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A Comparative Evaluation of Closed and Open Kinetic Exercises in the Management of Chronic Ankle Instability

Background: Repetitive damage to the ankle joint causes chronic ankle instability, and studies comparing the effects of exercise in open and closed chains as a treatment method are very rare.
Objectives: To investigate the effects of open and closed kinetic exercises on muscle activity and dynamic balance of ankle joint in adults with chronic ankle instability.
Design: Single-blind randomized controlled trial.
Methods: The selected 30 subjects are randomly divided into open kinetic chain exercise experimental group (EG I, n=10), closed kinetic chain exercise experimental group (EG II, n=10), and stretching control group (CG, n=10). Open and closed kinetic exercises lasted 30 minutes three times a week for six weeks and stretching exercises performed four actions for 20 seconds and five sets. The measurement tools using surface electromyography to measure muscle activity in the ankle joint. The dynamic balance of the ankle was evaluated using the Y-Balance test.
Results: Following the intervention, closed and open kinetic chain exercise group showed significant difference in tibialis anterior and gastrocnemius muscle activity and dynamic balance ($P<.05$). However, no significant difference in tibialis anterior and gastrocnemius muscle activity and dynamic balance between closed and open kinetic chain exercise group ($P<.05$).
Conclusion: This study provides evidence that closed and open kinetic chain exercise can be presented as an effective exercise for the muscle activity of ankle muscle and dynamic balance of the subject with chronic ankle instability.

Keywords: *Closed kinetic chain exercise; Open kinetic chain exercise; Dynamic balance; Muscle activity*

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INTRODUCTION

Humans strive for personal development by participating in leisure activities, such as sports, to improve their quality of life. In particular, the word "well-being" which has emerged in modern times, has been playing a large role in sports activities as leisure activities since life patterns started changing due to the five-day workweek. Leisure time, such as sports activities, rose from 49.2 percent in 2000 to 54.8 percent in 2014 and has been on a steady rise.[1] However, excessive sports activity will damage the ankle,[2] thereby degrading an individual's ability to live, make it impossible for athletes to participate in sports, and cause repeated damage and are frequently found among the public due to the large number of recent sporting activities.[3-5] Ankle sprains are one of the most common injuries among athletes, especially in jumping and landing.[4]

Ankle injuries are experienced by 1 in 10,000,[6] and a study on ankle sprain among the public showed no difference in the rates of ankle sprain in men and women (2.5 in 1000).[7] Eighty percent of people who suffer from ankle injuries can experience recurrence, and this symptom of that injury is called chronic ankle instability.[8] In patients with chronic ankle instability, the external structures, such as the lateral ligaments, talocrural joints, and subtalar joints, are subject to periodic damage. Moreover, the propensity of recurrence of ankle sprain is high.[8] Another symptom of ankle instability is posture insatiability due to proprioception and deformation of surrounding tissues, and mechanical receptors are damaged along with these structures.[9] Such mechanical damage results in a change in the vertical ground reaction force (VGRF) to movement, and the load of the lower structure on the changed VRGF is a component of injury.[10] In addition, degradation of proprioception function due to chronic ankle sprain affects postural adjustment and protective reflex, joint kinetic ability, and balance ability, which is to cope with external fluctuation.[11] The stability of the limb joints and the degradation of proprioception restrict the provision of information about the body's position in space, which results in poor efficiency and excessive movement; these in turn leads to posture sway, which prevents a person from applying a proper balancing strategy during a sudden change in posture.[12]

In addition to the mechanical instability experienced by these ligaments, continuous damage will develop into functional instability the feeling of "giving way" when one is standing or walking and can lead to chronic ankle instability; thus, the activity of ligaments should be reduced, and exercises strengthening the muscles around the ankles should be performed.[13]

Muscle strengthening movements around the ankle prevent chronic ankle instability by strengthening the tibialis anterior, gastrocnemius, and calf.[14] Sensory motor and postural control should be enhanced through balanced exercise, and the proprioceptor sensory ability must be improved.[15] Ankle stability can be maintained when the muscles around the ankle and the sense of proprioceptor acceptance are normal, thereby preventing damage and recurrence.[16] According to a prior study on several methods of strengthening the ankle, closed and open kinetic chain exercises influence muscle strength.[17] Open kinetic exercises is a movement in which the distal part moves freely. These exercises are typically a non-weight exercise that is used to the muscle strength of patients with limited of motion.[18] Open kinetic exercises are used at the early stage of patients recovering from the ankle joint damages.[19]

Closed kinetic chain exercises are performing that the distal part is fixed and cannot move. These exercises are typically weight bearing exercises, where an exerciser uses their own body weight and external weight.[18] Closed kinetic chain exercises allows for joint stability through co-contraction of the agonist and antagonist muscles and it stimulates the sense of proprioceptor under the pressure of the joint capsule.[20] Therefore, the current study compares the effects on the muscle activity and dynamic balance of the gastrocnemius and tibialis anterior in closed and open kinetic chain exercises group. The most effective motion is determined, and an effective intervention method is suggested for the treatment and rehabilitation of patients.

