Dual-Task Effect on Gait Balance Control in Adolescents With Concussion

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Abstract

Objective: To prospectively and longitudinally examine how concussion affects gait balance control in adolescents during single- and dual-task walking.

Design: Cohort, prospective, repeated-measures design.

Setting: Motion analysis laboratory.

Participants: Adolescents (N = 20) identified as suffering a concussion were matched with healthy control subjects (N = 20) and tested 5 times across a 2-month period after injury.

Interventions: Not applicable.

Main Outcome Measures: Gait temporal-distance parameters included average walking speed, step length, and step width; whole body center of mass (COM) parameters included medial/lateral displacement and peak COM medial/lateral and anterior velocities; dual-task cost, which was defined as percent change from single- to dual-task conditions; and Stroop test accuracy.

Results: No between-group differences were observed for step length and step width. The dual-task cost for average walking speed for subjects with concussion was greater than control subjects across the 2-month testing period (main effect of group P = .019), as was the dual-task costs for peak anterior COM velocity (main effect of group P = .017) and total COM medial/lateral displacement (main effect of group P = .013). The total COM medial/lateral displacement (group × task interaction P = .006) and peak COM medial/lateral velocity (main effect of group P = .027; main effect of task P = .01) were significantly greater in subjects with concussion compared with control subjects during dual-task walking. Subjects with concussion were significantly less accurate than controls on the Stroop test (main effect of group P = .004).

Conclusions: The findings suggest that concussion affects the ability of adolescents to control body posture during gait up to 2 months after injury. Furthermore, dual-task paradigms may provide additional useful information in the clinical assessment and recovery of concussion.
Despite no differences on measurements of symptoms and neuropsychologic tests between subjects with concussion and control subjects, individuals with concussion still displayed altered walking performance during dual-task conditions compared with control subjects at an average of 37 days postinjury. Furthermore, other work has identified disruptions to dynamic balance control during dual-task walking for up to 28 days after injury in young adults. Because these reports have elucidated information regarding recovery from concussion in the adult population, no studies, to our knowledge, have examined recovery of gait balance parameters specifically in the adolescent population. Thus, examining dynamic balance control longitudinally after concussion in adolescents can provide important information regarding its long-term effects.

It has been postulated that difficulties in locomotion while performing a concurrent cognitive task (dual-task) may be because of a reduction in attentional resources. The introduction of a cognitive task during walking allows for the simultaneous measurement of motor and cognitive performance, 2 domains commonly reported to be affected by concussion. The Stroop test, performed during walking, in particular provides information about conflict resolution by eliciting responses in a congruent or incongruent manner, thereby probing executive function, which has previously been shown to be significantly affected by concussion. Hence, a dual-task paradigm using the Stroop test represents a method to probe how an individual will perform when engaging in the regular activities of daily living during recovery from a concussion.

Therefore, the purpose of this study was to prospectively and longitudinally examine gait balance control during single- and dual-task walking in adolescents with concussion within a 72-hour acute postinjury interval and over the subsequent 2 months postinjury. It was hypothesized that walking while performing a concurrent secondary task would induce inordinate disruptions to gait performance in adolescent subjects with concussion when compared with matched healthy control subjects.

**Methods**

**Participants**

Forty high school students participating in school sports at 3 local high schools (36 boys/4 girls) were identified and recruited for testing. Twenty of the participants were identified by health professionals (certified athletic trainer/physician) as suffering a concussion consequent to sport participation. Concussion was defined according to McCrory et al as an injury caused by a direct blow to the head, face, neck, or elsewhere in the body with an impulsive force transmitted to the head, resulting in impaired neurologic function and acute clinical symptoms. Symptoms resulting from the injury were assessed using a 22-symptom inventory adapted from McCrory. The total range of the inventory was 0 to 132, with each symptom ranked 0 to 6 via a Likert scale. Each subject with concussion in the study was matched with a healthy control subject (n = 20) by sex, height, mass, age, and sport. Prior to data collection, the institutional review board reviewed and approved the protocol of the current study. All subjects and parents/guardians (if under the age of 18) provided informed consent. Permission was also granted by the respective school districts to conduct testing with student participants.

