J. Phys. Ther. Sci.
27: 1173–1176, 2015

Original Article

The relationship between motor recovery and gait velocity during dual tasks in patients with chronic stroke

Kyoung Bo Lee, PT, PhD[1)], Jang Hwan Kim, PT, CPO, PhD[2)], Kang Sung Lee, PT, CPO, PhD[2)*]

[1)] *St. Vincent Hospital, Republic of Korea*
[2)] *Department of Prosthetics and Orthotics, Hanseo University: 46 Hanseo 1-ro, Haemi-myun, Seosan-si, Chungcheongnam-do 356-706, Republic of Korea*

Abstract. [Purpose] The aims of this study were to identify the relationship between motor recovery and gait velocity during dual tasks in patients with chronic stroke and determine automatic gait ability following stroke. [Subjects and Methods] Thirty-three outpatients and twelve healthy subjects participated in a cross-sectional assessment. Community ambulation was assessed using a self-administered questionnaire. Outcome measures included the Motricity index, Berg Balance Scale, and gait speed under three conditions (self-paced ambulation for 10 m, ambulation while performing dual cognitive tasks, and ambulation while performing dual manual tasks). Gait automaticity was calculated. [Results] No significant differences were observed for muscle strength or balance between the limited community ambulation and the community ambulation groups. However, a significant difference in gait velocity was observed between the groups under the three conditions. In particular, a significant difference was detected only in the limited community ambulation group depending on the level of motor function recovery during cognitive and manual dual task ambulation. Additionally, we revealed that the community ambulation group had a lower level of gait automaticity compared with that in the normal group. [Conclusion] Our results show the influence of motor recovery on the change in gait velocity depending on the task if a patient is limitedly ambulatory. We revealed that community ambulators did not have a sufficient level of gait automaticity.
Key words: Chronic stroke, Dual task walking, Gait automaticity

(This article was submitted Oct. 27, 2014, and was accepted Dec. 11, 2014)

INTRODUCTION

Relearning community ambulation is a general rehabilitation goal for patients who have suffered from stroke. It is particularly important to recover independent, safe, fast, and sustainable ambulation ability[1)]. Perry et al. suggested 0.8 m/s as the mean gait velocity for community ambulation[2)]. If ambulation in an outside environment is a goal of rehabilitation, the focus should be on gaining proper gait velocity during rehabilitation. Gait velocity is an objective and sensitive tool that represents ambulatory changes in patients with stroke[3)]. However, community ambulation is the ability to ambulate while performing other tasks in a complex environment[4)].

After a stroke, the automaticity of postural control decreases, and the central nervous system requires more attention and resources to restructure postural control[5)]. Automaticity appears when cognitive attention is rarely required because of the ability to perform other tasks well at the same time[6)]. Cognitive processing can be used to improve poor control, and task performance becomes more proficient and automatic through repetition. A common method used to quantify the automaticity of motor skills is the dual- or multitask paradigm[7)]. The dual-task paradigm is the primary approach study of the interaction between cognitive processing and motor behavior[8)]. Moreover, gait training requires various tasks to be performed simultaneously by patients with stroke[4, 9–11)].

As recovery of gait ability and acquiring related factors have been emphasized, interest in gait training with the aim of community ambulation for mobility and advancement in society has increased[12)]. Lord et al. reported that 75% of patients with stroke state that the ability to walk freely around the community is a very important and necessary factor[12)]. As many activities of daily living include various exercise components, an evaluation of dual-task performance would provide a better functional daily life ability index compared with that of a single-task condition[13)]. However, an insufficient number of studies are available on what types of patient induce dual-task interference or what kind of damage interferes with dual tasks.

Improvement in gait velocity occurs through proficient use of already damaged exercise patterns. Therefore, it does not mean recovery of motor coordination[14)]. There is little evidence that gait ability can be improved in patients with chronic stroke by recovering complex motor coordination. Therefore, the purpose of this study was 1) to investigate the relationship between motor recovery and gait velocity during

*Corresponding author. Kang Sung Lee (E -mail: cpo114@hanseo.ac.kr)

©2015 The Society of Physical Therapy Science. Published by IPEC Inc. This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (by-nc-nd) License <http://creativecommons.org/licenses/by-nc-nd/3.0/>.

dual tasks in patients with chronic stroke and 2) to confirm whether normal automatic gait ability can be reacquired.

