

Dual-task-related gait changes in individuals with stroke

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Abstract

Many daily activities require people to complete a motor task while walking. The purpose of this study was to analyze subjects' ability to perform motor tasks while walking. Subjects were classified into three different groups. The first group included 15 full community ambulators post-stroke. The second group included 15 least limited community ambulators post-stroke. The final group included 15 age-matched healthy subjects. Gait performance was measured under three different conditions: (1) preferred walking (single task); (2) walking buttoning up (buttoning task); (3) walking while carrying a tray with glasses (tray-carrying task). Gait velocity, cadence, stride time, stride length, temporal and spatial symmetry indices were examined with the GAITRite system. Our results showed that there were no significant differences between full community ambulators and control subjects for all gait variables. However, there were significant differences in dual-task-related gait decrement between the full community ambulators and control subjects. There were also significant differences in dual-task-related gait decrement between least limited community ambulators and control subjects. The findings of this study suggest that subjects with stroke including the full community ambulators have difficulty performing two motor tasks concurrently.

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1. Introduction

Many daily activities in human life require a person to complete several tasks concurrently. Under normal circumstances, people are able to perform motor tasks and higher cognitive functions at the same time. The simultaneous performance of two tasks can have a deleterious effect or dual-task decrement on balance control particularly in elders, due to a reduction, or misallocation of attentional resources [1]. It is possible that carrying out two different tasks simultaneously will be more compromised for people who have acquired neurological damage comparing to

elderly people. It has been demonstrated that substantial gait decrements during simultaneous attention to a variety of cognitive tasks have been shown by a group of severely injured neurological patients of mixed etiology [2]. Bowen et al. [3] reported that performing a cognitive task while walking adversely affected stroke patients' balance and gait velocity. Cockburn et al. [4] also found positive evidence of dual-task gait decrements when a cognitive task was performed concurrently in subjects after stroke.

Research into the extent to which different tasks can be performed concurrently without interfering with one another has tended to focus on competition between two cognitive tasks or between cognitive and motor activities, with less interest being shown in competition between two motor tasks. Dual motor interference may be of considerable clinical

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importance for several reasons. Firstly, a therapy regime itself involves concurrent performance of two motor tasks (for example, walking while playing ball). Secondly, the level of dual-task interference may vary between patients. Therefore, assessment of a person's dual-task performance could contribute to treatment planning. Thirdly, since many daily activities involve concurrent motor components, assessment of dual-task performance may provide a better index of functional daily ability comparing to traditional assessment of single motor task conditions. Given that no previous investigation has studied the effects of secondary motor task performance on stroke gait, the aim of the present study was to compare the ability of subjects with stroke and age-matched control subjects to perform motor tasks while walking. Moreover, the ambulation disability in the stroke population has been classified by Perry et al. [5]. Using this classification system, the present study differentiated the hemiparetic subjects to full community and least limited community ambulators by gait velocity and compared their gait decrements while performing a motor task concurrently.

2. Methods

2.1. Subjects

Thirty subjects with stroke (15 full community ambulators and 15 least limited community ambulators) were recruited from local participating hospitals. The full community ambulators according to Perry's classification system were defined as patients with minimum gait velocity of 80 cm/s [5]. Patients with gait velocity between 58 and 80 cm/s were defined as least limited community ambulators [5]. The age, sex, affected side, and onset time of hemiparesis were obtained from subject interviews. This information was checked against the medical records for accuracy. Inclusion criteria were an ability to walk 10 m independently without an assistive device, an ability to carry a tray with glasses using both hands, stable medical condition to allow participation with testing protocol, and adequate language comprehension to follow instructions given. Exclusion criteria included any neurological or musculoskeletal diagnosis that could account for postural instability. Furthermore, 15 healthy subjects matched for age were recruited from local community groups. By self-report, none of these healthy subjects had any neurological or balance disorders.

2.2. Study protocol

The study protocol was reviewed and approved by the Institutional Review Board. Prior to data collection, the purposes and procedures were fully explained, and informed consents were obtained from the subjects. Each subject was evaluated individually and tested following a standard protocol. Subjects were tested under two dual-task conditions and under control single-task condition, i.e., walking

without a concurrent task. Trial order was randomized to compensate for effects of practice and/or fatigue.

