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Effects of Balance Training with Various Dual-Task Conditions on Stroke Patients

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Abstract. [Purpose] The aim of this study was to determine the effects of motor dual-task training (MDT), cognitive dual-task training (CDT), and motor and cognitive dual-task training (MCDT) on balance and daily living abilities of stroke patients. In addition, the relationships among assessment tools such as center of pressure (COP), Korean version of Berg Balance Scale (K-BBS), and the Functional Independence Measure (FIM) were investigated. [Subjects and Method] Thirty-eight stroke patients were randomly allocated to a MDT group, a CDT group, and a MCDT group, and training was performed three times a week for six weeks. The patients' balance was assessed with the mean area of COP movement and K-BBS, and the daily living abilities were evaluated with FIM before and after the training. [Results] Post-training, a significant difference in COP was found in each of the three groups, and between the CDT group and the MCDT group. K-BBS and FIM also showed a significant difference in each of the three groups, and comparison among the three groups showed that the improvement in the MCDT group was significantly better than those of the other two groups. Highly negative correlations were found between COP and K-BBS and between COP and FIM (r=–0.960, –0.874, respectively), and a highly positive correlation was found between K-BBS and FIM (r=0.870). [Conclusion] For effective training of balance and daily living abilities for stroke patients, it is more effective to implement both motor and cognitive dual-tasks than motor or cognitive dual-tasks alone.
Key words: Dual-task training, Balance, Daily living abilities

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INTRODUCTION

Stroke limits mobility over a long period of time by causing physical and functional disorders[1)], which result in difficulties in daily living because the patients activities' are limited both in their homes and in the community[2)]. In fact, 75% of stroke patients suffer from a disorder involving daily living abilities[3)]. Daily living abilities refers to all the motions needed for a human to live in the community. Loss of balance is one of the most important functional disorders of patients with hemiplegia caused by stroke. Balance is the ability to maintain the center of mass within a proximal area and keep a stable posture when moving the body[4)], and most activities of daily living require the ability to maintain balance while performing various tasks simultaneously[5)]. Impaired balance decreases subjects' abilities in independent daily living[6)].

The physical treatments that are frequently performed for improving balance and daily living abilities of stroke patients include the Bobath treatment, Proprioceptive Neuromuscular Facilitation (PNF)[7)], visual feedback training[8)], and weight-shifting to the paretic side[9)]. Recently, studies on dual-task training have been drawing attention.

A dual-task is two tasks that are carried out simultaneously[10)]. In relation to balance dual-tasks consist of postural control tasks and postural control meta-tasks, and the postural control meta-tasks are further divided into cognitive tasks and motor tasks[11)]. Dual-task interference is the reduction in performance of one or both tasks when two tasks are performed simultaneously[10)]. Most functional tasks performed by humans primarily require balance[6)], and training in the performance of two tasks simultaneously can be conducted to resolve the problem of impaired balance arising from dual-task interference[11)]. Dual-task training provides information regarding restoration of the automatism of balance control by influencing the reorganization process of the central nervous system with respect to postural stability[6)].

Yang et al.[12)] reported that walking ability was significantly improved after 23 stroke patients were given walking training with a motor dual-task using a ball for four weeks. Pellecchia[10] reported that body sway was significantly reduced in a dual-task training group when 18 normal subjects were given balance training with the cognitive dual-task of counting backwards while maintaining balance. Silsipadol et al.[11] conducted training with a fixed priority (FP) condition, in which only a motor dual-task was performed, and with a variable priority (VP) condition, in which a cognitive motor dual-task was added to the motor dual-task, for 23 elderly subjects for four weeks, and reported that balance and walking ability were more improved in the VP group than in the FP group.

Not many studies have investigated which dual-task method is more effective in dual-task training for the improvement of daily living abilities through balance restoration for stroke patients. Therefore, in this study, we investigated the effects of various dual-task training methods on the balance and daily living abilities of patients with chronic stroke, and the relationships between balance and function by examining the correlations among the assessment tools COP, K-BBS, and FIM used in this study.

