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Original Article

The Effect of Various Dual Task Training Methods with Gait on the Balance and Gait of Patients with Chronic Stroke

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Abstract. [Purpose] This study examined the effects of various dual task gait training methods (motor dual task gait training, cognitive dual task gait training, and motor and cognitive dual task gait training) on the balance and gait abilities of chronic stroke patients. [Subjects and Methods] Thirty-three outpatients performed dual task gait training for 30 minutes per day, three times a week, for eight weeks from June to August, 2012. Balance ability was measured pre-and posttest using the stability test index, the weight distribution index, the functional reach test, the timed up and go test, and the four square step test. Gait ability was measured by the 10 m walk test and a 6 min walk test before and after the training. The paired t-test was used to compare measurements before and after training within each group, and ANOVA was used to compare measurements before and after training among the groups. [Results] Comparisons within each group indicated significant differences in all variables between before and after the training in all three groups. Comparison between the groups showed that the greatest improvements were seen in all tests, except for the timed up and go test, following motor and cognitive dual task gait training. [Conclusion] In a real walking environment, the motor and cognitive dual task gait training was more effective at improving the balance and gait abilities of chronic stroke patients than either the motor dual task gait training or the cognitive dual task gait training alone.
Key words: Stroke, Dual task, Balancing

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INTRODUCTION

A stroke results in a damaged state of the peripheral external nervous system arising from the necrosis of nerve cells in specific brain areas, caused by the interruption of blood supply to brain cells due to the blockage or rupture of blood vessels transporting oxygen and glucose to the brain[1)]. Though various problems may be evident in the fields of exercise, sense, recognition, language and perception, depending on the part, size and cause of this damage, its main symptom is hemiplegia[2)].

Daily living requires balance and walking ability while performing other tasks. Thus, balancing and gait training for hemiplegic stroke patients should reflect the motor skills and cognitive function required in daily living dual tasks[3)]. Dual tasks fall into two main groups: motor dual tasks[4)], which require performance of a motor task and a postural control task at the same time; and cognition dual task[5)] which require performance of a cognition task and postural control task at the same time. Both types of dual task are noted as ways of training patients with neurological damage to recover their motor control ability.

Up to the present, research has emphasized the role of recognition and concentration during dual task performance for posture and gait control as a paradigm of motor learning[6)]. It is asserted that subjects need to simultaneously perform motor tasks and high cognitive functions, as daily living frequently requires the performance of several tasks simultaneously, and it has been reported that stroke patients who could carry out local community ambulation, had difficulties in simultaneously performing dual task while walking[7)].

Viewing the recent trend of studies of dual task training for stroke patients, we noticed that they elicited an interaction between gait and cognitive task through dual task methods, by making patients carry out cognitive tasks such as hearing, viewing or language tasks, together with walk-

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ing[8], and that most research mainly focused on the analysis of gait variance the course of training with motor dual tasks[7]. Few studies had conducted various dual task training methods in order to enhance the balance and gait abilities of stroke patients, and little comparative research has been conducted of the extent of improvement among the various dual task training methods.

Accordingly, this research investigated the changes occurring in terms of balance and gait abilities, when various dual task gait training were conducted for chronic ambulatory stroke patients to investigate the efficacy of dual task training methods in order to suggest new therapeutic interventions that would help chronic stroke patients to improve their daily living function.

SUBJECTS AND METHODS

Thirty-six chronic stroke outpatients who were receiving treatment during the period of June to August at J general hospital in Kyeong-gi Province, were randomly selected as the subjects of this research. Tables of random numbers were used to minimize selection bias. All the subjects were randomly assigned to 3 groups: the motor dual task gait training (MDGT) group of 12 subjects, the cognitive dual task gait training (CDTG) group of 12 subjects, and the motor and cognition dual task gait training (MCDGT) group of 12 subjects. Gait training for 8 weeks was conducted for all of these 3 groups. In the midst of training, one subject left the MDTG group due to hospital transfer one subject made a decision not to continue CDTG group training, and one subject was excluded from the analysis due to a poor attendance rate of less than 80% in MCDGT group training. Thus, 33 subjects completed the training planned for this research. This clinical research was performed with the consent of all the patients. The Ethics Committee of Namseoul University, Korea, also approved this study. The approval number is Research-20121227.