All subjects identified as suffering a concussion were removed from the injury site on the day of injury and did not return to preinjury levels of physical activity until cleared by a physician in accordance with state law. Exclusion criteria for subjects with concussion and control subjects included: (1) lower extremity deficiency or injury, which may affect normative gait patterns; (2) history of cognitive deficiencies, such as permanent memory loss or concentration abnormalities; (3) history of ≥3 previous concussions; (4) loss of consciousness from the concussion lasting > 1 minute; (5) history of attention deficit hyperactivity disorder; or (6) a previously documented concussion within the past year. A verbal history was taken for all subjects on their first visit to the laboratory to confirm all criteria were met for inclusion in the study.

**Testing timeline**

A prospective, repeated-measures design was employed in which each subject reported to the laboratory and was tested within 72 hours of sustaining a concussion as well as on 4 subsequent testing days at the following time increments: 1 week, 2 weeks, 1 month, and 2 months postinjury. Control subjects were similarly tested according to the same time schedule.

**Protocol**

Subjects walked barefoot at a self-selected speed along a walkway under 2 conditions: walking with undivided attention (single task) and walking while concurrently completing a continuous auditory Stroop test (dual task). The Stroop test consisted of the subject listening to 4 auditory stimuli: the recorded words high or low, each spoken in either a high pitch or low pitch. Subjects were instructed to correctly identify the pitch of the word, regardless of whether the pitch was congruent with the meaning of the word. The subjects were not instructed to focus attention specifically on the walking or cognitive task, but to continue walking while correctly responding to each pitch, and therefore neither the walking task nor the Stroop test were prioritized. Each of the 4 stimuli was presented in random order at a specific time while walking. The first stimulus was presented once subjects had achieved steady-state gait and was triggered by a photocell located several steps after gait initiation. Each of the 3 subsequent stimuli was presented 1 second after the previous response, while the subject continued to walk. Eight to 10 consecutive trials were completed for each of the 2 conditions (single and dual task).

A set of 29 retro-reflective markers were placed on bony landmarks of the subject, and whole body motion analysis was performed using a 10-camera motion analysis system at a sampling rate of 60Hz to capture and reconstruct the 3-dimensional trajectory of each marker. Marker trajectory data were low-pass filtered using a fourth-order Butterworth filter with a cutoff frequency set at 8Hz. External markers and estimated joint centers were used to calculate the center of mass (COM) position for each individual body segment. Whole body COM position data were then calculated as the weighted sum of all body segments, using data from Winter, with 13 segments representing the whole body (head-neck, trunk, pelvis, 2 upper arms, 2 forearms and hands, 2 thighs, 2 shanks, and 2 feet). Gait events were detected from ground reaction forces collected at 960Hz using 3 forceplates. Each Stroop test stimulus was presented in
random order using Super Lab Pro. Participants verbally responded to the Stroop test using a headset wireless system with microphone. For each trial, data were analyzed for 1 gait cycle, defined as heel strike to heel strike of the same limb. The targeted stride for analysis was after initial Stroop stimulus presentation and typically occurred during the first or second stimulus.

Data analysis

Accuracy on each Stroop test response was calculated as the total correct responses divided by the total trials completed during each testing session for each subject. For gait temporal-distance variables, average walking speed was calculated as the mean forward velocity throughout the gait cycle. Step length and width were calculated as the distances between right and left heel markers at each heel strike in the anterior/posterior and medial/lateral directions, respectively. Linear COM velocity was calculated using the cross-validated spline position from the COM position. The peak anterior and medial/lateral COM velocities were identified during the gait cycle. The total medial/lateral COM displacement during the gait cycle was also obtained. These variables were reported previously to provide sensitive detection of gait imbalance. In order to account for individual differences in attentional loading and walking speed, the relative change between the single- and dual-task condition for each subject was calculated and reported as the percent change from the single- to dual-task condition (dual-task cost). The mean of each block of trials for all variables was computed for further analysis.

Statistical analysis

Group demographic differences were tested using an independent t test for height, mass, and age. Three-way mixed-effects analyses of variance were used to analyze each walking dependent variable in order to determine the effect of group (concussion and control), time (72h, 1wk, 2wk, 1mo, and 2mo), task (single and dual), and the interactions between these 3 independent variables. The dual-task cost dependent variables were calculated as the percentage change between the single- and dual-task conditions and analyzed using a 2-way mixed-effects analysis of variance to examine the effect of group and time. Stroop test accuracy was also analyzed using a 2-way mixed-effect analysis of variance.

