

The Effect of Open and Closed Kinetic Chain Exercises on Dynamic Balance Ability of Normal Healthy Adults

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Abstract. [Purpose] This study investigated the effect of open and closed kinetic chain exercise on the dynamic balance ability of healthy young adults. [Subjects] Thirty-three healthy adults participated in this study. [Methods] Subjects were randomly assigned to either an open kinetic chain exercise group (n=17) or a closed kinetic chain exercise group (n=16). Both the open kinetic chain and closed kinetic chain exercise groups performed 3 sets of exercises 3 times per week for 6 weeks. Dynamic balance was measured at the beginning and end of the 6-week training period, including anterior-posterior, medial-lateral, and total displacement of the center of pressure. [Results] Both exercise groups showed improvement in balance parameters but the improvement was only statistically significant in the closed kinetic chain group. [Conclusion] Closed kinetic chain exercise appears to be more effective at improving of dynamic balance ability than open kinetic chain exercise within a 6-week training period.

Key words: Open kinetic chain exercise, Closed kinetic chain exercise, Dynamic balance ability

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INTRODUCTION

The ability to maintain balance, one of the important factors in performing everyday activities, is derived from complex interactions among the nervous system, musculature, and skeletal system¹⁾. Maintenance of balance requires visual, proprioceptive, and vestibular feedback in order to respond to the changing environment with appropriate balance strategies²⁾. Biomechanically, balance control is the ability to control the center of gravity of the body in both static and dynamic environments. Balance control secures postural stability by controlling the musculoskeletal system against gravity both at rest and when the body center of gravity is being moved³⁾. Thus, balance control is an important component in the rehabilitation of many neuromuscular disorders⁴⁾.

Rehabilitation of balance can target static or dynamic balance. Dynamic balance is the ability to maintain balance while the body is moving by keeping its center of gravity over the base of support⁵⁾. When a moving body stops and begins to move again, maintaining this equilibrium requires selective contraction and relaxation of various muscles to control the position of the center of gravity over the moving base of support⁶⁾.

Important parameters of balance performance include range of motion, muscle strength, somatosensory function, and the size and quality of the base of support⁶⁾. Muscles

can be strengthened through resistance training, which can be divided into open kinetic chain (OKC) and closed kinetic chain (CKC) exercises⁷⁾. Open kinetic chain exercise occurs when the movement allows the distal part of the limb to move freely while the proximal part is fixed. OKC exercise plays an important role in isolating individual muscle groups. It tends to generate more distraction and rotational forces and is often used with concentric muscle contraction⁸⁾. Closed kinetic chain exercise is a movement wherein the distal part is fixed, as when the sole of the foot makes contact with the ground or the exercise equipment. With the distal part fixed, movement at any one joint in the kinetic chain requires motion as well at the other joints in the kinetic chain. Thus both proximal and distal parts receive resistance training at the same time. In the case of the lower limb, CKC exercises are more functional, as weight bearing is, by definition, a closed kinetic chain activity of the lower limb. CKC exercise has been cited as producing superior eccentric contraction and co-contraction of muscles, as well as reducing shear forces while adding compressive forces to the joints, thereby enhancing joint stability⁹⁾. Several studies have investigated the effects of muscle strengthening using OKC and CKC exercise programs⁷⁻¹⁰⁾, but few studies have examined which exercise program would be helpful for improving dynamic balance performance. Therefore, the purpose of this study was to investigate the effect of OKC and CKC exercises on the dynamic balance performance of normal healthy adults.

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SUBJECTS AND METHODS

This study selected 33 college healthy students who had no cardiovascular, neurologic or orthopedic diseases, or problems with balance due to vestibular or visual impairment. They were healthy functional adults who did not regularly exercise. Subjects were randomly allocated to either an OKC or CKC exercise group, and each group performed the prescribed exercises three times a week for six weeks. A description of the purpose and methods of the study was provided to all the participants, and the experiments were conducted after the participants had read and signed an informed consent form. Subject characteristics are summarized in Table 1. The independent t-test was used to compare demographic variables (age, height and weight) and pre-balance measures of center of gravity displacement. There were no significant differences between demographic variables or pre-exercise balance abilities of the two groups.

