



Original Article

Effect of bilateral lower limb strengthening exercise on balance and walking in hemiparetic patients after stroke: a randomized controlled trial

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Abstract. [Purpose] To evaluate the effect of bilateral lower limb strengthening designed to improve balance and walking in stroke patients. [Subjects and Methods] Twenty hemiparetic stroke patients were divided into two groups: a unilateral therapy group (UTG) (n=10) and a bilateral therapy group (BTG) (n=10). The UTG completed strength training only in the paretic lower limb. The BTG completed strength training in the paretic and non-paretic lower limbs. Assessment tools included the functional reach test (FRT), the Berg balance scale (BBS), the timed up and go (TUG) test, and a 10-meter walk test (10MWT). [Results] In both groups, the lower limb strengthening exercise for balance and walking significantly improved the FRT, BBS, TUG, and 10MWT scores. Compared with UTG, the BTG attained significantly improved FRT and BBS scores. [Conclusion] Bilateral therapy using this lower limb strengthening exercise effectively promotes balance in hemiparetic stroke patients.

Key words: Bilateral therapy, Lower limb strengthening, Non-paretic side

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INTRODUCTION

A stroke occurs due to a rupture of blood vessels in the brain or an interruption to its blood supply¹⁾, and frequently results in residual physical impairment in patients²⁾. One of the most prominent characteristics of stroke is muscle weakness or the inability to generate normal muscle force³⁾. It is also associated with decreased functional performance⁴⁾. These functional performances include, but are not limited to, standing⁵⁾, transfers⁶⁾, stair climbing⁷⁾, and gait⁸⁾. Previous studies have reported many aspects of physiologic change after stroke. These changes include decreases in motor units, impaired motor unit recruitment, selective atrophy of type II muscle fibers, denervation potential, and decreased maximal contractions, all of which can cause muscle weakness⁹⁾. Strength assessment following stroke has been shown to predict the functional status of patients at discharge from inpatient rehabilitation, length of stay in inpatient rehabilitation¹⁰⁾, future motor function status¹¹⁾, and mortality¹²⁾. These correlational studies have provided evidence for the hypothesis that such intervention programs intended to increase muscle strength could ultimately improve functional performance¹³⁾. Recent studies have shown that lower limb strengthening programs for stroke patients can positively affect the ability to rise from a chair¹⁴⁾, climb stairs, and walk, as well as improve quality of life¹⁵⁾. To date, many strengthening exercise interventions have been used in attempts to prevent physical inactivity in stroke patients. Bilateral arm training with a rhythmic auditory cueing regimen, based on motor learning principles, has a proven positive effect on functional motor performance of the paretic upper extremity in hemiparetic stroke patients¹⁶⁾. However, to our knowledge, there have been few reports on the effect of bilateral lower limb strengthening exercise. There is sufficient evidence that motor function is abnormal on the non-paretic side of individuals

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following a stroke, as evidenced through muscle weakness^{17, 18}). Therefore, in this study, both the paretic and non-paretic lower limbs were trained. The purpose of this study was to examine the effects of bilateral lower limb strengthening exercises in hemiparetic stroke patients.

SUBJECTS AND METHODS

Participants were randomly allocated to either the UTG (n=10) or the BTG (n=10), using a random numbers table. The inclusion criteria were as follows: (1) age <65 years; (2) a diagnosis of hemiplegia; (3) <24 months after stroke; (4) an ability to understand and follow instructions; and (5) an ability to walk independently for 20 m without an assistive device. The exclusion criteria were as follows: (1) joint or muscular problems arising from conditions other than stroke; (2) an unstable hypertension or cardiovascular condition, as determined by a physician; and (3) stroke involving the brainstem. Patients in both groups received 60 minutes of therapy, 5 times a week, for a total of 4 weeks. The UTG completed the strengthening exercise only in the paretic lower limb (paretic side, 50 minutes; passive range of motion exercises, 10 minutes). The BTG completed the strengthening exercise in the paretic and non-paretic lower limbs (paretic side, 30 minutes; non-paretic side, 20 minutes; passive range of motion exercises, 10 minutes). The exercise program targeted the hip and the ankle regions. The hip exercise was performed in a prone position with the leg to be exercised positioned off the side of the examination table. With a straight leg, and with a dorsiflexed ankle, the patient slowly raised their leg as high as possible without causing pain, then slowly returned their leg to the starting position and repeated the motion. When performing this exercise, the therapist stabilized the pelvis to prevent the patient from twisting or arching their back. The ankle exercise was performed in a supine position on the examination table. From a relaxed ankle and foot position, the patient dorsiflexed their ankle, keeping the knee straight and holding the position, then slowly returned their foot to the starting position and repeated the motion. The exercises were initiated with moderate assistance and progressed to minimal assistance. The primary outcome measures were the FRT, BBS, TUG, and 10MWT scores. The Wilcoxon signed rank test was used to examine differences arising from treatment. Intergroup differences were analyzed using the Mann-Whitney U test. All statistical analyses were performed using SPSS version 18.0 with a significance level of 0.05. The data are expressed as mean \pm standard error. This study was approved by the Ethics Committee of Yong In University (Approval Number: 2-1040966-AB-N-01-20-1704-HSR-073-3), and all patients provided written informed consent.