For all omnibus tests, significance was set at P < .05. Follow-up pairwise comparisons were then examined using the Bonferroni procedure to control family wise type I error. All statistical analyses were performed with SPSS version 20.

Results

Participants

Subjects with concussion were tested in the following time increments: 2.75, 8±1.8, 17±3.6, 30±2.6, and 59±3.5 days after the injury. Control subjects followed a similar timeline and were tested at 8±2.1, 17±4.7, 31±3.7, and 57±6.4 days after their initial testing session. No significant differences were observed between the concussion and control group (table 1) for height (P = .812), mass (P = .395), or age (P = .558). Both groups contained 18 boys and 2 girls. In 1 case, a direct sport match was not obtained (see table 1). Three of the subjects with concussion had a previous history of concussion with the most recent concussion occurring >1 year prior to beginning the study, whereas no control subject had a history of concussion. Subjects with concussion presented at the 72-hour assessment with a mean symptom score ± SD of 40.7±23.1 (range, 10–99), whereas control subjects presented initially with a mean symptom score ± SD of 4.3±4.1 (range, 0–12). Clinical symptom resolution for subjects with concussion, defined by a symptom score within 2SDs of the control subject mean ± SD at the 2-month follow-up evaluation (4.8±6.7), occurred for all but 4 subjects with concussion.

Gait temporal-distance parameters

For average walking speed, both groups walked slower in the dual-task than in the single-task condition (group × task interaction, F1,37 = 5.53, P = .024, partial η2 = .130; time × task interaction, F4,148 = 6.29, P = .001, partial η2 = .145) (table 2); however, the dual-task cost was significantly greater for the subjects with concussion compared with control subjects across the 2-month testing period (main effect of group, F1,37 = 6.02, P = .019, partial η2 = .140; time, F4,148 = 6.08, P = .001, partial η2 = .141) (table 3).

No between-group or between-task differences were observed for step length and step width. However, concussion group step length significantly increased after 2 weeks postinjury compared with the 72-hour and 1-week testing sessions for single- and dual-task conditions (group × time interaction, F4,148 = 3.82, P = .012, partial η2 = .094) (see table 2). Step length dual-task cost analysis demonstrated no interaction (P = .762), main effect of time

Table 1 Demographic information for both groups of subjects

<table>
<thead>
<tr>
<th>Group</th>
<th>Sex (Boy/Girl)</th>
<th>Age (y)</th>
<th>Age (range)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Sport Played (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concussion</td>
<td>18/2</td>
<td>15.3±1.3</td>
<td>14–18</td>
<td>173.7±6.4</td>
<td>74.8±16.6</td>
<td>Football: 15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Soccer: 3</td>
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<td>Volleyball: 1</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Basketball: 0</td>
</tr>
<tr>
<td>Control</td>
<td>18/2</td>
<td>15.6±1.0</td>
<td>14–17</td>
<td>173.4±8.1</td>
<td>70.7±13.6</td>
<td>Football: 15</td>
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<td></td>
<td></td>
<td></td>
<td>Basketball: 1</td>
</tr>
</tbody>
</table>

NOTE. Values are group mean ± SD or as otherwise indicated.
Significantly slower than the single-task condition. (P = .102), or group (P = .096) (see table 2). Step width analysis revealed no significant interactions or main effects of group (P = .737), time (P = .064), or task (P = .860). Similarly, step width dual-task cost analysis revealed no main effects of group (P = .811) or task (P = .352) or interaction between the 2 (P = .520) (see table 3).

**Peak anterior COM velocity**

Subjects with concussion demonstrated a significant increase in peak anterior COM velocity from the initial time tested until the 2-month postinjury assessment, whereas control subjects showed no significant differences across time (group x time interaction, F_{1,48} = 3.23, P = .037, partial $\eta^2 = .080$) (fig 1A). Both groups demonstrated significantly higher peak anterior COM velocity in the single-task condition than in the dual-task condition (group x task interaction, F_{1,37} = 5.99, P = .019, partial $\eta^2 = .139$) (see fig 1A). During single-task walking, both groups exhibited a significantly higher peak anterior COM velocity at 2 months than any other previous testing session, whereas in the dual-task condition, both groups walked with a significantly lower peak anterior COM velocity at the 72-hour testing session than any other subsequent testing time (time x task interaction, F_{1,48} = 6.67, P = .001, partial $\eta^2 = .153$) (see fig 1A). The Stroop test perturbation induced a significantly greater peak anterior COM velocity reduction for subjects with concussion compared with controls (dual-task cost; main effect of group, F_{1,37} = 6.23, P = .017, partial $\eta^2 = .144$; time, F_{1,48} = 6.46, P = .001, partial $\eta^2 = .149$) (see table 3).