SUBJECTS AND METHODS

Subjects

Thirty-eight chronic stroke patients (20 males, 18 females), admitted to the Department of Physical Medicine and Rehabilitation, Rusk Bundang Rehabilitation Hospital, South Korea, were recruited for this study. The age, gender, diagnosis, and paretic side of the patients were obtained from patient interviews and confirmed via a review of medical records. The inclusion criteria were; hemiparetic from a single stroke occurring at least one year earlier; ability to walk 10 m independently without an assistive device; functional use of the affected upper extremity; a stable medical condition that allowed participation in testing and intervention; and ability to understand instructions and follow commands. The exclusion criteria were ; any disability other than stroke that would preclude dual-task training; any uncontrolled health condition for which exercise is not advised; or any neurologic or orthopedic disease that might interfere with the study. Informed consent to participation in this study was obtained from all the patients.

Methods

The 38 stroke patients were randomly allocated as follows: 12 to the MDT group, 13 to the CDT group, and 13 to the MCDT group. Training was performed three times a week for six weeks. Balance control tasks were added to the motor task for the MDT group. The patients first performed the posture control task of maintaining standing balance on an unstable balance pad. While maintaining balance, the patients performed exchanging a ball, receiving a ball with a basket[11], bouncing a ball on the floor[12], holding a glass with water in it, and exchanging a water glass[6]. Each of the tasks was implemented for three minutes for a total of 15 minutes, then repeated once again. Cognitive tasks were added to the postural control tasks for the CDT group. The patients first maintained standing balance after stepping onto an unstable balance pad. While maintaining balance, the patients counted backwards[10], calculated two subtractions (100–7 and 100–13)[13], called the correct names of objects[11], and recited words in reverse order[14]. Each of the tasks was implemented for three minutes for a total of 15 minutes, then repeated twice. Motor tasks and cognitive tasks were added to the postural control task for the MCDT group. Patients first performed the posture control task of maintaining standing balance on an unstable balance pad. While maintaining their balance, they performed the previously described motor task and cognitive task, one set of each for 15 minutes, for a total of 30 minutes.

The patients' balance before and after the training session was assessed using Gaitview and K-BBS, and daily living abilities were assessed using FIM. To measure COP with Gaitview (Gaitview AFA-50, alFOOTs Corp.), the subjects were asked to step on the Gaitview pad and look at a ball hanging from the ceiling while standing with their arms lowered comfortably; the mean area of COP movement was recorded. The measurement was repeated three times and the mean value was calculated. A short rest was given between the measurements. The other balance assessment tool was BBS, which is used to qualitatively measure balance ability in tasks such as closing the eyes while standing, standing while keeping the feet close together, and picking up an object with the fingers[11]. The assigned score is zero to four for each item, and the total score ranges from zero to 56. Kornetti et al.[15] predicted that there is a high risk of falling if the total score is less than 45. Qutubuddin et al.[16] used BBS as a predictive tool for movement and reported that a wheelchair is needed if the score is 0 to 20, assistance is required if the score is 21 to 40, and independent walking is possible if the score is 41 to 56. The inter-observer reliability of BBS is ICC=0.98, and the test-retest reliability is ICC=0.99[17].

We used FIM to measure daily living abilities. FIM consists of 18 items that measure physical and cognitive functions. A score based on an ordinal scale between 1 and 7 is given to each item depending on the degree of the patient's function. The lowest total score, 18, is given if the subject shows total dependence in all the items, whereas the highest score, 126, is given if the subject shows total independence. The inter-observer reliability of BBS is ICC=0.84–0.99, and the test-retest reliability is ICC=0.84–0.93[18].

