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Effects of 3-month Combined Functional Training at an Adult Day-care Facility on Lower Extremity Muscle Strength and Gait Performance in Community-dwelling People with Chronic Hemiplegia

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Abstract. [Purpose] The purpose of this study was to examine the effects of low-frequency combined functional training over a 3-month period on lower extremity muscle strength and gait performance in community-dwelling people with chronic post-stroke hemiplegia. [Subjects] The subjects were 23 individuals with chronic post-stroke hemiplegia, utilizing the services of an adult day-care facility. [Methods] All subjects performed functional training programs consisting of stretching, strengthening, postural balance training, and gait training once or twice a week for 3 months. Leg muscle strength measured using a leg press machine at one repetition maximum (1RM), comfortable gait speed (CGS), maximal gait speed (MGS), and the difference between MGS and CGS (ΔGS) were assessed before and after intervention. [Results] Comparison of each outcome before and after intervention revealed significant increases in 1RM, CGS, MGS, and ΔGS. The change rate of ΔGS was correlated only with that of MGS. [Conclusion] Three-month combined functional training was effective at enhancing lower extremity muscle strength and gait performance, and ΔGS was increased by enhancement of MGS in community-dwelling people with chronic post-stroke hemiplegia.
Key words: Chronic stroke, Combined functional training, Gait performance

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INTRODUCTION

In Japan, stroke is a leading cause of elderly people becoming reliant on continuing care (23.3%)[1)] and becoming bedridden (36.7%)[2)]. For community-dwelling people with chronic post-stroke hemiplegia, it is necessary to improve and maintain the physical function and activities of daily living (ADL) at an early stage of recovery. Therefore, in Japan, exercise intervention by home-based rehabilitation and adult day-care services provided by the long-term care insurance system play an important role in maintaining and/or improving the physical function and ADL in community-dwelling people with chronic post-stroke hemiplegia. This is particularly true when there is a close correlation between lower extremity muscle strength and gait function[3,4)]. Moreover, since gait function is an important characteristic which is closely related to ADL[5)], amount of activity[6)], participation[4)], and falls[7)], it is important to verify the influence of exercise intervention on lower extremity muscle strength and gait performance.

The effects of muscular power reinforcement and gait function improvement by task-oriented training and combined functional training, which comprehensively and inclusively executes muscle strength training, postural balance training, and gait training, have been investigated by randomized-controlled trials[8–13)], and the beneficial effects of the training on gait function and gait-related ADL have been confirmed[14,15)]. Most of these studies were performed to explore the effects of exercise intervention with a frequency of three times or more per week for 4–10 weeks. For community-dwelling people with chronic post-stroke hemiplegia, however, it is more common for the frequency of exercise intervention in adult day-care services to be once or twice a week. Because it has been reported that the intervention effect is due to intervention frequency[16)], it is necessary to verify intervention effects on lower extremity muscle strength and gait performance when exercise intervention is executed at a frequency lower than three or more times per week. Moreover, although the effects of home-based exercise have been reported[17–19)], the effects of combined functional training at an adult day-care facility on muscle strength of the lower extremities and gait performance have yet to be clarified.

Therefore, the purpose of this study was to examine the effects of 3-month low-frequency combined functional training at an adult day-care facility on lower extremity muscle strength and gait performance in community-dwelling people with chronic post-stroke hemiplegia.

SUBJECTS AND METHODS

Subjects

We recruited 23 community-dwelling subjects using adult day-care services provided by the long-term care insurance system in Japan. The inclusion criteria were: a minimum of 6 months post-stroke; present hemiplegia secondary to one cerebrovascular accident; first-time use of an adult day-care service; no cognitive dysfunction, hemi-neglect, visual deficit, or depression at the time of the study; an ability to understand both verbal and written information; and an ability to walk at least 20 m with or without an unilateral assistive device. Informed written consent was received from all subjects prior to their participation in this study. Subject characteristics, including demographic and clinical details (Brunnstrom recovery stage[20,21], Barthel index[22], Tokyo Metropolitan Institute of Gerontology index of competence[23]) are presented in Table 1.