RESULTS

A total of 20 patients participated in this study. Their clinical characteristics are presented in Table 1. In the BTG, the mean FRT score increased from 13.92 ± 0.78 cm to 18.02 ± 0.70 cm ($p < 0.05$). The mean BBS score increased from 40.20 ± 1.31 to 45.10 ± 1.15 ($p < 0.05$). The mean TUG score improved from 29.87 ± 3.36 sec to 24.31 ± 2.92 sec ($p < 0.05$). The mean 10MWT score improved from 25.77 ± 3.65 sec to 20.85 ± 3.92 sec ($p < 0.05$). In the UTG, the mean FRT score increased from 14.03 ± 0.36 cm to 15.50 ± 0.65 cm ($p < 0.05$). The mean BBS score increased from 38.50 ± 0.89 to 41.30 ± 1.00 ($p < 0.05$). The mean TUG score improved from 27.57 ± 2.63 sec to 25.98 ± 2.59 sec ($p < 0.05$). The mean 10MWT score improved from 25.62 ± 3.10 sec to 23.63 ± 3.39 sec ($p < 0.05$). Both BTG and UTG revealed statistically significant differences in the FRT ($p < 0.05$) and BBS ($p < 0.05$) scores. However, there were no statistically significant differences in the TUG ($p > 0.05$) and 10MWT ($p > 0.05$) scores (Table 2).

DISCUSSION

This study showed that 4 weeks of bilateral lower limb strengthening exercise was useful for improving balance in hemiparetic stroke patients. Compared with the UTG, the BTG exhibited greater improvement in FRT and BBS scores. In all the participants, the mean BBS score was 43.20 ± 0.86 , indicating that all the participants had a high risk of falls¹⁹). In previous studies, BBS scores of <45 indicated an increased risk for falls²⁰). Researchers have found that the BBS score on admission to acute inpatient rehabilitation was an important predictor of length of stay²¹). In all the participants, the FRT was 16.85 ± 0.56 cm. In another study, recurrent falls were associated with an FRT score of <17.78 cm²²). However, the FRT scores for 13 patients were <17.78 cm. Previous studies used the FRT to investigate the implications of balance and falls in hemiparetic patients after stroke²³). The FRT is a clinical tool to assess the limits of stability and was developed from leaning performance²⁴), which involves displacement of the center of pressure at the ankle joint through forward-leaning while maintaining hip extension²⁵). As with other forward-oriented movements, a leaning performance generates anticipatory muscle activation in the tibialis anterior muscle prior to displacement of the center of pressure²⁶). This consideration underlines how the FRT score was increased with ankle and hip strengthening exercises. Our study results showed improvements in gait speed in both groups. These results are consistent with findings in previous research²⁷). Regarding foot clearance, weakness of the dorsiflexors increased the swing time of the paretic limb²⁸). This may have led to inadequate eccentric contraction in the mid-stance phase, which resulted in decreased loading ability of the paretic limb and increased double-limb support time for slower preparation to the next single-limb support of the paretic limb²⁷). Weakness in the paretic limb dorsiflexors was the result of uncontrolled passive plantarflexor stiffness²⁸). Decreased ankle muscle power and plantarflexor moments

Table 1. Clinical characteristics of the stroke patients

| Variable | BTG (n=10) | UTG (n=10) |
|--|-------------|-------------|
| Age (years) | 42.3 ± 4.2 | 43.6 ± 5.6 |
| Height (cm) | 165.0 ± 2.8 | 166.9 ± 2.3 |
| Weight (kg) | 65.5 ± 4.2 | 64.0 ± 1.4 |
| Gender (M/F) | 6/4 | 7/3 |
| Time since stroke (months) | 15.4 ± 1.6 | 15.3 ± 1.5 |
| Paretic side (L/R) | 4/6 | 8/2 |
| Type of stroke (ischemic/hemorrhagic) | 5/5 | 2/8 |

BTG: bilateral therapy group; UTG: unilateral therapy group.

