Clinical feasibility and utility of a dual-task tandem gait protocol for pediatric concussion management

Mathew J. Wingerson, BA a, Corrine N. Seehusen, BA a, Gregory Walker, MD a,b, Julie C. Wilson, MD a,b,c, David R. Howell, PhD, ATC a,b

Author affiliations:
a Sports Medicine Center, Children’s Hospital Colorado, Aurora, CO, USA
b Department of Orthopedics, University of Colorado School of Medicine, Aurora, CO, USA
c Department of Pediatrics, University of Colorado School of Medicine, Aurora, CO, USA

Corresponding Author: David R. Howell, PhD, ATC. Sports Medicine Center, Children’s Hospital Colorado; Department of Orthopedics, University of Colorado School of Medicine. Address: 13123 E. 16th Avenue, B060 Aurora, CO 80045. Email: David.Howell@CUAnschutz.edu. Phone: 720-777-1502 ORCID: 0000-0002-2955-0191

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Context: Clinical management of sport-related concussion requires the assessment of various factors, including motor performance. The tandem gait test, a measure of post-injury motor performance, has demonstrated clinical utility, but is limited by time availability and test uniformity.

Objective: To assess intrasession reliability between tandem gait test trials and determine the number trials necessary for optimal utility and feasibility in clinical decision-making following concussion.

Design: Cross-Sectional Study

Setting: Pediatric Sport Medicine Clinic

Participants: Adolescent athletes who recently sustained a concussion (n=44; age=15.4±1.8 years; 39% female) and were seen for care within 14 days (7.3±3.2 days) of their injury, as well as uninjured control participants (n=73; age=15.8±1.3 years; 41% female). All participants completed three single-task and three dual-task tandem gait trials.

Outcome Measures: We collected test completion time and cognitive performance for each trial and calculated Pearson correlation coefficients between trials and Intraclass Correlation Coefficients to determine intrasession reliability. We also compared performance between groups, and calculated area under the curve (AUC) values to identify the ability of each trial to distinguish between groups.
Results: Both the concussion and control group demonstrated high intrasession reliability between tandem gait trials under single (R ≥ 0.82; ICC ≥ 0.93) and dual-task conditions (R ≥ 0.79; ICC ≥ 0.92). The greatest group classification values were obtained from the second single-task trial (AUC = 0.89) and first dual-task trial (AUC = 0.83). Test completion time provided excellent between-group discrimination in single-task and dual-task conditions. However, cognitive performance during dual-task trials demonstrated only marginally significant clinical utility (AUC ≤ 0.67).

Conclusion: Tandem gait assessments may only require two trials under single-task and one trial under dual-task conditions to effectively discriminate between concussion and control groups. This approach may improve the feasibility (time requirement) of the test, while maintaining excellent discriminatory ability.

Key words: tandem gait, assessment, concussion, adolescent

Key points:

1) Tandem gait assessment may require fewer than three trials to effectively discriminate between concussion and control groups. This approach may improve the feasibility of the test within many clinical settings.

2) Tandem gait motor performance during the words-backward cognitive task demonstrated the greatest group classification accuracy among dual-task conditions. Clinicians should consider using this task to detect identifiable concussion-related impairments in motor performance.

3) Test completion time provided the best between-group discrimination in single-task and dual-task conditions. Thus, motor performance impairment, as measured by time-to-completion
during tandem gait, may be a more accurate diagnostic approach than cognitive performance
under this specific dual-task paradigm.
The diagnosis and management of sport-related concussion requires assessment of an array of factors including symptom severity, injury history, neurocognitive disruption, and motor performance impairment (e.g., balance or gait instability).¹ One factor particularly affected by concussion is motor performance.²,³,⁴ Various measures of motor performance impairment are included in the most recent edition of the Sport Concussion Assessment Tool (SCAT-5) to assist physicians, athletic trainers or physical therapists in complex concussion management and decision-making.¹ One such measure of post-injury motor performance, the tandem gait test, has demonstrated excellent clinical utility for the management of concussion.⁵

