



Original Article

The effects of open and closed kinetic chain exercises on the static and dynamic balance of the ankle joints in young healthy women

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Abstract. [Purpose] The purpose of the present study was to analyze the effects of open kinetic chain and closed kinetic chain exercises on the static and dynamic balance of ankle joints in young healthy women. [Subjects and Methods] Twenty women in their 20s were randomly assigned to two groups of ten women each: an open kinetic chain exercise group and a closed kinetic chain exercise group. Each group performed five sets of exercises three times per week for four weeks. Exercise intensity was increased once after two weeks. The subjects' Romberg's test results and their limits of stability were measured to evaluate their static and dynamic balance. The data were analyzed using a two-way repeated measures analysis of variance test. [Results] In the results of Romberg's test, the main effect of the time showed a significant difference in the trace length with eyes closed (Effect size: $d=0.97$). In the result of limits of stability, the interaction effect showed a significant difference in the backward, and the main effect of the group showed a significant difference in the forward. [Conclusion] The open kinetic chain and closed kinetic chain exercises both improved the balance of the subjects. The closed kinetic chain exercise was more effective at improving the dynamic balance of young healthy women than the open kinetic chain exercise.

Key words: Balance, Closed kinetic chain, Open kinetic chain

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INTRODUCTION

The ankle bears more weight per unit area than any other joint in the body¹⁾. The ankle joint is important for the balance strategy of the body²⁾. Balance is a person's ability to keep their center of gravity within the base of support or by restoring their center of gravity to that position under the force of gravity. Balance is an important factor that affects stability when standing and walking³⁾.

The sensory modalities involved in maintaining balance incorporate somatoafferent, vestibular, and visual input in order to assess the body's current position and external disturbances and feedback from previous efferent movement strategies. Consequently, the motor process coordinates the trunk and lower limb muscles into combined postural strategies to decrease body sway and maintain it within the base of support⁴⁾.

Improving mobility (e.g., the ability to change walking speed and direction) is a common rehabilitation goal for patients. One essential aspect of mobility is accelerating or decelerating the body effectively while maintaining dynamic balance⁵⁾. This aspect is closely related to a person's ability to adapt to different physical circumstances⁶⁾. For example, a woman wearing high-heeled shoes must change their balance mechanism in order to adapt to kinematic changes in the musculoskeletal system that occur while wearing such shoes⁷⁾. If balance is impaired, falls, which are a major source of morbidity and disability in the aging population, can easily happen⁸⁾.

The term "kinetic chain" is used to describe how the body moves, with the limbs functioning either in an open kinetic

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chain (OKC) or a closed kinetic chain (CKC) condition. The difference between these two conditions is determined by whether the terminal ending of the limb is free or fixed—for example, whether one is moving against a hard or soft surface^{9, 10}. OKC and CKC exercises generate different patterns of muscle activities and ligament forces^{9, 11–13}. CKC exercises activate antagonistic muscle groups across multiple joints and therefore cannot be used to isolate or examine a single muscle group^{9, 12, 14}. Examples of CKC exercises include push-ups, pullups, squats, and lunges. All types of CKC exercises may be performed with or without weights¹⁰. Conversely, OKC exercises isolate specific muscle groups, which is useful for strengthening and evaluation purposes.

A study was conducted to analyze the balance and function recovery of the extensor muscles of the knees and to re-establish joint stability. In this study, OKC and CKC exercises have also been employed in rehabilitation programs to treat patellofemoral disturbances¹⁵. In another study, different rehabilitation exercises, such as OKC flexion and extension exercises, were employed for the non-operative and post-operative management of joint disorders. The results of these studies are helpful in the design of efficient OKC exercises used during rehabilitation and performance enhancement programs⁹.

Several studies have reported that using the Thera-Band in exercises for strengthening the lower extremities improves balance ability. Therefore, conducting strengthening exercises with a Thera-Band is a suitable home-based exercise program for improving balance for activities of daily living¹⁶.

