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Dual-task gait differences in female and male adolescents following sport-related concussion

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ABSTRACT

Concussion may affect females and males differentially. Identification of gender-related differences after concussion, therefore, may help clinicians with individualized evaluations. We examined potential differences in dual-task gait between females and males after concussion. Thirty-five participants diagnosed with a concussion (49% female, mean age = 15.0 ± 2.1 years, 7.5 ± 3.0 days post-injury) and 51 controls (51% female, mean age = 14.4 ± 2.1 years) completed a symptom inventory and single/dual-task gait assessment. The primary outcome variable, the dual-task cost, was calculated as the percent change between single-task and dual-task conditions to account for individual differences in spatio-temporal gait variables. No significant differences in symptom severity measured by the post-concussion symptom scale were observed between females (32.0 ± 18.0) and males (27.8 ± 18.2). Compared with males, adolescent females walked with significantly decreased cadence dual-task costs after concussion (−19.7% ± 10.0% vs. −11.3% ± 9.2%, $p = 0.007$) when adjusted for age, height, and prior concussion history. No significant differences were found between female and male control groups on other dual-task cost gait measures. Females and males with concussion also walked with significantly shorter stride lengths than controls during single-task (females: 1.13 ± 0.11 m vs. 1.26 ± 0.11 m, p = 0.001; males: 1.14 ± 0.14 m vs. 1.22 ± 0.15 m, p = 0.04) and dual-task gait (females: 0.99 ± 0.10 m vs. 1.10 ± 0.11 m, p = 0.001; males: 1.00 ± 0.13 m vs. 1.08 ± 0.14 m, p = 0.04). Females demonstrated a significantly greater amount of cadence change between single-task and dual-task gait than males after a sport-related concussion. Thus, differential alterations may exist during gait among those with a concussion; gender may be one prominent factor affecting dual-task gait.

1. Introduction

Prior studies have identified movement deficits after concussion when an individual performs a motor and cognitive task simultaneously [1–3]. Virtually all sport and daily-living activities require attentional allocation across motor and cognitive domains. Therefore, examining the motor and cognitive performance interactions following concussion may provide unique and meaningful insights into functional recovery after injury.

Monitoring motor function through gait analysis allows for the examination of functional capabilities in a way that reflects demands similar to everyday life [4]. Furthermore, dynamic evaluations of motor performance have been recommended during concussion assessments due to their practicality and reliability [5]. Dual-task paradigms measure the influence of attentional capacity on motor and cognitive functions, and can augment clinical decisions related to return-to-play after a sport-related concussion [6]. Recently, dual-task gait deficits among children were observed after concussion symptom resolution [7]. Furthermore, persistent executive dysfunction after concussion may be identified via dual-task gait [3], indicating the sensitivity of dual-tasks to post-concussion deficits not observed with traditional clinical exam methods. Prior investigations have observed greater dual-task costs in those with a recent concussion relative to controls [2,3]. Accordingly, dual-task costs represent the change from a focused-attention single-task relative to a divided attention dual-task condition, in order to account for individual differences in attentional loading and walking speed [4].

After concussion, females may report more concussion symptoms

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than males [8] and require a longer duration of time to achieve full symptom resolution [9]. Therefore, clinical presentation and recovery following concussion may vary between genders. In contrast, a prior study indicated that gender was not associated with standardized assessment of concussion (SAC) and Balance Error Scoring System (BESS) test outcomes [10]. Whether dual-task gait differences between females and males exist after a concussion remains unknown. Further understanding the influence of gender on motor and cognitive abilities after sport-related concussion could help promote an individualized approach to concussion management. Therefore, the purpose of this study was to examine how gender and a recent concussion affect dual-task gait costs among adolescents. We hypothesized that female athletes who recently sustained a concussion would demonstrate greater dual-task costs than males who recently sustained a concussion.

2. Methods

2.1. Participants

Prior to the study, the institutional review board reviewed and approved this protocol. All participants and their parents/guardians (if < 18 years of age) provided written informed consent to participate in the study. Study participants included individuals who reported to a regional sport concussion clinic within the first 2 weeks of their injury as well as uninjured control participants who participated in an injury prevention evaluation at a sports injury prevention center.