According to the SCAT-5, tandem gait testing requires patients to walk in a heel-toe pattern along a 3-meter line,¹ assessing complex motor control as the individual ambulates with a narrow base of support. This test can be performed under single-task, with undivided attention, and dual-task conditions, where the individual is asked to simultaneously complete a cognitive task.⁵,⁶,⁷ Single-task tandem gait time, the total number of seconds from commencement to completion, has demonstrated the capacity to distinguish concussed individuals from healthy controls when testing occurs within one week of injury.⁶,⁸,⁹ Furthermore, dual-task tandem gait time can differentiate concussed patients from healthy controls even after symptom resolution, demonstrating its ability to provide useful information within concussion management beyond that of typically used measures, such as symptom severity.⁶,⁸,⁹ When compared to pre-injury scores, collegiate athletes who sustained a concussion performed significantly slower on tandem gait testing within 48 hours of injury, as opposed to their non-concussed peers who showed no difference relative to baseline scores, indicating that baseline testing may be useful when assessing and interpreting post-injury tandem gait.⁵
Tandem gait assessment was first presented within the SCAT-3, in which performance was quantified as the best (fastest) time among 4 total trials.\textsuperscript{10} Despite emerging research demonstrating the utility of a timed tandem gait in the assessment of concussion,\textsuperscript{5,6,8,9} the most recent SCAT-5 transitioned to a pass/fail evaluation,\textsuperscript{1,11} defining a failing score as separation between the heel and toe, stepping off the line, or using the administrator to regain balance. Regardless of this transition to a pass/fail system, recent studies have quantified single and dual-task tandem gait performance among concussed patients as either the \textit{average} or the \textit{best} time-to-completion for three trials under each condition.\textsuperscript{5,8,9} Furthermore, the SCAT-5 offers no direction or standardization of cognitive function for use in dual-task conditions.\textsuperscript{1,11} As such, incorporating a question & answer cognitive task during tandem gait trials represents a feasible option to increase task complexity, create a more challenging and sport-like test environment, and better detect identifiable concussion-related motor performance impairments.\textsuperscript{6,8,9,12}

However, the feasibility of the clinical assessment of tandem gait may be limited by a variety of factors. Primarily, clinician time availability is limited, given the numerous other recommended assessments performed during a clinical examination of concussion.\textsuperscript{1} A single tandem gait trial can last approximately 20 to 30 seconds following concussion.\textsuperscript{8,9} With intermittent preparation, instruction, and transition, a full assessment that contains multiple trials and conditions may take up to 10 minutes to conduct. Furthermore, previous studies have demonstrated a significant difference between post-injury tandem gait times and baseline scores obtained prior to injury.\textsuperscript{5} As such, the inclusion of the tandem gait assessment in pre-injury baseline testing is further limited by test administration time. This limitation is intensified when baseline testing is performed in one session for a significant number of athletes, as is the case for many adolescent school and club sports. By reducing the time clinicians spend on test
administration, the test feasibility can improve, specifically in time-limited situations such as sideline assessment, baseline testing, or clinical evaluation.

Concomitantly, the lack of uniformity in tandem gait testing, specifically for cognitive task use within dual-task testing and optimal number of trials, can create unnecessary variability among clinicians evaluating sport-related concussions. Therefore, establishing a uniform tandem gait protocol, currently missing from the SCAT-5, can improve test feasibility and reduce test variability. Although high test-retest reliability of tandem gait has been established for pediatric patients, the intra-session reliability of the assessment is currently unknown.

Therefore, the purpose of our investigation was to determine the number of tandem gait test trials necessary for optimal clinical feasibility (number of trials required and intra-session reliability) and utility (discriminatory ability) to assist in clinical decision-making following concussion. A secondary objective was to evaluate the discriminatory ability of three separate cognitive tests within the dual-task framework.

