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Effect of Dual-task Rehabilitative Training on Cognitive and Motor Function of Stroke Patients

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Abstract. [Purpose] To determine the effect of dual-task training with cognitive tasks on cognitive and walking ability after stroke. [Subjects and Methods] Twenty patients diagnosed with stroke participated in this study. All participants were receiving a traditional rehabilitation program 5 days a week. Dual-task and single-task training were additionally performed for 4 weeks, 3 days a week. The Stroop test, Timed Up and Go (TUG) test, 10-Meter Walk Test (10MWT), and Figure-of-8 Walk Test (F8WT) were used to measure cognitive and walking abilities and were evaluated 3 times (before and after training and at the 2-week follow-up). [Results] Dual-task training improved cognitive and walking abilities, and dual-task training subjects' performance was better than single-task training subjects' performance. In addition, these training benefits were maintained for 2 weeks. [Conclusion] Dual-task training improves cognitive and walking abilities of patients with stroke.

Key words: Cognitive, Gait, Dual task

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INTRODUCTION

Cerebrovascular disease-related mortality rates have been increasing, and 1 out of every 4 cerebrovascular disease patients dies within a month after the onset of disease[1)]. Among the surviving patients, 15–30% become severely handicapped, and 40% are left with functional deficits, resulting in problems with the major components of functional independence: motor, sensory, and cognitive functions[2, 3)].

Cognitive function refers to the ability to understand the things that occur in daily life. It is the capacity to adapt to various situations as one begins activities, plans and considers issues, and resolves problems. The cognitive domain includes the abilities of concentration, memory, planning, systematization, problem solving, abstraction, and use of language[4)]. Because movements cannot be performed without intent, cognitive processing is crucial for motor control[5)]. During the rehabilitative training process, stroke patients with decreased cognitive ability cannot adequately utilize the cognitive function needed for motor learning[6)]. Thus, the normal mechanisms of postural control that were once automatic, such as the maintenance of a standing position, walking, and dual-task performance, are temporarily or permanently lost, and are changed into a conscious and slow response with a limited extent[7, 8)]. Thus, the evaluation of cognitive function in patients with early stroke is important for planning treatment for their functional recovery and return to daily life[9)].

In addition to cognitive function, walking is one of the major physical functions that is highly affected by stroke[10)]. Stroke patients exhibit inefficient walking because of decreased dynamic balance ability, as well as decreased musculoskeletal and cardiovascular function, and expend a significant amount of energy compensating for this deficiency[11)]. Compared with healthy persons, therefore, stroke patients have lower walking speeds and shorter duration of walking. Their daily functions are also limited and they cannot complete certain simultaneous tasks, such as conversing while walking[12)].

The relationship between cognition and motor control after neurological damage due to factors such as stroke has significant implications for understanding the recovery of motor function. Thus, it has been the center of much research, and the number of studies investigating the role of cognition and walking in elderly populations and clinical disease research has increased[13, 14)].

Cognitive-motor interference refers to the phenomenon that occurs when 1 or 2 tasks that interfere with each other are being performed, such as engaging in cognitive and motor tasks simultaneously[15)]. Interference between cognitive tasks and motor control activities (such as walking) is important for functional improvement in patients with neurological deficits. Thus, the therapist must address both cognitive and motor training in planning rehabilitation therapy[16)].

A dual task requires subjects to perform complex tasks simultaneously, and emphasizes the role of cognition and

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concentration using a dual-task method that involves a cognitive task combined with postural and walking control[15, 17]. Typically, the concurrent performance of motor and cognitive tasks in dual-task training affects the performance of one or both tasks[18]. Various studies on the interaction between cognitive tasks and cognitive characteristics, and between motor tasks and dynamic characteristics are under way[19].

According to the task integration hypothesis, single-task training has lower demands than dual-task training. Single-task training does not permit the concurrent performance of 2 tasks, whereas dual-task training allows the coordination of various tasks via the simultaneous performance of 2 or more tasks[17]. However, the majority of gait training for stroke patients focuses on functional recovery via exercise under single-task, rather than dual-task, conditions. Therefore, the therapeutic approaches available currently fall short of addressing cognitive deficits.

Thus, the present study aimed to investigate the effects of dual-task training including a cognitive task component on the cognitive and walking abilities of chronic stroke patients using objective measurement equipment and functional evaluation tools.

SUBJECTS AND METHODS

The present study included 20 patients who consented to participate in the study from among patients who had received a diagnosis of hemiparalysis due to stroke. The study was performed at the C hospital in Gwangju, began in August 2012, and lasted for 4 weeks. All the subjects voluntarily consented to participate in this study prior to its initiation. Data collection was carried out after approval had been granted by the Institutional Review Board of Donshin University.