SPSS 12.0 for Windows was employed for the statistical analysis. For all the variables, the Kolmogorov-Smirnov normality test was performed. Homogeneity of the general characteristics was tested by the chi-squared test and by one-way ANOVA for the dependent variables. The paired t-test was performed to compare the measurements before and after the training in each of the three groups, and analysis of covariance (ANCOVA) and the LSD post-hoc test were performed to compare changes among the three groups. In addition, Pearson's correlation coefficients were calculated to examine the relationships among the assessment tools. For all the data, the significance level was

Table 1. General characteristics of the subjects (N=38)

		MDT (n=12)	CDT (n=13)	MCDT (n=13)
Age (year)		64.8 ± 5.2	64.5 ± 4.8	63.5 ± 6.4
Gender	Male	7 (58.33)	5 (38.46)	8 (61.54)
	Female	5 (41.67)	8 (61.54)	5 (38.46)
Diagnosis	Infarction	5 (41.67)	7 (53.85)	9 (69.23)
	Hemorrhage	7 (58.33)	6 (46.15)	4 (30.77)
Paretic side	Left	6 (50.00)	6 (46.15)	7 (53.85)
	Right	6 (50.00)	7 (53.85)	6 (46.15)

Values are N (%) or Mean ± standard deviation. MDT: Motor dual-task training. CDT: Cognitive dual-task training. MCDT: Motor and cognitive dual-task training.

Table 2. Comparison of COP, K-BBS, FIM among the three groups (N=38)

Group		MDT (n=12) Mean ± SD	CDT (n=13) Mean ± SD	MCDT (n=13) Mean ± SD
COP (cm^2)	Pre-	3.34 ± 1.05	3.28 ± 1.19	3.16 ± 1.30
	Post-	2.86 ± 0.63	2.72 ± 0.77	2.34 ± 0.60
	Change	–0.47 ± 0.58*	–0.56 ± 0.55*[3]	–0.82 ± 0.78*[2]
K-BBS	Pre-	27.25 ± 11.76	28.77 ± 11.78	30.08 ± 12.35
	Post-	32.17 ± 8.31	33.54 ± 8.24	39.08 ± 7.08
	Change	4.92 ± 4.08*[3]	4.77 ± 4.14*[3]	9.00 ± 5.71*[1,2]
FIM	Pre-	86.50 ± 16.93	87.62 ± 15.65	86.08 ± 15.39
	Post-	91.33 ± 13.97	92.54 ± 12.00	97.38 ± 8.16
	Change	4.83 ± 3.21*[3]	4.92 ± 4.48*[3]	11.31 ± 7.39*[1,2]

*p<0.05. COP: Center of pressure (cm^2). K-BBS: Korean version of the Berg balance scale. FIM: Functional independence measure. MDT: Motor dual-task training. CDT: Cognitive dual-task training. MCDT: Motor and cognitive dual-task training. [1]: significantly different from MDT, [2]: significantly different from CDT, [3]: significantly different from MCDT.

chosen as α=0.05.

RESULTS

Table 1 shows the general characteristics of the subjects. No significant difference was found among the groups in the general characteristics of the subjects such as gender, age, diagnosis, and paretic part, or in the dependent variables, such as mean area of COP movement, balance ability, and daily living abilities before the training.

A significant difference in the mean area of COP movement in the dual-task training was found before and after the training in each of the three groups (p<0.05), and between the CDT group and the MCDT group. The K-BBS assessment of balance showed a significant pre- to post-training difference in each of the three groups (p<0.05), and the comparison among the three groups showed that the improvement in the MCDT was significantly different from those of the other two groups (p<0.05) (Table 2). The FIM assessment of daily living abilities showed a significant pre- to post-training difference in each of the three groups (p<0.05), and the comparison among the three groups showed that the improvement in the MCDT group was significantly better than that of the other two groups (p<0.05) (Table 2). The correlation coefficient between COP and K-BBS and that between COP and FIM were r= –0.960 and –0.874, respectively. The correlation coefficient between K-BBS and FIM was high r=0.870 (Table 3).

Table 3. Relations among the COP, K-BBS, and FIM (N=38)

	COP	K-BBS	FIM
COP	1		
K-BBS	–0.960*	1	
FIM	–0.874*	0.870*	1

* p<0.05. COP: Center of pressure (cm^2). K-BBS: Korean version of berg balance scale. FIM: Functional independence measure.