SUBJECTS AND METHODS

Subjects

The study was a single-blinded and randomized controlled clinical trial. This study was conducted on 30 adults who have chronic ankle instability. The sample size for this study was calculated using the G* Power program 3.1. The purpose and content of this study were explained to all the study participants, and the consent forms were distributed to them. The selected 30 subjects are randomly divided into open kinetic chain exercise experimental group (EG I, n=10), closed kinetic chain exercise experimental group (EG II, n=10), and stretching control group (CG, n=10). The human subject ethics was approved by the Institutional Review Board of the Kyungwoon University Institution (KW-2019-A-11). Exercise was conducted three times a week for 6-weeks during the study period. There were no significant differences between the three groups in terms of general characteristics (Table 1).

The selection conditions of the study subjects are as follows.[21]

1) A person with a score of 24 or less in the Cumberland and ankle Facility tool (CAIT), ankle instability questionnaire
2) A person who has no fracture or deformity under the knee joint
3) Those who have no neurological problems with the balance ability
4) Those who free from cognitive impairment

Exercise method

The exercise programs for each group are shown in Table 2.

Table 1. General characteristic of the subject (M±SD)

General characteristic	EG I	EG II	CG
Age (years)	21.00 ± 2.49	20.50 ± 0.84	21.30 ± 1.49
Height (cm)	167.00 ± 9.80	164.60 ± 6.34	171.80 ± 6.74
Weight (kg)	64.80 ± 2.49	59.60 ± 14.19	62.80 ± 11.94
CAIT (score)	20.95 ± 1.50	21.50 ± 2.20	20.32 ± 3.21

M±SD: mean ± standard deviation, CAIT: Cumberland ankle instability tool
EG I : Open kinetic chain exercise group, EG II : Closed kinetic chain exercise group
CG: Stretching group

Open kinetic chain exercise (EG I)

The experimental group performing the open kinetic chain exercise performed exercise treatments that were commonly applied to patients with instability in the ankle joint. The ankle joint exercises using elastic bands consisted of ankle joint dorsi flexion, plantar flexion, ankle inversion, and ankle eversion movement. Elastic band color coding denotes the resistance levels. It includes following colors: yellow (thin), red (medium), green (heavy), bule (extra heavy), silver (super heavy), golden (max). In this study, a green elastic band was used to provide sufficient resistance to adults with ankle instability during the open kinetic chain exercises.[22] The exercise was conducted three times a week for six weeks and was performed in three sets of 10 times per session according to each direction of movement. Each exercise was repeated ten times with holding time and relaxation time of 15 counts (Figure 1).

Table 2. Exercise program

Division	Contents (6 week / 3 times a week)	Number time
Open kinetic chain exercise	With elastic band 1. Gastrocnemius exercise 2. Tibialis anterior exercise 3. Peroneus muscles exercise (30 seconds after one set)	Repeat 3 sets 10 times per set / 30 minutes
Closed kinetic chain exercise	1. Stabilization exercise (30 seconds after one set) 2. Stabilization exercise add elastic band from 2 week (30 seconds after one set)	Repeat 5 sets 20 times per set / 30 minutes
Control group	1. Pushing the soles of one's feet 2. Pulling the soles of your feet 3. Stretching gastrocnemius 4. Draw alphabet	Repeat 20 seconds and 5 sets per set / 10 minutes disturbance

Figure 1. Open kinetic chain exercise

Closed kinetic chain exercise (EG Ⅱ)

Groups performing closed chain kinetic exercise movements performed a stabilization exercise. The movement of the feet by pointing eight directions around the center point on the floor and facing each other. Perform five-set movements 20 times in each direction. Later, apply resistance by hanging a elastic band on the ankle to give resistance and then perform exercise. The exercise was conducted three times a week for six weeks (Figure 2).