Materials and Methods

Participants and Study Design

We conducted a cross-sectional study of youth athletes ages 13-17 years who had recently sustained a concussion, or were uninjured control participants. Concussion participants were seen for care at the institution’s Sports Medicine Center and diagnosed with a concussion within 14 days of their injury. All concussions were diagnosed by board-certified sports medicine physicians, consistent with the definition provided by the most recent international consensus statement on concussion in sport at the time of data collection. Participants completed the Post-Concussion Symptom Inventory (PCSI), a validated measure of concussion-related symptoms, at the time of assessment. Concussed individuals reported significantly higher PCSI
scores, indicating an elevated level of concussion-related symptoms, compared to healthy controls. Participants in the concussion group were excluded if they received a diagnosis for any injury other than a concussion or related sequelae (e.g. neck strain) at the time of assessment. Control participants were tested during routine pre-participation sport physical evaluations. All control group participants received clearance to participate in sport without restriction from a physician at the time of assessment, thus confirming their healthy status. No patients in the concussion group were among those tested during the pre-participation physical evaluations. Exclusion criteria for both groups included: history of epilepsy or seizure, pre-existing neurological or psychiatric disorder, or a diagnosed concussion within 6 months of the assessment (other than the injury for which the concussion participants were being seen). Prior to commencement, the local institutional review board approved the study protocol and all participants, and their parent/legal guardian provided written informed assent and consent respectively to participate in the study.

Tandem Gait Protocol

Tandem gait assessments occurred within the concussion visit at which the patient presented for evaluation (concussion group) or as a part of a pre-participation physical evaluation (control group). The testing environment for tandem gait was a space free from clutter, furniture or equipment which may interfere with gait, large enough for participants to comfortably ambulate without nearing walls or doorways, and secluded from obvious noise or distraction. Prior to test initiation, a study or clinical team member affixed a 3-meter length of sports tape linearly to the ground in the testing area to delineate the test distance.

Participants received verbal instruction from a clinical or research team member prior to test initiation. Participants were instructed to walk using an alternating heel-to-toe pattern along
the entire length of sports tape, complete a 180° turn with feet still on the tape, then continue the same gait pattern back to the starting position without interruption. Participants were asked to perform this task as quickly as possible, without separation of heel and toe during gait, stepping off the tape, or using the test administrator to regain balance. During both single and dual-task trials, the test administrator told participants when to begin each trial. The primary outcome measure was time-to-completion, measured in seconds by the administer using a stopwatch or smartphone timer. The timer started immediately as the administrator instructed participants to begin the trial and stopped when their back foot reached the end of the sports tape. The test administrator recorded time-to-completion during a 5-15 second break between trials.

Dual-task conditions mirrored that of single-task with the addition of a simultaneous cognitive task. The test administrator informed participants that, for the next three trials, they will respond aloud to cognitive tasks while simultaneously completing the aforementioned tandem gait protocol. Three separate cognitive tasks were used in dual-task conditions consistent with previous research:6,7,12 1) backward spelling of a simple 5-letter word, 2) serial subtraction by 6 or 7 from a 2-digit number, and 3) reciting of the months in reverse order. All patients completed dual-task trials in the same order of cognitive task completion (i.e. trial 1 = words-backward, trial 2 = serial-subtraction; trial 3 = months-in-reverse).

Prior to each trial in the dual-task condition, participants were informed of the cognitive task to be completed, and a verbal description of the task was provided. If needed, participants were offered a simplified practice prompt of similar nature to the task used in that trial (e.g. backward spelling of the word “Cat” or subtraction of 7 from “14”) to ensure comprehension. No instructions were provided to patients related to the prioritization of either gait or cognitive response. The primary outcome measure in dual-task conditions remained time-to-completion.
Test administrators also recorded cognitive task accuracy (number of correct responses divided by the total number of responses) and response rate (number of seconds per response, calculated as: trial time ÷ total number of responses) as secondary outcomes. Failed trials, defined as separation between the heel and toe in tandem gait, stepping off the tape, or using the administrator to regain balance, were not included in the subsequent analysis. In the event of a failed trial, the participants were asked to complete the same trial again until the successful completion of three trials in each condition was achieved. An inability to accurately respond to cognitive tasks was not considered a failed trial.

