

Changes of One-Leg Standing Balance of Ipsilateral and Contralateral Lower-Limb Following Unilateral Isokinetic Exercise of Ankle Joint in Young Adults

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Purpose: The purpose of this study was to investigate the effects of a four week unilateral isokinetic exercise program applied to ankle on the one-leg stance balance performance of ipsilateral and contralateral lower-limbs.

Methods: Subjects were randomly assigned to either a right ankle training program (n = 12) or a control group (n = 12). The training group received unilateral ankle isokinetic exercise of the dominant side for 4 weeks, whereas control group did not. Ipsilateral and contralateral one-leg balance were measured before and after intervention using the Biodex Balance System.

Results: Improvements of stability scores, such as APSI, MLSI, and OSI, from pre-test to post-test were significantly different greater for the training group when the control.

Conclusion: The results of this study suggest unilateral ankle strengthening exercise transfers benefit to the untrained limb by a cross-education effect, and that this type of exercise should be considered to improve one-leg standing balance of trained and untrained lower-limbs.

Keywords: Cross-education, Strength training, One-leg stance

INTRODUCTION

Strength training of one limb can enhance performance of the same task by the contralateral untrained homologous limb.¹⁻³ This phenomenon is known as cross-education, cross-training, or the contralateral-strength-training effect, and is known to occur after motor skill and strength training.⁴⁻⁶ Cross-education is thought to be primarily controlled by neural mechanisms,^{5,7} but the natures of these mechanisms have not been determined. The enhancement of strength in an untrained limb is related to the gain achieved by the trained limb, and on average is 52% of the strength gain of the trained limb.⁸

Ankle and hip strategies have been used to demonstrate maintenance of postural control through specific actions at these two joints,^{9,10} and ankle strength is known to be correlated with postural stability.¹¹⁻¹³ In general, lower-limb resistance training provides an

effective way of enhancing balance ability. In fact, previous studies have shown that strength training provides an effective intervention for enhancing postural control and balance.¹⁴⁻¹⁶

Kim et al. investigated the effect of unilateral isokinetic training of a hip joint on the one-leg standing balance of the contralateral untrained lower-limb, and found a significant improvement in the stability balance scores of untrained lower-limb.¹⁷ Accordingly, we considered enhancement of untrained limb strength after unilateral isokinetic exercise of an ankle joint would also influence one-leg standing balance of the untrained lower-limb.

The ankle activation are mediated by automatic response and require shorted delays compared to activation of other joints, the strategy of ankle joint become important for postural control.¹⁸ However, no previous study has investigated the effect of unilateral ankle muscular training using an isokinetic training program on one-leg standing balance of the contralateral untrained lower-limb,

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although many studies have addressed changes in contralateral limb muscle strength due to cross-education. We considered that this theme could be expanded to contralateral balance performance after an ipsilateral strength exercise. Therefore, the purpose of the present research was to investigate the effects of a four week unilateral isokinetic exercise program of the ankle on one leg stance balance performance of ipsilateral and contralateral lower extremities in untrained young adults.

METHODS

1. Subjects

Twenty four healthy, right-handed university students volunteered for this study, the Edinburgh handedness inventory was used to determine handedness. No of the 24 subjects had participated in any kind of strength training exercise during the previous 6 months, and all were free of any peripheral or neurological impairment that prevented independent single limb stance, such as, a history of lower-limb fracture or surgery, a ligamentous ankle injury, or vestibular impairment. The investigator explained the experimental procedures to subjects before study commencement. Characteristics of the subjects are presented in Table 1.

2. Experimental methods

The 24 subjects were randomly assigned to a training group that performed a 4-week strength training program for the right ankle ($n = 12$) or a control group ($n = 12$), members of which did not train. All subjects participated in a testing session before and after the 4-week intervention period.