For each subject the gait performance was measured in three conditions: (1) preferred walking (single task); (2) walking buttoning up (buttoning task); (3) walking carrying a tray with glasses (tray-carrying task). The instructions for each test condition were as follows: (1) "Walk with your comfortable speed right to the end of the walkway." (2) "Walk with your comfortable speed right to the end of the walkway buttoning up four shirt buttons with your preferred hand(s)." (3) "Walk with your comfortable speed right to the end of the walkway carrying this tray and glasses in front of you with both hands." During the buttoning task subjects have to button up four buttons while walking otherwise the trial would be recorded as failure. For the tray-carrying task subjects have to keep the glasses on top of the tray without any dropping or else that would be considered as failed. To obtain representative samples, each test condition was repeated three successful times and the means of the three successful trials were used for further data analysis.

2.3. Measurement

Gait was measured using GAITRite (CIR Systems, USA), an instrumented walkway. The GAITRite system provided temporal (time) and spatial (distance) gait parameters via an electronic walkway connected to the serial port of a personal computer. The standard GAITRite walkway contained six sensor pads encapsulated in a roll-up carpet with an active area of 3.66 m long and 0.61 m width. As the subject walked through the walkway, the sensors captured each footfall as a function of time and transferred the gathered information to a personal computer to process the raw data into footfall patterns. The computer computed the temporal and spatial gait parameters. The validity and reliability of GAITRite system has been well established [6,7]. Subjects were asked to walk with their comfortable speed without assistive device through a 10 m hallway. The GAITRite walkway was placed in the middle of the 10 m hallway to eliminate the effect of acceleration or deceleration.

The temporal-spatial parameters recorded were: velocity (cm/s), cadence (steps/min), stride time (s), stride length (cm), affected (or left for control subjects) single-limb support (% of gait cycle), unaffected (or right for control subjects) single-limb support (% of gait cycle), affected (or left) step length (cm), and unaffected (or right) step length (cm). The symmetry index was calculated using the formula: unaffected (or right) side/affected (or left) side [8]. The temporal and spatial symmetry indices were derived from the single limb support (% of gait cycle) and step length, respectively, for the affected (or left) and unaffected (or right) legs.

2.4. Data analysis

Information from all subjects were entered into a computerized database and analyzed using the SPSS

statistical package. To compare the demographic characteristics between groups, one-way analysis of variance (ANOVA) or independent-samples *t*-tests were used for means and chi-square tests were used for frequencies. Repeated measures were used to analyze differences of each dependent variable within group across single-task and dual-task conditions. Dual-task decrements were calculated using the formula: decrement = (single-task score – dual-task score)/single-task score × 100% [4]. One-way ANOVA and post-hoc analysis using Bonferroni test were used to determine the differences of dual-task decrements between groups. A significance level of 0.05 was set for all analyses.

3. Results

3.1. Descriptive characteristics

Thirty subjects with hemiparesis and 15 healthy subjects participated in this study. Using Perry's classification system, 15 subjects with hemiparesis were full community ambulators (gait velocity ≥80 cm/s) and the remaining 15 subjects with hemiparesis were least limited community ambulators (gait velocity between 58 and 80 cm/s). Table 1 indicates the group means and standard deviations for age and/or stroke onset and the frequency counts for gender and/or hemiparetic side. Among the full community ambulators, 8 were male and 7 were female with a mean age of 61.27 ± 6.69 years (ranging from 53 to 74 years old) and 5 had a right hemiparetic side and 10 had a left hemiparetic side with a mean onset duration of 20.93 ± 11.15 months (ranging from 4 to 36 months). Among the least limited community ambulators, 7 were male and 8 were female with a mean age of 61.93 ± 13.48 years (ranging from 41 to 77

years old) and 6 had a right hemiparetic side and 9 had a left hemiparetic side with a mean onset duration of 20.00 ± 19.03 months (ranging from 2 to 60 months). Moreover, 15 age-matched healthy adults participated in this study. Among these healthy subjects, 7 were male and 8 were female with a mean age of 62.73 ± 9.02 years (ranging from 42 to 73 years old). There were no statistically significant differences between groups for age, gender, stroke onset duration, and hemiparetic side (Table 1).