This protocol is consistent with procedures used in previous studies.\(^5\,6\,7\) Psychometric properties for tandem gait have been established previously, with reported sensitivity (0.63), specificity (0.61), and area under the curve (0.70) values.\(^5\) In addition, the tandem gait test in single-task (intra-class correlation coefficient = 0.86) and dual-task (intra-class correlation coefficient = 0.84) conditions has demonstrated suitable levels of test-retest reliability for repeat clinical assessment over multiple sessions on different days.\(^7\)

**Statistical Analysis**

Data are presented as means (standard deviations) for continuous variables, and the number included (corresponding percentage) for categorical variables. We compared demographic and medical history characteristics between groups using independent samples t-tests and chi-square analyses. To assess test completion time and cognitive performance differences on each individual trial, we compared concussion and control groups using independent samples t-tests. To adjust for multiple comparisons, we defined a significant difference between groups as \(p < 0.01\). To assess within-session test reliability, we calculated Pearson correlation coefficients (\(r\) values) between trial 1-trial 2, and between trial 2-trial 3,
separately for concussion and control groups and for single-task and dual-task conditions. For interpreting correlations between trials, we used the following values: <0.39 as a low correlation, 0.4-0.59 as a moderate correlation, 0.60-0.79 as a moderately high correlation, and ≥ 0.80 for a high correlation. Furthermore, we calculated the intraclass correlation coefficient (ICC\(_{2,k}\)) values across the three trials using a two-way random effects, absolute agreement, multiple raters/measurements approach, separately for concussion and control groups, and for single-task and dual-task conditions.

To examine the ability of the obtained measures to discriminate between concussion and control groups, we also calculated area under the curve (AUC) values from Receiver Operating Characteristic (ROC) curves for each trial separately. We defined AUC values as outstanding (>0.9), excellent (0.8-0.9), acceptable (0.7-0.8), or poor (< 0.7).

Finally, to compare concussion and control group performance on each trial while adjusting for potential confounders, we constructed a series of multivariable linear regression models. The outcome variable in each model was tandem gait completion time on each trial, the predictor variable was group assignment, and covariates included height, concussion history, and symptom severity (PCSI rating). Any missing data were treated as such, and no imputations were performed. All statistical tests were two-sided and performed using Stata Statistical Software: Version 15 (College Station, TX: StataCorp, LLC).

**Results**

A total of 117 participants completed the study protocol: n=44 had sustained a concussion within 2 weeks of the assessment (mean=7.3±3.2 days; range=2-14 days) and n=73 uninjured controls. The concussion group was shorter, had a greater proportion of individuals
with a previously diagnosed concussion, and reported significantly greater symptom severity compared to the control group (Table 1).

The concussion group completed the tandem gait test slower than the control group during both single-task and dual-task conditions on all three trials (Figure 1). In addition, the single-task tandem gait test demonstrated excellent discriminatory ability between groups during all three trials (AUC ≥ 0.85; Figure 1). Both groups demonstrated high correlations and ICC values across all single-task trials (Figure 1). Similarly, the concussion group performed the dual-task tandem gait test slower than the control group on all three trials, and the dual-task condition demonstrated excellent discriminatory ability (AUC ≥ 0.80) between groups (Figure 2). Concussion and control groups demonstrated high correlations and ICC values across all dual-task trials (Figure 2). Classification accuracy was high between groups at the following cut-points for single-task (trial 1: 20.3 s = 82% accuracy; trial 2: 20.8 s = 82% accuracy; trial 3: 17.1 s = 83% accuracy) and dual-task (words backward: 29.2 s = 80% accuracy; subtraction: 26.8 s = 79% accuracy; months backward: 27.6 s = 75% accuracy).

No significant differences in cognitive performance were observed during the tandem gait test (Table 2). Specifically, there were no accuracy or response rate differences between groups for any of the three cognitive tasks, and AUC values were low (0.61-0.64).