Unilateral ankle strengthening training was performed using the Biodex 3PRO System (Biodex, Inc., Shirley, NY, USA) to strengthen ankle dorsiflexion and plantar flexion, and inversion and eversion. Strengthening training of ankle was performed on dominant sides using five sets of 10 repetitions at the angular velocity of 60°/s with a

rest period of 2 min between sets. This velocity was chosen because the majority of daily activities are related to the ability to generate power at low velocities. For ankle strength training, each participant was seated in chair of the Biodex unit in an upright position with the back of the seat tilted at an angle of 85°. Stabilization was provided by two shoulder straps that crossed the subject's chest, a waist strap, and a thigh strap. The lateral femoral epicondyle was aligned with the axis of rotation of the dynamometer, and length of the attachment was adjusted to ensure that the ankle pad rested comfortably above the lateral and medial malleoli. Range of motion was determined for subjects on an individual basis. The subject of training group received five times per week for four consecutive weeks. The subjects in the control group attended health education programs, such as, fall prevention, balance, exercise, and provided general information regarding health promotion during four hour long lectures (one per week for 4 weeks). In addition, control groups were asked to maintain their physical activity level for 4 weeks and to not participate in any strengthening exercise programs.

For the one-leg standing balance test of ipsi- and contralateral lower-limbs, subjects in both groups were assessed using a commercial balance device, the Biodex Stability System (Biodex, Inc., Shirley, NY, USA), which possesses a movable balance platform that provides up to 20° of surface tilt in all directions. The measures of postural stability used were recognized stability indexes, that is, APSI (anteroposterior stability index), MLSI (mediolateral stability index), and OSI (overall stability index). One leg standing balance was assessed using the 10 levels of stability (1 to 12 where level 12 is the most stable) of the Biodex Stability System using a test period of 20 seconds. Subjects were instructed to stand on the untrained or trained leg with the knee of the weight-bearing leg slightly flexed, to place arms across the chest and maintain them as motionless as possible, to look straight ahead at a monitor, and to lift the trained knee from the floor and flex it to 90° at the start of the assessment.

Subjects were allowed to practice this position once before two measurements were taken on trained and untrained leg. Mean values of these two measurements were used in the analysis. Testing orders of trained and untrained leg was chosen randomly, the second leg was tested 1 hour after the first.

3. Statistical analysis

Statistical analyses were performed using SPSS version 18.0 soft-

Table 1. The general characteristics of subjects

	Training group (n= 12)	Control group (n= 12)
Age (year)	23.4±2.2	24.3±2.7
Height (cm)	166.0±4.7	164.5±8.9
Weight (kg)	56.2±6.9	59.3±11.2
Foot length (mm)	247.4±14.1	247.1±19.2
Male/Female	5/7	5/7

Mean±SD.

Table 2. Comparison of one-leg standing balance of experimental and control subjects

Parameters	Training group (n = 12)		Control group (n = 12)		F-value	P-value	
	Pre	Post	Pre	Post			
Right OLB	APSI (°)	0.55±0.19	0.35±0.10* [†]	0.55±0.21	0.54±0.21	12.46	0.020
	MLSI (°)	0.59±0.33	0.38±0.22* [†]	0.55±0.23	0.56±0.27	4.44	0.047
	OSI (°)	0.76±0.26	0.54±0.25* [†]	0.75±0.20	0.74±0.27	10.68	0.006
Left OLB	APSI (°)	0.61±0.19	0.48±0.16* [†]	0.60±0.19	0.58±0.19	4.98	0.036
	MLSI (°)	0.62±0.23	0.50±0.19* [†]	0.61±0.22	0.59±0.25	5.21	0.032
	OSI (°)	0.78±0.16	0.66±0.20* [†]	0.77±0.19	0.73±0.21	4.33	0.049

OLB: one-leg balance; APSI: Anterior-posterior stability index, MLSI: Medial-lateral stability index, OSI: Overall stability index.