The 20 stroke patients were randomly assigned to 2 groups (n = 10 per group). The experimental group received dual-task gait training with cognitive tasks, whereas the control group received single-task gait training.

To evaluate the cognitive and walking abilities of stroke patients, we used the Stroop test, Timed Up and Go (TUG) test, 10-Meter Walk Test (10MWT), Figure-of-8 Walking Test (F8WT), and dynamic gait index (DGI). Three repeated measurements were taken (before the intervention, after the intervention, and 2 weeks after intervention).

The Stroop test was used as part of the cognitive assessment. The assessment involved showing the subjects words written using inks of various colors, and having the subjects state the color of the ink[20, 21]. The number of correct answers completed within a given time was counted.

The TUG test is an assessment tool that quickly assesses basic motor and balance control. It is currently being used to assess the elderly, as well as patients with stroke, Parkinson's disease, and arthritic diseases[22]. The TUG test measures the time it takes a subject to rise from an armchair, walk 3 m, and then return to the chair and sit down. The TUG test was administered under both the single-task and dual-task conditions.

For the 10MWT, a walkway of 14 m was measured and marked with marks at 2 and 12 m. The person taking the measurement assured the safety of the subjects. The time taken by the subjects to walk the 10 m between the 2 and 12 m marks was recorded[23].

For the F8WT, distances of approximately 5 feet (1.5 m) and 4 feet (1.2 m) were measured. Cones were placed at either end of this area, and the subjects stood in the center, facing the front. The subjects chose the direction in which to walk and walked at a natural gait speed when ready around the two cones, finally returning to the start position, thereby drawing a figure-of-8. The parameters measured include speed (time to completion), number of steps taken during the performance, accuracy (whether the subject deviated from the walking direction), and continuity of walking[24].

The DGI test is comprised of 8 different gait tasks including walking on a level surface, walking while changing gait speeds, walking with vertical or horizontal head turns, walking with pivot turns, stepping over or around obstacles, and walking up and downstairs. Subjects' performance of each test item was rated on a 4-point scale (0–3), with the total score ranging between 0 and 24[25].

In the present study, the speed and number of steps were evaluated, whereas accuracy and continuity of walking were not.

Single-task and dual-task gait trainings were conducted 30 min per day, 3 days a week, for a total of 4 weeks. The single-task gait training group performed gait training based on the research of Silsupadol et al. and Silsupadol et al. with modified and supplemental methods to meet the needs of stroke patients[17, 26]. The dual-task walking group performed a cognitive task concurrently with the single-task training program. While moving during dual-task training, changes in priority are divided into fixed priority (FP) and variable priority (VP). In the present study, VP conditions were applied so that participants had to give the same priority to the 2 tasks.

Data analyses were performed using SPSS for Windows 17.0. Normal distribution of the data was confirmed using the Shapiro-Wilk test. A repeated measures 2-way analysis of variance (ANOVA) was performed to compare changes in cognition and walking according to the 2 types of exercise (dual-task training or single-task training) and the time points of each training condition (pre-training, post-training, or follow-up). A multiple comparison post hoc analysis was also performed using Bonferroni's multiple comparisons test. Statistical significance was accepted for values of $\alpha < 0.05$.

RESULTS

Twenty subjects participated in the study. The average age of the dual-task training (DT) group was 58.4 years, and that of the single-task training (ST) group was 58.2 years. The average height and weight of the DT group were 164.1 cm and 67.7 kg, respectively, and those of the ST group were 160.9 cm and 61.2 kg. Disease duration was 16.6 months in the DT group and 19.3 months in the ST group. The DT group scored an average of 26.8 points in the Korean version of the mini-mental state examination

Table 1. General characteristics of subjects

	Single-task training group (n = 10)	Dual-task training group (n = 10)
Age (years)	58.2 ± 8.07	58.4 ± 7.58
Height (cm)	160.9 ± 9.11	164.4 ± 6.59
Weight (kg)	61.2 ± 6.60	67.7 ± 10.07
Prevalence (months)	19.3 ± 14.12	16.6 ± 11.88
K-MMSE (score)	26.1 ± 2.42	26.8 ± 1.99

Table 2. Stroop test performance (unit: No. of correct answers)

	Before Intervention	After Intervention	Follow up
Single-task training group	32.50 ± 14.30	33.10 ± 13.07	34.20 ± 14.80
Dual-task training group	40.70 ± 15.68	51.00 ± 15.88	52.10 ± 16.62*

Values are represented as mean ± SD
*p < 0.05 relative to the single-task training group before intervention by 2-way ANOVA

Table 3. TUG test times under single tasks after dual-task training (unit: sec)

	Before Intervention	After Intervention	Follow up
Single-task training group	33.88 ± 19.86	30.39 ± 22.69	31.64 ± 22.51
Dual-task training group	31.34 ± 19.54	21.66 ± 14.97	22.66 ± 14.97$^{*,\#}$

Values are represented as mean ± SD
*p < 0.05 relative to the single-task training group before intervention by 2-way ANOVA
$^{\#}$p < 0.05 relative to the single-task training group after intervention by 2-way ANOVA

(K-MMSE) test and the ST group scored an average of 26.1 points (Table 1). All values are the mean ± SD.