SUBJECTS AND METHODS

We conducted a cross-sectional assessment of outpatients at St. Vincent's Hospital of the Catholic University of Korea who were diagnosed with hemiplegia after acquiring their consent. The participants included 33 subjects in the patient group and 12 in the normal control group. We chose subjects who could walk at least 15 m without help, those who had a stroke > 6 months ago, those who had sufficient hearing and visual abilities to perform the task requirements, those who had the ability to understand the tasks through oral direction, and those who scored > 24 points on the Mini-Mental State Examination (MMSE) to control for the effect of cognitive skills on task performance. This study was conducted with subjects admitted to St. Vincent's Hospital of the Catholic University of Korea. It followed the principles of the Declaration of Helsinki, and all patients gave informed consent.

This study classified the independent community ambulation group according to a survey completed based on patient self-judgment[12]. Patients classified as level 4 according to Lord's classification were classified as the community ambulation group, and those classified as levels 1–3 were classified as the limited community ambulation group. We evaluated the effect of muscular strength on gait velocity in normal control and patient groups[15], including balancing ability, Brunnstrom's functional recovery level, and three conditions. Muscular strength was evaluated using the Motricity Index. This is a reliable method when evaluating paralysis in patients with stroke. We only used the lower extremity strength score. We evaluated 14 functional movements for dynamic balancing ability using the Berg Balance Scale (BBS) and added each performance ability score. The reliability of the BBS for stroke survivors has been documented[16]. We used six of Brunnstrom's functional recovery levels[17]. Lower extremity function of the proximal parts of the body was classified into poor recovery for recovery levels 3 and 4 and good recovery for recovery levels 5 and 6. In particular, we used Brunnstrom's evaluation tool, as it reflects motion control ability, and is a good clinical tool for evaluation of the quality of movements[18]. The three conditions for evaluation of gait velocity included ambulation under normal gait velocity, ambulation while performing dual cognitive tasks, and ambulation while performing dual manual tasks[7]. Gait velocity was measured as the time taken to walk 10 m. Considering the acceleration and deceleration phases, we added 2.5 m to the start and end points, and the subjects walked 15 m without assistance. We used a color distinction task as the dual cognitive task. The study subjects were presented with a task orally by an evaluator. They were asked to answer "yes" for "red" and "no" for "blue." The evaluator conducted the task at 3-s intervals behind the subjects to avoid disturbing their ambulation. They sat down and understood the tasks before ambulation. The subjects were asked to fill a 15-cm-tall cup with water 1 cm from the top and walk with the cup using their normal-side hand for the dual manual task. They were asked not to spill the water. When they failed, the test was conducted again. Under all conditions, ambulation was performed twice, and we used the mean value of the two attempts. Gait automaticity was calculated by dividing the dual-task gait velocity by the normal gait velocity[6].

Table 1. General characteristics of the study subjects

	Limited community ambulators (n = 20)	Community ambulators (n = 13)	Normal ambulators (n = 12)
Gender (n, %)			
Male	11 (24.4%)	7 (15.6%)	1 (2.2%)
Female	9 (20.0%)	6 (13.3%)	11 (24.4)
Side of stroke (n, %)			
Right hemisphere	10 (30.3%)	7 (21.2%)	
Left hemisphere	10 (30.3%)	6 (18.2%)	
Stroke type (n, %)			
Infarction	9 (27.3%)	4 (12.4%)	
Hemorrhage	11 (33.3%)	9 (27.3%)	
Age (yrs)	52.6 ± 10.4	49.0 ± 13.4	54.7 ± 7.6
Body weight (kg)	63.5 ± 12.3	62.5 ± 10.4	60.9 ± 8.1
Height (cm)	164.2 ± 6.6	164.8 ± 7.9	159.2 ± 6.3
Time from stroke (y)	5.9 ± 6.9	4.2 ± 2.6	
MMSE	27.2 ± 2.1	28.0 ± 2.3	

