
One leg standing (s)							
	NTG[a]	18.4 ± 4.4	13.0 ± 8.4	Period	11.768	0.003	
	SEG[b]	15.1 ± 10.3	21.2 ± 4.9	Group	5.369	0.015	a,b < c
	PEG[c]	15.6 ± 5.2	34.1 ± 5.9	Period × Group	13.572	0.001	
Anterior of YBT (%LL)							
	NTG[a]	75.4 ± 4.1	73.3 ± 6.4	Period	9.951	0.005	
	SEG[b]	73.1 ± 10.0	75.8 ± 8.5	Group	0.774	0.476	
	PEG[c]	66.5 ± 4.1	75.1 ± 4.7	Period × Group	10.049	0.001	
Posteromedial of YBT (%LL)							
	NTG[a]	93.0 ± 6.6	83.8 ± 10.1	Period	1.425	0.248	
	SEG[b]	87.0 ± 10.0	98.2 ± 8.2	Group	0.415	0.667	a < c
	PEG[c]	84.2 ± 8.1	93.3 ± 6.6	Period × Group	17.237	0.001	
Posterolateral of YBT (%LL)							
	NTG[a]	100.8 ± 8.0	88.5 ± 7.0	Period	2.082	0.166	
	SEG[b]	96.0 ± 3.5	105.8 ± 7.4	Group	1.679	0.214	a < b,c
	PEG[c]	92.0 ± 10.5	102.4 ± 7.6	Period × Group	16.547	0.001	
COP 95% confidence ellipse area (cm/s^2)							
	NTG[a]	47.6 ± 19.9	67.2 ± 11.2	Period	4.839	0.041	
	SEG[b]	55.0 ± 33.0	32.3 ± 8.1	Group	3.840	0.041	b,c < a
	PEG[c]	59.1 ± 19.4	21.6 ± 4.3	Period × Group	7.767	0.004	

All data represents mean ± standard deviation. YBT, Y-balance test; COP, center of pressure; NTG, non-treated group; SEG, traditional strength exercise group; PEG, proprioceptive exercise group; %LL, percentage of leg length.

ROM and decreased inversion ROM in the ipsilateral ankle compared to NTG. According to a previous study, it has been suggested that strength training and proprioceptive exercise programs stabilize the abnormal ankle ROM of CAI patients within the normal range by strengthening the muscles around the ankle [36], increasing flexibility of the atrophied ankle muscles and ligaments, and extending the threshold time of the muscle spindle and Golgi tendon organ [19, 37].

In patients with CAI, reduction in the muscle and ligament strength around the ankle leads to a decrease in static and dynamic balance capacities, resulting instability of the center of gravity during movements such as walking, changing direction, and landing in daily life and sports activities [38]. The YBT is calculated by summing the three reach directions. Patients with CAI have a decreased reach distance in the anterior and posteriormedial directions [39, 40]. The present study applied one-leg standing with eyes closed and YBT to evaluate static and dynamic balances, respectively. We found that the PEG maintained posture for a longer time in the static balance test compared to the SEG, and in the YBT, the reach distance in the posterormedial direction was significantly increased in the PEG than in the SEG and NTG, and the posterior-lateral directions showed a significant difference in both SEG and PEG compared to the NTG. Alahmari *et al.* [22], who examined the balance ability in patients with CAI, found that proprioceptive exercises were effective in improving static balance by facilitating neuromuscular signal transduction and adductor muscle functions as well as combined lower extremity strength and proprioceptive exercises, which increased the dynamic balance capacity in patients with CAI [41]. These results of previous studies are similar to those obtained in our study.

Patient with CAI have been reported to experience various sports injuries due to ankle instability during landing, which is an essential movement not only in sports situations but also in daily life [42]. To evaluate ankle instability of patients with CAI, GRF was measured using methods such as the gait test, vertical jump, and drop landing [30, 31, 43]. In the present study, the COP 95% confidence ellipse area was measured during drop landing and it was confirmed that both PEG and SEG significantly decreased the ellipse area compared to NTG. In a study by Lee *et al.* [44], patients with CAI were asked to perform dynamic lower extremity balance exercises for 4 weeks, and significant differences were found in both the anterior/posterior, left/right velocity, and movement range of the COP. This means that 4 weeks of balance exercise led to an increase in proprioceptor and joint receptor thresholds, sensory function, ankle stability and dynamic postural control function in patients with CAI.

5. Conclusions

Overall, the proprioceptive exercise program not only had a positive effect on improving ankle ROM, static and dynamic balance ability, and pain in college students with CAI but it was also as effective as traditional resistance training in the rehabilitation of ankle instability. Therefore, we believe that proprioceptive exercise is a suitable therapeutic exercise to overcome dysfunction in patients with CAI. However, the limitations of this study are first, patients with CAI were not classified in detail, second, a sufficient number of participants were not secured to generalize the results in this study, and finally, the effect of exercise type according to ankle severity and number of re-injuries was not analyzed in patients with CAI. In future studies, it will be necessary to recruit enough participants to generalize the results after subdividing the characteristics of CAI.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

YJP and TBS—conceived the idea. YJP and YHC—verified the background and methods section and drafted the manuscript and designed the figures and tables. All authors discussed the interpretation of the results and contributed to final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by Jeju National University Institutional Review Board (JJNU-IRB-2021-049).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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