After adjusting for the potential confounding variables of height, concussion history, and symptom severity, significant associations between concussion group and slower tandem gait test times were found for all three single-task trials, and for the dual-task trials where participants completed the words-backward and months-in-reverse tasks (Table 3).

**Discussion**
The data from our investigation support previous research on the capacity of the tandem gait test to identify concussion-related motor performance impairment after a concussion.\textsuperscript{5,6,8,9}

Although all trials were able to distinguish between groups, the most accurate group classification was obtained from tandem gait time-to-completion values during the second single-task trial and the first dual-task trial (words-backward). Additionally, under both conditions, tandem gait time showed high intra-session reliability, demonstrating that values obtained from one test trial did not significantly differ from those of another trial within the existing testing session. This builds on previous research illustrating high test-retest reliability between sessions approximately two weeks apart.\textsuperscript{7} As such, our data suggest that a tandem gait protocol for use in concussion assessment among adolescent patients may only require two single-task trials, and one dual-task trial, with concurrent words-backward task completion.

Under single-task conditions, the second trial (where the greatest AUC value was found) provided the best discriminatory ability, indicating that two timed trials may be adequate for clinical examination purposes. In dual-task conditions, tandem gait time-to-completion during the words-backward cognitive task most accurately predicted group classification (concussed vs. non-concussed). This suggests that only one dual-task trial with this cognitive cue may be required for clinicians to obtain clinically relevant information during concussion assessment. Therefore, the previously accepted quantification of motor performance as the best (fastest) or average time-to-completion among four separate trials, as used in prior studies,\textsuperscript{8,9,10} may not be necessary. Our data suggest that 1-2 trials per condition may be sufficient in providing clinically useful information and is likely the most streamlined protocol for tandem gait testing. This trial reduction is particularly significant under dual-task conditions, which require additional cognitive task instruction between each trial. The clinical utility of these data thus suggests an
option for clinicians to reduce the time required for the tandem gait test within concussion evaluations.

A slight learning effect for tandem gait time-to-completion was observed as participants marginally improved in later trials, similar to learning effects demonstrated by other concussion measures, such as the mBESS. This further supports the use of fewer trials in single and dual-task tandem gait to reduce the influence of potential practice effects on obtained values. Previous repeated measure designs have identified high reliability across time for the tandem gait test (ICC values > 0.8), suggesting small learning effects across time. Our results support these previous findings, but within the existing testing session where trials are administered consecutively. Furthermore, previous research has supported the ability of tandem gait to identify concussion-related impairments in motor control, beyond that detected by the BESS and mBESS (tandem gait, AUC = 0.704; BESS, AUC = 0.508; mBESS, AUC = 0.535). Although the tandem gait test may be slightly more complex in preparation, instruction, and administration than the mBESS, our findings align with previous research to further support the use of the tandem gait test as the primary assessment in motor control evaluations, particularly following improved test feasibility. Given that mean differences for each trial exceeded 95% confidence reliable change values (>5.3 seconds for single-task, >8.5 seconds for dual-task), our data suggest this approach contains utility within the assessment of athletes with a concussion.

No significant differences in cognitive performance were observed during the tandem gait test. Specifically, there were no accuracy or response rate differences between groups for any of the three cognitive tasks, and AUC values were low. Furthermore, tandem gait time-to-completion appeared to be a stronger discriminator between groups than cognitive performance. Thus, our data indicate motor performance impairment, as measured by time-to-
completion during tandem gait, may be a more accurate diagnostic approach than cognitive performance under this specific dual-task paradigm. In addition, prior work identified that athletes displayed worse cognitive performance than controls on the words-backwards test during a steady-state gait task. These findings, paired with our observations, suggest the utility of this cognitive task as an appropriate dual-task cognitive cue for concussion management.