Fisher's exact test was used for normal variables, and the independent t-test and one-way analysis of variance were used for the equivalence check of continuous variables. Balancing ability and the Motricity Index for the limited community ambulation and community ambulation groups were calculated using the independent t-test. The gait abilities of the three groups, including the normal group, were assessed using a multivariate analysis of variance. We conducted post hoc tests with Bonferroni's method. In addition, we used the Mann-Whitney U-test and independent t-test to confirm the difference in gait abilities between the groups based on neurological recovery level and the level of gait automaticity in the community ambulation and normal groups, respectively. The results were analyzed using SPSS ver. 12.0 (SPSS Inc., Chicago, IL, USA). A p-value < 0.05 was considered to indicate significance.

RESULTS

Among the subjects who experienced chronic stroke, 20 were limited ambulation patients, and 13 were ambulation patients (Table 1). There were 18 males and 15 females in the patient group and 1 male and 11 females in the normal group. In total, 17 patients had right-sided hemiplegia, and 16 had left-sided hemiplegia. In addition, 13 were diagnosed with a cerebral infarction, and 20 were diagnosed with cerebral hemorrhage. The durations of the diseases were 5.9 ± 6.9 years and 4.2 ± 2.6 years, respectively. The MMSE scores were 27.2 ± 2.1 and 28.0 ± 2.3.

The limited community ambulation group scored 49.7 ± 14.9 on the Motricity Index, whereas the community ambulation group scored 59.1 ± 15.8 ($p > 0.05$). The limited community ambulation group scored 43.1 ± 8.3 on the balancing ability test in the BBS, whereas the community ambulation group scored 47.8 ± 5.3 ($p > 0.05$) (Table 2).

Table 2. Muscular strength and balancing ability according to community ambulation level (mean ± SD)

	Limited community ambulators	Community ambulators	Significant difference
Motricity index	49.7 ± 14.9	59.1 ± 15.8	
Berg balance scale	43.1 ± 8.3	47.8 ± 5.3	

Table 5. Comparison of gait automaticity between the community ambulation and normal groups (mean ± SD)

	Community ambulators	Normal ambulators	Significant difference
Automaticity (CT)	0.83 ± 0.02	0.96 ± 0.03	*
Automaticity (MT)	0.72 ± 0.04	0.98 ± 0.03	*

*$p < 0.05$. CT: cognitive task; MT: manual task

Table 3. Walking speed under the three conditions (mean ± SD)

	Limited community ambulators	Community ambulators	Normal ambulators
Self-paced walking speed (m/s)	0.56 ± 0.06	0.83 ± 0.08*	1.23 ± 0.08†
Cognitive dual-task walking (m/s)	0.52 ± 0.06	0.69 ± 0.07*	1.19 ± 0.08†
Manual dual-task walking (m/s)	0.47 ± 0.05	0.59 ± 0.06*	1.20 ± 0.06†

*$p < 0.05$: limited community ambulators vs. community ambulators.
†$p < 0.05$: community ambulators vs. normal ambulators.

Table 4. Gait speed according to motor recovery level (mean ± SD)

	Limited community ambulators			Community ambulators		
	Poor recovery	Good recovery	Significant difference	Poor recovery	Good recovery	Significant difference
Self-paced walking speed (m/s)	0.50 ± 0.27	0.76 ± 0.06		0.65 ± 0.03	1.03 ± 0.28	
Cognitive dual-task walking (m/s)	0.46 ± 0.24	0.75 ± 0.08	*	0.57 ± 0.28	0.82 ± 0.33	
Manual dual-task walking (m/s)	0.41 ± 0.23	0.68 ± 0.08	*	0.51 ± 0.26	0.68 ± 0.18	

*$p < 0.05$

A significant difference was observed in gait velocity between the groups under the three conditions. Moreover, all three groups showed significant differences in gait velocity in a post hoc test (Table 3).

No significant difference was observed in self-paced gait velocity depending on motor function recovery when comparing gait velocity in a subgroup of the two groups. No significant difference was observed during cognitive and manual dual-task ambulation in the community ambulation group depending on the level of motor function recovery. However, a significant difference was observed in the limited community ambulation group depending on the level of motor function recovery (Table 4).