Table 1. Characteristics of the study subjects

Age, yr*	71.0 ± 9.8
Gender, male/female**	18/5
Affected side, right/left**	11/12
Main disease, cerebral hemorrhage/ cerebral infarction**	7/16
Time since stroke, month*	37.2 ± 39.4
Brunnstrom stage, stage*	
Upper extremity	4.9 ± 1.1
Finger	4.7 ± 1.3
Lower extremity	5.1 ± 0.8
Care (support) need certification in Japan**	
Those certified as on the support 1/2	4/9
Those certified as on the care level 1/2/3/4/5	6/3/0/1/0
Height, cm*	160.0 ± 9.2
Weight, kg*	62.6 ± 8.9
BMI, kg/cm^2*	24.6 ± 4.1
Barthel index, point*	92.8 ± 12.0
Tokyo Metropolitan Institute of Gerontology index of competence, point*	
Total score	6.9 ± 3.3
Instrumental self-maintenance	2.0 ± 1.7
Intellectual activity	3.1 ± 1.0
Social role	1.8 ± 1.3

Presented data represent the *mean ± standard deviation and **number.

Methods

Before commencement of the training program, all subjects underwent a pre-intervention evaluation. After the initial evaluation, subjects began combined functional training programs consisting of stretching, strengthening, postural balance training, and gait training. A post-intervention evaluation was conducted 3 months after the intervention.

Pre- and post-interventionally, lower extremity muscle strength measured by one repetition maximum (1RM) on a leg press machine[24,25], comfortable gait speed (CGS)[26], and maximum gait speed (MGS)[26] were assessed using methods with demonstrated reliability and validity. For measurement of 1RM using the leg press, subjects started in a sitting position with approximately 90° of knee flexion and extended their bilateral legs to a position approximating 0°. A standardized protocol was executed that consisted of warm-up repetitions and a sequence of progressively increased resistance approaching the subjects' 1RM, each separated by fixed rest periods. The resistance was then adjusted, and 1RM attempts were performed, each separated by a set rest period, until the 1RM was determined. For CGS and MGS, subjects were timed on a walkway. The total distance was 16 m and the subjects were timed over the middle 10 m. Subjects were informed that they would be timed over part of the 16-m walkway. For CGS, subjects were asked to walk at a self-selected comfortable pace. For MGS, the subjects were asked to walk as fast and as safely as possible without running. The time in seconds for CGS and MGS were used to calculate the two velocities (in m/min). In addition, the difference between MGS and CGS ($\Delta GS = MGS - CGS$) was calculated to indicate the range of gait speed control.

In this study, the combined functional training program was a 3-month, 90-minute program supervised by a physical therapist, a nurse, and caregivers. The program was conducted once or twice a week according to the frequency with which participants used the adult day-care service. The program comprised the following: a 10–15-minute warm-up, consisting of mild stretching, and a range of motion exercise; strength training; postural balance training; gait training; and a cool-down period consisting of 5–10 minutes of relaxation and stretching exercises. During each session, emphasis was put on stretching the trunk and lower extremity muscles.

Functional strength training exercises were performed utilizing isometric, concentric, and eccentric muscle contractions for approximately 30 minutes for bilateral hip flexors, extensors, abductors, knee flexors and extensors, and ankle dorsiflexors and plantarflexors. Apart from using body weight and ankle weight, no special resistance equipment was used. Additionally, repetitive sit-to-stand exercise with raising the upper extremities and partial squats were performed. Subjects were instructed to perform one set of 10 repetitions for each exercise with a 1–2-minute rest period between sets. Postural balance training was performed with one-legged standing, tandem standing, and marching on foam with the eyes opened and closed for approximately 15 minutes. Gait training included tandem walking, walking with bilateral ankle weights, and outdoor walking, for approximately 15 minutes. The programs were devised for subjects according to each of their capacities, pain, and fatigue. In addition, training was generally similar to tasks familiar to the subjects (e.g., rising from a chair) and

Table 2. Comparison of lower extremity muscle strength and gait performances between before and after intervention.

