

Effects of 6 Months Combined Functional Training on Muscle Strength, Postural Balance and Gait Performance in Community-dwelling Individuals with Chronic Stroke Hemiplegia

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Abstract. [Purpose] We conducted a noncontrolled intervention study in community-dwelling individuals with chronic stroke hemiplegia as subjects to examine the effectiveness of a 6 month low-frequency combined functional training program on enhancing factors related to physical performance, such as leg muscle strength, postural balance, and gait function. We also examined whether medium-term changes in physical performance correlated with time from stroke onset or degree of hemiplegia. [Subjects and Methods] Twenty-two individuals with chronic stroke hemiplegia who were using an adult day-care facility were enrolled in a combined functional training program consisting of stretching, muscle strengthening, postural balance training, and gait training once or twice a week for 6 months. The main outcomes measured were indices of physical performance — such as leg muscle strength (measured at about 1 repetition maximum [1RM] on a leg press machine), the functional reach test, the timed “up and go” test, comfortable gait speed, and maximum gait speed — and the Brunnstrom recovery stage (BRS). [Results] After 6 months of intervention, significant improvements were observed in all of the above-mentioned outcome measures of physical performance. No significant correlations were found between the percentage changes of physical performances after the intervention and time from stroke onset or BRS. [Conclusion] The 6 month low-frequency combined functional training program at an adult day-care facility results in medium-term improvements in leg muscle strength, postural balance and gait performance in community-dwelling individuals with chronic stroke hemiplegia.

Key words: Chronic stroke, Combined functional training, Physical performance

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INTRODUCTION

Stroke is one of the major causes of death and long-term disability¹⁾, a leading cause of long-term impairments and limitations in activity and social participation²⁾, and the primary cause of stroke sufferers needing care³⁾ and becoming bedridden⁴⁾. Although reports show that motor recovery typically shows the greatest improvements between 3 and 6 weeks post-injury, and a clear plateau is reached by 90 days^{5,6)}, one of the challenges of post-stroke management is the provision of ongoing programs that maintain and/or improve performance and activities of daily living (ADL), rather than tolerating secondary disuse and adaptive behaviors that aggravate the remaining disabilities after discharge from rehabilitation⁷⁾. It is especially important to enhance factors that affect physical performance, such as leg muscle strength, postural balance and gait function, which are closely related to community

ambulation⁸⁾, amount of physical activity⁹⁾, community participation¹⁰⁾ and reintegration¹¹⁾, and risk of falling^{12,13)}. Therefore, exercise intervention through home-based rehabilitation^{14–16)} or community-based exercise programs^{17–22)} has an important role in maintaining and/or improving ADL in community-dwelling individuals with chronic stroke hemiplegia.

Many studies have assessed the effectiveness of exercise intervention on enhancement of leg muscle strength, postural balance and gait function in individuals with chronic stroke^{7,17–25)}, and the effects of these interventions are well recognized^{26–28)}. Improvements in muscle strength^{19,20,23)}, postural balance^{7,17–22,24,25)}, mobility or gait function^{7,17–25)}, and ADL^{22,23)} in people with chronic stroke have been reported after group-based exercise programs providing resistance training²³⁾, agility and weight-shifting exercises¹⁸⁾, task-oriented training^{7,24,25)}, and multidimensional exercise programs^{17,19–22)}. Although the

intervention frequency in the majority of these studies was three times a week or more^{7,16–25}), many adult day-care facilities perform exercise intervention only once or twice a week for community-dwelling people with chronic stroke hemiplegia. A previous study showed that a difference in intervention frequency results in a difference in the intervention effect²⁸); thus, it is necessary to verify the intervention effects on leg muscle strength, postural balance, and gait performance when exercise intervention is executed at frequencies lower than 3 times a week. Furthermore, although most of these previous studies examined the effects of exercise intervention using various functional outcomes^{17,18,23–25}), few studies have examined the medium-term effects of such intervention using indices of muscle strength, postural balance, gait function and ADL^{19–22}). Moreover, most individuals with stroke are more likely to engage in prolonged use of adult day-care services because of long-term impairments and limitations in activity and social participation²). However, the medium-term effect of exercise intervention of more than 3 months at adult day-care facilities has not been clarified.