**Peak medial/lateral COM velocity and displacement**

No significant 3-way or 2-way interactions were found for the peak medial/lateral COM velocity. However, subjects with concussion demonstrated significantly higher peak medial/lateral COM velocity than control subjects (main effect of group, F_{1,37} = 5.32, P = .027, partial $\eta^2 = .126$) (fig 1B). Both groups walked with a significantly greater medial/lateral COM velocity

### Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>Task</th>
<th>72h</th>
<th>1wk</th>
<th>2wk</th>
<th>1mo</th>
<th>2mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average walking speed (m/s)</td>
<td>Concussion</td>
<td>Single</td>
<td>1.16±.19</td>
<td>1.22±.16</td>
<td>1.25±.15</td>
<td>1.26±.17</td>
<td>1.32±.14</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>Dual*</td>
<td>1.06±.14</td>
<td>1.14±.17</td>
<td>1.16±.16</td>
<td>1.18±.16</td>
<td>1.20±.16</td>
</tr>
<tr>
<td>Step length (m)</td>
<td>Concussion</td>
<td>Single</td>
<td>0.64±.06</td>
<td>0.65±.05</td>
<td>0.67±.06</td>
<td></td>
<td>0.68±.06</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>Single</td>
<td>0.67±.04</td>
<td>0.66±.05</td>
<td>0.67±.05</td>
<td>0.68±.05</td>
<td>0.68±.05</td>
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<tr>
<td></td>
<td>Control</td>
<td>Dual*</td>
<td>0.61±.05</td>
<td>0.63±.06</td>
<td>0.65±.05</td>
<td></td>
<td>0.66±.07</td>
</tr>
<tr>
<td>Step width (m)</td>
<td>Concussion</td>
<td>Single</td>
<td>0.09±.03</td>
<td>0.09±.03</td>
<td>0.09±.02</td>
<td>0.09±.02</td>
<td>0.09±.02</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>Single</td>
<td>0.10±.02</td>
<td>0.09±.02</td>
<td>0.09±.03</td>
<td>0.09±.03</td>
<td>0.10±.03</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>Dual*</td>
<td>0.08±.03</td>
<td>0.09±.04</td>
<td>0.09±.03</td>
<td>0.09±.03</td>
<td>0.09±.03</td>
</tr>
</tbody>
</table>

* Significantly slower than the single-task condition.
† Significantly >72-hour assessment.
‡ Significantly >1-week assessment.

### Table 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>72h</th>
<th>1wk</th>
<th>2wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak anterior COM velocity*</td>
<td>Concussed</td>
<td>-8.23±7.5</td>
<td>-5.66±7.0</td>
<td>-7.17±6.1</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>-7.11±8.0</td>
<td>-1.93±4.2</td>
<td>-2.38±3.2</td>
</tr>
<tr>
<td>Peak medial/lateral COM velocity*</td>
<td>Concussed</td>
<td>8.85±22.4</td>
<td>2.99±20.1</td>
<td>11.77±30.0</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>3.64±33.6</td>
<td>4.84±20.2</td>
<td>14.40±29.8</td>
</tr>
<tr>
<td>Medial/lateral COM displacement*</td>
<td>Concussed</td>
<td>13.92±35.1</td>
<td>18.17±28.2</td>
<td>14.34±17.5</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>3.68±21.4</td>
<td>2.06±26.1</td>
<td>14.15±40.3</td>
</tr>
<tr>
<td>Average walk speed*†</td>
<td>Concussed</td>
<td>-8.65±8.0</td>
<td>-6.22±7.0</td>
<td>-7.33±5.7</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>-6.74±7.7</td>
<td>-2.44±4.3</td>
<td>-2.59±3.4</td>
</tr>
<tr>
<td>Step length</td>
<td>Concussed</td>
<td>-4.46±7.2</td>
<td>-3.94±4.9</td>
<td>-3.73±6.3</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>-3.29±5.9</td>
<td>-0.76±3.9</td>
<td>-1.73±3.0</td>
</tr>
<tr>
<td>Step width</td>
<td>Concussed</td>
<td>4.16±20.8</td>
<td>1.73±22.4</td>
<td>-2.49±17.5</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>-1.89±18.3</td>
<td>7.30±15.6</td>
<td>-0.96±11.3</td>
</tr>
</tbody>
</table>

NOTE. A positive value indicates an increase from the single- to dual-task condition, whereas a negative value indicates a decrease. All values are percentages.

