J. Phys. Ther. Sci.
26: 1267–1269, 2014

Original Article

Influence of Resistance Exercise Training to Strengthen Muscles across Multiple Joints of the Lower Limbs on Dynamic Balance Functions of Stroke Patients

Sung Min Son, MS, PT[1)], Myung Kyu Park, PhD[2)], Na Kyung Lee, MS, PT[3)*]

[1)] *Department of Physical Therapy, College of Rehabilitation Science, Daegu University, Republic of Korea*
[2)] *School of Mechanical and Automotive Engineering Technology, Yeungnam University College, Republic of Korea*
[3)] *Department of Physical Therapy, College of Rehabilitation Science, Daegu University: 15 Jilyang, Gyeongsan-si, Kyeongbuk 712-714, Republic of Korea*

Abstract. [Purpose] The objective of this study was to evaluate the effects of resistance exercise training for strengthening muscles across multiple joints on the dynamic balance function of stroke patients. [Subjects and Methods] Subjects in the training group (n=14) and the control group (n=14) received conservative physical therapy for 30 minutes per day, five days per week, for a period of six weeks. The training group additionally performed three sets (eight to 10 repetitions per set) of resistance exercise at 70% of the 1-repetition maximum (1RM) to strengthen muscles across multiple joints. The control group did the same exercises for the same duration but without resistance. To assess dynamic balance function, before and after the intervention, we measured antero-posterior (A-P) and medio-lateral (M-L) sway distances, the Berg balance scale (BBS), and the timed up and go (TUG) times. [Results] Compared to pre-intervention values, the BBS score showed significant increases in both groups, and A-P and M-L sway distances and TUG times showed significant decreases in both groups. Changes in A-P and M-L sway distances, BBS scores, and TUG times were significantly different between the muscle training group and the control group. [Conclusion] Training involving muscle strength across multiple joints is an effective intervention for improvement of dynamic balance function of stroke patients.
Key words: Muscle strength exercise, Dynamic balance, Stroke

(This article was submitted Jan. 7, 2014, and was accepted Feb. 20, 2014)

INTRODUCTION

Many factors, such as reduction in muscle strength and range of motion, abnormal muscle tone, and loss of sensory and motor coordination contribute to difficulties of postural control in stroke patients[1–3)]. In addition, reduced balance function increases the risk of fall[4, 5)] and results in significant economic costs and increased hospitalization period[6)].

In particular, the aim of rehabilitation for patients with stroke is to increase muscle strength, because muscle strength is closely related to functional balance and gait performance[7–9)]. Resistance exercise is used in athletic and rehabilitation programs to increase muscle strength[10)]. Several studies have reported that strength training has a positive impact on functional ability[11–13)]. In general, resistance exercises can be distinguished by training involving muscle strength across a single joint and multiple joints. Most previous studies associated with resistance training for stroke patients have reported that training for strengthening muscles across a single joint, such as knee extension or flexion, is commonly used to improve the strength and functional abilities of the lower limbs[8, 11, 14)]. However, previous study emphasized that resistance training for strengthening muscles across multiple joints is more closely related to functional movement[15)].

Until now, no studies have investigated resistance training for strengthening muscles across multiple joints on the dynamic balance of stroke patients. Therefore, the purpose of this study was to investigate the effects of six weeks of training for strengthening muscles across multiple joints on the dynamic balance ability of stroke patients.

SUBJECTS AND METHODS

The subjects were 28 patients with stroke who had been admitted to hospital and agreed with the study's aim and methods. Eligibility criteria included the following: a Brunnstrom stage higher or equal to stage 3, ability to

*Corresponding author. Na Kyung Lee (E-mail: dlskrud21@hanmail.net)

independently walk 10 m with or without supervision oran aid or orthotis, and a minimum score of 20 on the Korean Mini-Mental State Examination (K-MMSE). The exclusion criteria were joint contracture, pain or fracture of the musculoskeletal system, and hemianopsia. All of the participants understood the purpose of this study and gave their written informed consent before experimental involvement. The study was performed in compliance with the Declaration of Helsinki, and was approved by the local committee of the Institutional Review Board of a university hospital.