The main objective of this study was to examine the effect of a 6 month low-frequency combined functional training program at an adult day-care facility on leg muscle strength, postural balance and gait performance in community-dwelling individuals with chronic stroke hemiplegia. A second objective was to evaluate whether medium-term changes in physical performances correlated with the time from stroke onset or the degree of hemiplegia.

SUBJECTS AND METHODS

Subjects

We recruited 22 community-dwelling subjects who were using an adult day-care service provided by the long-term care insurance system of Japan. The inclusion criteria were: the presence of hemiplegia secondary to a stroke; a minimum of 6 months since the onset of stroke; full discharge from a rehabilitation program; first time user of an adult day-care service; no cognitive dysfunction, hemineglect, visual deficit, or depression at the time of the study; ability to understand both verbal and written cues; and ability to walk at least 20 m with or without a unilateral assistive device. Before participating in this study, informed written consent was obtained from all subjects. Subjects' characteristics, such as demographic and clinical details (including Brunnstrom recovery stage (BRS)^{29,30}), Barthel index (BI)³¹), and Tokyo Metropolitan Institute of Gerontology index of competence (TMIG-IC)³²), are presented in Table 1.

Methods

A single-group, repeated measures design was used for this study. Before commencement of the combined functional training program, all subjects underwent a baseline assessment. After this baseline assessment, the subjects participated in a 6 month combined functional training program focused on stretching, strength training,

Table1. Characteristics of subjects

Age, years*	71.7 (11.2)
Gender, male/female**	16/6
Affected side, right/left**	10/12
Main disease, cerebral hemorrhage/ cerebral infarction**	8/14
Time from stroke onset, months*	51.6 (68.1)
Brunnstrom recovery stage*	
Upper extremity	4.9 (1.1)
Finger	4.8 (1.2)
Lower extremity	5.2 (0.7)
Care (support) need certification in Japan**	
Those certified as on the support level 1/2	4/9
Those certified as on the care level 1/2	6/3
Height, cm*	159.0 (10.3)
Weight, kg*	63.0 (10.4)
Body mass index, kg/cm ² *	25.1 (4.5)
Barthel index, point*	95.7 (7.0)
Tokyo Metropolitan Institute of Gerontology index of competence, point*	6.5 (3.3)

Data indicate *mean (standard deviation) or **number.

postural balance training, and gait training. At 6 months after the intervention, the subjects underwent a post-intervention assessment.

The following outcomes were measured before and after intervention: leg muscle strength measured by one repetition maximum (1RM) on a leg press machine^{33,34}), the functional reach test (FR)³⁵), the timed "up and go" test (TUG)^{36,37}), comfortable gait speed (CGS)³⁸), and maximum gait speed (MGS)³⁸).

For measurement of 1RM on the leg press, the subjects started in a sitting position with approximately 90° knee flexion, then extended both legs to approximately 0° knee flexion. A standardized protocol was executed that consisted of warm-up repetitions and a sequence of progressively increasing resistance approaching each subject's 1RM, and were separated by fixed rest periods. The resistance was then adjusted, and 1RM attempts were performed, separated by a set rest period, until 1RM was determined. In the FR test, each subject was positioned next to a wall, with one arm raised at 90° with the fingers extended; a yardstick was mounted on the wall at shoulder height. The FR was measured as the distance in centimeters that a subject was able to reach forward from an initial upright posture to the maximum anterior leaning posture without moving or lifting the feet; this measurement was made by visual observation of the position of the tip of the third finger against the mounted yardstick. The FR test was conducted for both the affected and unaffected upper extremities. In the TUG test, subjects were asked to stand up from sitting on a chair, walk a 3 m distance at a comfortable normal pace, turn, walk back to the chair, and sit down. The time in seconds was measured from the word "go" to when the subject's hip touched the seat of the chair. For CGS and MGS measurements, the subjects were timed on a 16 m walkway. The subjects were timed over the middle 10 m, and the subjects were informed that they would be timed