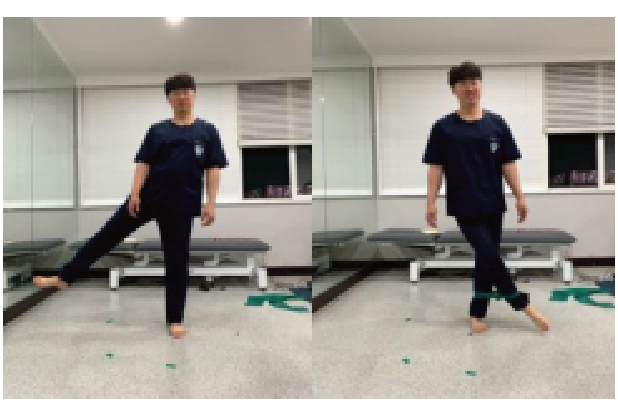

Figure 2. Closed kinetic chain exercise

Ankle stretching (CG)

The control group, the ankle stretching group, consists of pushing the sole of the foot, pulling the sole of the foot, stretching the gastrocnemius, and drawing the alphabet. The footpad push is located behind the ankle, and then perform a stretch of the front shin muscles through the foot bottom push in 20:5. After the footpad pull is located behind the ankle, perform stretching of the hips through the footpad pull for 20:5 sets. For calf muscle stretching, hold both hands to the wall, stretch the legs you want to stretch back, and perform five sets of stretching 20 times to prevent the heels from falling off. For Alphabet drawing stretching, use the ankle to draw the alphabet from A to Z in one set (Figure 3).

Figure 3. Ankle stretching

Measuring equipment and method

To enhance the reliability of this experiment, one researcher averaged out the results obtained from three measurement and used the following methods of measurement.

Ankle instability assessment

To assess chronic ankle joint instability, the scores used by previous study were translated to assess chronic ankle joint instability. And the CAIT had excellent test−retest reliability (ICC=.96).[23] Scores are in the form of questionnaires and consist of 9 items and 41 questions and are evaluated by scores of 0 to 30. The scores of 0 to 10 are divided by the severe instability stage, 10.5 to 21 points by the moderate instability stage, the mild instability stage, the mini−mum stability level by 24.5 to 27 points, and the nor−mal score by 27 to 30.5 points. Of these, subjects with a score of 24 or less were selected and the experimental and control groups were assigned.

Muscle activation test

Surface Electromyography (sEMG) equipment MP35 (MP35, Biopac System, USA) was used to measure muscle activity of the ankle joint. After cleaning the electrode attachment, the electrode was attached to the center of the muscle to be measured parallel to the direction of the muscle fiber, and the ground electrode was attached to the lateral malleolus. The electrode attachment was attached to two muscles, the tibialis anterior and the gastrocnemius. To obtain the average value of muscle activity, three repeated measured amplitudes were converted to effective val−ues and in this study standardized using maximal voluntary isometric contraction (MVIC), considering active adults. The reference value of the MVIC was expressed as a percentage of the average value of the activity measured for three seconds from the start of the muscle activity by inducing the hoof and heel of the ankle joint. The mean value was used as MVIC by measuring each measurement three times. To increase the objectivity of data due to differences in individual muscle strength of the ankle instability, data on contraction of the TA, GCM muscles were calculated as root mean square (RMS) and as ratios (%MVIC) to compare muscle activity during maximal voluntary contraction (MVC) and while in the ankle plantar and dorsi flexion (Figure 4).

Figure 4. Surface EMG

Dynamic balance test

Y−balance test is a tool for selecting and examining three directions, anterior, posterior−lateral, posteri−or−medial, which are reported to have very high confidence (ICC=0.91) in determining subjects with chronic ankle instability (Figure 5) and is used to assess the proprioception and dynamic balance of the ankle. The distance from the center line to the point where the target's leg was extended was measured in cm, and the direction of the measurement was meas−ured in anterior, posteriolateral, and posteromedial. The angle posteriolateral and posteriomedial are 135 degrees. A standardized formula has been used to compensate for differences in leg length, and the for−mula is as follows (Figure 6). The mean value was used as cm by measuring each measurement three times and the measured leg was set as the affected side leg.