	Before intervention	After intervention	p value
1RM (kg)	55.0 ± 22.1	63.1 ± 18.9	0.011
CGS (m/min)	42.5 ± 21.5	45.0 ± 20.3	0.049
MGS (m/min)	52.4 ± 28.0	57.2 ± 27.4	0.02
ΔGS (m/min)	9.9 ± 7.7	12.2 ± 8.2	0.043

1RM: one repetition maximum on a leg press machine, CGS: comfortable gait speed, MGS: maximum gait speed, ΔGS: MGS–CGS.

used in everyday mobility.

To investigate the effects of intervention, pre- and post-intervention physical function data were compared using the paired-sample t-test. To investigate the relationship among changes in lower extremity muscle strength and gait performances, Pearson's correlation coefficients were calculated for the change rates (%) of lower extremity muscle strength and gait performances between pre- and post-intervention. All of these analyses were performed with the SPSS 12.0J statistical package, and the level of significance for all analyses was chosen as $p<0.05$.

Table 3. Pearson's correlation coefficients for the change rates of lower extremity muscle strength and gait performance

	CGS	MGS	ΔGS
1RM	0.697**	0.684**	0.172
CGS		0.922**	0.130
MGS			0.415*

1RM: one repetition maximum on a leg press machine, CGS: comfortable gait speed, MGS: maximum gait speed, ΔGS: MGS–CGS. Change rate = (the result after intervention × 100) / the result before intervention. *: $p<0.05$, **: $p<0.001$.

RESULTS

In the comparison of outcome measures before and after intervention, the 1RM after the intervention averaged 63.1 ± 18.9 kg, which was significantly higher than that before the intervention (55.0 ± 22.1 kg), an improvement of 36.4% (p = 0.011). CGS and MGS after the intervention averaged 45.0 ± 20.3 m/min and 57.2 ± 27.4 m/min, respectively, which were significantly faster than before the intervention (42.5 ± 21.5 m/min and 52.4 ± 28.0 m/min), improvements of 11.1% (p = 0.049) and 14.4% (p = 0.020), respectively. In addition, ΔGS after intervention averaged 12.2 ± 8.2 m/min, which was significantly higher than before the intervention (9.9 ± 7.7 m/min), an increase of 52.6% (p = 0.043) (Table 2). Pearson's correlation analysis showed that there were significant correlations among 1RM, CGS, and MGS. Moreover, the change rate of ΔGS was correlated only with that of MGS (Table 3).

DISCUSSION

One of the challenges of post-stroke management is the provision of ongoing programs that maintain and/or improve performance and ADL, rather than allowing secondary disuse and adaptive behaviors to increase the remaining disability after discharge from rehabilitation[8]. Gait speed has been shown to be particularly reliable and sensitive to changes in motor recovery, regardless of the initial functional level[27]. Increases in gait speed have been associated with training in chronic stroke individuals[28–30]. In this study, CGS and MGS showed significant increases after combined functional training, with improvements of 11.1% and 14.4%, respectively. Despite the chronic nature of the participants' hemiplegia, improvements were found in both their CGS and MGS. Motor recovery typically shows the greatest improvements between 3 and 6 weeks post-stroke, and a clear plateau is reached by 90 days[31,32]. Our subjects were a minimum of 6 months post-stroke and were therefore at the "chronic" stage. At this stage in their recovery, standard rehabilitation procedures are expected to provide little benefit. The positive results of this study contribute to the growing body of research demonstrating that chronic post-stroke subjects are able to improve their performances[17,33,34]. This suggests that stroke rehabilitation needs to continue in the long term in order to maximize its potential. Accessible ongoing programs that are designed to increase the strength of bilateral lower limbs and improve functional gait performance may not only improve the quality of life, but also reduce the need for, and duration of, future institutionalized care.

The improvement in performance observed in the present study were substantially lower than those reported previously by Salbach et al.[10] and Teixeira-Salmela et al.[35], and higher than those reported by Sharp et al.[28]. Salbach et al. reported increases of approximately 21.9% and 25.3% in CGS and MGS after task-oriented functional exercise[10], and Teixeira-Salmela et al. reported increases of 28% in gait speed after lower extremity muscle strengthening and aerobic exercises[35]. These gains are considerably higher than those observed in the present study. These differences might reflect the fact that the previous studies used a higher intensity and higher frequency (three or more times per week) than those used in this study protocol, which may have resulted in a greater improvement in gait speed. Sharp et al. reported an increase of 5.3% in gait speed after isokinetic strengthening training[28]. Although statistically significant, this gain was lower than that seen in the present study, and may not reflect a functionally significant change. This difference might reflect the fact that their study used a shorter intervention duration than that used in the present study, which may have resulted in smaller improvements in gait speed. Our results suggest that a combined functional training program with low frequency and low intensity may contribute to significant gains in CGS and MGS.

