



Running head: Symptomatic head trauma predicts dual task gait

Title: Self-reported head trauma predicts poor dual task gait in retired NFL players

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ABSTRACT

Objective: Symptomatic head trauma associated with American-style football (ASF) has been linked to brain pathology, along with physical and mental distress in later life. Still, the longer-term effects of such trauma on objective metrics of cognitive-motor function remain poorly understood. We hypothesized that ASF-related symptomatic head trauma would predict worse gait performance, particularly during dual task conditions (i.e., walking while performing an additional cognitive task), in later life.

Methods: Sixty-six retired professional ASF players aged 29-75 years completed a health and wellness questionnaire. They also completed a validated smartphone-based assessment in their own homes, during which gait was monitored while walking normally and while performing a verbalized serial-subtraction cognitive task.

Results: Participants who reported more symptomatic head trauma, defined as the total number of impacts to the head or neck followed by concussion-related symptoms, exhibited greater dual task cost (i.e., percent increase) to stride time variability (i.e., the coefficient of variation of mean stride time). Those who reported ≥ 1 hit followed by loss of consciousness, compared to those who did not, also exhibited greater dual task costs to this metric. Relationships between reported trauma and dual task costs were independent of age, BMI, NFL career duration, and history of musculoskeletal surgery. Symptomatic head trauma was not correlated with average stride times in either walking condition.

Interpretation: Remote, smartphone-based assessments of dual task walking may be utilized to capture meaningful data sensitive to the long-term impact of symptomatic head trauma in former professional ASF players and other contact sport athletes.

INTRODUCTION

Repeated exposure to biomechanical head trauma—especially during participation in contact sports such as American-style football (ASF)—has been linked to subjective complaints of physical, mental and emotional distress in life,¹ as well as chronic traumatic encephalopathy (CTE) upon autopsy.² Still, the longer-term effects of such repeated head trauma on objective, clinically-meaningful metrics of cognitive-motor function remains largely unknown.³ This gap in knowledge significantly hinders current efforts to identify those at risk of developing chronic brain disease, as well as to design interventions aimed at assessing, preventing, and ultimately alleviating the potential clinical disability. There is thus an urgent need to identify and validate low-cost and widely-accessible cognitive-motor assessment tools, and subsequently, characterize and prospectively track large numbers of individuals who have been exposed to repetitive head trauma in early life.

Assessment of walking provides clinically-meaningful insights into cognitive-motor function and underlying brain health.⁴ In addition to the peripheral and spinal neuromuscular systems, the complex task of walking depends upon “higher-level” sensory-motor integration and various cognitive functions.⁵ Moreover, in daily life, walking is almost always performed in the context of cognitive tasks such as talking, reading signs, or making decisions. Within experimental paradigms, such dual tasking (e.g., walking while counting backwards) affects numerous metrics of gait.⁶ Acute, sport-related head trauma in younger adults has been linked to greater dual task cost (i.e., percent decrement) to gait performance.^{7,8} At the same time, worse dual task gait performance in older adults has been linked to executive cognitive dysfunction,⁹ chronic pain,¹⁰ increased likelihood of suffering a fall,¹¹ increased risk of converting from mild cognitive impairment to dementia,^{12,13} alterations in brain structure¹⁴ and a reduced capacity to activate appropriate brain networks in response to cognitive-motor tasks.¹⁵

Based upon the above evidence, we hypothesized that metrics of dual task walking performance would be sensitive to chronic brain dysfunction induced by repeated sports-related head trauma in young adulthood, and therefore, could ultimately be useful for the detection of

consequences of such head trauma, potentially before cognitive complaints and other clinical symptoms arise. To this end, we developed and validated a smartphone App that utilizes the phone's internal movement sensors and offers multi-media instructions to enable remote assessment of dual task walking performance in larger numbers of individuals.¹⁶ The purpose of this study was to examine the cross-sectional relationship between dual task walking performance and self-reported history of football-related symptomatic head trauma during their professional playing careers in a sub-sample of former professional ASF players participating in the Football Players Health Study at Harvard University (FPHS).

METHODS

Participants

The FPHS is a portfolio of studies aimed to further our understanding of the benefits and risks of participation in ASF, identify risks that are potentially preventable or reversible, and develop interventions or approaches to improve the health and wellbeing of former professional ASF players. At the time of this study, the FPHS comprised 3506 former professional ASF players who had completed a health and wellness questionnaire probing demographics, football exposure including history of football-related symptomatic head trauma, medical history, physical function, cognitive health, and mental well-being. A self-selected subset of this cohort (n = 66) who owned an iPhone™ also participated in “TeamStudy,” which used an App designed for iPhones to gather health data that included a remote assessment of dual task walking performance.

Ethics Committee Approval

All TeamStudy procedures and its informed consent form were approved by the Beth Israel Deaconess Medical Center Institutional Review Board. The consent form was integrated into the App and all participants reviewed the form, were quizzed in its content to ensure understanding, and consented to the study as part of the App's set-up procedures. Each participant completed the FPHS health and wellness questionnaire and the TeamStudy walking

assessment within one year of one another.