Subjects were asked to perform repetitive exercise using open and closed kinetic chain exercise equipment. For OKC exercise, subjects sat on a knee extensor machine (HUR, Finland) and extended their knees starting from 90 degrees of knee flexion. For CKC exercise, subjects used the Shuttle 2000-1 (Contemporary Design Company, USA), extending their knee by pushing on the foot stand of the device from 90 degrees knee flexion. A resistance level of 80% of 1RM was used by both groups, as described by Holten¹¹⁾. Three sets of ten repetitions were performed in each exercise session and the sessions were conducted three times a week for six weeks. The exercise was halted if the therapist observed subject fatigue, pain, or decrease in coordination ability. To minimize muscle fatigue, there were two-minute breaks between sets¹²⁾. The HUR knee extensor uses pneumatic air resistance while the Shuttle 2000-1 uses variable elastic resistance as well as body weight; thus, quantifying and comparing the resistance levels between of the devices was not feasible. By using a resistance level of 80% RM for each device, comparable levels of resistance could be maintained for both exercise groups.

This study used the Good Balance System (GBS) Ver.3.06 (METITUR, USA) to assess subjects' ability to control dynamic balance following open or closed kinetic chain exercise. The GBS uses a diagonal force platform to convert shifts in weight to digital data to obtain a quantita-

tive assessment of maintenance of balance. The GBS measures anterior-posterior (AP), medial-lateral (ML) and total displacement (TD) of the center of gravity over time. Subjects were asked to step forward diagonally to the right and back and then to step forward to the left and back to a marker on the force platform and the amount of sway from the target was recorded. Balance was measured before and after the six-week exercise period. Data analysis was performed using SPSS 12.0 for Windows. The paired t-test was used to measure the change in balance within each group between pre-and post-training sessions, with a level of significance of 0.05. Estimated reliability coefficients for the GBS variables have been reported by Ceria-Ulep et al.¹³⁾ as ranging from 0.22 to 0.73, but these measures were recorded during 15 to 30 seconds of static balance. There are no reports of the reliability of the GBS for dynamic balance.

RESULTS

Table 2 shows the mean changes in anterior-posterior, medial-lateral and total displacement of COP of both exercise groups at pre- and post-training. All mean displacement values decreased in both groups, demonstrating improvement in dynamic balance ability, but in the OKC group the change was not statistically significant for any measure, while in the CKC group the change in displacement was statistically significant for all three measures. As seen in Table 2, the pre-exercise balance scores of the CKC group were all poorer than those of the OKE group. Although the mean scores were not statistically different at baseline, this raises that question as to whether the CKC group had more room for improvement, as they had somewhat poorer balance to start with. This possibility could be addressed with a larger sample size. However, the present data shows that not only was the change in balance greater in the CKC group, but also the final balance scores were all lower in the CKC group. This means that the CKC group, on average, started off with poorer balance than the OKC group, but finished with better balance than the OKC group, which is suggestive of a true treatment effect.

Table 1. Baseline characteristics of subjects

Group Variable	OKC group (n=17)	CKC group (n=16)
Age (year)	23.1±0.7	22.0±0.6
Height (cm)	159.1±33.4	164.8±7.7
Weight (kg)	60.1±11.3	56.2±7.8
APD (mm)	688.6±146.0	748.2±188.8
MLD (mm)	578.2±165.7	635.1±196.7
TD (mm)	1005.8±220.4	1093.3±299.9

Values are expressed as mean ± SD, * p<0.05

OKC: Open kinetic chain; CKC: Closed kinetic chain; APD: Anterior-posterior displacement; MLD: Medial-lateral displacement; TD: Total displacement

Table 2. Mean COP displacement in the open- and closed-kinetic chain exercise groups

	OKC		CKC	
	Before Training	After Training	Before Training	After Training
APD (mm) (±SD)	688.5 (±146.0)	646.5 (±133.2)	748.2 (±188.8)	641.6* (±99.3)
MLD (mm) (±SD)	578.1 (±165.7)	527.1 (±134.5)	635.1 (±196.7)	508.9* (±72.3)
TD (mm) (±SD)	1005.2 (±220.4)	943.4 (±186.5)	1093.3 (±299.9)	914.9* (±124.1)

Values are expressed as mean ± SD, * p<0.05

OKC: Open kinetic chain; CKC: Closed kinetic chain; APD: Anterior-posterior displacement; MLD: Medial-lateral displacement; TD: Total displacement

DISCUSSION

Muscle strength decreases if there are lesions in the muscular tissues or their nerves, lesions in the joints controlled by the muscles, or as a person ages. In addition, if muscle activity is not performed for a long time, muscle strength decreases through muscular atrophy. When muscle activities are consistently increased through resistance exercise, muscle strength gradually increases^{14, 15}). Although the present study population did not have any disorders that would have affected muscle strength, they were not regular exercisers and therefore had the potential for strength gains within a relatively short time period.