The results of the 2-way ANOVA performed to examine the interaction between the training groups and measurement time points (to analyze cognitive function based on the Stroop test performances) did not reveal a significant difference in the interactions between measurement time points and training groups. There was a significant difference in the number of performances according to the measurement time point (F = 6.49, p = 0.016). The results of the post hoc test showed an absence of significant differences between the pre- and post-intervention time points; while there was a significant difference in the comparison between the pre-intervention and follow-up time points (p = 0.028), no significant difference was observed between the post-intervention and follow-up time points. Finally, there was a significant main effect of group (F = 5.29, p = 0.033) (Table 2).

The average and standard deviation values of dynamic balance ability according to training group and measurement time points were obtained from the TUG time measured under single-task conditions. The results of the 2-way ANOVA are shown in the form of a graph. There was a significant difference in the interactions between measurement time points. Moreover, there was a significant difference in the change in speed according to measurement time points (F = 12.23, p = 0.002). The results of the post hoc test revealed the presence of a significant difference between the pre- and post-intervention time points (p = 0.004), as well as of a significant difference in the comparison of the pre-intervention and follow-up time points (p = 0.015). In addition, there was a significant difference between the post-intervention and follow-up time points (p = 0.001). Finally, there was no significant difference in the speed in either of the training groups (Table 3).

The average and standard deviation values of dynamic balance ability according to training group and measurement time points were obtained from the TUG time measured under dual-task conditions. The results of the 2-way ANOVA are shown in the form of a graph. There was no significant difference in the interactions between measurement time points and training group. However, there was a significant difference in the change in speed according to the measurement time points (F = 8.094, p = 0.010). The results of the post hoc test revealed the presence of a significant difference between the pre- and post-intervention time points (p = 0.019); however, there was no significant difference between the pre-intervention and follow-up time points. In addition, there was no significant difference between the post-intervention and follow-up time points. There was no significant difference in the speed in either of the training groups (Table 4).

The average and standard deviation values of walking ability according to training group and measurement time points were obtained by measuring the walking speed during the 10MWT. The results of the 2-way ANOVA are presented in the form of a graph. There was no significant difference in the interactions between measurement time points and training groups. However, there was a significant difference in the change in speed according to measurement

Table 4. TUG test times under dual tasks after dual-task training (unit: sec)

	Before Intervention	After Intervention	Follow up
Single-task training group	42.41 ± 24.40	40.41 ± 22.88	40.60 ± 23.63
Dual-task training group	33.56 ± 20.71	24.19 ± 15.82	25.38 ± 16.13

Values are represented as mean ± SD

Table 5. Ten-meter walk test times (unit: sec)

	Before Intervention	After Intervention	Follow up
Single-task training group	30.86 ± 14.85	27.46 ± 14.65	28.90 ± 14.58
Dual-task training group	26.20 ± 11.93	18.16 ± 12.17	19.44 ± 12.16

Values are represented as mean ± SD

Table 6. Figure-of-8 walk test times (unit: sec)

	Before Intervention	After Intervention	Follow up
Single-task training group	28.60 ± 14.61	27.10 ± 19.63	25.03 ± 16.63
Dual-task training group	24.48 ± 13.17	19.76 ± 14.33	21.74 ± 15.40

Values are represented as mean ± SD

Table 7. Number of steps in the figure-of-8 walk test (unit: step)

	Before Intervention	After Intervention	Follow up
Single-task training group	35.20 ± 17.54	35.50 ± 18.22	35.60 ± 18.08
Dual-task training group	27.50 ± 11.89	29.60 ± 10.94	30.50 ± 10.76$^{*,\#}$

Values are represented as mean ± SD
*$p < 0.05$ relative to the single-task training group before intervention by 2-way ANOVA
$^{\#}p < 0.05$ relative to the single-task training group after intervention by 2-way ANOVA

Table 8. The dynamic gait index values (unit: score)

	Before Intervention	After Intervention	Follow up
Single-task training group	10.30 ± 5.20	10.00 ± 5.53	9.60 ± 5.14
Dual-task training group	13.00 ± 5.88	15.20 ± 6.35	15.20 ± 6.35

Values are represented as mean ± SD

time points (F = 14.688, p = 0.000). The results of the post hoc test revealed the presence of a significant difference between the pre- and post-intervention time points (p = 0.001), as well as between the pre-intervention and follow-up time points (p = 0.006). In contrast, there was no significant difference in the comparison of the post-intervention and follow-up time points. Finally, there was no significant difference in the speed in either of the training groups (Table 5).