The research period was from June, 2012 to August, 2012. Before the intervention, subject's general features, balance ability and gait ability were measured and recorded. To improve the reliability of the results, one researcher gave an outline and demonstrated in person the task performance and experimental order, one week prior to the preliminary measurements for the smooth progress of training and for the prevention of accidents. Also, for the purpose of enhancing inter tester reliability, the testers who were to carry out the same test, were allowed to have sufficient discussion and prior education on the test procedures. In order to prevent any selection bias, the subjects were randomly divided into 3 groups, and11 subjects in the MDGT group, 11 subjects in the CDGT group and 11 subjects in the MCDGT group completed the training of 30 minutes exercise, 3 times a week, for 8 weeks.

Subjects in the MDGT group were instructed to perform some motor tasks while continuously walking on a treadmill. While walking on the treadmill, they performed 5 types of motor tasks: 'tossing up and catching a ball', 'rehanging loops on different hooks', 'doing up buttons after unbuttoning'[7], 'holding a cup of water without spilling it' and 'receiving and returning a cup of water'. Three minutes were allowed for each task, so 15 minutes were allowed for the set of 5 tasks, and 2 sets of tasks were carried out by the subjects[9]. The subjects carried out the cognitive dual tasks while maintaining their gait on the treadmill. They performed 5 types of cognitive dual tasks: 'discerning colors', 'mathematical subtraction', 'verbal analogical reasoning', 'spelling words backward'[10], and 'counting backward'[11]. Three minutes were allowed for each task, so 15 minutes were allowed for the set of 5 tasks, and 2 sets of tasks were carried out by the subjects. The subjects of the MCDGT group received a total of 30 minutes training. They performed the set of motor dual tasks for 15 minutes and the set of cognitive dual tasks for 15 minutes, while maintaining gait on the treadmill.

PASW Statistics 18.0 program for Windows was used in this research to carry out all the statistical analyses. In order to compare gender, paretic side and stroke type of the 3 groups, the χ^2 test was used, and one-way ANOVA was used to compare age, height, and weight, and to test the homogeneity of the dependent variables before training. The Kolmorogov-Smirnov test was used to test the normality of the data. The paired t-test was used to check the difference between pre- and post-treatment in each group. In order to compare the difference depending on the type of therapy among the 3 groups, we used analysis of covariance (ANCOVA), setting the group variable of 3 groups as the fixed factor, and the post-training scores as dependent variables after having controlled for the pre-test score of dependent variables as covariance. The Bonferroni method was used as the post hoc test. The statistical significance level was $\alpha = 0.05$ in all analyses.

RESULTS

The changes in balance and gait abilities between pre- and post- training are shown in Table 1. The differences in the stability test index (STI) and the weight distribution index (WDI) with the eyes open and closed conditions were between the significant within each of the 3 groups, as were the differences in STI and WDI between pre-training and post-training ($p<0.05$). Their inter-group differences were also significant. The functional reach test distances of the 2 groups excluding the CDGTgroup, showed significant differences between pre-training and post-training ($p<0.05$). The differences in FRT between pre- and post-training showed a significant difference among the 3 group ($p<0.05$), and the extent of improvement in the MDGT group and MCDGT groups was significantly greater than that of the CDGT group ($p<0.05$). The differences in the timed up and go test (TUG) times between pre- and post training, were significant ($p<0.05$) within each group, but there were not significant inter-group difference. The differences in the four square step test (FSST) between pre- and post- training were significant ($p<0.05$) within each group and the extent of improvement in the MDGT group and MCDGT group was significantly greater than that of the CDGT group ($p<0.05$). The 10 m walk test (WT) was used to assess gait ability between pre- and post- training. It showed