Composite reach distance =
(Anteror + Posteriolateral + Posteriolmedial)/
(Leg length × 3) × 100

Figure 5. Y−Balance normalization

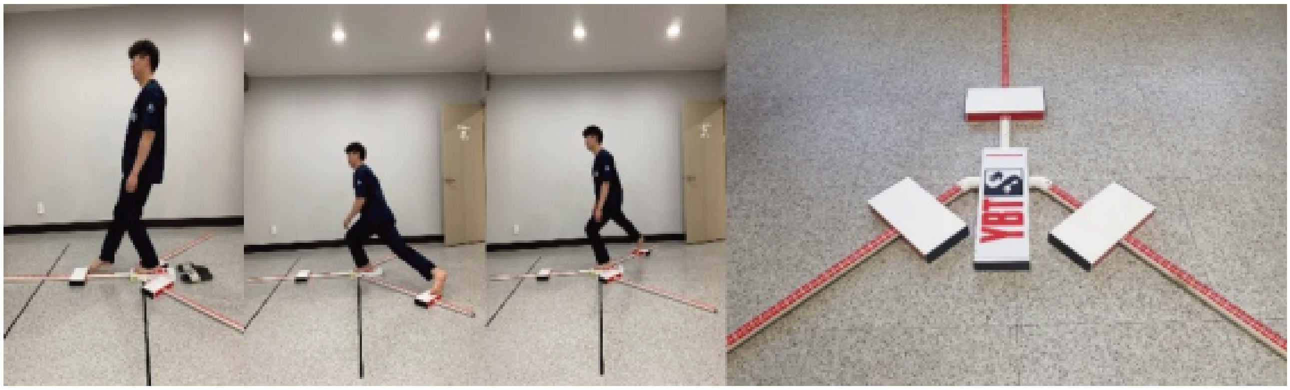

Figure 6. Y–balance measurement and kit

Data analysis

All data were subjected to normality test, statistical analysis was performed using SPSS 18.0 for Window. Statistical significance was α=.05. The results of the experiments obtained in this study are described in Mean±Standard Deviation (Mean±SD). To verify the differences between the groups before and after the exercises, a paired t–test was performed, and a one–way ANOVA was performed for comparison among the groups. Post–hoc analysis was performed using the LSD method.

RESULTS

This study was conducted in patients with chronic ankle instability to find out about the effect of closed and open chain exercise on muscle activity of the ankle joint and dynamic balancing ability.

Comparison of the results of muscle activity pre– and post–intervention in three group

In the changes in tibialis anterior and gastrocnemius before and after intervention, EG I, EG II showed significant differences ($P<.05$), and CG the values increased but did not show any significant difference ($P>.05$) (Table 3). The one–way ANOVA for comparison among the three group of tibialis anterior and gastrocnemius showed a significant difference ($P<.05$). The post–hoc analysis results showed a significant difference between CG and EG I, EG II ($P<.05$), but EG I and EG II did not show significant difference ($P>.05$) (Table 4).

Table 3. Comparison of change in muscle activity between three group (%MVIC)

Sortation		Pre	Post	t	*P*
CG	TA	38.57 ± 10.98	40.05 ± 11.14	–1.657	.132
	GCM	28.81 ± 14.16	30.80 ± 12.86	–2.145	.061
EG I	TA	29.77 ± 8.97	39.51 ± 9.07	–4.219	.002*
	GCM	26.02 ± 17.47	19.71 ± 6.23	–4.936	.004*
EG II	TA	40.62 ± 10.08	50.38 ± 13.97	–3.056	.014*
	GCM	29.13 ± 13.74	42.05 ± 18.81	–5.426	.000*

*$P<.05$
TA: Tibialis anterior, GCM: Gastrocnemius
CG: Stretching group, EG I : Open kinetic chain exercise group
EG II : Closed kinetic chain exercise group

Table 4. Comparison of changes in muscle activity in three group

(%MVIC)

Sortation		Pre–Post	F	*P*	LSD
TA	CG	1.50 ± 2.85	4.167	.026*	CG < EG I = II
	EG I	9.73 ± 7.29			
	EG II	9.76 ± 10.10			
GCM	CG	2.00 ± 2.94	8.887	.001*	CG < EG I = II
	EG I	12.65 ± 8.10			
	EG II	9.19 ± 8.21			

*$P<.05$
TA: Tibialis anterior, GCM: Gastrocnemius
CG: Stretching group, EG I : Open kinetic chain exercise group
EG II : Closed kinetic chain exercise group

Comparison of the results of dynamic balance pre- and post-intervention in three group

The dynamic balance was significantly different from the paired t-test results of EG I , EG II ($P<.05$), but in CG did not show any significant difference ($P>.05$) (Table 5). The one-way ANOVA for comparison among the three group of dynamic balance showed a significant difference ($P<.05$), EG I and EG II showed no difference ($P>.05$), but CG and EG I , EG II showed significant difference ($P<.05$) (Table 6).