Table 2. Comparison of physical performances before and after intervention

	Before intervention	After intervention
1RM (kg)	55.9 ± 22.3	70.3 ± 22.8**
FR of affected side (cm)	23.9 ± 9.6	29.5 ± 9.9**
FR of unaffected side (cm)	28.7 ± 6.8	32.3 ± 8.3*
TUG (s)	27.7 ± 26.4	16.2 ± 7.1*
CGS (m/min)	41.7 ± 21.8	47.4 ± 19.7*
MGS (m/min)	51.3 ± 28.8	60.4 ± 24.3*

1RM: one repetition maximum on the leg press machine; FR: functional reach; TUG: timed “up and go” test; CGS: comfortable gait speed; MGS: maximum gait speed

*: $p < 0.05$; **: $p < 0.01$.

Table 3. Spearman correlation coefficients between the percentage changes of physical performances and time since stroke or Brunnstrom recovery stage

	Time from stroke onset	BRS: upper extremity	BRS: finger	BRS: lower extremity
1RM	0.077 (0.733)	0.144 (0.523)	0.160 (0.477)	0.302 (0.171)
FR of affected side	0.015 (0.949)	-0.149 (0.519)	-0.157 (0.497)	-0.091 (0.694)
FR of unaffected side	0.167 (0.459)	-0.178 (0.427)	-0.172 (0.444)	0.019 (0.934)
TUG	-0.050 (0.826)	-0.020 (0.928)	-0.037 (0.870)	0.024 (0.916)
CGS	0.090 (0.691)	-0.130 (0.564)	-0.110 (0.627)	-0.061 (0.786)
MGS	-0.015 (0.946)	-0.131 (0.560)	-0.120 (0.596)	-0.187 (0.405)

Data indicate the correlation coefficient (p value). All correlation coefficients were not significant. BRS: Brunnstrom recovery stage; 1RM: one repetition maximum of leg press machine; FR: functional reach; TUG: timed “up and go” test; CGS: comfortable gait speed; MGS: maximum gait speed.

only on part of the 16 m walkway. For CGS, the subjects were told to walk at a self-selected comfortable pace. For MGS, the subjects were told to walk as fast and as safely as possible without running. The recorded times in seconds were used to calculate the CGS and MGS (m/min).

The combined functional training program was performed 90 min/day for 6 months, and was supervised by a physical therapist, a nurse, and caregivers. The program was conducted once or twice a week according to the subjects' frequency of use of the adult day-care service. The program consisted of: a 10 to 15 min seated upper- and lower-limb stretching exercises focusing on range of motion, including trunk mobility; strength training; postural balance training; gait training; and a cool-down period consisting of 5–10 min of relaxation and stretching exercise.

Strength training was performed through exercises inducing isometric, concentric and eccentric muscle contractions for about 30 min for hip flexors, extensors and abductors, knee flexors and extensors, and ankle dorsiflexors and plantarflexors of both sides. Apart from using the body weight and ankle weights, no special resistance equipment was used. Additionally, repetitive sit-to-stand exercises with upper extremity raises and partial squats were also performed. Subjects were instructed to perform one set of 10 repetitions for each exercise with a 1 to 2 min rest period between sets. Postural balance training consisted of one-legged standing, tandem standing, and marching on foam for about 15 min with the eyes open or closed. Gait training was performed by tandem walking, walking with ankle weights on both ankles, and outdoor walking for about 15 min. The programs were individually tailored to each subject's capacity, and level of pain and

fatigue. In addition, the exercise movements were generally similar to tasks that were familiar to the subjects (e.g., sitting up from a chair) and are involved in everyday mobility.