Individuals who reported to the clinic within 14 days of injury, were diagnosed by a board-certified sports medicine physician with a concussion during their first clinic visit, and were experiencing concussion symptoms at the time of examination were eligible for inclusion in the study. Potential participants were excluded from the study if they were older than 18 years of age, reported an existing lower extremity injury that might have affected their normal gait or balance control, a history of permanent memory loss, learning disability, Down syndrome, developmental delay. Control participants were identified during an injury prevention evaluation, an assessment that entails an evaluation of prior medical history and measurements of biomechanical, neuromuscular, anatomical, and physiological function, and has been described previously [11]. Control participant prior concussion history was self-reported using a standardized questionnaire; they were excluded if they reported a concussion within the past year.

2.2. Experimental protocol

During the examination, concussion participants completed standardized forms documenting demographic and clinical information such as prior concussion history, prior medical history, and symptom severity. In order to describe the number and severity of concussion symptoms, they completed the post-concussion symptom scale (PCSS). If necessary, parents were available to assist with concussion symptom ratings or other survey questions for younger participants. As some participants without a concussion may endorse symptoms included on the PCSS, participants were instructed to only rate symptoms that started at the time of injury and were still present within the prior 24 h of examination. During the PCSS, participants rated the level of severity of 22 concussion symptoms on a Likert-like scale from 0 (asymptomatic) to 6 (severe), resulting in a range from 0 to 132. As prior research has observed that vestibulo-ocular signs are a risk factor for prolonged recovery after concussion in youth athletes [12], we also conducted a sub-analysis of vestibulo-ocular symptoms by calculating the sum of scores for the following symptoms: “balance problems”, “dizziness”, and “blurry vision”, resulting in a rating that ranged from 0 to 18. Control participants did not complete the symptom inventory.

In order to evaluate gait and cognitive abilities, participants completed a dual-task protocol. They completed 5 single-task walking trials (walking without a cognitive demand) and 5 dual-task walking trials (walking while concurrently completing a cognitive test). During all trials, participants walked without shoes at a self-selected pace in a clinic hallway adjacent to their examination room. They were instructed to walk toward a target placed 8 m in front of them, walk around it, and return to the original starting position.

Gait variables were obtained using a portable inertial sensor system (Opal Sensors, APDM Inc., Portland, OR). Participants wore the sensors, attached with an elastic belt, on the spine at the level of the lumbosacral junction, and on the dorsum of the left and right feet. Data were collected at a sampling frequency of 128 Hz, synchronized, and transmitted to a laptop computer wirelessly. This system is a reliable and valid technique to quantify gait and balance performance in clinical settings; gait variables were calculated using Mobility Lab software [13]. This software has been used to analyze spatio-temporal gait variables during straight-line walking [14,15]. Specifically, we selected four variables to compare dual-task cost and unadjusted gait values between genders: average walking speed, stride length, cadence, and double support time, selected due to prior work documenting concussion-related dysfunction [4,16,17]. Gait cycle duration was not included due to its inverse relationship with cadence. Average walking speed was calculated as the average stride velocity for left and right feet across all gait cycles in each trial. Stride length was calculated as the average distance for the left and right distance between two consecutive foot falls at the moment of initial contact on all trials. Cadence was calculated as the rate of steps per minute, also defined as foot falls at the moment of initial contact. Double support time was defined as the percentage of time in each gait cycle that both feet were on the ground. The normative reference ranges for these variables have been previously documented among collegiate athletes [18].

During the dual-task condition, participants walked and completed a cognitive test consisting of 3 different forms: (1) spelling a five-letter word backwards, (2) subtracting by 6s or 7s from a randomly presented 2-digit number, or (3) reciting the months in reverse order starting from a randomly chosen month. The cognitive test was chosen due to its ability to sensitively identify deficits after concussion when used within a dual-task paradigm [16] and its high test-retest consistency during gait [19]. The specific test form varied from trial to trial in order to avoid potential learning effects from one trial to the next, and no duplicate cues were used.

2.3. Outcome variables

The dual-task cost was the primary outcome variable, calculated as the percentage change between single-task and dual-task conditions. This outcome variable accounts for normal gait variability between study participants by normalizing dual-task performance relative to their own single-task performance. For each participant, the dual-task cost was calculated as: [(dual-task value–single-task value)/single-task value] and expressed as a percentage. Therefore, a positive value indicates an increase from the single- to dual-task condition, whereas a negative value indicates a decrease. The outcome variables of interest were those relating to the dual-task cost for each of the quantified gait characteristics.

2.4. Statistical analysis

Continuous variables are presented as the mean ± SD and were compared between groups using *t*-tests for demographic and injury history variables. Similarly, categorical variables are presented as numbers included (n) or percentage of the total and were compared