Table 1. Comparison of balance and gait abilities within and among the three groups

Group Variable		MDGT Mean ± SD	CDGT Mean ± SD	MCDGT Mean ± SD
NO STI*	Pre	28.70 ± 7.83	28.39 ± 5.07	28.76 ± 3.69
	Post	19.01 ± 6.99	24.52 ± 4.82	12.95 ± 2.19
	change	−9.68 ± 2.17 2,3*	−3.87 ± 1.70 1,3*	−15.81 ± 4.17 1,2*
NC STI*	Pre	47.39 ± 10.84	47.21 ± 9.60	47.26 ± 13.66
	Post	35.87 ± 10.60	43.35 ± 8.63	24.92 ± 10.60
	change	−11.52 ± 2.32 2,3*	−3.86 ± 1.91 1,3*	−22.35 ± 9.80 1,2*
NO WDI*	Pre	8.32 ± 1.36	8.30 ± 0.98	8.82 ± 0.74
	Post	7.01 ± 1.12	7.14 ± 0.69	6.22 ± 0.40
	change	−1.31 ± 0.56 3*	−1.15 ± 0.77 3*	−2.60 ± 0.61 1,2*
NC WDI*	Pre	10.13 ± 2.13	10.34 ± 1.46	10.47 ± 0.86
	Post	7.42 ± 1.44	9.22 ± 1.33	7.31 ± 0.66
	change	−2.71 ± 2.16 2*	−1.12 ± 0.77 1,3*	−3.15 ± 0.74 2*
FRT* (cm)	Pre	22.56 ± 7.86	22.36 ± 5.55	22.27 ± 6.13
	Post	26.14 ± 8.06	23.82 ± 5.91	27.82 ± 6.32
	change	3.57 ± 0.50 2,3*	1.45 ± 3.56 1,3*	5.55 ± 1.13 1,2*
TUG (sec)	Pre	19.28 ± 9.50	19.33 ± 10.99	19.45 ± 7.92
	Post	15.35 ± 6.68	17.31 ± 9.90	15.75 ± 7.73
	change	−3.94 ± 3.53*	−2.02 ± 1.87*	−3.69 ± 2.31*
FSST* (sec)	Pre	21.17 ± 9.30	21.08 ± 11.70	21.07 ± 7.73
	Post	18.92 ± 8.86	18.59 ± 12.34	16.16 ± 7.34
	change	−2.25 ± 1.67 2*	−2.49 ± 2.12 *	−4.91 ± 3.16 1*
10 m WT* (m/s)	Pre	0.85 ± 0.38	0.93 ± 0.48	0.89 ± 0.38
	Post	0.98 ± 0.49	0.96 ± 0.51	1.26 ± 0.54
	change	0.13 ± 0.11 3*	0.03 ± 0.04 3*	0.38 ± 0.21 1,2*
6 min WT* (m)	Pre	223.00 ± 82.33	253.83 ± 123.42	246.68 ± 97.00
	Post	242.07 ± 82.33	263.90 ± 123.61	277.66 ± 89.94
	change	19.07 ± 0.83*	10.07 ± 0.83 2*	30.98 ± 30.45 1*

*Expressed as $p<0.05$

NO: Normal eyes open; NC: Normal eyes closed; STI: Stability test index; WDI: Weight distribution index; FRT: Functional reach test; TUG: Timed up and go test; FSST: Four square step test; 10 m WT: 10 m Walk test; 6 min WT: 6-min Walk test; MDGT:motor dual task gait training group; CDGT:cognition dual task gait training group; MCDGT: Motor and cognition dual task gait training group.

1 significantly different compared with MDGT

2 significantly different compared with CDGT

3 significantly different compared with MCDG

significant difference both within each group and among the 3 groups ($p<0.05$), and the MCDGT group showed a significantly greater improvement than the other 2 groups ($p<0.05$). The 6 min WT showed significant differences both within each group and among the 3 groups ($p<0.05$), and the MCDGT and CDGT groups showed significantly greater improvement than the MDGT group ($p<0.05$).