Our study has limitations that should be considered while interpreting the results of our data. Our cross-sectional study design does not allow us to generalize to post-injury tests that are performed closer to clinical recovery (e.g. at return to play clearance), rather than our assessment timeframe of approximately one week post-injury. Furthermore, we recruited both concussed and control participants from one geographic area, within a relatively small age range, and only through our sports medicine clinic and community partnerships. Our results, therefore, may not generalize to other geographic locations, practice settings, or age groups.

In addition, our results demonstrate lower intra-session reliability in tandem gait time-to-completion between trials for the concussion group, compared to the control group. While this variability can likely be explained, at least in part, by differences in sample size between groups, it may also be that concussed individuals experience greater variation in tandem gait times. Thus, it may be relevant to investigate the clinical significance of this variability in future studies. Moreover, the order of cognitive task completion in dual-task conditions remained unchanged in our study, such that all individuals performed cognitive tasks in the same trial order. Thus, although we indicate that cognitive task complexity and novelty may be an appropriate explanation for group classification (AUC) differences among dual-task trials, we cannot determine the impact of cognitive task order on tandem gait performance with our current methodology. It is possible that AUC values obtained during dual-task trials are not due to the
specific cognitive task used, but rather the trial number during which that cognitive task occurred (e.g. first, second, or third trial).

While the clinical utility of the tandem gait test for concussion decision-making is well established, limitations of the test include the time to administer a series of trials within a comprehensive multifaceted concussion evaluation, and the lack of uniformity among cognitive tasks used in dual-task paradigms and optimal number of trials required. Our results suggest multiple (i.e. 4) trials, may not be required to obtain useful clinical information under each condition, thus improving the feasibility of the test, while maintaining group classification ability. Likewise, the words-backward cognitive task demonstrated the greatest group classification accuracy among dual-task conditions. Our findings indicate specific cognitive tasks may be more useful for dual-task testing, and their incorporation into standardized evaluations may improve uniformity of tandem gait assessment among clinicians, thus improving overall test feasibility beyond reducing time requirements. Consequently, clinicians seeking valuable information on post-injury motor performance should consider using two single-task trials and one dual-task trial (words-backward) in tandem gait for an appropriate balance between test feasibility and clinical utility during concussion evaluation.
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Figure 1. Single-task Tandem Gait Performance\textsuperscript{a,b}

\textsuperscript{a} Data are presented as means; error bars represent 95\% confidence intervals. The concussion group is represented as black circles, and the control group is represented as white squares.

\textsuperscript{b} AUC = area under the curve (derived from Receiver Operating Characteristic analysis). R values represent the trial-to-trial correlation within each group. ICC values represent the Intraclass Correlation Coefficients (95\% confidence interval).

Figure 2. Dual-task Tandem Gait Performance\textsuperscript{a,b}

\textsuperscript{a} Data are presented as means; error bars represent 95\% confidence intervals. The concussion group is represented as black circles, and the control group is represented as white squares.

\textsuperscript{b} AUC = area under the curve (derived from Receiver Operating Characteristic analysis). R values represent the trial-to-trial correlation within each group. ICC values represent the Intraclass Correlation Coefficients (95\% confidence interval).
Table 1. Concussion and Control Group Participant Characteristics.

| Variable                      | Concussion Group (n=44) | Control Group (n=73) | P value |
|-------------------------------|-------------------------|----------------------|---------|
| Age (years)                   | 15.4 (1.8)              | 15.8 (1.3)           | 0.12    |
| Sex (female)                  | 19 (39%)                | 30 (41%)             | 0.87    |
| Height (cm)                   | 166.7 (9.7)             | 171.8 (9.1)          | < 0.001*|
| **Mass** (kg)                 | 66.0 (23.6)             | 63.5 (17.7)          | 0.52    |
| History of previous concussion| 23 (52%)                | 17 (23%)             | 0.002*  |
| ADD or ADHD diagnosis         | 5 (11%)                 | 4 (5%)               | 0.25    |
| Symptom severity (PCSI rating)| 50.0 (27.1)             | 5.8 (8.1)            | < 0.001*|
Table 2. Cognitive Performance During Dual-task Tandem Gait Trials for Concussion and Control Groups.