We also analyzed the level of gait automaticity in patients with chronic stroke who were capable of community ambulation. The results showed that the community ambulation group had a lower level of gait automaticity compared with the normal group (Table 5).

DISCUSSION

The focus of this study was on analysis of the difference in ambulation tasks depending on motor recovery ability and on understanding the recovery of gait automaticity ability in patients with chronic stroke. The results confirmed that the difference in gait velocity is an important variable for community ambulation. The gait velocities of the limited community ambulation and community ambulation groups were 0.56 and 0.83 m/s, respectively, whereas the gait velocity of the normal group was 1.23 m/s. These results are in agreement with those of Perry et al., who suggested that the average community gait velocity is ≥ 0.8 m/s. The normal group showed no difference in velocity, whereas the stroke patient group showed reduced velocity when performing dual manual tasks compared with that when performing dual cognitive tasks. Plummer-D'Amato and Altmann conducted a pilot study confirming the correlation between motor function and dual-task interference (DTI) depending on the task. However, gait velocity during DTI is correlated with motor level only in a speech task[19]. Although our study investigated working memory and manual tasks, we confirmed a difference in gait velocity depending on motor ability.

Although differences in mean muscle strength and balancing ability were observed between the two groups, they were not significant. However, the level of difference was a similar, with a minimal detectable change of 5[20]. Although we did not verify a significant difference in self-paced gait speed in the limited community ambulation group depending on motor recovery, a significant difference was detected in terms of dual-task gait velocity. This result indicates that motor recovery function has a significant influence on ambulation when a subject has limited community ambulation and a low gait velocity.

Moreover, we evaluated gait automation abilities of patients with stroke who were capable of community ambulation. Automation ability explains the performance of well-learned exercise techniques, and we used a method that is clinically easy to apply. A previous study suggested an ambulation automation ability level > 90%. However, our patients with stroke who were capable of community ambulation demonstrated only 83% for cognitive tasks and 72% for manual tasks. These levels were lower than those of normal individuals, which were 96% and 98%, indicating that gait automaticity had not been relearned completely. This result is in agreement with a study by Bowen et al., who suggested that ambulation is not completely re-automated[10]. We only considered cognitive ability when selecting subjects. However, it will be necessary to further investigate whether reduced ambulation automaticity is the result of stroke, age, cognitive ability, or other factors.

Kautz et al. could not demonstrate recovery of motor control ability simply by increased gait velocity after stroke, as the skilled use of damaged exercise patterns was evident. This indicates increased muscle strength and endurance, as well as improved skills with respect of previously used patterns. In community ambulation group, there was no significant difference among the three gait velocities, depending on the motor recovery level. However, the limited community ambulation group had a different gait velocity depending on the motor recovery level, indicating that the motor recovery level in the limited community ambulation group may be a major limiting factor for patients with chronic stroke in relearning gait ability.

It is necessary to emphasize the cognitive resources required during ambulation after a stroke. When the level of processing requirement for two tasks exceeds the cognitive system capacity, interference appears between the tasks. Therefore, the ability to perform one or two tasks decreases[21, 22]. All subjects showed decreases in gait velocity when they were performing dual tasks. In particular, the decrease in gait velocity during the manual task was more distinct compared with that during the cognitive task, even though we did not test the results statistically. Dual-task interference is greater when a manual task is performed. Another possibility is that the manual task interferes with ambulation, as it uses the same pathways as ambulation.

Our results must be interpreted with caution due to our small sample size. Moreover, the higher proportion of female subjects in the normal group may have caused a homogeneity problem in the study group. In addition, analyses of gait ability and motor recovery compared only the level of lower limb motor recovery. As ambulation is a cooperative movement of the entire body, upper limb and trunk recovery levels should have been considered. The completeness of dual-task performance should have been considered, rather than simply considering changes in gait velocity. Theoretically, other factors, such as physical, cognitive, and mental factors (lack of confidence or fear), could have influenced gait ability and community ambulation.

We analyzed the influence of motor recovery on the change in gait velocity depending on the task. It is necessary to analyze the differences in adaptive changes in ambulation factors depending on the task, as well to consider the completeness of task performance, through a more precise spatial-temporal gait analysis.