Table 2. Changes in outcome measures related to balance and walking after lower limb strengthening exercise

| Variable | BTG | | | UTG | | |
|--------------|--------------|----------------|-------------|--------------|----------------|-------------|
| | Pre-test | Post-test | Changes | Pre-test | Post-test | Changes |
| FRT (cm) | 13.92 ± 0.78 | 18.20 ± 0.70*† | 4.28 ± 0.08 | 14.03 ± 0.36 | 15.50 ± 0.65*† | 1.47 ± 0.29 |
| BBS (scores) | 40.20 ± 1.31 | 45.10 ± 1.15*† | 4.90 ± 0.16 | 38.50 ± 0.89 | 41.30 ± 1.00*† | 2.80 ± 0.11 |
| TUG (sec) | 29.87 ± 3.36 | 24.31 ± 2.92* | 5.56 ± 0.44 | 27.57 ± 2.63 | 25.98 ± 2.59* | 1.59 ± 0.04 |
| 10MWT (sec) | 25.77 ± 3.65 | 20.85 ± 3.92* | 4.92 ± 0.27 | 25.62 ± 3.10 | 23.63 ± 3.39* | 1.99 ± 0.29 |

BTG: bilateral therapy group; UTG: unilateral therapy group; FRT: functional reach test; BBS: Berg balance scale; TUG: timed up and go; 10MWT: 10-meter walk test.

*p<0.05=significant difference between pre-test and post-test.

†p<0.05=significant difference between BTG and UTG.

in non-paretic limbs have previously been studied during gait in stroke patients²⁹). Our results indicate that lower limb strengthening exercises should also be emphasized for stroke patients to achieve faster walking speed. Deficits in lower limb muscle strength are a critical aspect of functional disability and are frequently assessed in rehabilitation³⁰). There is a significant relationship between non-paretic lower limb muscle strength and functions such as stair climbing and walking³¹). Researchers have shown that substantial weakness is present in the paretic and non-paretic limbs of stroke patients³²). Indeed, there are several mechanisms that impair voluntary muscle activation, and disuse atrophy and alterations in skeletal muscle composition and structure have been implicated in this muscle strength deficit after stroke³³). One report on weakness in the non-paretic limb has suggested that consideration should also be given to the muscle strength of both limbs¹⁷). It is possible that these neurophysiological and structural alterations, suggested as mechanisms for muscle weakness, may cause secondary problems, due to disruption of the corticospinal tract (CST). Consequently, the extent of CST damage may affect muscle weakness after stroke³⁴). The extent of CST damage has been demonstrated to predict the degree of clinical amelioration after stroke³⁵). In addition, evidence indicates that the physiological integrity of the CST positively affects motor performance in the lower limb in stroke patients³⁶). It is well documented that some CST do not cross at the pyramidal decussation. The estimated percentage of uncrossed tracts is approximately 10–20%. These uncrossed ipsilateral tracts have been implicated as a possible after-stroke recovery mechanism³⁷), and researchers have proposed that they could be activated with bilateral training³⁸). Anatomically, the “unmasking” of uncrossed ipsilateral CST from the non-paretic hemisphere³⁹) may be accountable for offsetting of the normal inhibition of the spinal circuits with bilateral homologous activation⁴⁰). Alterations of descending circuitry and somatosensory feedback from the non-paretic limb can modulate muscle activation in the paretic limb. Moreover, tracts connecting the lower limbs appear to be enhanced after stroke⁴¹). Kautz et al.⁴¹) proposed that, after stroke, individuals may experience a loss of inhibition of the excitatory interlimb pathways that become activated for bilateral activation. The results of this study have meaningful implications for physical therapists and researchers who focus on improving rehabilitation after stroke. However, considering the small number of patients, caution must be applied since this finding might not be generalizable to all hemiparetic patients after stroke. Further studies should examine whether strengthening exercises in the bilateral lower limbs of hemiparetic patients after stroke are beneficial for balance. Although rehabilitation is usually focused on the paretic side, it appears that more attention needs to be given to the non-paretic side to improve balance.

Conflict of interest

None.

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