Software was used to randomly allocate the subjects. Participants in the training group (n=14) and in the control group (n=14) received conservative physical therapy for 30 minutes per day, five days per week, for a period of six weeks. Conservative physical therapy consisted of joint mobilization, muscle strengthening, and balance training. In addition, participants in the training group performed resistance exercise training to strengthen their muscles across multiple joints of the lower limbs. Resistance exercise training was performed in a sitting position, with the paretic foot fixed on the pedal of a Leg Press Rehap exercise machine (HUR, Finland) with pneumatic resistance of 10 bars. Participants were asked to fully extend the paretic leg and then slowly flex the knee joint to 90 degrees of knee flexion. They were then asked to slowly extend the knee joint to the starting position. The 30-minute exercise sessions took place 5 times a week. Training sessions started with a warm-up of four repetitions at 25% of subjects'one-repetition maximum (1RM), followed by three sets (eight to 10 repetitions per set) at 70% of 1RM. The training intensity was adjusted weekly with reassessments of 1RM. All exercises were performed individually and supervised by a physical therapist. Prior to each session, participants' feedback regarding adverse effects, such as post exercise pain and stiffness, were also considered in the progression of the exercise. The control group exercises were the same as for the training group, including the frequency and number of repetitions, except that extermal resistance was applied with weights.

Postural balance (dynamic balance) was assessed using the Good Balance system (Metitur, Finland), which consists of a portable equilateral triangular force platform (800 mm × 800 mm × 800 mm) with strain gauge transducers connected to a three-channel DC amplifier and a 12-byte analogue-to digital (A/D) converter connected to a computer. Amplified analogue signals were digitized with a sampling frequency of fs = 50 Hz and input to the computer through a serial port. All filtering and data processing were carried out in digital form using Good Balance software.

In the postural balance tests, the subjects were asked to stand barefoot on the force platform in a relaxed posture, and look at a monitor placed at eye level. The monitor for visual feedback was located on a table directly in front of the subject. Nine boxes, consisting of eight peripheral targets and one central target, were shown on the monitor. Subjects shifted their weight forward toward the target when one of the peripheral targets was presented randomly, and then back to the central target. After demonstrating the tests, the subjects were allowed to practice once before the measurements were taken. Each subject performed the test three times. At the beginning of each trial, the examiner checked that the subject was standing symmetrically on both legs and did not lean backwards or forwards. Subjects were instructed to try to reach the targets as quickly and accurately as possible, and to avoid unnecessary and uneconomic movements. A-P, M-L, and total COP distance were measured. BBS assessments and TUG time measurements were performed twice, and the best trial was accepted. BBS and TUG were performed twice, and the best trial was accepted.

SPSS version 17.0 software was used for statistical analyses. Tests for normality were performed for all continuous variables. Pre- and post-intervention data were examined using the paired t-test for within group comparisions and the independent t-test was used for between the group comparisions. The level of statistical significance was chosen as 0.05.

RESULTS

The characteristics of the patients in the training group [8 males and 6 females: age: 57.4 years; type of stroke: ischemic 7/ hemorrhagic 7; paretic side: right 6/ left 8; height: 165.4 cm/ weight: 67.3 kg/ time since stroke onset: 17.9month] did not differ significantly from those of the control group [7 male and 7 females: age: 56.6/ type of stroke: ischemic 8/ hemorrhagic 6; paretic side: right 7/ left 7; height: 166.7 cm/ weight: 69.2 kg/ time since stroke onset: 18.7 month]. After six weeks of intervention, compared to pre-intervention, the BBS score showed a significant increase in both groups ($p<0.05$). In addition, A-P and M-L sway distances, and TUG times showed significant decrease in both groups ($p<0.05$).

