Attentional Demands for Static Postural Control After Stroke

Lesley A. Brown, PhD, Ryan J. Sleik, MSc, Toni R. Winder, MD, FRCP


Objective: To assess the attentional demands associated with postural control among people who have had a stroke.

Design: Nonrandomized matched case-control study.

Setting: University research laboratory in Canada.

Participants: Six individuals who had suffered a left or right cerebral ischemic attack in the past year and a sample of 6 age- and gender-matched controls. Participants in the stroke group had a mean age of 64.17±13.14 years; control participants had a mean age of 64.00±13.91 years. Mean National Institute of Health Stroke Scale scores for these patients were 7.67±4.92 at the time of stroke and 1.66±1.36 at the time of testing. None of the patients were taking medications that would alter cognitive status or balance abilities.

Intervention: Participants performed a verbal reaction-time test while engaged in 3 postural tasks (sitting, standing, standing with feet together).

Main Outcome Measure: Reaction time: latency between visual stimulus and verbal response.

Results: Reaction times in the stroke group differed significantly in all conditions from the controls (410±72ms vs 320±54ms, P<.01). A significant interaction was found between group and postural task (P=.05), with reaction-time scores showing a progressive increase in postural task difficulty among participants who had suffered a stroke. Post hoc comparisons revealed that sitting reaction-time scores were significantly slower than reaction-time scores for feet together standing (P=.008) among participants in the stroke group.

Conclusion: Individuals who have suffered a stroke showed increased attentional demands for tasks of static postural control compared with healthy, age-matched participants.

Key Words: Accidental falls; Attention; Cerebrovascular accident; Equilibrium; Posture; Reaction time; Rehabilitation.

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The ability to keep our balance and preserve an upright posture is maintained by a delicate interplay among our sensory, motor, and cognitive systems. Impairment or disruption of the mechanisms responsible for postural control can lead to unsteadiness and a tendency toward instability. Although the statistics detailing the prevalence of falls and fall-related injuries are extremely well cited for the elderly population,1,4 instability and falls are also major concerns among pathologic populations. For instance, fall occurrence increases by 25% among persons with cognitive deficits compared with cognitively healthy controls.5 In addition, patients with Parkinson’s disease are known to experience gait disorders that increase the risk of falls.6 Falling has also been implicated as a significant problem during rehabilitation after an acquired brain injury such as a cerebrovascular accident (CVA) or stroke.7 Reports indicate that approximately 75% of people who have suffered a stroke experience a fall within 6 months of hospitalization.8

Insult to the central (CNS) or peripheral nervous system is a primary factor in reducing the ability to maintain balance.9 Geurts et al10, for example, have shown that postural control is markedly reduced among lower-limb amputees until the CNS can compensate for the loss of proprioception by using balance-specific sensory input from other sources. However, balance and locomotion may be uniquely challenged after an acquired brain injury because the CNS may be unable to compensate for damaged tissue at the site of the insult. Furthermore, absent or impoverished motor output and/or a compromised ability, or a complete inability, to use sensory input present further challenge to the efficacy of the postural control system after brain injury. Consequently, individuals who suffer a brain injury, such as a stroke, often show decreased postural control11 altered gait patterns,12 and a reduced ability to perform a motor task (eg, gait) concurrently with a cognitive task.13

The capacity model for attention14 indicates that performing 2 tasks simultaneously will lead to performance decrement in 1 or both tasks, provided that the tasks share common processing substrates. The observation by Haggard et al15 that individuals who have suffered a stroke are less able than healthy control subjects to simultaneously perform a motor and cognitive task carries 2 implications: (1) that the information-processing demands for motor tasks, such as locomotion, are altered after a cerebral injury or (2) that the information-processing capacity in this population may be altered as a consequence of brain injury. Even in the absence of pathology, the seemingly effortless tasks of standing and walking are not automatic, but instead draw on contributions from the cognitive system.15 Work in this area has also revealed that the cognitive resources dedicated to tasks of postural control and locomotion are greater for older adults compared with younger adults.16 In addition, greater attentional demands are required when sensory information is altered or reduced17,18 or when the difficulty of the postural task increases.19 Given the added physical challenges for balance and locomotion after a stroke,11,12,20 it is understandable that the information-processing demands for motor tasks, such as postural control and locomotion, may be altered in this population.