In contrast, while previous studies reported improvements ranging from 18% to 54% for knee extensors or flexors[35)], the results of the present study showed improvements in 1RM (36.4%) generated by the major muscle groups of the lower extremity, despite the lower frequency and intensity of our study protocol. In general, previous studies have supported the contention that the muscle weakness observed in chronic stroke subjects can be modified through appropriate exercise[28,36,37)]. The performance of normal movement requires the ability to execute alternating movements at various functional speeds, while maintaining appropriate timing between antagonist muscle groups. Practice and training are likely to reduce the amount of co-contraction and facilitate proper timing, resulting in a greater net force generated in the desired direction of movement[38)]. Additionally, 1RM is mainly a measure of the strength of hip extensors[39)], knee extensors[4,40)], and ankle plantarflexors[41)] and it may be an important determinant of gait speed. The observed improvement in 1RM can be explained, in part, by an increased ability to activate specific muscle groups. Indeed, Pearson's correlation analysis showed that there were significant correlations among the change rates of 1RM, CGS, and MGS. Therefore, it is important to increase lower extremity muscle strength in order to improve gait function.

There was a significant increase in ΔGS. We consider that ΔGS showed the range of gait speed control, which is a necessary component of most ADL. In previous studies, it has been reported that gait speed is an important factor related to community walking[5)], and that the difference in gait performance between comfortable speed and maximum speed is related to gait endurance and instrumental ADL, particularly the performance of outdoor activities[42)]. Accordingly, the increase in ΔGS may have ripple effects on improvements in ADL. Moreover, it is interesting to note that the change rate of ΔGS was correlated only with that of MGS, even though improvements were seen in both CGS and MGS in this study. Although numerous studies have used CGS and MGS for assessing gait performance, it may be important to focus on maximum gait function, using parameters such as MGS rather than CGS, for assessing improvement in gait performance related to ADL.

It is meaningful to observe these gains in lower extremity muscle strength and gait performance produced by exercise intervention at an adult day-care facility. One of the most consistent observations in stroke rehabilitation, is that patients spend a large proportion of the day alone and inactive[43–45)]. These observations suggest that individuals after stroke are at risk of becoming socially isolated and more disabled after discharge from rehabilitation, particularly since most individuals are discharged with functional ambulation skills that are inferior to the level required for effective community ambulation[46,47)]. The adult day-care service with combined functional training used in this study provided both social interaction and exercise specifically designed to improve ambulation skills. Despite a large range of abilities, all subjects in this study showed some improvement in 1RM, CGS, and MGS. This suggests that the combined functional training offered at the adult day-care service was managed in an efficient way, providing training to a group of subjects while managing to tailor the intensity and amount of training to each subject's ability, and without the need of specialized settings and expensive equipment.

The study had several limitations. First, although the results were positive, the small sample size and potential for type 1 errors arising from the number of statistical comparisons means that the study should be repeated with a larger number of subjects. Such a study should include measures of the quality of life, community participation, and handicap, thereby enabling a detailed analysis of the relationship between impairment levels, functional changes, and handicap. Second, 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 termination of the program. A larger sample size and long-term follow-up is required to determine the long-term benefits and adherence to an on-going combined functional training program. Third, 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.

The results of this study show that a short-term intervention of combined functional training can increase lower extremity muscle strength, gait speed, and range of gait speed control in chronic stroke individuals. In addition, this intervention can have a demonstrable impact that is meaningful to the participants wich may in turn promote exercise adherence. Such programs in adult day-care facilities have the potential to improve activity tolerance and reduce the risk of cardiac events and falls resulting in fractures, which are secondary complications that frequently occur in community-dwelling people with chronic post-stroke hemiplegia.

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