한국전문물리치료학회지 2014년 21권 4호 34-39
Phys Ther Korea 2014;21(4):34-39
ISSN (Print) 1225-8962, ISSN (Online) 2287-982X
http://dx.doi.org/10.12674/ptk.2014.21.4.034

Effects of Cognitive-Motor Interference on Cognitive Tasks Requiring Different Types of Concentration During Preferred and Fast Walking in Stroke Patients

Yeon-seung Choo[1], BHSc, PT, Mi-sun Kim[1], MSc, PT, Jong-duk Choi[2], PhD, PT
[1]Dept. of Physical Therapy, The Graduate School, Daejeon University
[2]Dept. of Physical Therapy, College of Natural Science, Daejeon University

Abstract

The purpose of this study was to examine the effect of three cognitive tasks on gait at a preferred walking speed, and at a fast speed, using dual-task methodology. A total of 29 stroke patients participated in the study. All 29 subjects performed 2 motor tasks (10-meter walk task and timed up and go task each at a preferred and a fast speed) and three cognitive tasks [Stroop, word list generation (WLG), serial subtraction (SS)] under dual-task conditions [cognitive-motor interference (CMI)] in a randomized order. Gait speeds were measured in six different conditions. A repeated-measure analysis of variance was employed to compare the results of the Stroop training, WLG, and SS tasks during preferred and fast walking. A Bonferroni adjustment use for post hoc analysis. The level of statistical significance was set at $\alpha=.05$. A CMI effect occurred for performance of a 10-meter walking task at two different speed and a cognitive task ($p<.05$). Stroop had a significantly greater effect than SS and WLG ($p<.05$). The timed up and go task was affected when performed with fast walking speed during Stroop cognitive task ($p<.05$), but was not affected if performed with preferred walking speed during a cognitive task ($p>.05$). This study showed that CMI of Stroop can be used as a rehabilitation program for stroke patients.

Key Words: Cognitive-motor interference; Sensory; Stroke.

Introduction

A stroke refers to neurological dysfunction caused by local abnormalities in brain tissues due to the continuous insufficient supply of oxygen and glucose following a cerebrovascular event (Jørgensen et al, 1997). Cognitive functions refer to a person's ability to understand events that occur in daily life and adapt to his/her circumstances while starting, planning, and thinking about actions and resolving problems. Cognitive areas include concentration, memory, systematization ability, problem-solving ability, abstraction ability, and the use of languages (Campbell et al, 1990). Movements cannot be performed without prior intention. Thus, cognitive processes are an indispensable element in motor control.

Patients with reduced cognitive abilities after a stroke do not have the full use of their cognitive functions for motor learning during rehabilitation training (Mulder, 2007). They cannot actively participate in physical training and may experience temporary or permanent loss of mechanisms governing normal postural control, such as walking and dual tasks, that were processed automatically before the stroke (Huxhold et al, 2006).

Yogev-Seligmann et al (2008) reported that those patients treated with rehabilitation training showed high levels of activation in the brain area related to cognitive functions. Rehabilitation of stroke patients focuses on physical therapy programs, with the aim of recovering walking functions. Increases in cognitive-motor interference (CMI), which is exhibited by stroke patients

Corresponding author: Jong-duk Choi choidew@dju.kr

ISSN (Print) 1225-8962, ISSN (Online) 2287-982X
http://dx.doi.org/10.12674/ptk.2014.21.4.034

with reduced cognitive functions while walking, result from a reduced ability to process cognitive and motor functions at the same time (Regnaux et al, 2005).

CMI occurs when individuals simultaneously perform two or more mutually disturbing tasks, and it is related to phenomena that occur during the simultaneous performance of cognitive and motor tasks. Typically, this interference occurs due to conflicting demands for attention capacity. According to one study, the interference occurs because the simultaneous performance of two tasks requires mental efforts beyond a maximum operable capacity (Wollacott and Shumway-Cook, 2002). CMI is observed in individuals of all ages, but it has been reported more often in elderly people (Dubost et al, 2008) and stroke patients (Yang et al, 2007). Regaining mobility is essential for independence in daily life and the first goal in the treatment of stroke patients.

Dual tasks are those that require individuals to perform complex tasks at the same time (Silsupadol et al, 2009). The role of cognition and concentration is emphasized in dual-task methods, including a cognitive task in postural and gait control (Silsupadol et al, 2009).

CMI during gait leads to changes in gait patterns due to walking speed decreases, gait changes, or reduced abilities to carry out cognitive tasks, such as visual motor processing and language fluency. The existence of CMI during the gait of stroke patients has not been investigated in detail thus far. Only a limited number of previous studies have dealt with the effects of CMI (Lord et al, 2006). Moreover, most studies of CMI have focused on preferred walking speeds (Bowen et al, 2001) rather than fast walking speeds. Therefore, the purpose of this study was to identify the effects of CMI when patients simultaneously carried out cognitive tasks requiring different types of concentration during preferred and fast walking.