Table 5. Comparison of changes in dynamic balance between three group

(unit: %leg length)

Sortation	Pre	Post	t	*P*
CG	72.96 ± 5.72	74.71 ± 7.04	–2.094	.066
EG I	62.90 ± 10.30	81.83 ± 9.71	–4.647	.001*
EG II	64.22 ± 8.12	85.66 ± 10.00	–5.580	.000*

*$P<.05$
TA: Tibialis anterior, GCM: Gastrocnemius
CG: Stretching group, EG I : Open kinetic chain exercise group
EG II : Closed kinetic chain exercise group

Table 6. Comparison of changes in dynamic balance in three group

(unit: %leg length)

Sortation	Pre–Post	F	*P*	LSD
CG	1.74 ± 2.64	9.837	.001*	CG < EG I = II
EG I	18.93 ± 12.88			
EG II	19.61 ± 11.82			

*$P<.05$
TA: Tibialis anterior, GCM: Gastrocnemius
CG: Stretching group, EG I : Open kinetic chain exercise group
EG II : Closed kinetic chain exercise group

DISCUSSION

This study was conducted to determine the effectiveness of muscular and dynamic balancing exercises in preventing ankle instability and to examine changes in dynamic balance muscle activity. The overall goals are to present a basis for subsequent exercise programs for ankle instability and to suggest a solution for the reduction of ankle instability. The instability of the ankles is caused by proprioception and weakened ankle muscles.[9] Repeated damage to the ankle joint can lead to functional instability in the ankle, and without treatment, the frequency of symptoms will increase, thus heightening anxiety.[2]

The causes of ankle instability include ligaments or tendons around the ankle, lack of motor sense, muscle weakness, and poor coordination. Maintaining the muscle strength of the ankle joint and its proprioception help keep stability and consequently prevent repeated damage to the ankle.[16] It is correlated with loss of body control as a cause of early ankle damage, as it reduces balance and ankle muscle strength.[9] Weakening of the lower extremities and loss of balance not only limit one's walking ability but also makes it uncomfortable to travel in daily life.[25]

Therefore, in this study, closed and open kinetic chain exercises were performed by adults with ankle instability three times a week for six weeks. Then, their balance capability and muscle activity were evaluated to identify the kinetic effect on their ankle instability.

In this study, sEMG was used to measure the muscle activity of muscles responsible for ankle stability. In addition, sEMG can indirectly measure the muscle activity of a voluntary movement. To identify muscle activity of ankle stability, muscle activity during standing motion for maximum muscle activity of tibialis anterior and gastrocnemius was measured. Studies of muscular activity showed significant differences between three group, but closed and open kinematic chain exercise group showed no significant difference. It also showed significant difference from the stretching group. These results have once again demonstrated the effects of closed and open kinetic chain exercise on patients with ankle instability, closed chain exercises using eight weeks of visual feedback for adults with ankle instability were consistent with studies showing significant differences in muscle activity in ankle muscles.[26] It is believed that closed and open kinetic chain exercises stimulated the proprioceptor of muscle, thereby controlling the movement of muscles around the ankle joint and activation muscle system.

Y-balance was used to assess the effect of the intervention in this study on dynamic balance. The results showed significant differences in the closed and open kinetic chain exercise groups before and after the experiment, and no significant difference in the stretching group. This was consistent with the study that the six weeks of coordination and equilibrium training improved the ability of posture control and reduced posture sway of the subject showing functional ankle instability.[27] In addition, it was consistent with a study in 24 patients with angle sprain that the balance exercise showed significant differences in the balanced ability of the target.[28] The significant difference in the evaluation of dynamic balance capability of this study is thought to have had a positive effect on dynamic balance by seeking to improve the balance strategy by increasing muscle strengthening and muscle activation around the ankle in the same context as the preceding study.

The limitations of this study are thought to be too much for a generalized interpretation of all patients with ankle instability (CAI). Furthermore, the differences in the lifestyles and individual muscle flexibility of the subjects were not controlled for, and changes were determined only after the exercise program of adult. Finally, because of the small number of people studied, the accuracy of the results is limited. Therefore, this work should be supplemented because research is needed for different age groups, and daily life or activities must be considered. For this reason, it is believed that closed and open kinetic chain exercise for increased muscle activity and dynamic balance of the ankle can be presented in one way when selecting a rehabilitation program for ankle instability.

CONCLUSION

This study was conducted three times a week for four weeks, using CAIT questionnaire to randomly select a total of 30 people as three different exercise groups to find out their impact on muscular activity and dynamic balance ability. As a result, the closed and open kinetic chain exercise showed a significant difference in the muscle activation and dynamic balancing ability of the subject with chronic ankle instability. Based on these results, closed and open kinetic chain exercise in patients with chronic ankle instability, could be presented as better way to exercise than stretching exercise.

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