Recently, Lajoie et al21 explored the issue of cognition and postural control among individuals with CNS damage caused by spinal cord injury (SCI). Their findings revealed that, even in the absence of higher-order deficit, persons with SCI dedicate more attentional resources to maintain their balance than do normal subjects. However, despite an increased rate of falling, impoverished postural control ability,11 and reduced dual task performance capacity13 among those who have ex-
Table 1: Demographics for Control and Post-CVA Groups

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Gender</th>
<th>Age (y)</th>
<th>Gender</th>
<th>Age (y)</th>
<th>Time Since CVA (y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>F</td>
<td>66.59</td>
<td>F</td>
<td>66.76</td>
<td>0.91</td>
</tr>
<tr>
<td>B</td>
<td>F</td>
<td>90.50</td>
<td>F</td>
<td>88.75</td>
<td>1.21</td>
</tr>
<tr>
<td>C</td>
<td>F</td>
<td>65.50</td>
<td>F</td>
<td>64.51</td>
<td>0.32</td>
</tr>
<tr>
<td>D</td>
<td>M</td>
<td>64.00</td>
<td>M</td>
<td>61.62</td>
<td>1.11</td>
</tr>
<tr>
<td>E</td>
<td>M</td>
<td>68.30</td>
<td>M</td>
<td>57.06</td>
<td>0.33</td>
</tr>
<tr>
<td>F</td>
<td>M</td>
<td>45.25</td>
<td>M</td>
<td>49.23</td>
<td>0.67</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Stroke Group</th>
<th>Location</th>
<th>NIH Stroke Scale (at stroke)</th>
<th>NIH Stroke Scale (at testing)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left frontoparietal</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Left frontal</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Right frontal</td>
<td>5</td>
<td>3</td>
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<td>Right frontal</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Left frontal</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Left frontal</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Abbreviations: F, female; M, male; NIH, National Institute of Health.

ATTENTIONAL DEMANDS AMONG PATIENTS WITH STROKE, Brown

Participants

Twelve participants (6 with stroke, 6 age- and gender-matched controls) were selected for this study. All participants were informed about the procedures of the study before signing a consent form in accordance to human research services guidelines at the University of Lethbridge, Lethbridge, Alb. The stroke group (mean, 64.17±13.14y; range, 49.73–88.75y) consisted of 3 men (mean, 55.97±6.27y) and 3 women (mean, 73.34±13.40y) who had suffered from a unilateral motor cortical ischemic infarct (precentral gyrus) within the past year (mean time since last CVA, 9.10±4.60mo). Participants were selected on the basis of type, severity, and recency of their cerebral infarct. Four of the participants had unilateral damage in the left hemisphere, and the remaining 2 participants experienced unilateral damage to the right hemisphere. Mean National Institute of Health Stroke Scale scores for these patients were 7.67±4.92 at the time of stroke and 1.67±1.36 at the time of testing. None of the patients were taking medications that would alter cognitive status or balance abilities. All participants were able to walk without the assistance of an aid. Descriptive details of the patient group are provided in table 1. The control group comprised a gender- and age-matched sample (mean, 64.00±13.91y; range, 45.25–90.50y) with no known neurologic, sensory, or cognitive impairments.

Design and Procedure

We assessed the attentional requirements for postural control according to the principles of the dual task paradigm. According to this paradigm, participants perform a secondary cognitively demanding task while engaged in a primary motor task. Disruptions in the performance of the secondary task are regarded as reflecting alterations in the attentional requirements associated with performing the primary motor task. For our study, the secondary (cognitive) task was a verbal reaction-time task and the primary (motor) task varied between sitting, standing with feet comfortably apart, and standing with feet together. These postural tasks present a progressive reduction in the dimensions of the base of support within which the center of mass of the body must be controlled and, thus, introduce a progressive increase in task difficulty. In addition, all participants in this study could perform these tasks without observable difficulty.