3.2. Gait performance under single task

The gait parameters during single task are also summarized in Table 1. Velocity, cadence, stride time, stride length, and temporal symmetry index on the least limited community ambulators all showed significant deterioration compared to those for healthy subjects (Table 1). However, no significant differences were found between the full community ambulators and healthy subjects for all gait variables. The analysis also revealed significant deteriorations in velocity, cadence, stride time, stride length, and temporal symmetry index on the least limited community ambulators compared to those for the full community ambulators (Table 1).

3.3. Gait performance under buttoning task

As shown in Table 2, these results indicate that both the healthy subjects and hemiparetic subjects showed significant gait deterioration under buttoning task condition compared to walking alone (single task). All gait variables with the exception of the temporal and spatial symmetry indices were significantly different between single task and buttoning task in healthy subjects. All gait variables with the

Table 1
Basic demographic and gait characteristics

	Healthy subjects (<i>n</i> = 15)	Stroke subjects with full community (<i>n</i> = 15)	Stroke subjects with least limited community (<i>n</i> = 15)
Demographic variables			
Age (years)	62.73 ± 9.02	61.27 ± 6.69	61.93 ± 13.48
Gender			
Male	7	8	7
Female	8	7	8
Months post-stroke	–	20.93 ± 11.15	20.00 ± 19.03
Hemiparetic side			
Right	–	5	6
Left	–	10	9
Gait variables			
Velocity (cm/s)	112.51 ± 23.68	98.49 ± 15.62 [‡]	67.55 ± 5.25 ^{**}
Cadence (steps/min)	110.06 ± 12.95	103.61 ± 5.55 [‡]	91.99 ± 7.33 ^{**}
Stride time (s)	1.10 ± 0.12	1.15 ± 0.066 [‡]	1.31 ± 0.10 ^{**}
Stride length (cm)	122.59 ± 17.63	114.81 ± 13.23 [‡]	89.31 ± 8.98 ^{**}
Temporal symmetry index	0.98 ± 0.073	0.98 ± 0.043 [‡]	1.10 ± 0.19 [*]
Spatial symmetry index	0.98 ± 0.031	1.02 ± 0.018	1.04 ± 0.11

Values are mean ± standard deviation or *n*. Between group difference: * *p* < 0.05, ** *p* < 0.005 for healthy subjects vs. least limited community ambulators; † *p* < 0.05, ‡ *p* < 0.005 for full community ambulators vs. least limited community ambulators.

Table 2
Dual-task-related gait change

	Healthy subjects (n = 15)			Full community ambulators (n = 15)			Least limited community ambulators (n = 15)		
	Single task	Buttoning task	Tray-carrying task	Single task	Buttoning task	Tray-carrying task	Single task	Buttoning task	Tray-carrying task
Velocity (cm/s)	112.51 ± 23.68	101.15 ± 21.55**	103.67 ± 11.22**	98.49 ± 15.62	84.20 ± 15.13**	80.87 ± 17.18**	67.55 ± 5.25	56.07 ± 8.28**	54.27 ± 6.77**
Cadence (steps/min)	110.06 ± 12.95	103.47 ± 13.67**	108.81 ± 8.38	103.61 ± 5.55	99.38 ± 3.70*	99.89 ± 7.72**	91.99 ± 7.33	89.17 ± 5.64*	84.06 ± 4.91**
Stride time (s)	1.10 ± 0.12	1.17 ± 0.15**	1.10 ± 0.077	1.15 ± 0.066	1.20 ± 0.040*	1.20 ± 0.010**	1.31 ± 0.10	1.37 ± 0.049*	1.43 ± 0.075**
Stride length (cm)	122.59 ± 17.63	117.21 ± 16.76**	115.91 ± 13.14**	114.81 ± 13.23	101.88 ± 16.49**	96.55 ± 13.05**	89.31 ± 8.98	76.01 ± 11.99**	77.86 ± 10.34**
Temporal symmetry index	0.98 ± 0.073	1.00 ± 0.036	1.00 ± 0.039	0.98 ± 0.043	1.02 ± 0.086*	1.11 ± 0.15**	1.10 ± 0.19	1.18 ± 0.13*	1.21 ± 0.21*
Spatial symmetry index	0.98 ± 0.031	0.98 ± 0.043	1.00 ± 0.026	1.02 ± 0.018	1.01 ± 0.039	0.99 ± 0.081	1.04 ± 0.11	1.07 ± 0.13	0.99 ± 0.16

Values are mean ± standard deviation. Within group difference: * $p < 0.05$, ** $p < 0.005$ for single task vs. dual task.

exception of the spatial symmetry index were significantly different between single task and buttoning task in the full community ambulators and the least limited community ambulators.