Differences between the measurements before and after the intervention were assessed with the two-tailed t-test for continuous variables. The changes between before and after intervention were calculated for each subject together with the percentage differences for the mean of each measurement, and the relationships between the percentage changes after combined functional training in relation to their baseline values and time from stroke onset or BRS were assessed by Spearman's rank correlation coefficient. All statistical tests were two-tailed, and all calculations were performed using SPSS 12.0J software for Windows. Significance levels less than 0.05 were considered statistically significant.

RESULTS

In comparison of outcome measures before and after intervention, 1RM after intervention averaged 70.3 ± 22.8 kg, which was significantly greater than before intervention (55.9 ± 22.3 kg), an improvement of 46.3% ($p = 0.001$). The FR of the affected and unaffected sides after intervention averaged 29.5 ± 9.9 cm and 32.3 ± 8.3 cm, respectively, which were significantly longer than before intervention (23.9 ± 9.6 cm and 28.7 ± 6.8 cm, respectively), improvements of 28.7% ($p = 0.002$) and 16.1% ($p = 0.027$), respectively. TUG after intervention averaged 16.2 ± 7.1 s, which was significantly faster than before intervention (27.7 ± 26.4 s), an improvement of 25.1% ($p = 0.025$). CGS and

MGS after intervention averaged 47.4 ± 19.7 m/min and 60.4 ± 24.3 m/min, respectively, which were significantly faster than before intervention (41.7 ± 21.8 m/min and 51.3 ± 28.8 m/min, respectively), improvements of 20.8% ($p = 0.045$) and 34.8% ($p = 0.010$), respectively (Table 2). Spearman's correlation analysis showed that there were no significant correlations between the percentage changes of physical performances (1RM, FR of affected/unaffected side, TUG, CGS, and MGS) after intervention in relation to their baseline values and time from stroke onset or BRS (Table 3).

DISCUSSION

The findings of this noncontrolled study show that a 6 month low-frequency combined functional training led to meaningful functional improvements in leg muscle strength, postural balance and gait performance. In addition, no correlations were found between the percentage changes of physical performances after intervention and the time from stroke onset or the degree of hemiplegia. These findings provide evidence that a medium-term combined functional training program is effective at improving the mobility of individuals with chronic stroke.

The effects of training programs comprising basic functional-type exercises have been reported in numerous studies involving individuals with chronic stroke. As in our study, significant improvements in leg muscle strength, postural balance, and gait performance were observed after combined functional training. One of the main differences between those other studies and our present study is the number of exercise sessions per week; that is, once or twice in our study as opposed to three or more times in the other studies^{7,16-25}. Our results show that individuals with chronic stroke can obtain similar gains in physical performance by doing less frequent but supervised exercises.

The improvements observed in clinical assessments of physical performance following participation in the combined functional training program may have a positive impact on the maintenance of the physical independence of stroke patients.

After a stroke, a reorganization of the nervous system through plasticity occurs to compensate for the loss of cells with normal function³⁹. Recovery takes place mainly within the first 6 months^{5,6,40}. Altered muscle components in patients with long-standing paresis⁴¹ and loss of motor units⁴² have been reported. Other studies support the theory that changed mechanical properties constitute one limiting factor during voluntary activation in hemiparetic muscles^{43,44}. Because reorganization of the central nervous system and peripheral muscle changes occur to varying degrees after a stroke, it is important that functional approaches are combined with muscle-strengthening programs for individuals with chronic stroke⁴⁵. Previous studies have suggested that the muscle weakness observed in individuals with chronic stroke can be improved through appropriate strengthening exercises^{23,45-50}. Especially, in previous studies that used 1RM on a leg press as an outcome