Methods

Subjects

Twenty-nine subjects participated in this study. The participants included 18 males and 11 females. The mean age of the study participants was 59.9±9.8 years. The mean onset of the stroke was 20 months ranging 6 to 50 months. They satisfied the following conditions: 1) diagnosed with a stroke six months ago or earlier, 2) capable of walking a 14-meter distance using a walking assistance device, 3) scored at least 24 points in the Korean version of the Mini-Mental State Examination and thus were able to follow the researcher’s instructions.

Experimental procedures

The experiment was conducted with 29 stroke patients. The subjects first sat on a chair and performed three cognitive training tasks. They then walked a 14-meter distance three times at each speed (preferred and fast). In the test, the average speed during a 10-meter walk was measured. Next, the subjects were instructed to perform Stroop training (ST), word list generation (WLG), and serial subtraction (SS) while walking at the fast speed. The walking speed was measured three times, and the average was recorded. They also performed ST, WLG, and SS simultaneously during their preferred walking. The walking speed was measured three times, and the average was recorded. The timed up and go (TUG) test was also conducted using the same method as in the 10-meter walk test. The subjects started the walking and cognitive tasks at the same time, and they were instructed to do their best to perform the three cognitive tasks while maintaining their preferred walking speeds. A larger CMI value in the experiment indicated a corresponding higher level of inference between the motor and cognitive tasks.

Evaluation tools and methods 10-meter walking test

The 10-meter walking test is generally used as a walking speed test for patients with neurological damage. The subjects were instructed to walk in a straight line for 12 meters. Considering the accel-

ISSN (Print) 1225-8962, ISSN (Online) 2287-982X
http://dx.doi.org/10.12674/ptk.2014.21.4.034

eration and deceleration sections, the time when each subject passed the 10-meter section, excluding 2 meters at the start and end of the walking line, was calculated in seconds and recorded (Yang et al, 2008). The subjects had to walk at both their preferred and fast speed. For each subject, walking at each speed was measured three times, and the average was recorded.

Timed up and go (TUG) test

The TUG was used to test the subject's functional walking ability. After each subject sat on a chair with a backrest, he/she got up and walked to a 3-meter point, returned, sat on the chair again, and leaned against it. The time taken for this entire process was calculated (Podsiadlo and Richardson, 1991). The subjects walked at both their preferred and fast speed. For each subject, walking at each speed was measured three times, and the average was recorded.

Training methods

Stroop training (ST)

ST is frequently used as part of a battery of cognitive tests, particularly to measure control functions, mental control, and flexible responses to functions that activate the frontal lobe (Goethals et al, 2004). This test shows words written in various colored inks to participants and asks them to name the color of each ink.

Word list generation (WLG)

Subjects in the WLG test are instructed to create words starting with specific letters, and then the total number of words created during 10 seconds is calculated (Dubost et al, 2008). For example, the present study asked the subjects to produce words starting with "ㄱ," such as 가위 and 고구마. In this study, the cognitive test focused on language fluency.

Serial subtraction (SS)

The SS cognitive task focuses on memory and instructs participants to subtract a certain figure from a certain double-digit number in a reverse manner (Beauchet et al, 2005). For example, this study asked the subjects to subtract each number by three starting from 100 or 50, and the number of accurate answers during 10 seconds was recorded.

Data analysis

This study used SPSS ver. 18.0 (SPSS Inc., Chicago, IL, USA) for all the statistical analyses. The Shapiro-Wilk test was performed for a normality test. A repeated-measure analysis of variance was used to compare the results of the ST, WLG, and SS tasks during preferred and fast walking. A Bonferroni adjustment was used for post hoc analysis. In all analyses, the level of statistical significance was set at α=.05.

Results

The walking time was measured while the 10-meter walking test and the cognitive tasks were undertaken simultaneously. The results showed statistically significant increases when the subjects performed the ST, WLG, and SS simultaneously while walking at their preferred ($F=78.76$, $p<.05$) and fast speed ($F=62.11$, $p<.05$). This points to interference between motor and cognitive function and increased walking times when cognitive tasks are undertaken during walking. ST had a significantly greater effect than serial subtraction (SS) and word list generation (WLG) (Table 1).

The walking time was measured while the TUG and the cognitive tasks were undertaken simultaneously. The simultaneous application of the WLG, SS, and ST during walking at fast speed resulted in statistically significant increases ($F=61.39$, $p<.05$), indicating the occurrence of CMI. The timed up and go (TUG) task was affected when performed with fast walking speed only during Stroop cognitive task ($p<.05$).