3.4. Gait performance under tray-carrying task

As presented in Table 2, the results showed significant decreases in walking velocity and stride length when healthy subjects were performing tray-carrying task rather than performing single task. The full community ambulators and the least limited community ambulators showed significant deterioration in all gait variables except for spatial symmetry index under tray-carrying task condition compared to under single-task condition.

3.5. Dual-task-related gait decrement

Table 3 gives the gait decrements between single task and dual task. When comparing the buttoning task-related gait decrements between groups, the analysis revealed significant increase in percentage decrement of stride length on the full community ambulators compared to healthy subjects. The analysis also showed significant increases in percentage decrement of walking velocity and stride length on the least limited community ambulators compared to healthy subjects. When comparing the tray-carrying task-related gait decrements between groups, the analysis revealed significant differences in percentage decrement of walking velocity, stride length, and temporal symmetry index between the full community ambulators and healthy subjects and showed significant differences in percentage decrement of all gait variables except for spatial symmetry index between the least limited community ambulators and healthy subjects.

4. Discussion

Changes of gait patterns due to a simultaneously performed cognitive task have been reported previously among hemiparetic subjects [3,4]. Little is known on whether the motor task challenges matters for gait interference in hemiparetic subjects. The results of this study suggest that motor-task-related gait decrements are present for both healthy and hemiparetic subjects (full community ambulators and least limited community ambulators). Many researches have found significant attentional demands associated with the control of gait in older adults, compared to young ones [9,10]. Our results also showed that elderly controls experienced marked deterioration in their gait patterns when they were required to perform a motor task at the same time as walking. Dual-task interference during locomotion is also problematic for people with neurological conditions such as Parkinson's disease [11], Huntington's disease [12], and Alzheimer's

Table 3
Dual-task-related gait decrement (%)

	Healthy subjects (n = 15)		Full community ambulators (n = 15)		Least limited community ambulators (n = 15)	
	Buttoning task	Tray-carrying task	Buttoning task	Tray-carrying task	Buttoning task	Tray-carrying task
Velocity (%)	10.08 ± 5.39	6.43 ± 6.85	14.68 ± 5.22	16.62 ± 8.20**	17.04 ± 9.60 [†]	18.74 ± 6.91 [‡]
Cadence (%)	6.01 ± 5.59	0.76 ± 3.35	3.72 ± 4.73	3.87 ± 4.25	2.83 ± 5.13	5.65 ± 4.44 [†]
Stride time (%)	-6.74 ± 6.11	-0.98 ± 3.39	-4.71 ± 5.76	-4.47 ± 4.94	-5.46 ± 8.72	-6.02 ± 5.70 [†]
Stride length (%)	4.33 ± 3.49	5.63 ± 5.27	11.57 ± 6.61*	14.22 ± 7.28**	15.13 ± 8.03 [‡]	14.61 ± 6.66 [‡]
Temporal symmetry index (%)	-1.84 ± 6.32	1.50 ± 5.60	-4.30 ± 7.06	-9.98 ± 8.88*	-9.69 ± 20.40	-9.91 ± 18.62 [†]
Spatial symmetry index (%)	0.86 ± 3.49	-0.97 ± 2.63	1.05 ± 4.90	0.78 ± 6.98	-3.11 ± 8.97	0.29 ± 8.39

Gait decrement was calculated using the formula: decrement = (single-task score – dual-task score)/single-task score × 100%.

Between group difference: * $p < 0.05$, ** $p < 0.005$ for healthy subjects vs. full community ambulators; [†] $p < 0.05$, [‡] $p < 0.005$ for healthy subjects vs. least limited community ambulators.

disease [13]. Information processing psychology has modeled attentional operation using a limited capacity information-transmission channel [14]. According to this, dual-task performance would exceed available information capacity in the patients, even in elderly controls and full community ambulators post-stroke. In the present study, full community ambulators and least limited community ambulators were also shown to display dual-task interference in their walking performance. In contrast with healthy individuals, hemiparetic subjects exhibit deterioration in temporal symmetry index when performing buttoning and tray-carrying tasks while walking.