REFERENCES

1) Hesse S: Gait training after stroke: a critical reprisal. Ann Readapt Med Phys, 2006, 49: 621–624. [Medline] [CrossRef]
2) Perry J, Garrett M, Gronley JK, et al.: Classification of walking handicap in the stroke population. Stroke, 1995, 26: 982–989. [Medline] [CrossRef]
3) Lord SE, Rochester L: Measurement of community ambulation after stroke: current status and future developments. Stroke, 2005, 36: 1457–1461. [Medline] [CrossRef]
4) Yang YR, Wang RY, Chen YC, et al.: Dual-task exercise improves walking ability in chronic stroke: a randomized controlled trial. Arch Phys Med Rehabil, 2007, 88: 1236–1240. [Medline] [CrossRef]
5) Brown LA, Sleik RJ, Winder TR: Attentional demands for static postural control after stroke. Arch Phys Med Rehabil, 2002, 83: 1732–1735. [Medline] [CrossRef]
6) Paul SS, Ada L, Canning CG: Automaticity of walking-implications for physiotherapy practice. Phys Ther Rev, 2005, 10: 15–23. [CrossRef]
7) Canning CG, Ada L, Paul SS: Is automaticity of walking regained after stroke? Disabil Rehabil, 2006, 28: 97–102. [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) An HJ, Kim JI, Kim YR, et al.: The effect of various dual task training methods with gait on the balance and gait of patients with chronic stroke. J Phys Ther Sci, 2014, 26: 1287–1291. [Medline] [CrossRef]
10) 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]
11) Shim SH, Yu JH, Jung JH, et al.: Effects of motor dual task training on spatio-temporal gait parameters of post-stroke patients. J Phys Ther Sci, 2012, 24: 845–848. [CrossRef]
12) Lord SE, McPherson K, McNaughton HK, et al.: Community ambulation after stroke: how important and obtainable is it and what measures appear predictive? Arch Phys Med Rehabil, 2004, 85: 234–239. [Medline] [CrossRef]
13) 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]
14) Kautz SA, Duncan PW, Perera S, et al.: Coordination of hemiparetic locomotion after stroke rehabilitation. Neurorehabil Neural Repair, 2005, 19: 250–258. [Medline] [CrossRef]
15) Cameron D, Bohannon RW: Criterion validity of lower extremity Motricity Index scores. Clin Rehabil, 2000, 14: 208–211. [Medline]
16) Berg K, Wood-Dauphinee S, Williams JI: The Balance Scale: reliability assessment with elderly residents and patients with an acute stroke. Scand J Rehabil Med, 1995, 27: 27–36. [Medline]
17) Brunnström S: Movement Therapy in Hemiplegia: A Neurophysiological Approach. New York: Harper and Row, 1970.
18) Chen CL, Wong MK, Chen HC, et al.: Correlation of polyelectromyographic patterns and clinical upper motor neuron syndrome in hemiplegic stroke patients. Arch Phys Med Rehabil, 2000, 81: 869–875. [Medline] [CrossRef]
19) Plummer-D’Amato P, Altmann LJ: Relationships between motor function and gait-related dual-task interference after stroke: a pilot study. Gait Posture, 2012, 35: 170–172. [Medline] [CrossRef]
20) Hiengkaew V, Jitaree K, Chaiyawat P: Minimal detectable changes of the Berg Balance Scale, Fugl-Meyer Assessment Scale, Timed “Up & Go” Test, gait speeds, and 2-minute walk test in individuals with chronic stroke with different degrees of ankle plantarflexor tone. Arch Phys Med Rehabil, 2012, 93: 1201–1208. [Medline] [CrossRef]
21) Haggard P, Cockburn J, Cock J, et al.: Interference between gait and cognitive tasks in a rehabilitating neurological population. J Neurol Neurosurg Psychiatry, 2000, 69: 479–486. [Medline] [CrossRef]
22) McCulloch K: Attention and dual-task conditions: physical therapy implications for individuals with acquired brain injury. J Neurol Phys Ther, 2007, 31: 104–118. [Medline] [CrossRef]