Changes in A-P and M-L sway distances, BBS scores, and TUG times differed significantly between the muscle training group and the control group ($p<0.05$) (Table 1).

DISCUSSION

In the current study, we investigated the effects of muscle strength training across multiple joints of the lower limbs on the dynamic balance of chronic stroke subjects. The results of our study showed improvements in A-P and M-L sway distances, BBS score, and TUG time in the training group, which were better than those in the control group. These results imply that muscle strength training across multiple joints of the lower limbs enhances balance ability.

Many studies have reported a correlation between muscle strength and functional balance[7, 8, 16], and resistance exercise training leads to increased muscle strength[17, 18]. Strength training should be widely adopted, in order to improve functional activities such as standing, balance, and walking. Positive effects associated with motor performance on strength training have been demonstrated in several studies[7, 8, 12, 13, 17]. Using the Motor Assessment Scale, Bale and Strand[19] reported that progressive resistance training performed by chronic stroke patients led to improvements in their lower limb function, and Jorgensen et al.[20] also reported a significant increase in gait speed in the six-minute walk test. Conflicting results regarding the effect of lower

Table 1. Comparisons of mean dynamic balance of the two groups

Parameters		Training group		Control group	
		Pre	Post	Pre	Post
Balance	A-P sway distance (mm)	1,681.7±47.3	1,467.6±47.5*†	1,687.1±34.6	1,630.8±46.1*
	M-L sway distance (mm)	1,740.8±29	1,540.6±27*†	1,741.7±30.9	1,689.6±27.8*
	BBS (score)	33±2.6	37.21±2.6*†	32.7±2.6	33.8±2.5*
	TUG (sec)	24.4±1.5	18.6±0.5*†	25.9±2.1	25.1±1.9*

* significant difference between pre- and post-test (p<0.05).
† significant difference compared with the control group (p<0.05).
A-P (Anteroposterior), M-L (Mediolateral)

limb strength gains on functional motor performance have been reported especially in studies using resistance training as the sole intervention for the lower limbs[21, 22]. These differences may reflect varying degrees of stroke severity, the exercise training protocol, or the recruitment of the number of training joints (one or multiple joints). Our study can be distinguished from previous studies by the fact that resistance exercise training was conducted not for a single joint, but across multiple joints of the lower limbs, including the hips, knees, and ankles. Training involving muscle strength across multiple joints requires use of all the muscles of the lower limbs. Resistance training of multiple joints, which induces movement of the entire lower limbs, is closer to the functional movement. Therefore, training to strengthen muscles across multiple joints may result in a greater increase in motor unit activity and muscle re-education, compared to training of muscle strength across a single joint of the lower limbs, thereby influencing dynamic balance functions due to improved motor coordination in the lower limbs.

Resistance exercise training involving muscle strength across multiple joints of the lower limbs resulted in significant improvements in four clinical measures of postural balance (dynamic balance) of stroke patients. Our finding suggest that this type of training offers clinicians a viable option for improving dynamic balance that will help their patients to improve postural control, independence, and gait. Thus, we are more than confident that this training can be used as an effective rehabilitation program for stroke patients who have a fear of falling. The limitations of our study are that it only investigated the effects of training for muscle strength across multiple joints. Therefore, we did not consider effects on multiple joint training, compared with single joint training. Further studies may be needed in order to clarify this issue.