To maintain balance of the human body, several systems interact with each other. To maintain the center of gravity over the base of support, the body combines input acquired through vision, somesthesia, and vestibular senses and controls movement through synchronized muscle contraction based on that information. The body reacts to new positions based on changes in the base of support to maintain balance²⁻⁴). Various exercises such as aerobic exercise, open and closed kinetic chain exercise, and Tai Chi exercise have been used to improve balance¹⁶⁻¹⁸).

This study investigated whether open and closed kinetic chain exercises improve dynamic balance ability in healthy adults who had no exercise habit. The anterior-posterior, medial-lateral, and total displacements of center of pressure, representative of dynamic balance ability, were significantly reduced in the CKC group at post-test, whereas no significant differences were found in the OKC group. The OKC exercise was isolated to the knee extensors, while the CKC exercise involved hip, knee and ankle muscles. CKC exercise, by virtue of being weight bearing, also involves more joint compression. Thus, both the neuromuscular activation of multiple muscle groups and the proprioceptive feedback from the sole of the foot and the lower extremity joints during CKC exercise is closer to that required in weight bearing balance.

Improvement in balance can be achieved by either strength gains or improved motor control (or both). Strength was not measured before or after training, so it is not known how much of the improvement in balance was derived from strength gains. However, the CKC exercises performed in this study were done while on a seated apparatus, as opposed to performing CKC exercises while weight bearing, as in squats. Therefore any motor control training that did occur was not the result of targeting balance mechanisms, as the vestibular and visual systems were not challenged during seated CKC training. However, the CKC training did involve more coordination and co-contraction of anti-gravity muscles. Therefore the benefits of CKC exercises may have accrued from a combination of more muscles being strengthened and those muscles being trained to co-contrast together.

Because both exercise devices strengthened muscles that act primarily in the sagittal plane (knee and hip extensors) the balance parameter that would be expected to show the greatest improvement from strength gains is the anterior-posterior displacement. However, medial-lateral balance

(and total balance) measures improved even more than the anterior-posterior measure, suggesting a training effect that goes beyond simply muscle strengthening.

Only one other study has examined the effect of CKC exercises on balance. Dannelly et al.⁷) examined balance performance in the Star Excursion Balance Test (SEBT) before and after performance of CKC and OKC exercises. They found that following 13 weeks of resistance training, both strength training methods resulted in a significant improvement in left leg balance in the posteromedial direction and marginally significant improvements in right leg balance in the posteromedial direction; however, there were no significant changes in balance in the anterior direction in either leg. The SEBT used in their study focuses on the ability to reach while standing on one leg, while the present study measured displacement of center of pressure without reaching. Danelly et al.⁷) also used different exercise equipment and a different training period and examined only women. The difference in exercise equipment is of particular importance. The device used by Dannelly et al.⁷) for CKC exercise was a type of sling suspension that provides resistance to push-ups and pull-ups while being suspended above the ground. This would recruit muscles in a completely different fashion from CKC exercises that give resistance through the sole of the foot, which should better mimic weight bearing muscle recruitment during balance.

In previous studies, lower body CKC training has been shown to be more effective than OKC training for improving vertical jump performance^{19, 20}), and CKC training has generated muscular co-contraction, resulting in greater joint stability^{17, 21}). These findings agree with the results of present study, because CKC exercise would develop better joint coupling at the hip and knee than OKC exercise focusing on knee extension alone.

In conclusion, CKC exercise for 6 weeks significantly improved dynamic balance of healthy adults, while OKC exercise produced a positive, but not significant improvement. Limitations of this study include a small sample size, and the lack of strength measurement of subjects' ankles, knees, and hips. Future studies should employ larger sample sizes, and compare the effect of open and closed kinetic chain strengthening exercises on dynamic balance of patients with ankle instability or knee or hip osteoarthritis.

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