In the past, many studies analyzed the knee joint's relation to knee disease and the knee muscles by performing OKC and CKC exercises. The purpose of the present study was to analyze how balance was affected by OKC and CKC exercises that were performed on the ankle joint by women in their 20s who were able to decrease their balance ability by wearing high-heeled shoes.

SUBJECTS AND METHODS

Twenty women in their early 20s participated in the present study. None of the subjects had musculoskeletal or neurological impairments, a history of ankle surgery or vestibular deficits, or a history involving athletics, and none had received any training for muscle strengthening within the past six months.

The procedures of the experiment were explained to the participants, who voluntarily agreed to participate and signed informed consent forms. Each participant was randomly assigned either the OKC exercise group or the CKC exercise group, each of which consisted of ten women. The present study was approved by the Institutional Review Board of Namseoul University (NSU-151005-2). And participants provided informed consent prior to participation.

In order to measure the physical characteristics of the subjects, Body Composition Analyzers (Inbody 720, Biospace, Seoul, Republic of Korea) were used. In order to measure each subject's balance ability, a professional balance assessment and training platform (BT4, HUR labs Oy, Tampere, Finland) was used before and after each exercise.

Each subject's balance was measured using Romberg's test, and their limit of stability (LOS) was measured. To obtain the Romberg's test results, each subject was asked to bend one leg along the anterior-posterior axis of the balance platform at 30 degrees and stand on the opposite leg in order to maintain as stable a stance as possible¹⁷ for 60 seconds once with their eyes open (EO) and once with their eyes closed (EC). The measured variables were trace length (TL), Mean X, and Mean Y. To measure LOS, each subject's feet were aligned along the heel and medial malleolus landmarks printed on the top of the platform. Each subject was then instructed to shift her body weight (using her ankle joints as the primary axis of motion without changing their feet's position) in different directions (one direction at a time) as quickly as possible following the appearance of a target on the monitor. Each direction of the target was randomly selected by the researcher and displayed for eight seconds only once each¹⁸. The measured directions were forward (FW), backward (BW), left (LT), and right (RT).

Before the exercise period began, the physical characteristics of each subject were measured. The exercises were performed on each subject's non-dominant side¹⁹. Each subject kicked a ball to determine their dominant lower extremity⁷. The exercise protocols of either the OKC or the CKC exercise were performed for 60 minutes, which was based on a referred study²⁰. The exercise protocol consisted of a warm-up exercise for 10 minutes, the main exercise for 40 minutes, and a cool-down exercise for 10 minutes (Table 2). The subjects had one minute of rest between sets to avoid fatigue²¹.

Statistical analyses were performed using SPSS for Windows v.22.0. The subjects' physical characteristics were reported as mean (standard deviation (SD)). The dependent variables were tested for normality using the Kolmogorov-Smirnov test and for homogeneity of variance using Levene's test. A two-way repeated measures analysis of variance was used to examine the significance of differences in balance and to compare the balance of the subjects in each group and time (before and after exercise). The statistical significance level was as $\alpha=0.05$.

RESULTS

Twenty healthy women participated in the present study (Table 1). In the results of Romberg's test, the main effect of the time showed a significant difference in TL with EC ($p<0.05$) (Table 3). In the result of LOS, the interaction effect showed a significant difference in BW ($p<0.05$), and the main effect of the group showed a significant difference in FW ($p<0.05$) (Table 4).

Table 1. General characteristics of the participants (N=20)

	OKC (n=10)	CKC (n=10)
Age (years)	22.2 ± 5.1	21.6 ± 2.6
Height (cm)	161.2 ± 4.1	161.7 ± 5.0
Weight (kg)	57.8 ± 13.4	56.5 ± 5.6
BMI (kg/m ²)	22.2 ± 5.1	21.6 ± 2.6

Variables are expressed as mean ± SD; BMI: body mass index; OKC: open kinetic chain exercise; CKC: closed kinetic chain exercise

Table 2. Exercise protocol (for four weeks)

