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COMPLEXITY OF COGNITIVE TASK AFFECTS GAIT BALANCE CONTROL IN CONCUSSED ADOLESCENTS

David R Howell, Louis R Osternig, Li-Shan Chou

Department of Human Physiology, University of Oregon, Eugene, OR, USA

The purpose of this study was to prospectively examine the effect of different secondary tasks performed during gait on balance control ability in acutely concussed individuals. Individuals suffering from concussion subsequent to sport participation (n = 20) and healthy, matched controls (n = 20) were assessed in their ability to walk and complete three different cognitive tasks simultaneously over a period of two months following injury. Gait balance control deficits appeared to be greater as the complexity of the task increased. This finding may assist clinicians utilizing dual-task assessments in their diagnosis and management of concussion.

KEY WORDS: Dual-Task, Sport Concussion, Mild Traumatic Brain Injury

INTRODUCTION: It has been estimated that approximately 1.6 to 3.8 million concussions occur annually as a result of sport participation in the United States (Langlois, Rutland-Brown, & Wald, 2006). A standard component of the clinical exam following injury is patient-reported symptom monitoring. However, it has been reported that deficits may exist longer than reported by the patient (Broglio, Macciocchi, & Ferrara, 2007). Thus, a need exists to develop and validate objective measurement tools in order to help determine appropriate timing of a safe return to play (Harmon et al., 2013).

The adolescent brain may be particularly vulnerable to the effects of concussion as it has not yet reached full maturation (Luna, Padmanabhan, & O'Hearn, 2010). Despite reports that head injury during this time of life may result in deleterious long-term effects (Baillargeon, Lassonde, Leclerc, & Ellemberg, 2012), little literature examining the long-term effects of concussion exist in this particular population.

As both cognitive and motor systems appear to be affected following sport-related concussion (Sosnoff, Broglio, & Ferrara, 2008), a way in which to monitor both systems independently and their interaction with each other is through the use of dual-task testing. Such assessments necessitate proper allocation of attentional resources, thus challenging the brain to effectively execute both tasks simultaneously (Yogev-Seligmann, Hausdorff, & Giladi, 2008). While dual-task experiments have been used in the assessment and potential treatment of sport related concussion (Ross et al., 2011; Teel, Register-Mihalik, Blackburn, & Guskiewicz, 2012), no investigations to this point have compared the effect of different types of secondary tasks on the motor or cognitive performance outcome of individuals suffering from concussion. Two common secondary tasks which have been reported during a balance or gait task to monitor concussion recovery have been a simple mental task, such as numerical processing (Catena, Van Donkelaar, & Chou, 2007) and the Stroop task (Teel et al., 2012). Therefore, the purpose of this study is to prospectively examine how three different secondary cognitive tasks of varying complexity affect gait balance control in concussed and healthy adolescents.

METHODS: Twenty high school students (mean age = 15.3 ± 1.3 years) were identified by a health professional (certified athletic trainer/physician) as suffering a concussion while participating in sports. Each subject was referred to the laboratory for testing within 72 hours of injury and returned one week, two weeks, one month, and two months post-injury. Each concussed subject was matched with a healthy control subject (n = 20, mean age = 15.6 ± 1.0 years) by sex, height, mass, age, and sport. Controls were tested in a similar timeline.

Subjects walked barefoot at a self-selected speed along a walkway under four conditions: walking with undivided attention (WALK) and walking while completing three different

secondary tasks: a single auditory Stroop (SS), a continuous auditory Stroop (CS), or a question and answer task (Q&A).

The SS task consisted of the subject listening to the word “high” or “low” played in a high or low pitch with the goal of identifying the pitch of the word, regardless of whether the pitch was congruent with the meaning of the word one time during a walking trial. The CS task consisted of the subject listening to the word “high” or “low” played in a high or low pitch four times in random order during a walking trial. Similar to the SS, the subject was instructed to identify the pitch of the word, regardless of whether the pitch was congruent with the meaning of the word. The Q&A task consisted of spelling a five-letter word backwards, subtracting by 6s and 7s, or reciting the months in reverse order while completing a walking trial. All conditions were completed in blocks of 8-12 consecutive trials, in the same order for all subjects, and rotated each testing session. Subjects were not instructed to focus on either the cognitive or walking task specifically.

A total of 29 retro-reflective markers were placed on bony landmarks and whole body movement was recorded using a ten camera motion analysis system (Motion Analysis Corp., Santa Rosa, CA) at a sampling rate of 60 Hz. The whole body COM position was then calculated with a 13-link model (Hahn & Chou, 2003). Peak linear COM anterior (Av) and medial/lateral (MLv) velocities were identified during the gait cycle as well as total COM frontal plane excursion (MLdisp). These variables have previously been reported to provide sensitive detection of gait imbalance (Hahn & Chou, 2003).