ISSN (Print) 1225-8962, ISSN (Online) 2287-982X
http://dx.doi.org/10.12674/ptk.2014.21.4.034

Table 1. Comparison of the speed of 10-meter walk task in three different CMI conditions

	Word list generation	Serial subtraction	Stroop training	p
FAST[a]	22.95±14.19	24.25±17.34	26.35±19.14*†	.00
PREF[b]	28.06±16.19	27.63±17.36	30.75±19.26*†	.02

[a]fast walking speed, [b]preferred walking speed, *significant difference compared with word list generation,
† significant difference between serial subtraction and Stroop training.

Table 2. Comparison of the speed of TUG walk task in three different CMI conditions

	Word list generation	Serial subtraction	Stroop training	p
FAST[a]	27.02±18.63	28.04±19.98	32.38±23.15*†	.03
PREF[b]	32.45±24.38	32.30±22.00	35.90±28.45	.43

[a]fast walking speed, [b]preferred walking speed, *significant difference compared with word list generation,
† significant difference between serial subtraction and Stroop training.

However, there were no statistically significant differences ($F=56.55$, $p>.05$) during the simultaneous application of the WLG, SS, and ST while walking at preferred speeds (Table 2).

Discussion

This study was conducted to identify CMI during the performance of various cognitive tasks at different waling speeds. Research has shown that strategic methods are employed to improve the performance of dual tasks (Bherer et al, 2005; Ruthruff et al, 2006) and that improvements in the performance of these tasks is achieved through dual-task training, not through single task training (Silsupadol et al, 2009).

Interference during dual exercises is regarded as important for the following reasons: First, the simultaneous performance of two exercise tasks can be used as a treatment method itself. Second, patients exhibit various levels of interference during dual tasks. Therefore, each individual's ability to perform exercise tasks can influence his/her treatment plan. Third, most daily activities involve various exercise elements. For this reason, tests of the performance of dual tasks may provide better indicators of their ability to carry out functional activities of daily living compared to tests of their performance of single tasks (Yang et al, 2007).

In this study, the subjects took part in the 10-meter walking test at preferred and fast speed while performing the ST, WLG, and SS tasks. They also completed the TUG test in the same manner as in the 10-meter walking test. When the subjects performed the ST, WLG, and SS at fast speed during the 10-meter walk, gradual speed decreases were observed. When they performed the three cognitive tasks during the 10-meter walk at their preferred speeds, speed decreases were also discovered. This suggests that the performance of cognitive tasks during walking can slow down walking speeds and expose walkers to higher risks by causing cognitive distraction in response to external environments (Hatfield and Murphy, 2007).

O'Shea et al (2002) examined changes in gait features, such as walking speed and stride distance, during the performance of cognitive tasks, including subtraction during standing and walking, by patients with Parkinson's disease who had reduced motor abilities. They confirmed improvements in the performance of cognitive tasks and overall walking ability and declines in the number of wrong answers. Stroke patients with reduced cognitive functions or walking difficulties experience declines in the ability to process cognitive and motor functions simultaneously. Therefore, they show increases in CMI (Regnaux et al, 2005). Eventually, this leads the patients to avoid dual-task training for safe walking, and they experience substantial difficulties in their daily and social life (Plummer-D'Amato et al, 2008). One study that reported CMI in stroke patients during walking stressed the necessity for walking speed changes, depending on the conditions of CMI after the stroke (Dennis et al, 2009). In the present study, speed decreases were observed when the patients underwent the TUG test at fast speed while performing the three cognitive tasks, indicating the occurrence of CMI during fast walking while performing cognitive tasks. However, in the TUG test, the walking speed was statistically significant differences only in the WLG and SS tasks. On the other hand, the walking speed during the simultaneous performance of the ST, WLG, and SS at the patients' preferred speeds increased, but this result was not statistically significant. One study where the subjects were trained to walk while performing SS and calls in a reverse manner found no differences between the test group and control groups in improved walking speeds and the number of strides according to time (Han, 2012). This may have been due to the absence of a curved path in the intervention among the components of the study's gait training program. In the present study, when the subjects completed the TUG at their preferred speeds while performing the various cognitive tasks, the effects of CMI were not statistically significant. This was probably largely due to the subjects losing their concentration during walking because of their fear of walking around a corner.

A number of existing studies trained patients to perform walking and cognitive tasks simultaneously. However, only a few studies have identified the most effective dual tasks. Therefore, this study examined the most effective task among various cognitive tasks. The method used to measure the effects of CMI in this study is likely to be applicable as an intention method in gait training.

The limitation of this study is the small number of subjects, which makes it difficult to generalize the study's findings. Additional studies should identify whether the application of consistent training produces any differences in CMI. Based on the results of this study, the simultaneous performance of walking and ST may be used for cognitive-motor dual-task training in rehabilitation programs aimed at stroke patients.