DISCUSSION

This research investigated how various dual task training methods influenced the balance and walking abilities of chronic stroke patients who were capable of local community ambulation. The subjects were assigned to the MDGT, CDGT, and MCDGT groups, and the difference between pre-training and post-training was compared within and among these 3 groups.

In all the assessments of balance ability in this research, except the TUG test improvement in the MCDGT group was significantly greater than in the other 2 groups. In the tests of walking ability, both the 10 m walk test and 6 min walk test, performed before and after the training, showed significant improvements in the 3 groups, and the MCDGT group showed more significant improvement than the other 2 groups.

There were differences in the STI (stability test index) and WDI (weight distribution index) between pre- and post-training in each of the 3 groups and the MCDGT group showed greater improvement than the other 2 groups (MDGT group and CDGT group). In 3 different types of balance training were performed by 21 elderly persons with balance impairments. The study of Silsupadol et al.[12], the postural sway of the group that carried out the single task together with the dual task, declined by 56% showing their balance ability was improved. The result of our present research agrees with the results of previous research, in that the performance of dual task decreased postural sway and improved postural stability[13]. Hyndman et al. investigated how the degree of postural sway varied with performance of a dual task while walking, using patients who had had hemiplegia for 16 months on average as subjects. They reported that the degree of postural sway decreased while the patients were carrying out a dual task. This research result of Hyndman et al.[14] is also consistent with our present findings.

In the FRT (functional reach test), the MDGT group and MCDGT group showed improvements after training, and they showed greater improvement than the CDGT group. Riley et al.[15] reported that postural sway was corrected better when patients performed a dual task of just keeping in contact with a curtain without pulling it, than when they carried out a single task of balance. Their result is supported by the research of Wulf and Prinz[16], who concluded that the external focus of attention, concentrating on the result of the movement, is more effective than the internal focus of attention, concentrating on the movement itself. All the groups showed significant improvements in TUG times after training.

Silsupadol et al.[12] conducted a study in which healthy elderly subjects performed dual tasks 3 times a week for 4 weeks. The subject performed single tasks such as standing up, standing up with their eyes closed, tandem standing, standing on a moving surface, standing while holding a cup, catching balls, and walking forward and backward, together with other space perception tasks. Silsupadol et al.[12] suggested that dual task training improved the TUG times, which is consistent with the result of our present research. Cheng et al.[17] reported that they found the difference of vertical ground reaction force between the two lower limbs was lessened in the action of standing up, after patients had performed a training course in which they repeated the move of standing up with symmetrical posture. Sahrmann[18] reported the position of the trunk relative to the pelvis of stroke patients is changed because the muscles are asymmetrically shortened by neurological injuries, and the shortened muscles are more easily mobilized than the stretched antagonistic muscle on the unaffected side, so the level of tension of the shortened muscle increased. We consider that Sahrmann's suggestion explains the results of Cheng et al[17].

All the groups showed significant improvements in the four square step test, which is designed to assess the balance ability of chronic stroke patients. The MDGT group and the MCDGT group showed significantly greater improvements than the CDGT group. We consider this result is consistent with that of Reqnaux et al.[19], who reported attention was allocated more to the execution of exercise than to cognitive performance when stroke patients performed tasks of differing levels of difficulty while walking on a treadmill.

When the gait speed was compared among the 3 groups in the 10 m WT, which is designed to measure the gait competence of chronic stroke patients, the MCDGT group showed significantly greater improvement than the other 2 groups. This result can be construed as agreeing with the results of Yang et al.[7], who reported that subjects exhibited a significant improvement in gait speed after performing the 3 motor tasks of simple walking, walking with buttoning task, and walking with the task of carrying a cup on a tray. Their subjects were a group of 15 normal adults, a group of 15 stroke patients with some difficulty with local community ambulation, and a group of 15 chronic stroke patients with no difficulty with local community ambulation.