measure, an improvement of 16.2%⁴⁹ or no change⁵⁰ in 1RM was reported after high-intensity resistance training. In contrast, the results of this study show improvements of approximately 46.3% in 1RM, despite the lower frequency and intensity of training. These differences may be attributable to the fact that previous studies used higher intensity and higher frequency but shorter duration than those used in this study, and that only resistance training intervention was performed in those studies. This suggests that low-intensity strengthening incorporated into combined functional training may prove more effective than strengthening alone. Although the physiological mechanisms underlying the increases in 1RM cannot be determined on the basis of the current data, it is probable that improved motor unit recruitment^{51,52} and motor learning (the development of neuromotor patterns of coordination between agonist and antagonist muscles through practice of a skill)^{53,54} may have contributed to some degree. Additionally, the performance of normal movement requires an ability to execute alternating movements at various functional speeds and while maintaining appropriate timing between antagonist muscle groups. Moreover, practice and training are likely to reduce the amount of cocontraction and facilitate proper timing, resulting in greater net force generated in the desired direction of movement⁵⁵. The observed improvement in 1RM after combined functional training might be explained, in part, by an increased ability to activate specific muscle groups.

The results of this study show a significant increase in the FR of the affected and unaffected sides after the intervention, which likely resulted from the increased use of somatosensory, visual, and vestibular information while performing the various postural balance training exercises under conditions of sensory deprivation. This sensory compensation might have improved the sensorimotor integration of postural control in the central nervous system, serving to activate and coordinate motor processes⁵⁶⁻⁵⁸. After balance training involving sensory manipulation of the visual, vestibular, and somatosensory systems, changes in muscle and movement characteristics of postural responses were characterized by a reduction in the latency of muscle activation and kinematic patterns, and by a decrease in the response frequency of antagonist muscles in reaction to platform-translation perturbations⁵⁶. Moreover, postural balance of stroke sufferers improved more after training with visual deprivation than with free vision⁵⁸. These results indicate that enhanced multisensory interaction resulting from sensory training could improve the sensorimotor integration of postural stability of hemiparetic stroke sufferers⁵⁹. Our findings show that standing balance measured by FR on both the affected and unaffected sides was significantly improved after the combined functional training program, which included postural balance training under sensory deprivation conditions. One possible explanation for this improvement is that stroke sufferers are able to select reliable sensory information for postural control more efficiently following postural balance training under sensory deprivation

conditions^{56–58}). Additionally, previous reports have shown that postural imbalance might be due more to a higher-level inability to select reliable sensory input than to elementary sensory impairment⁵⁸). When the subjects were standing on the soft foam, their postural balance was challenged because of the unstable surface and the lack of accurate somatosensory information. In this condition, the pertinent sensory inputs for postural stability might come from the vestibular and visual systems. Improvements in FR of the affected and unaffected sides suggest that these mechanisms might be able to occur and be improved by postural balance training. Furthermore, in this study, the average distances of FR on the affected and unaffected sides of the participants in the combined functional training program were increased from 23.9 cm and 28.7 cm, respectively, at baseline to 29.5 cm and 32.3 cm, respectively, after the 6 months of intervention. This improvement is probably significant from a clinical viewpoint as a 15.0 cm cutoff length of FR can be interpreted as a severe risk of falling. It is important to perform postural balance training involving sensory manipulation to enhance postural balance to reduce the risk of falling, because the senses for postural balance have to be specifically targeted when designing balance-retraining programs for hemiparetic subjects⁵⁹).

The functional gains of gait performance achieved by the combined functional training were clinically significant. The mean TUG decreased by 25.1% from 27.7 s at baseline to 16.2 s after the 6 month intervention. We observed improvements in TUG that were similar to or greater than those observed in chronic stroke sufferers enrolled in a task-oriented intervention that reported an improvement of 17.5% in TUG^{60,61}). These differences may be attributable to the fact that previous studies used a similar intervention method but a shorter duration than those used in the present study. This suggests that conducting combined functional training for a longer period may result in greater improvements in gait performance and mobility. In contrast, other researchers reported no effect on TUG of a task-oriented intervention^{7,24}) or isokinetic strengthening⁶²). These differences may be attributable to the fact that previous studies used a higher intervention frequency but shorter duration than those used in the present study. Moreover, our present study used functional training comprising multiple interventions (e.g., lower muscle strengthening, postural balance training, and gait training) to enhance physical performance related to TUG tasks. It is clinically important to reduce the TUG score to less than 20 s because a 20 s cutoff time of TUG can be interpreted as the ability to independently perform basic tub or shower transfers, climb most stairs, and go outside alone, whereas a TUG time of longer than 30 s is usually associated with major difficulties in mobility³⁶). TUG is correlated with the strength of the affected ankle plantarflexors, gait speed, and gait endurance³⁷). Additionally, functional tasks such as TUG comprise various components and require balance and coordination⁶³); therefore, strengthening of multiple muscles related to the specific tasks may be important for achieving improvements in more complex tasks.