The reaction-time task required participants to verbally respond as quickly as possible with the word “top” to illuminations of a light. The word top was used because it was unrelated to the task and is an easily articulated 1-syllable word. Reaction-time scores were collected for 6 trials in each motor task condition in a completely counterbalanced manner, for a total of 18 trials per participant. The first trial in each condition was omitted from data analysis to remove any initial order effects. In each testing condition, a warning buzzer preceded illumination of the light and signaled that the trial was to begin. The time interval between the warning signal and the light illumination was randomized across 9 delay intervals of 0.5 seconds between 1.5 and 5.5 seconds.

Materials

Participants wore a headset microphone for the collection of audio data. A light display unit was placed at eye level 2m in front of the participants. The light display unit consisted of a box (60×15cm) with 5 different colored lights, 3.5cm in diameter, positioned horizontally. All lights were covered, except for the center red light. The light display unit was controlled by a delay and color selector interface that was connected to the collection computer.

Data Analysis

Reaction-time scores were calculated as the latency between the onset of the visual stimulus and the onset of the participant’s verbal response. All scores were calculated by using a custom written algorithm and are accurate to within ±1ms. The effects of increased task difficulty on reaction-time scores in stroke and control participants were analyzed by using a 2×3×5 (group [stroke vs control] × postural task [sitting vs standing vs standing with feet together] × trial [1–5]) repeated-measures analysis of variance. Post hoc analyses involved paired samples t tests when appropriate, and α was set at .05.

RESULTS

All participants were able to perform the postural tasks without difficulty and successfully perform the reaction-time task in each postural condition. In addition, all participants were able to perform simultaneously the reaction-time task without observable decrement to the performance of the primary task.

A significant between-groups main effect was found between the reaction-time scores of the stroke and age-matched
The findings of our study, however, revealed that regardless of the differences in reaction-time scores between groups, performance on the secondary task among participants in the stroke group deteriorated as a function of the difficulty of the postural task. Furthermore, reaction-time task performance deteriorated independent of any observable deterioration in the performance of the postural tasks. This finding implies that the automaticity of postural control declines after a stroke, particularly as postural task demands increase. Indeed, as suggested by Lajoie et al, it is possible that the CNS needs to devote greater attentional resources to the restructuring of motor patterns for postural control in response to physical damage. However, because statistical significance from baseline sitting reaction-time scores did not emerge until participants adopted the most difficult postural task, it is possible that a threshold of postural task difficulty exists, beyond which substantial deficits in cognitive performance will emerge. Whether this threshold is subject-dependent or varies with the stage of rehabilitation presents a question for further study.

An interesting observation from our results was the absence of any change in reaction-time scores across postural task conditions among the control participants. This finding implies that the demands of the postural tasks were not sufficient to necessitate alterations in the allocation of attentional resources among the control subjects. Lajoie et al have shown that, on the contrary, the attentional requirements for postural control are greater for narrow-based standing than for broad-based standing. However, this finding was supported among older adults only and was not upheld among a younger cohort. Thus, it is possible that the potential effect of postural task difficulty among the control participants was masked by variability in the ages of our subject sample (mean, 64.0±13.91y); had the age range of our subject sample been tighter, and biased toward ages of mid-to-older adults, it is possible that the effect of postural task difficulty would have also emerged among the control participants.

Our findings have shown that the attentional requirements for postural control increase with task difficulty among individuals who have suffered a stroke incident. The postural tasks used in our study, however, present minimal challenge to the postural control system because the center of mass of the body is disturbed only by internal physiologic disruptions (ie, heart rate, respiration) and the force of gravity. Given the demonstrated trend of increasing attentional demands according to postural task difficulty, we speculate that, as previously demonstrated among young and older adults, allocation of attentional resources would continue to increase across dynamic postural tasks such as locomotion and postural recovery. According to the model of limited capacity of attention, reduced automaticity for the control of upright standing after a stroke injury may present the possibility of a greater risk for instability and a higher probability of falling in this population. In particular, the increased demand on the cognitive system that accompanies postural task performance will alter the availability of attentional resources that can be directed to other tasks. Brown et al, for example, have shown that recovering from external balance disturbance is also a cognitively demanding task. Consequently, if faced with a situation in which balance recovery is required, individuals who have suffered a stroke may have insufficient attentional resources to meet the demands of the task, and a fall episode will prevail. Further work is warranted to explore this issue among individuals with acquired brain injury caused by stroke.