* Main effect of group.
† Main effect of time.
during the dual-task condition compared with the single-task condition (main effect of task, $F_{1,37}=7.42$, $P=.01$, partial $\eta^2=.167$) (see fig 1B). The dual-task cost analysis for peak medial/lateral COM velocity (see table 3) demonstrated no interaction ($P=.701$), main effect of time ($P=.355$), or group ($P=.583$).

The group with concussions walked with significantly greater medial/lateral COM displacement in the dual-task condition compared with the single-task condition and the dual-task condition of the control group (group $\times$ task interaction, $F_{1,37}=8.65$, $P=.006$, partial $\eta^2=.189$) (fig 1C). The medial/lateral COM displacement dual-task cost was significantly greater

**Fig 1** Results across the 2-month testing period for peak anterior COM velocity (A), peak medial/lateral COM velocity (B), and total medial/lateral COM displacement (C). Statistically significant results from a 3-way analysis of variance with pairwise follow-up comparisons are listed to the right of each figure. Abbreviation: M/L, medial/lateral.
for subjects with concussion compared with controls across the 2 months of testing (dual-task cost; main effect of group, $F_{1,39} = 6.75$, $P = .013$, partial $\eta^2 = .154$) (see table 3).

**Stroop test accuracy**

The accuracy of the control subjects on the Stroop test was significantly greater than subjects with concussion throughout the 2-month testing period (main effect of group, $F_{1,37} = 9.45$, $P = .004$, partial $\eta^2 = .203$) (table 4).

**Discussion**

The results of this study indicate adolescents with concussion are disrupted in their ability to control forward momentum and maintain gait balance control to a greater degree than control subjects while walking and performing a concurrent cognitive task. Subjects with concussion demonstrated a greater dual-task cost on peak anterior COM velocity and medial/lateral COM displacement variables throughout the 2-month testing period compared with control subjects. Subjects with concussion also displayed a higher medial/lateral COM velocity and displacement within the dual-task condition compared with control subjects across the 2 months of testing, whereas step length resolved within 2 weeks of the injury and step width was not significantly affected by the testing period.

Previous literature has reported subjects with moderate to severe traumatic brain injury adopt shorter stride lengths postinjury compared with a cohort of healthy controls. The current data revealed the step length of subjects with concussion significantly increased 1 week after the injury, whereas no change was observed across time in the control group. Although no significant between-group differences were observed for step length, the values of the concussed group more closely approximated the controls after 1 week postinjury.

Temporal distance and COM parameters have been used as measurements central to understanding balance control. Previous work has demonstrated the utility of COM analysis in detecting disturbances in individuals with concussion, and suggests deficits in COM control may indicate a disrupted ability to maintain gait stability. The current data are in agreement with those findings in that medial/lateral COM displacement and velocity were significantly higher in the concussed group compared with controls during dual-task walking for 2 months after injury.

The greater peak anterior COM velocity dual-task cost for subjects with concussion noted in the current study may be the result of an adaption previously reported to reflect a mobility impairment, and may be due in part to an effort to reduce COM forward momentum in order to accommodate divided attention. This may indicate a disruption in motor or cognitive function during walking, or a disruption of the integration between these 2 functions. This is consistent with other literature, which suggests that attentional resources are limited in young adults suffering from concussion.