The results of this study show significant increases in

CGS and MGS after the combined functional training, with improvements of 20.8% and 34.8%, respectively. We observed improvements in CGS and MGS that were similar to or greater than those observed for chronic stroke sufferers enrolled in a program of muscle strengthening and functional training²³), a motor re-education program based on providing sensory feedback⁴⁸), an exercise group focusing on strengthening and practicing functional tasks¹⁷), and a task-oriented functional exercise²⁴), which showed improvements of 28% (CGS), 25% (CGS), 13% (CGS) and 11% (MGS), and 22% (CGS) and 25% (MGS), respectively. These differences may be attributable to the fact that previous studies used a shorter duration than that used in the present study, and the similar trends of improvement supports the validity and usefulness of combined functional training for improving gait speed. The positive changes are probably significant and clinically important, as Perry et al. have demonstrated that a gait speed of 25 m/min or less restricts a stroke individual's capacity for community ambulation⁶⁴), while gait speed and mobility of chronic stroke sufferers are important factors related to community ambulation⁸), amount of activity⁹), participation¹⁰), and risk of falling^{12,13}).

In the correlation analysis, no significant correlations were found between the percentage improvements of physical performances (1RM, FR, TUG, CGS, and MGS) after the intervention and the time from stroke onset or BRS. Most of the functional motor recovery processes occur between 3 and 6 weeks following the stroke onset^{5,6,40}), and after this period, the patient's motor functions become stable, suggesting that functional recovery comes to a halt in the so-called chronic stroke phase, which usually occurs between 3 and 6 months following the stroke onset^{5,40}). In this study, it is likely that the spontaneous recovery of motor functions had a very limited influence on the results because each subject in the present study had a stroke at least 6 months (group mean, 51.6 months) before the intervention. Moreover, these results also suggest that the time from onset of stroke and the degree of hemiplegia are not always limiting factors on the improvement of physical performances in the chronic stroke phase. Therefore, despite their impairments and disabilities, individuals with chronic stroke are able to participate in a combined functional training program and achieve significant gains in their physical performance, such as leg muscle strength, postural balance, and gait performance even years after a stroke.

Because of the small number of subjects, individual differences could not be statistically adjusted, limits the interpretation of our findings. Additionally, the subjects in our study had to demonstrate a relatively high functional level to fulfill the study inclusion criteria; that is, to be able to participate fully in the combined functional training program and assessment sessions. Thus, our results cannot be generalized to all individuals who have severe hemiplegia. Furthermore, no attempts were made to help participants develop exercise habits on a long-term basis. It is not known whether the participants continued to exercise during the program. Another limitation of our study design was the absence of a control group. Future studies should

use a randomized controlled trial design to better isolate the intervention effects on leg muscle strength, postural balance, and gait performance of chronic stroke sufferers. However, the clinical implications of the improvements in leg muscle strength, postural balance, and gait performance realized in this small study have far-reaching implications and show that it is possible to induce clinically meaningful medium-term improvements long after stroke onset using a combined functional training program in adult day-care facilities. Furthermore, time from stroke onset and the degree of hemiplegia had very little influence on the improvements of physical performance in community-dwelling individuals with chronic stroke hemiplegia.

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