DISCUSSION

This study was conducted to investigate the changes in balance and daily living abilities of chronic stroke patients after implementing balance training with various dual-task conditions, and to examine the relationship between balance and daily living abilities. Balance was assessed by the mean area of COP movement and K-BBS, and daily living abilities were evaluated by FIM. The results show that improvements in the K-BBS and FIM scores were greater in the MCDT group than in the other two groups, and the correlation between the assessment tools was high. Thus, MCDT is a physical therapy intervention which can help stroke patients to return to daily living, considering that most daily living tasks require simultaneous motor and cognitive tasks.

The mean area of COP movement in the standing posture, which was used to assess balance, showed an improvement in each of the three groups after training, and the comparison among the three groups showed that the improvement was greater in the MCDT group than in the CDT group. This result is partially consistent with the result of Pellecchia[10], who reported reduced sway of COP after cognitive dual-task training. In quiet standing, the position of the center of mass varies continuously, resulting in changes in the forces exerted by the human body on the support surface and in the corresponding ground reaction forces, i.e. COP[19]. Nardon et al.[20] reported that the mean area of COP movement in the standing posture is greater in hemiplegic patients than in healthy adults. The reduction in postural sway found in our present study may have been due to the dual-task training, which included cognitive dual-task training. In the present study, sway of COP was measured only in the standing posture, not while performing the dual-task, but the correlation coefficient between sway of COP and K-BBS, and between sway of COP and FIM were $r= –0.96$ and $r= –0.87$, respectively, suggesting that dynamic balance and daily living abilities improve as sway of COP is reduced.

K-BBS was also used to assess the balance of stroke patients and it showed an improvement in each of the three groups after training. Comparison among the three groups showed that the improvement was greater in the MCDT group than in the other two groups. According to Silsapadol et al.[11], improvement in balance and walking ability was greater in the group which performed both the motor and cognitive tasks than in the group which only performed the motor task. Shumway-Cook and Woollacott[6] reported that various methods of training are necessary to induce appropriate movements for various tasks.

Post-training daily living abilities were improved in each of the MDT, CDT, and MCDT groups. In the comparison among the three groups, the MCDT group showed greater improvement than the other two groups. Duarte et al.[21] conducted a postural control test with 28 stroke patients as subjects and reported that their daily living abilities were closely related to their improvement of balance ability. Moreover, Raine et al.[22] recommended dual-task training for daily living, noting that dual-task performance is necessary in actual daily living. Because daily living abilities are affected not only by motor functions but also by cognitive functions, higher improvement was seen in the daily living abilities of the MCDT group, which performed both the motor and cognitive tasks for balance training.

Meyer[23] reported that a correlation coefficient $r \geq 0.8$ indicates high correlation, $0.6 \leq r < 0.8$ indicates good correlation, $0.4 \leq r < 0.6$ indicates moderate correlation, and $r < 0.4$ indicates poor correlation. In this study, the correlation coefficient between K-BBS and FIM was high ($r=0.87$). K-BBS and FIM are representative assessment tools that are used to clarify the effects of physical treatment for stroke patients. Wee et al.[24] reported that change in balance ability is an important factor that affects the functional restoration of chronic stroke patients during hospitalized rehabilitation treatment, and improvement in balance ability influences improvement in daily living abilities.

The limitations of this study were that the effects of dual-task training on body sway were not accurately investigated, as the mean area of COP movement, was not measured while performing the dual-task and the effects of the training were not investigated in relation to the difficulties of the given tasks. Future studies should be conducted on a larger scale, without these limitations.

In spite of its limitations, the present study may have implications for physical therapists who design and implement interventions aimed at optimizing patient safety and independence. Traditionally, the focus of interventions for individuals with movement disorders has been on improving motor performance. In recent years, however, physical therapists have become increasingly aware of the role of dual-tasks in daily living. The results of this study suggest that in interventions aimed at improving balance and daily living abilities of stroke patients, motor and cognitive tasks should be incorporated as dual-task training.

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