Walking ability is a major goal of many rehabilitation programs and is an integral part of many activities of daily living. Our results showed that the walking performance of full community ambulators post-stroke is similar to that of age-matched healthy subjects (Table 1). Since many daily living tasks involve concurrent movements, measures of dual-task decrement is important. Our findings suggest that full community ambulators display a statistically significant increase in dual-task-related gait decrement when compared with healthy subjects (Table 3). Given the results of the present study, it can be suggested that gait velocity may be an appropriate primary endpoint in clinical trials for interventions to improve community mobility. However, it is not sufficient as a single measure of community ambulation function and should be supplemented by dual-task gait assessment. Moreover, Lord et al. [15] also indicated that a self-reported level of community ambulation and measures of social integration and community participation would be necessary to assess the level of community ambulation.

In the present study, we used two different walking-associated tasks in dual-task gait assessment, buttoning and tray-carrying tasks. The results for dual-task-related gait change from these two different tasks were not similar (Table 2). Our results showed that elderly controls experienced marked gait changes in four of six variables, including decreased velocity, cadence, and stride length and increased stride time, when they performed buttoning task while walking (Table 2). In contrast, the elderly controls experienced significantly gait changes in two of six variables,

including decreased velocity and stride length, when they performed tray-carrying task while walking (Table 2). Different results from these two motor tasks may be due to the difficulty of the tasks. According to the capacity-sharing model, a central mechanism exists that allocates appropriate attentional resources to the performance of tasks [16,17]. The allocation of resources changes continuously depending on the resources needed by a given task at a particular time and is graded according to the difficulty of the task [17,18]. It could be speculated that the buttoning task may be more difficult to perform comparing to tray-carrying for elderly controls. Furthermore, most of our elderly controls reported that buttoning task is more difficult to perform comparing to tray-carrying. The role of visual control during execution of those motor tasks may be different. The tray-carrying task would not obstruct the visual control, whereas the buttoning task would. Vision plays an important role in judging distance and maintaining stability when standing [19] and stepping [20]. Visual interference could be another plausible explanation for the different results obtained from the two motor tasks performed.

Our results also showed that the dual-task-related gait decrement from these two different tasks in subjects with stroke were not similar (Table 3). In contrast to healthy subjects, full community ambulators and least limited community ambulators showed significant gait differences in one and two of the six variables, respectively, when they were required to perform the buttoning task at the same time as walking (Table 3). By contrast, full community ambulators and least limited community ambulators showed significant tray-carrying task-related gait differences in three and five out of six variables, respectively, when compared with healthy subjects (Table 3). These results suggested that the gait decrement for subjects with stroke is more marked in performing tray-carrying task than in performing buttoning task. This finding could be explained by the characteristics of tray-carrying task and the pathological condition of the hemiparetic subjects. Both tray-carrying task and walking can be classified as balance control tasks. According to the bottleneck model, similar tasks performed concurrently cause “bottleneck” interference because they

compete for the use of the same pathway [21]. Balance control is frequently disturbed following stroke. Therefore subjects with stroke would demonstrate gait deterioration when asked to execute concurrently two of the balance control tasks. On the other hand, our study suggested that the buttoning task may be more difficult to perform comparing to performing tray-carrying task for elderly controls. Therefore, it is reasonable to speculate that gait difference between hemiparetic and healthy subjects during the buttoning task would be insignificant.

The findings of the present study indicate that different motor tasks can have a different impact on gait performance. We, therefore suggest the additional motor task in dual-task gait assessment in subjects with hemiparesis must be chosen carefully. Our results suggest that the tray-carrying task may be a suitable test for subjects with stroke.

Rehabilitation after stroke should involve the assessment of the person's ability to carry out dual tasks. Physiotherapy treatment may include practicing the motor task while walking. This design of therapy may lead to benefits and enhance functions.

There are several limitations of this study. Firstly, the number of subjects was limited. Secondly, the study was limited to subjects who were willing to participate and, therefore, were a self-selected group of motivated individuals. Finally, the post-stroke period of the subjects in this study is lengthy (with a mean of 20 months). It could be argued that gait changes may not have just been affected by the stroke. Post-stroke activity level and other factors may also affect gait changes during this period. Further study may be needed to examine the gait decrements while performing a motor task concurrently in subjects with acute stroke.

In summary, the results of this study suggest that subjects with stroke have difficulty performing two motor tasks concurrently. It is important that the effects of dual-task performance on walking be evaluated at regular intervals.

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