Conclusion

This study examined stroke patients cognitive exercise interference when WLG, SS, and ST tasks were applied at the same time while their walking at a fast speed and a preferred speed. The result was that time increased while both walking tasks and stroop cognitive tasks were undertaken simultaneously. Therefore, based on this study results, simultaneous gait and Stroop training may be used as a training program suitable for stroke patients' rehabilitation purposes in dual-task cognitive exercise training when treating them.

References

Beauchet O, Dubost V, Aminian K, et al. Dual-task-related gait changes in the elderly: Does the type of cognitive task matter? J Mot Behav. 2005;37(4):259-264.

Bherer L, Kramer AF, Peterson MS, et al. Training effects of dual-task performance: Are there age-related differences in plasticity of attentional control? Psychol Aging. 2005;20(4):695-709.

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(4):319-323.

Campbell AJ, Borrie MJ, Spears GF, et al. Circumstances and consequences of falls experienced by a community population 70 years and over during a prospective study. Age Ageing. 1990;19(2):136-141.

Dennis A, Dawes H, Elsworth C, et al. Fast walking

ISSN (Print) 1225-8962, ISSN (Online) 2287-982X
http://dx.doi.org/10.12674/ptk.2014.21.4.034

under cognitive-motor interference conditions in chronic stroke. Brain Res. 2009;1287:104-110. http://dx.doi.org/10.1016/j.brainres.2009.06.023

Dubost V, Annweiler C, Aminian K, et al. Stride-to-stride variability while enumerating animal names among healthy young adults: Result of stride velocity or effect of attention-demanding task? Gait Posture. 2008;27(1):138-143.

Goethals I, Audenaert K, Jacobs F, et al. Cognitive neuroactivation using SPECT and the stroop colored word test in patients with diffuse brain injury. J Neurotrauma. 2004;21(8):1059-1069.

Hatfield J, Murphy S. The effects of mobile phone use on pedestrian crossing behaviour at signalized and unsingalized intersections. Accid Anal Prev. 2007;39(1):197-205.

Han MR. The studies of cognitive and walking ability under dual task training applying cognitive task in stroke patients. Naju, Dongsin University, Master Thesis. 2012.

Huxhold O, Li SC, Schmiedek F, et al. Dual-tasking postural control: Aging and the effects of cognitive demand in conjunction with focus of attention. Barain Res Bull. 2006;69(3):294-305.

Jørgensen HS, Nakayama H, Reith J, et al. Stroke recurrence: Predictors, severity, and prognosis. The copenhagen stroke study. Neurology. 1997; 48(4):891-895.

Lord SE, Rochester L, Weatherall M, et al. The effect of environment and task on gait parameters after stroke: A randomized comparison of measurement conditions. Arch Phys Med Rehabil. 2006;87(7):967-973.

Mulder T. Motor imagery and action observation: Cognitive tools for rehabilitation. J Neural Transm. 2007;114(10):1265-1278.

O'Shea S, Morris ME, Iansek R. Dual task interference during gait in people with parkinson disease: Effects of motor versus cognitive secondary tasks. Phys Ther. 2002;82(9):888-897.

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(4):683-688.

Podsiadlo D, Richardson S. The timed up & go: A test of basic functional mobility for frail elderly persons. J Am Geriatr Soc. 1991;39(2):142-148.

Regnaux JP, David D, Daniel O, et al. Evidence for cognitive processes involved in the control of steady state of walking in healthy subjects and after cerebral damage. Neurorehabil Neural Repair. 2005;19(2):125-132.

Ruthruff E, Van Selst M, Johnston JC, et al. How does practice reduce dual-task interference: Integration automatization or just stage-shortening? Psychol Res. 2006;70(2):125-142.

Silsupadol P, Lugade V, Shumway-Cook A, et al. Training-related changes in dual-task walking performance of elderly persons with balance impairment: A double-blind, randomized controlled trial. Gait Posture. 2009;29(4):634-639. http://dx.doi.org/10.1016/j.gaitpost.2009.01.006

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(3):381-387.

Woollacott M, Shumway-Cook A. Attention and the control of posture and gait: A review of an emerging area of research. Gait Posture. 2002;16(1):1-14.

Yang YR, Chen YC, Lee CS, et al. Dual task-related gait changes in individuals with stroke. Gait Posture. 2007;25(2):185-190.

Yang YR, Tsai MP, Chuang TY, et al. Virtual reality-based training improves community ambulation in individuals with stroke: A randomized controlled trial. Gait Posture. 2008;28(2):201-206. http://dx.doi.org/10.1016/j.gaitpost.2007.11.007

Yogev-Seligmann G, Hausdorff JM, Giladi N. The role of executive function and attention in gait. Mov Disord. 2008;23(3):329-342.

This article was received September 30, 2014, was reviewed September 30, 2014, and was accepted November 10, 2014.