Three-way mixed effects ANOVAs were used to analyze each walking dependent variable to determine the interactions and main effects of group, time, and task. 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.

RESULTS: ***Anterior COM velocity:*** Peak anterior COM velocity (Av) analysis revealed that concussed subjects walked with a decreased Av within 72 hours of injury compared with all other subsequent testing times and their peak Av at the one and two week was significantly less than the 2 month assessment. Control subjects walked with a lower Peak Av at the initial testing assessment than the one month testing assessment (time x group interaction $F(4, 148) = 3.29$, $p = .032$, $\eta_p 2 = .082$). Concussed subjects also demonstrated significant Av differences between all four conditions (See Figure 1) while control subjects demonstrated significantly greater WALK Av than all three dual-tasks, and significantly greater SS Av than the CS or Q&A conditions (task x group interaction $F(3, 111) = 3.54$, $p = .035$, $\eta_p^2 = .087$). Furthermore, all subjects demonstrated a decreased Av at the initial testing time than each follow-up in all dual-task conditions, and a greater WALK Av than all other conditions at each time point (time x task interaction $F(12, 444) = 4.19$, $p < .001$, $\eta_p^2 = .102$).

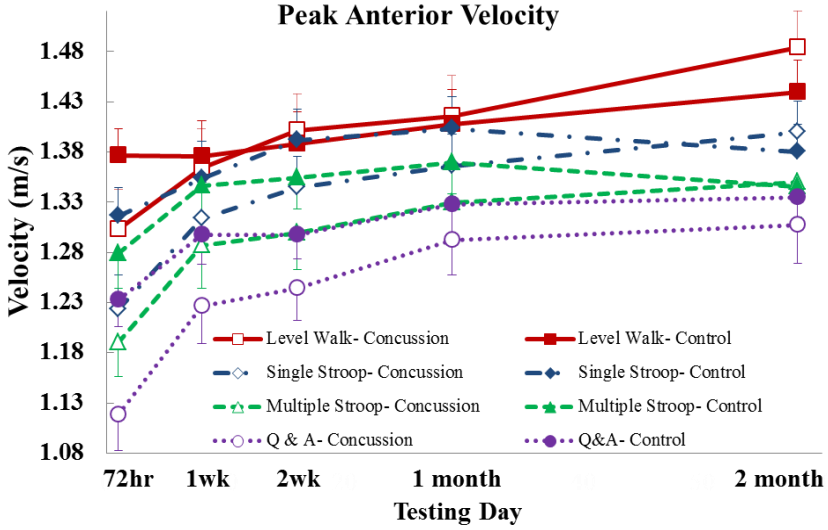

Figure 1: Mean (+/- SE) peak anterior velocity for concussed and control subjects for each of the four walking conditions, across the two month testing period. A time x group interaction ($p = .032$), task x group interaction ($p = .035$), and time x task interaction ($p < .001$) were all found to be significant.

***Medial/Lateral COM velocity*:** Peak medial/lateral COM velocity (MLv) analysis revealed no significant three-way or two-way interactions. Concussed subjects walked with a significantly greater MLv than control subjects across the two months of testing (See Figure 2; main effect of group $F(1, 37) = 4.27$, $p = .046$, $\eta_p^2 = .103$). All subjects walked with a significantly greater Q&A MLv compared with the WALK and CS conditions (main effect of task, $F(3, 111) = 9.19$, $p < .001$, $\eta_p^2 = .199$).

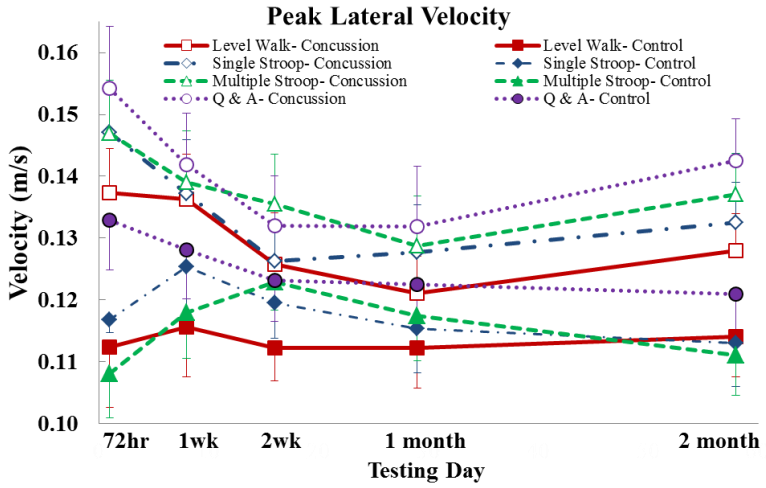

Figure 2: Mean (+/- SE) peak medial/lateral velocity for concussed and control subjects for each of the four walking conditions, across the two month testing period. Main effects of group ($p = .046$) and task ($p < .001$) were found to be significant.