In the 6-min walk test, all of the groups exhibited significant improvements after performing the training. In the research of Salbach et al.[20], 44 stroke patients were assessed in terms of gait ability after they had practiced functional tasks for 6 weeks and their walking distance increased from 209 to 249 m after the intervention. Dean et al.[21] asked an experimental group of stroke patients to perform strengthening exercises for the paretic lower limb together with various functional tasks, and a control group of stroke patients to perform strengthening exercises mainly for the upper limbs, and assessed the outcome with a circuit walking task. They[21] investigated, and found that the experimental group's gait ability improved more than the control group's. We consider their result is consistent with the results of our present study.

Our present research showed that the extent of improvement was greater in the MDGT group than in the CDGT group after the training. The correlative between cognition and motor functions has been the focus of research on dual task, as it is essential for understanding how the recovery of motor control occurs after injury to the central nervous system[8]. Morioka et al.[22] asked healty individuals to perform a single task of maintaining a standing posture on a force plate, and to perform a motor dual task of maintaining posture while performing a cognitive dual task of a mathematic calculation. They reported that the subject's postural sway incresed during performance of the cognitive dual task, a mathematical calculation, and there was no direct relation with the maintenance of correct posture, while postural sway decresed during the performance of the motor dual task for which the subjects were required to hold a tray with cups of water on it. They further noted that the subjects consciously tried to hold the tray horizontally while they performed the motor task of holding the tray with cups of water on it, and that this conscious effort reduced the postural sway. Their findings were confirmed by Vereijken et al.[23], who reported that the internal focus of attention, concentrating on the movement itself, during the performance of a motor task inhibits self-operating postural control due to conscious control of the posture, while the external focus of attention, concentrating on the result of the movement during the motor task, promotes self-operating postural control.

Our present research could not thoroughly exclude the influence of subjects' daily living activities on their balance and gait because it was not possible to entirely control the experimental subjects' daily living activities, and this is a limiting factor of this research. Additionally, the generalization of our results should be performed with care as the number of subjects in this research was limited and the subjects of this research comprised only ambulatory chronic stroke patients. This additional fact also limits interpretation of this research. We suggest that future research should investigate the effects of dual motor task gait training for patients with neurological deficit from various viewpoints, addressing the limitations of the present study.

This research was conducted to examine whether various kinds of dual task gait training could improve the gait and balance abilities of chronic stroke patients. The subjects, ambulatory chronic stroke patients, were, divided into 3 groups: the MDGT group, the CDGT group, and the MCDGT group. They performed the prescribed training for 30 minutes, 3 times a week for 8 weeks. After the training, a comparison of the improvement of gait and balance abilities was made within and among the 3 groups. All of the 3 groups showed improvements, especially the MCDGT group which exhibited the greatest improvements in gait and balance abilities among 3 groups.

This study demonstrated that MCDGT was more effective at improving gait and balance abilities than MDGT or CDGT, and it can be recommended as the most efficient training forchronic stroke patients capable of local community ambulation.