Exercise	OKC	CKC	
Warm-up (ankle stretching for 10 minutes)	Dorsiflexion and pulling the towel on the mat	Dorsiflexion and pushing the wall	
Main exercise (for 40 minutes)	Week 1–2 (20 times, 5 sets)	Dorsiflexion and inversion	Lunging
		Plantar flexion and inversion	Rolling the towel with toes extended
	Week 3–4 (20 times, 7 sets)	Plantar flexion (with red Thera-Band)	Rolling the towel with inversion
		Dorsiflexion and inversion	Lunging
	Plantar flexion and inversion	Rolling the towel with toes extended	
	Plantar flexion (with green Thera-Band)	Rolling the towel with inversion	
Cool-down (Ankle stretching for 10 minutes)	Dorsiflexion and pulling the towel on the mat	Dorsiflexion and pushing the wall	

OKC: open kinetic chain exercise; CKC: closed kinetic chain exercise

Table 3. Romberg's test with eyes open and closed for each group (mm)

Variable	Group	Pre-test	Post-test
Trace Length	EO	OKC	1,015.6 ± 384.9
		CKC	771.4 ± 238.0
	EC	OKC	2,052.1 ± 500.9
		CKC	2,259.0 ± 921.7
Mean X	EO	OKC	-10.4 ± 6.0
		CKC	-14.1 ± 18.6
	EC	OKC	-10.0 ± 5.9
		CKC	-12.2 ± 15.0
Mean Y	EO	OKC	-2.84 ± 11.86
		CKC	-6.41 ± 14.12
	EC	OKC	0.39 ± 8.52
		CKC	1.17 ± 14.55

Variables are expressed as mean ± SD; *Statistically significant main effect of the time (p<0.05); EO: eyes open; EC: eyes closed; OKC: open kinetic chain exercise; CKC: closed kinetic chain exercise

Table 4. Limit of stability for each group (degrees)

Variable	Group	Pre-test	Post-test
Forward*	OKC	35.7 ± 25.5	35.6 ± 35.8
	CKC	-20.3 ± 38.0	5.9 ± 34.0
Backward ⁺	OKC	-64.0 ± 20.4	-80.6 ± 23.9
	CKC	-95.2 ± 20.5	-78.9 ± 18.3
Left	OKC	-69.7 ± 12.4	-78.2 ± 16.1
	CKC	-77.7 ± 53.2	-59.6 ± 42.6
Right	OKC	70.7 ± 27.0	68.4 ± 26.4
	CKC	59.8 ± 15.7	72.1 ± 25.9

Variables are expressed as mean ± SD; *Statistically significant main effect of the group (p<0.05); ⁺Statistically significant interaction effect (p<0.05); OKC: open kinetic chain exercise; CKC: closed kinetic chain exercise

DISCUSSION

When maintaining a standing posture, the ankle joint strategy, hip joint strategy, and step strategy are the three movement strategies used to counter anterior-posterior translational motion. The purpose of the present study was to analyze static and dynamic balance using a Thera-Band and a towel to perform either OKC or CKC exercises on the ankle joint.

In the present study, in the results of the Romberg's test, the main effect of time showed a significant difference in TL with EC. A previous study investigated the effects of OKC and CKC exercises on knee extensor strength and balance ability in patients that recently had a stroke. In this study, there were significant differences in knee extensor strength and balance ability between the pre- and post-exercise of all groups²²). Another previous study examined the effects of OKC and CKC exercises on muscle activation of the paretic lower limb and balance in chronic stroke subjects. The study reported that anterior-posterior and medio-lateral sway velocities decreased both with eyes open and eyes closed with CKC exercise. These findings indicate that CKC exercise can improve balance in chronic stroke patients, and this improvement may carry over into an improvement in functional performance²³). Maintaining balance requires the ability to accept and inhibit the afferent stimulation of visual sensory, vestibular sensory, and somatosensory input. Measuring a subject's balance with their eyes open can identify their visual sensory, vestibular sensory, and somatosensory function. Measuring a subject's balance with their eyes closed can measure their vestibular sensory and somatosensory function without visual sensory function²⁴).