The average and standard deviation values of walking ability according to training group and measurement time points were obtained by measuring the walking speed during the F8WT. The results of the 2-way ANOVA are shown in the form of a graph. There was no significant difference in the interactions between measurement time points and training groups. Moreover, there was no significant difference in the speed according to the measurement time points, and no significant difference in the speed in either of the training groups (Table 6).

The average and standard deviation values of walking ability according to training group and measurement time points were obtained by measuring the steps taken during the F8WT. The results of the 2-way ANOVA are shown. There was no significant difference in the interactions between measurement time points and patient groups. In addition, there was no significant difference in the change in the number of steps according to the measurement time points, and no significant difference in the number of steps in either of the training groups (Table 7).

The mean and standard deviations of DGIs by group and measurement time are shown in Table 8. Significant differences were observed in the correlation between measurement time points and training groups.

DISCUSSION

The present study sought to investigate the effects of 4 weeks of dual-task training including a cognitive task component on cognitive function and walking ability of stroke patients using functional evaluation tools.

The evaluation of cognitive function of stroke patients is important for the identification of treatment strategies for functional recovery and their return to daily living[27)].

The Stroop test was used to measure cognitive function in the present study. This test simultaneously reflects reaction time (speed aspect) and accuracy. Here, the effect of different performance levels among the subjects was minimized by specifying the reaction time as the number of items performed within a given time. In addition, accuracy was measured using the number of errors made.

Cognitive function increased with time, and differences were observed in the degree of improvement in the Stroop test according to training group. The DT group displayed greater improvement than the ST group, and these improved cognitive capacities were sustained at the follow-up, which was performed 2 weeks after the end of the intervention.

Hiyamizu et al. divided 45 elderly subjects into dual-task and single-task training groups and studied the effects of dual-task balance training on cognition and concurrent standing postural control. Their results show that the dual-task group had significantly improved performance compared to the single-task group in the Stroop test[28)]. That study also showed that balance training for the elderly under dual-task conditions led to improvement in dual-task performance during standing postural control.

Vasques et al. conducted a dual-task training combined with aerobic training for depressed elderly subjects. Their data showed improvements in cognitive assessments, including the Stroop test, which led them to suggest that dual-task training is a safe and useful approach for cognitive function training[29)].

Walking is the most basic means of human transport in daily life, and is the movement that is most easily performed concurrently with other tasks, such as conversing with another person or moving an object[30)]. Hemiplegia resulting from stroke has serious effects on an individual's walking ability. Even when functional walking is possible, it is different from the walking of a healthy person.

Various capacities, including the maintenance of appropriate walking speed, endurance, curved-path walking, and balance while walking, are required[24, 31)] for independent walking in daily life.

Cho et al. studied the effects of lower extremity circuit training based on a task-oriented training program on the walking ability of stroke patients, and proved that there were significant improvements in straight-line and curved-line walking speed[32)].

Seo et al. reported that 4 weeks of a dual-task training program with VP conditions effectively improved the static balance, dynamic balance, and walking abilities of patients with stroke-induced hemiplegia[33)]. In addition, Lee et al. found that the training group with VP conditions exhibited statistically significant differences in TUG single and TUG double tasks compared with other training groups. There was also a statistically significant difference in the dynamic gait index (DGI) score[34)].

In the present study, TUG was performed under single-task and dual-task conditions to evaluate dynamic balance ability. In addition, the 10MWT, DGI, and the F8WT were used to evaluate walking ability. Under single-task conditions, TUG gait speed increased with time in both groups. In single-task conditions, TUG speed remained increased at 2 weeks after the end of the intervention.

We observed that, under dual-task conditions, both training groups exhibited significant increases in walking speed in the TUG and 10MWT with time. We think that the gait-training program, which was performed identically by both training groups, influenced the improvements of the DT group as well as those of the ST group. The pattern of change in DGI was different between the two groups: the DT group showed higher increases in DGI than the ST group.

There were no differences between the groups regarding improvements with time in the F8WT, as measured by speed and number of steps. This result was likely due to inadequate intervention in the gait-training program components that involve curved paths.

The present study was performed to investigate the effects of dual-task training with a cognitive task component on cognition and walking of stroke patients. Dual-task training improved cognition and walking ability. However, the sample size of our study was small; therefore, we could not draw generalized conclusions from our results. Additional studies with larger sample sizes will be required to validate our findings. The gait-training program showed limited improvement in complex evaluation tasks requiring a sense of direction, such as the F8WT. This may be attributable to the fact that the gait-training program, selected as the intervention method, did not include a variety of training components. Further research using a gait-training program with more diverse training components would help to identify a broader rehabilitation strategy for clinical use.

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