REFERENCES

1) Cauraugh JH, Kim S: Two coupled motor recovery protocols are better than one: electromyogram-triggered neuromuscular stimulation and bilateral movements. Stroke, 2002, 33: 1589–1594. [Medline] [CrossRef]
2) Kelley RE, Borazanci AP: Stroke rehabilitation. Neurol Res, 2009, 31: 832–840. [Medline] [CrossRef]
3) Bowen A, Wenman R, Mickelborough J, et al.: Dual-task effects of talking while walking on velocity and balance following a stroke. Age Ageing, 2001, 30: 319–323. [Medline] [CrossRef]
4) Yang YR, Wang RY, Chen YC, et al.: Dual-task exercise improves walking ability in subjects with chronic stroke: a randomized controlled trial. Arch Phys Med Rehabil, 2007, 88: 1236–1240. [Medline] [CrossRef]
5) Dennis A, Dawes H, Elsworth C, et al.: Fast walking under cognitive-motor interference conditions in chronic stroke. Brain Res, 2009, 1287: 104–110. [Medline] [CrossRef]
6) Yardley L, Gardner M, Bronstein A, et al.: Interference between postural control and mental task performance in patients with vestibular disorder and healthy controls. J Neurol Neurosurg Psychiatry, 2001, 71: 48–52. [Medline] [CrossRef]
7) Yang YR, Chen YC, Lee CS, et al.: Dual-task-related gait changes in individuals with stroke. Gait Posture, 2007, 25: 185–190. [Medline] [CrossRef]
8) Plummer-D'Amato P, Altmann LJ, Saracino D, et al.: Interactions between cognitive tasks and gait after stroke: a dual task study. Gait Posture, 2008, 27: 683–688. [Medline] [CrossRef]
9) Lee DJ, Cho YM, Lee WH: The effect of a task-related training on static balance and walking in chronic stroke patients. J Korea Sport Research, 2007, 18: 61–70.
10) Hollman JH, Kovash FM, Kubik JJ, et al.: Age-related differences in spatiotemporal markers of gait stability during dual task walking. Gait Posture, 2007, 26: 113–119. [Medline] [CrossRef]
11) Pellecchia GL: Dual-task training reduces impact of cognitive task on postural sway. J Mot Behav, 2005, 37: 239–246. [Medline] [CrossRef]
12) Silsupadol P, Shumway-Cook A, Lugade V, et al.: Effects of single-task versus dual-task training on balance performance in older adults: a double-blind, randomized controlled trial. Arch Phys Med Rehabil, 2009, 90: 381–387. [Medline] [CrossRef]
13) Mazaheri M, Salavati M, Negahban H, et al.: Postural sway in low back pain: effects of dual tasks. Gait Posture, 2010, 31: 116–121. [Medline] [CrossRef]
14) Hyndman D, Ashburn A, Yardley L, et al.: Interference between balance, gait and cognitive task performance among people with stroke living in the community. Disabil Rehabil, 2006, 28: 849–856. [Medline] [CrossRef]
15) Riley MA, Stoffregen TA, Grocki MJ, et al.: Postural stabilization for the control of touching. Hum Mov Sci, 1999, 18: 795–817. [CrossRef]
16) Wulf G, Prinz W: Directing attention to movement effects enhances learning: a review. Psychon Bull Rev, 2001, 8: 648–660. [Medline] [CrossRef]
17) Cheng PT, Wu SH, Liaw MY, et al.: Symmetrical body-weight distribution training in stroke patients and its effect on fall prevention. Arch Phys Med Rehabil, 2001, 82: 1650–1654. [Medline] [CrossRef]
18) Sahrmann SA: Diagnosis and treatment of movement impairment syndromes. St. Louis: Mosby, 2002, pp 135–143.
19) Regnaux JP, Roberston J, Smail DB, et al.: Human treadmill walking needs attention. J Neuroeng Rehabil, 2006, 3: 19. [Medline] [CrossRef]
20) Salbach NM, Mayo NE, Wood-Dauphinee S, et al.: A task-orientated intervention enhances walking distance and speed in the first year post stroke: a randomized controlled trial. Clin Rehabil, 2004, 18: 509–519. [Medline] [CrossRef]
21) Dean CM, Richards CL, Malouin F: Walking speed over 10 metres overestimates locomotor capacity after stroke: a systemic review. Clin Rehabil, 2001, 15: 415–421. [Medline] [CrossRef]
22) Morioka S, Hiyamizu M, Yagi F: The effects of an attentional demand tasks on standing posture control. J Physiol Anthropol Appl Human Sci, 2005, 24: 215–219. [Medline] [CrossRef]
23) Vereijken B, Whiting HT, Beek WJ: A dynamical systems approach to skill acquisition. Q J Exp Psychol A, 1992, 45: 323–344. [Medline] [CrossRef]