*significant difference between pre- and post-test ($p < 0.05$), [†]significant difference compared with the control group ($p < 0.05$).

ware. The independent t-test was used to analyze differences between the training and control groups with respect to age, height, weight, and foot length. Normalities of distributions of variables were checked using the Shapiro-Wilk test. In order to compare and contralateral balance on the impact of ipsilateral ankle strength training, two-way analysis of variance 2×2 ANOVA for repeated measures was used. Statistical significance was accepted for p values of < 0.05 .

RESULTS

All 24 subjects completed the training and assessments and no subject reported any discomfort during the study period. No significant intergroup difference was observed for subject age, height, or foot length. A summary of subject demographic variables is provided in Table 1. Changes in Stability Index Scores, including APSI, MLSI, and OSI, of ipsilateral and contralateral one-leg standing balances before and after isokinetic exercise in the training and the controls are summarized in Table 2. Two-way ANOVA with repeated measures of ipsilateral and contralateral one-leg standing balance showed group ($p < 0.05$), time ($p < 0.05$), and group-by-time interaction ($p < 0.05$) had significant main effects. Statistical analysis indicated that the APSI, MLSI, and OSI in the training group were significantly lower after training than before training. The improvement of stability scores, such as APSI, MLSI, and OSI, from pre-test to post-test were significantly different greater for the training group when comparing the control.

DISCUSSION

In the current study, we attempted to investigate the effects on one

leg stance balance performance of ipsilateral and contralateral lower extremity following unilateral isokinetic exercise of ankle musculature during four weeks. This is the first study to assess change in one-leg standing balance in the untrained lower-limb following unilateral isokinetic exercise of ankle joint. Our findings showed that there were significant improvements in the APSI, MLSI and OSI of ipsilateral and contralateral lower extremity during one-leg standing balance in the training group, compared to the gender and age-matched control group.

In addition, improvements in one-leg standing balance of untrained lower-limbs and of trained lower-limbs were observed after 4 weeks of unilateral isokinetic exercise of an ankle joint. However, the control group showed no change in balance scores after training. Our results indicate that cross-education does appear to have a positive influence on stability balance, as assessed using APSI, MLSI, and OSI. Our findings are supported by several previous studies, in which untrained limbs shows positive gains after different training programs involving, such as, muscle muscular activation, transcranial magnetic stimulation activation.^{6,19-22} Similarly, Kim et al. reported that cross-education training using unilateral isokinetic exercise of hip joint increased one-leg balance of untrained lower-limb following a short duration of training.¹⁷

In the present study, after unilateral isokinetic ankle strengthening, one-leg standing stability balance scores of trained lower-limbs decreased by 30-36%, and those of untrained lower-limbs decreased by 15-22%. Carroll et al.'s conducted a meta-analysis of cross-education effects and reported that a mean increase in strength of the untrained limb of - 52% of the increase gained by the trained limb.⁸ However, although it is evident that unilateral training has a cross-education effect, the mechanisms responsible for this effect have not been determined. Carroll et al. suggested two plausible mechanisms

by which force-generating capacity could increase in the untrained side.⁸ First, unilateral strength training could cause 'cross-activation' (a spill-over of neural drive from the active to the inactive hemisphere that induces adaptations in the control system of the opposite limb), and second, unilateral strength training could cause 'bilateral access' (neuromuscular adaptations in the control system of the trained limb accessible by the opposite limb).^{5,7,8}

Our findings emphasize that unilateral ankle strengthening exercise can be transferred to the untrained limb by a cross-education effect, and suggest that such training should be considered a form of exercise that may assist individuals improve one-leg standing balance in trained and untrained lower-limbs. Nevertheless, our results should be interpreted with caution for the following reasons. First we did not measure the effect of unilateral ankle strengthening exercise on the strengths of lower limbs, and thus, were not able to evaluate the possible correlation between ankle strength and one-leg standing balance improvements. Second, despite its potential clinical relevance, the cross-education strength training effect is relatively small, which raises questions about its therapeutic relevance. Third, the study had a small sample size, which may have obscured the detection of physiologically interesting effects.

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