In the present study, the subjects' Romberg's test results showed a statistically significant difference in TL with EC between the pre- and post-exercise. These findings indicated that static balance could be improved without visual sensory function because the OKC and CKC exercises improved vestibular sensory and somatosensory function, which allow a person to maintain balance.

Although the subjects were given what appears to be a simple instruction (sway as little as possible), undisturbed upright stance control is, in fact, a complex task based on an integrated process involving predominantly visual and, when available, tactile and proprioceptive cues²⁵). The visual system assists in the maintenance and orientation of an erect posture. The conscious and unconscious correction of posture is possible through visual input. Although the visual system is an important reference source of verticality and for the maintenance of the natural oscillation of the body within the limits of stability, it is not essential to postural control; maintaining balance with one's eyes closed is possible²⁶).

In the current study, no significant difference was shown in the other variables with EO. These findings shows that visual feedback, which requires a subject's eyes to be open, provided information that helps maintain postural control. The participants used visual information and could maintain balance with a one-leg stance without any difference between the first measurement and the measurement after four weeks.

In the present study, in the results of the LOS, the interaction effect showed a statistically significant difference in BW, and the main effect of the group showed a statistically significant difference in FW. One previous study investigated the effect of OKC and CKC exercise on the dynamic balance ability of the ankle joints of healthy young adults. The results of this study showed that the balance of the subjects in both exercise groups improved, but the improvement was only statistically significant in the CKC group. This study concluded that CKC exercise appears to be more effective at improving dynamic balance ability than OKC exercise within a six-week training period²⁷). Another study examined whether the quadriceps femoris muscles are activated differently in OKC and CKC tasks. The study reported that the CKC exercise promotes more balanced initial quadriceps activation than OKC exercise²⁸). Another study investigated the effects of OKC and CKC exercise on knee joint function and on knee joint position sense in normal adults. The results of this study suggested that both OKC and CKC exercise increased knee joint proprioception. In particular, this study found that CKC exercise could be more useful than OKC exercise for improving proprioceptive sense²⁹). Another study analyzed the therapeutic effects of OKC and CKC exercises on the treatment of patellofemoral pain syndrome (PPFS). The study reported that CKC exercises were more effective than OKC exercises for this purpose³⁰). A study reported that the improvement of dynamic balance was significantly higher in the CKC group than in the other groups in the study. Another study to examine the exercise effects of OKC aimed and CKC exercise on balance in chronic stroke subjects. Anterior-posterior medio-lateral sway velocities (both with EO and EC) decreased with the application of CKC exercise. These findings indicate that CKC exercise can improve balance in chronic stroke patients, which may carry over into an improvement in functional performance²³). During CKC exercises, a group of muscles and joints works simultaneously, whereas in OKC exercises, they work separately. The effects of CKC exercise are remarkable; the co-contractions and complex actions of many muscles can greatly enhance joint stability³¹).

In the present study, in the results of the LOS, the interaction effect of the time and group was statistically in FW. This result is likely due to the changes in dynamic balance before and after exercise caused by both the OKC and CKC exercises. Additionally, the main effect of the group showed there was a statistically significant difference in the BW. These findings indicated that CKC exercise is more effective than OKC exercise because of the simultaneous muscle contractions and actions in CKC exercise compared to the separate actions of OKC exercise.

In the present study, OKC and CKC exercise using the ankle joint was performed by healthy young women for four weeks. As the Romberg's test, the main effect of the time showed a significant difference in TL with eyes closed. As the results of the LOS, the interaction effect showed a significant difference in the BW, and the main effect of the group showed a significant difference in the FW. Both OKC and CKC exercise improved the static balance of the subjects in this study, and the CKC

exercise improved dynamic balance more than the OKC exercise. These results can be useful in the formulation of both home exercise and clinical exercise programs intended to improve balance training by allowing therapists who formulate these programs to choose the most effective exercises for these programs.

Conflict of interest

The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article. No funding for study has been used.

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