REFERENCES

1) Allum JH, Bloem BR, Carpenter MG, et al.: Proprioceptive control of posture: a review of new concepts. Gait Posture, 1998, 8: 214–242. [Medline] [CrossRef]
2) Canning CG, Ada L, O'Dwyer N: Slowness to develop force contributes to weakness after stroke. Arch Phys Med Rehabil, 1999, 80: 66–70. [Medline] [CrossRef]
3) Horak FB, Henry SM, Shumway-Cook A: Postural perturbations: new insights for treatment of balance disorders. Phys Ther, 1997, 77: 517–533. [Medline]
4) Gehlsen GM, Whaley MH: Falls in the elderly: Part II, Balance, strength, and flexibility. Arch Phys Med Rehabil, 1990, 71: 739–741. [Medline]
5) Lord SR, Ward JA, Williams P, et al.: Physiological factors associated with falls in older community-dwelling women. J Am Geriatr Soc, 1994, 42: 1110–1117. [Medline]
6) Campbell AJ, Robertson MC, Gardner MM, et al.: Randomised controlled trial of a general practice programme of home based exercise to prevent falls in elderly women. BMJ, 1997, 315: 1065–1069. [Medline] [CrossRef]
7) Flansbjer UB, Downham D, Lexell J: Knee muscle strength, gait performance, and perceived participation after stroke. Arch Phys Med Rehabil, 2006, 87: 974–980. [Medline] [CrossRef]
8) Kim CM, Eng JJ: The relationship of lower-extremity muscle torque to locomotor performance in people with stroke. Phys Ther, 2003, 83: 49–57. [Medline]
9) Richards CL, Malouin F, Dean C: Gait in stroke: assessment and rehabilitation. Clin Geriatr Med, 1999, 15: 833–855. [Medline]
10) Kraemer WJ, Ratamess NA: Fundamentals of resistance training: progression and exercise prescription. Med Sci Sports Exerc, 2004, 36: 674–688. [Medline] [CrossRef]
11) Engardt M, Knutsson E, Jonsson M, et al.: Dynamic muscle strength training in stroke patients: effects on knee extension torque, electromyographic activity, and motor function. Arch Phys Med Rehabil, 1995, 76: 419–425. [Medline] [CrossRef]
12) Langhorne P, Coupar F, Pollock A: Motor recovery after stroke: a systematic review. Lancet Neurol, 2009, 8: 741–754. [Medline] [CrossRef]
13) Morris SL, Dodd KJ, Morris ME: Outcomes of progressive resistance strength training following stroke: a systematic review. Clin Rehabil, 2004, 18: 27–39. [Medline] [CrossRef]
14) Hess JA, Woollacott M: Effect of high-intensity strength-training on functional measures of balance ability in balance-impaired older adults. J Manipulative Physiol Ther, 2005, 28: 582–590. [Medline] [CrossRef]
15) Palmitier RA, An KN, Scott SG, et al.: Kinetic chain exercise in knee rehabilitation. Sports Med, 1991, 11: 402–413. [Medline] [CrossRef]
16) Wiacek M, Hagner W, Hagner-Derengowska M, et al.: Correlations between postural stability and strength of lower body extremities of women population living in long-term care facilities. Arch Gerontol Geriatr, 2009, 48: 346–349. [Medline] [CrossRef]
17) Flansbjer UB, Miller M, Downham D, et al.: Progressive resistance training after stroke: effects on muscle strength, muscle tone, gait performance and perceived participation. J Rehab Med, 2008, 40: 42–48.
18) Lee MJ, Kilbreath SL, Singh MF, et al.: Effect of progressive resistance training on muscle performance after chronic stroke. Med Sci Sports Exerc, 2010, 42: 23–34. [Medline] [CrossRef]
19) Bale M, Strand LI: Does functional strength training of the leg in subacute stroke improve physical performance? A pilot randomized controlled trial. Clin Rehabil, 2008, 22: 911–921. [Medline] [CrossRef]
20) Jørgensen JR, Bech-Pedersen DT, Zeeman P, et al.: Effect of intensive outpatient physical training on gait performance and cardiovascular health in people with hemiparesis after stroke. Phys Ther, 2010, 90: 527–537. [Medline] [CrossRef]
21) Dickstein R, Hocherman S, Pillar T, et al.: Stroke rehabilitation. Three exercise therapy approaches. Phys Ther, 1986, 66: 1233–1238. [Medline]
22) Sharp SA, Brouwer BJ: Isokinetic strength training of the hemiparetic knee: effects on function and spasticity. Arch Phys Med Rehabil, 1997, 78: 1231–1236. [Medline] [CrossRef]