Medial/Lateral COM displacement: Analysis of the total M/L displacement (MLdisp) during the gait cycle revealed that concussed individuals displayed less MLdisp in the single-task condition than in the continuous Stroop condition and displayed more MLdisp in the Q&A condition than any of the other three conditions. Concussed individuals displayed a significantly greater MLdisp in both the Q&A and continuous Stroop conditions than control subjects (See Figure 3; task x group interaction $F(3, 111) = 5.57$, $p = .001$, $\eta_p^2 = .131$)

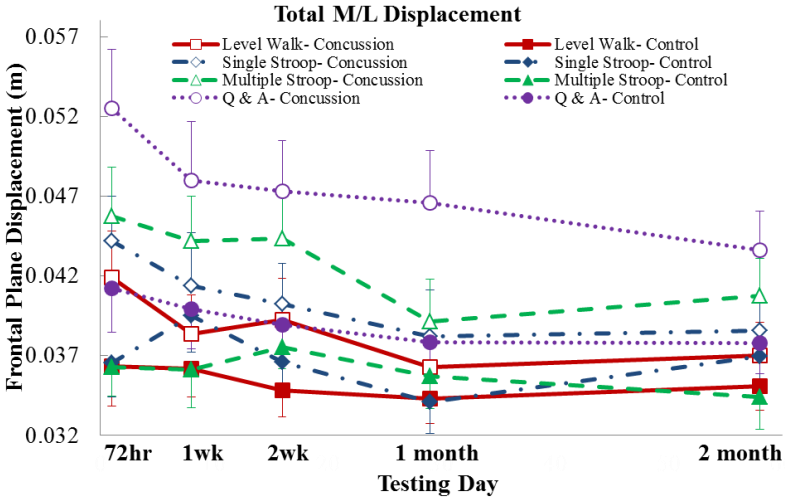

Figure 3: Mean (+/- SE) total medial/lateral displacement for concussed and control subjects for each of the four walking conditions, across the two month testing period. A task x group interaction ($p = .001$) was found to be significant.

DISCUSSION: The results from this study indicate that the gait balance control deficits from concussion may be more pronounced with the use of a secondary task utilized during walking, and that task complexity affects the degree of deficit observed in adolescent athletes. As the addition of a secondary task while walking appears to disrupt motor ability, sport situations, which require more complex cognitive and motor functioning, may create large disturbances which may leave the individual vulnerable to subsequent trauma. This type of assessment may provide sensitive detection of such disruptions.

The peak Av variable, which has been documented as an indication of mobility and forward momentum control (Yogev-Seligmann et al., 2008) significantly decreased as the task

increased in complexity for concussed subjects, while control subjects were not affected to the same degree. This indicates those suffering from concussion are highly sensitive to the type of dual-task employed in their forward momentum control after injury.
The MLdisp variable appeared to be sensitive to the addition of more complex tasks, as seen by the increased MLdisp in the Q&A condition. As a balance control indicator, the MLdisp data reveals that the secondary task employed affects balance control, and that deficits may still be present in the adolescent population for a time up to two months following injury.
The MLv did not reveal a large difference between tasks, but rather a distinct difference between groups. As the main effect of group indicates, it is evident that concussed individuals walk with a faster side to side movement than control subjects regardless of secondary task and that this deficit remains for up to two months following injury.
Dual-tasks have been indicated in the management of concussion (Teel et al., 2012) as both the gait and secondary tasks are attention demanding. Therefore if these capacities are limited, at least one of them may deteriorate when performed simultaneously (Yogev et al., 2005). The applicability of dual-task assessments in the clinical management of sport related concussion has recently been documented as a way to increase sensitivity to subtle deficits following injury (Ross et al., 2011). Thus, this type of testing may represent an additional tool through which accurate assessment of recovery from concussion can occur, and could potentially help to uncover previously undetected disturbances.

CONCLUSION: Gait balance control deficits appear to be greater in concussed individuals with a more complex secondary cognitive task following a sport concussion and may still be present for a time up to two months following injury. This finding may assist sports medicine clinicians in the monitoring of recovery to full brain health following concussion.

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