In the current study, the accuracy of control subjects on the Stroop test was significantly greater than subjects with concussion throughout the 2-month testing period. These data suggest that in adolescents, concussion not only affects gait performance, but appears to affect response accuracy during walking. Because all subjects were not instructed to focus their attention on either task, it is possible that the adolescents with concussion were not able to properly allocate their attentional resources to the same degree as healthy adolescents. Those suffering from concussion have been reported to have difficulty properly allocating attentional resources while performing ≥1 task simultaneously. Furthermore, it has been previously observed that the reaction time cost of switching from one task to another is significantly greater in adolescents with concussion when compared with control subjects throughout a 2-month testing period after injury. Hence, because the frontal regions of the brain are believed to play a role in attentional focus, and are among the last to develop, this region of the adolescent brain may be more susceptible to the effects of concussion and deficits may last longer than older age groups. The accuracy difference between groups along with the peak anterior COM velocity dual-task cost and increased medial/lateral COM displacement group differences indicates both cognitive and motor domains are affected for up to 2 months after concussion. These data also suggest that challenging cognitive and motor systems simultaneously after concussion may provide insights into how an affected individual may respond to mental and physical activities common in daily living, which requires complex cognitive and motor interactions.

Greater medial/lateral COM displacement and faster medial/lateral COM velocity were observed in the dual-task condition for subjects with concussion compared with control subjects for a period of 2 months after injury. These differences may reflect a balance control deficiency in the subjects with concussion rather than intentional gait disruption to accommodate incoming cognitive stimuli. Previous reports have linked increased frontal plane COM sway and velocity with balance impairments in young adults suffering from concussion, suggesting that a tradeoff between forward and side-to-side movement is brought on by a necessary reduction in COM forward velocity, and may reflect an inability to control balance. This impairment is consistent with the literature, which has described balance deficits in those suffering from a single concussion in young adult populations.

The Stroop test, when performed in conjunction with another task, such as walking, has been shown to activate the prefrontal cortex, which has been postulated to be crucial for the coordination of mental operations, and has been reported to be affected by concussion for up to 1 month after injury. The prefrontal cortex also contributes to goal-directed action by configuring, modulating, and processing information to complete goal-related task demands. The current study findings are consistent with others, because the simultaneous execution of a secondary task during walking resulted in decreased forward gait velocity, and this reduction was significantly greater in the group of adolescents with concussion than matched control subjects. During physical activities of daily living, an individual must move and think simultaneously to perform the intended task efficiently and safely.

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Stroop test accuracy rates during walking for subjects with concussion and control subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing Day</td>
<td>Concussion*</td>
</tr>
<tr>
<td>72h</td>
<td>96.6±5.0</td>
</tr>
<tr>
<td>1wk</td>
<td>96.8±4.6</td>
</tr>
<tr>
<td>2wk</td>
<td>96.6±4.8</td>
</tr>
<tr>
<td>1mo</td>
<td>97.7±3.9</td>
</tr>
<tr>
<td>2mo</td>
<td>97.5±3.2</td>
</tr>
</tbody>
</table>

**NOTE.** Values are in percentages.
* Main effect of group, $P = .004$. www.archives-pmr.org
If the ability to walk is inordinately affected by the implementation of a single additional task, individuals suffering from concussion may be less able to avoid hazards during normative activities, and thus are susceptible to further injury for a prolonged period of time during the postconcussion period.\textsuperscript{41}

**Study limitations**

Concussion severity was likely not uniform across all subjects, because it has been documented that concussion severity is quite variable.\textsuperscript{32} This variability possibly results from differences in injury history and mechanism of injury. Because it would be extremely difficult to prospectively constitute a concussion group of homogeneous severity, strict inclusion criteria were incorporated in this study to mitigate this limitation. Additionally, some subjects were cleared to return to unrestricted physical activity within 1 week of injury, whereas others did not return within the 2 months of testing. It is possible that variability in treatment could have affected the results; however, no subject was diagnosed with a second concussion while completing the course of the current study.

**Conclusions**

Concussion reduces balance control ability during dual-task walking up to 2 months after injury in adolescents. The results of the study suggest examination of dynamic balance control during dual-task walking may provide additional useful information in the clinical assessment and recovery from concussion.

**Suppliers**

a. Motion Analysis Corp, 3636 N Laughlin Rd, Ste 110, Santa Rosa, CA 95403.
b. Advanced Mechanical Technologies Inc, 176 Waltham St, Watertown, MA 02472.
c. Cedrus Corp, PO Box 6309, San Pedro, CA 90734.
d. AKG Acoustics, 8500 Balboa Blvd, Dock 15, Northridge, CA 91329.
e. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.

**Keywords**

Attention; Brain concussion; Brain injuries; Gait; Postural balance; Rehabilitation

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