control participants (F1,10=14.33, P=0.04, R²=.58). Follow-up t tests revealed significantly longer reaction-time scores for stroke patients compared with control subjects across all postural tasks (sitting: t58=4.059, P=.000; standing: t58=5.377, P=.000; feet together: t58=6.86, P=.000; fig 1). There was no main effect for trial (F1,40=1.075, P=.382, R²=.097) or for postural task (F2,20=1.19, P=.322, R²=.107); however, a significant interaction between postural task and group (F2,20=3.50, P=.05, R²=.259) emerged. Follow-up t test comparisons revealed a significant difference for reaction-time scores between the sitting (.389±.06ms) and feet together (.435±.09ms) conditions (t20=2.84, P=.008) among the stroke group only. Although reaction-time scores for normal standing exceeded those for sitting among participants who had suffered a stroke, post hoc comparison of means indicated that this difference approached significance (t20=1.734, P=.094). As shown in figure 1, there was a progressive increase in reaction-time scores for participants in the stroke group between sitting, standing comfortably, and standing with feet together.

**DISCUSSION**

The goal of our study was to assess whether stroke alters the allocation of attention to postural control across static postural tasks of increasing difficulty. Our findings imply that stroke alters the attentional requirements for static postural tasks and present the possibility for a greater risk of instability among stroke patients as postural task demands increase. The group differences in reaction-time scores were consistent across all postural tasks and revealed that participants in the stroke group had significantly longer reaction-time scores compared with control participants. Although it is possible that this difference reflects greater information-processing demands for motor tasks after stroke, it is equally possible that the information-processing capacity is altered as a consequence of the acquired brain injury. Based on previous work indicating that deficits in attentional capacity can accompany the onset of cerebrovascular injury, it is likely that the observed group differences in reaction-time scores are not solely indicative of increases in the cognitive processing requirements for postural control after a stroke, but instead occur as a consequence of brain injury. Nonetheless, if brain injury does alter information-processing capacity, decrements in reaction-time performance should be consistent across all motor tasks.
Limitations

The findings of this study are limited to patients who have suffered unilateral motor cortical infarct within 1 year of testing. Whether these findings can be generalized to individuals who have lesions beyond the motor cortex remains to be determined. Furthermore, whether the cognitive requirements of postural control change beyond the 1-year post infarct interval cannot be addressed by the findings presented in this study.

CONCLUSION

The results of our study indicate that individuals who have suffered a stroke dedicate more attention to controlling their balance during static postural tasks than do control participants, particularly as the difficulty of the postural task increases. This alteration in the allocation of attentional resources may increase the risk of falling among those who have suffered a stroke by reducing residual cognitive capacity and limiting the availability of attentional resources for tasks such as postural recovery. The need to reduce falls in rehabilitation settings has been emphasized by Nyberg and Gustafson7 who found that that 39% of 161 post-CVA patients admitted to a geriatric rehabilitation unit suffered a fall in a 1-year period. Identifying factors that place stroke patients at a higher risk for falling may alter current rehabilitative strategies by increasing the awareness on the potential consequences of dual task interference and increasing the availability of attentional resources for tasks such as postural recovery. The results of our study indicate that individuals who have suffered a stroke dedicate more attention to controlling their balance during static postural tasks than do control participants, particularly as the difficulty of the postural task increases. This alteration in the allocation of attentional resources may increase the risk of falling among those who have suffered a stroke by reducing residual cognitive capacity and limiting the availability of attentional resources for tasks such as postural recovery. The need to reduce falls in rehabilitation settings has been emphasized by Nyberg and Gustafson7 who found that that 39% of 161 post-CVA patients admitted to a geriatric rehabilitation unit suffered a fall in a 1-year period. Identifying factors that place stroke patients at a higher risk for falling may alter current rehabilitative strategies by increasing the awareness on the potential consequences of dual task interference and ultimately help to reduce injurious circumstances faced during the rehabilitative period and contribute to reducing the long-term incidence of instability among this population.

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References


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