| Variable                  | Concussion Group Mean (Standard Deviation) | Control Group Mean (Standard Deviation) | P value | AUC value |
|---------------------------|------------------------------------------|----------------------------------------|---------|-----------|
|                           | **Accuracy**                             | **Response rate**                      |         |           |
| **Words-backward task**   |                                          |                                        |         |           |
| Accuracy                  | 67.2 (34.2)%                             | 83.6 (29.4)%                           | 0.013   | 0.67      |
| Response rate             | 9.8 (4.5)                                | 8.6 (5.9)                              | 0.28    | 0.64      |
| **Serial-Subtraction task** |                                         |                                        |         |           |
| Accuracy                  | 83.1 (25.6)%                             | 79.2 (26.8)%                           | 0.48    | 0.54      |
| Response rate             | 7.9 (6.2)                                | 6.2 (4.4)                              | 0.11    | 0.61      |
| **Months-in-Reverse task** |                                         |                                        |         |           |
| Accuracy                  | 94.2 (10.2)%                             | 93.6 (10.8)%                           | 0.82    | 0.53      |
| Response rate             | 3.0 (2.2)                                | 2.2 (1.2)                              | 0.04    | 0.63      |

a % of questions answered correctly.

b Number of seconds per response.
Table 3. Multiple Regression Results for Each Tandem Gait Trial After Adjusting for Height, Concussion History, and Symptom Severity.\textsuperscript{a}

| Trial Number, Condition | β coefficient | 95% confidence interval | P value |
|-------------------------|--------------|------------------------|---------|
| Single-task: Trial 1    | 7.87         | 3.33, 12.40            | 0.001*  |
| Single-task: Trial 2    | 7.76         | 3.30, 12.22            | 0.001*  |
| Single-task: Trial 3    | 5.73         | 1.75, 9.70             | 0.005*  |
| Dual-task: Trial 1 (words-backward) | 9.40 | 3.11, 15.70            | 0.004*  |
| Dual-task: Trial 2 (serial-subtraction) | 8.44 | 1.37, 15.52            | 0.020   |
| Dual-task Trial 3 (months-in-reverse) | 7.33 | 1.86, 12.80            | 0.009*  |

\textsuperscript{a} Multiple regression results, describing the expected difference between concussion/control groups (beta coefficient value) on each tandem gait trial after adjusting for height, concussion history, and symptom severity.
Single-Task Tandem Gait

**Trial Time (s)**

| Trial | Concussion Group | Control Group |
|-------|------------------|---------------|
| 1     | R = 0.92         |               |
| 2     | R = 0.82         |               |
| 3     | R = 0.92         |               |

**Between group statistics:**

**Concussion Group:**
- $P < 0.001$
- $AUC = 0.96 (0.92, 0.98)$
- Mean difference: $10.0 \text{ s (7.1, 12.8)}$

**Control Group:**
- $P < 0.001$
- $AUC = 0.93 (0.90, 0.95)$
- Mean difference: $10.7 \text{ s (8.0, 13.4)}$

**Overall:**
- Between group: $P < 0.001$
- $AUC = 0.85$
- Mean difference: $10.0 \text{ s (7.1, 12.8)}$
Dual-Task Tandem Gait

Trial Time (s)

Concussion Group:
ICC\(_{2,k}\) = 0.94 (0.91, 0.97)

Control Group:
ICC\(_{2,k}\) = 0.92 (0.88, 0.95)

Between group: 
- Between group: 
P < 0.001 
AUC = 0.83
Mean difference:
12.9 s (9.0, 16.9)
- Between group: 
P < 0.001 
AUC = 0.81
Mean difference:
12.4 s (8.0, 16.8)
- Between group: 
P < 0.001 
AUC = 0.80
Mean difference:
10.1 s (6.7, 13.5)

Words backwards
Subtraction
Months in reverse order

Trial