Self-reported health, wellness, and football exposures

Self-reported demographics, medical history, and health status: We extracted data related to: 1) age at time of questionnaire completion, 2) race, 3) history of musculoskeletal surgery involving major joints that may significantly influence gait (neck, spine, hips, knees, or ankles), 4) report of physician-diagnosed hypertension, arthritis, diabetes, stroke, Parkinson's disease, dementia, and depression 5) chronic pain, 6) global physical function, and 7) global mental function. Chronic pain was assessed by the question "In the past seven days, how would you rate your pain on average on a scale of 0 (no pain) to 10 (worst pain imaginable)." Global physical health and global mental health were queried using the PROMIS Global Health Instrument and standard scoring procedures.¹⁷

Football-related exposures: We extracted the age at which participants first played organized football, the number of seasons played in the National Football League (NFL), and the position most often played professionally. For the latter, participants were classified as either linemen (including offensive or defensive line) or non-linemen (including linebacker, defensive back, running back, wide receiver, tight end, quarterback, kicker/punter, special teams).

Players were asked to report the number (with choices of 0, 1, 2-5, 6-10, and 11 or more) of times they experienced a "hit or blow to the head, neck, or upper body followed by..." each the following symptoms: headaches, nausea, dizziness, loss of consciousness, memory problems, disorientation, confusion, seizure, visual problems, weakness on one side of the body, and feeling unsteady on your feet. We then created a continuous "symptomatic head trauma" score for the total burden of hits followed by concussion-related symptoms (by coding each response as 0, 1, 3.5, 8, and 13, and then summing the responses for all 11 symptoms. We also created a yes/no dichotomous variable for at least one self-reported hit followed by loss of consciousness, as we felt that this item in particular may be more reliably determined by self-report.

Remote assessment of dual task walking performance

Data acquisition

Dual task walking performance was measured remotely in the participant's home by the validated TeamStudy smartphone App, created in collaboration with Sage Bionetworks (Seattle, WA).¹⁶ Participants first watched an animation developed by Wondros Inc. (Los Angeles, CA) that provided a general overview of the assessment. The user was then presented with several on-screen text instructions. The gait assessment was designed to evaluate walking under normal conditions, and again while performing verbalized serial subtractions of three from a random number between 200 and 999.

Participants were encouraged to complete the walking assessment in an empty room or hallways within their own home. Each assessment included one 45-second trial of normal walking followed by one 45-second trial of dual task walking. Trails were separated by at least 90 seconds. Trial start and end cues triggered acquisition of accelerometer, gyroscope, and magnetometer data, which was stored on the phone's internal storage capacity. Kinematic and questionnaire data were then automatically uploaded via Wi-Fi to a remote, cloud-based data server for offline analyses.

Data capturing and preprocessing

We extracted two outcomes from each walking trial—average stride time and stride time variability—using procedures that have been shown to produce accurate results when compared to the GAITRite mat within the laboratory, and high test-retest reliability over multiple days in user homes.¹⁶

Walking trials completed within user homes typically included variable amounts of turning, which alters stride timing.¹⁸ Turning also influences Z-axis accelerations derived from the phone and thus the ability to accurately detect heel strikes. We therefore utilized a method we previously developed and validated to identify and remove relatively sharp, rapid turns using rotated Z-axis gyroscope data (i.e., rotations about the global vertical axis). Stride times for the current analysis were thus calculated from all Z-axis acceleration data that occurred outside of detected periods of turning. To ensure reliability of results, we excluded any trials that contained less than 10 identified strides.

Primary gait outcomes included the dual task cost to stride time and dual task cost to stride time variability; that is, the percent change in each outcome from normal walking to dual task walking conditions. Secondary outcomes included stride time and stride time variability derived from each walking condition separately. Only these specific metrics were chosen because each 1) can be accurately derived from smartphone motion data captured during walking with the phone in the pants pocket, and 2) is sensitive to cognitive status,^{9,12,13} chronic pain,¹⁰ falls,¹¹ and markers of brain health^{14,19} in older adults.

Statistical Analysis

Descriptive statistics were used to summarize cohort characteristics and gait outcomes, followed by model estimation and hypothesis testing. We examined relationships between self-reported burden of hits followed by concussion-related symptoms and primary and secondary gait outcomes using three separate approaches. First, one-way analysis of variance (ANOVA) was used to examine the main effect of symptomatic head trauma score *quartile* on each gait outcome. Second, linear regression models were used to examine the correlation between the symptomatic head trauma score, modeled as a continuous variable (see above), and each gait outcome. Third, one-way ANOVAs were used to examine the influence of self-report of at least one hit to the head or neck followed by loss of consciousness on each gait outcome. In each of these three analyses, models were completed both with and without adjustments for age, BMI, exposure to ASF defined as the number of NFL seasons played, and injuries unrelated to head trauma that may influence gait as defined by the total number of reported musculoskeletal injuries to the neck, spine, hips, knees, or ankles. Tests allowed for Type-I error probability of $\alpha=0.05$. Analyses were performed using JMP software version 13 (SAS Institute, Cary, NC).

RESULTS

Participant characteristics

Sixty-six participants of the FPHS joined TeamStudy in response to a broadly publicized advertisement and used their smartphone to complete a remote dual task gait assessment. Two of

these participants were excluded from analysis because, after removal of periods of turning during the assessment, fewer than ten strides were identified in single and dual-task trials. Within all trials of the included 64 participants, a mean (standard deviation; SD) of 3.5 (2.1) periods of turning were detected and removed. Twenty-seven phone-side leg strides (SD: 8, range=12-35 strides) were identified from the remaining, relatively straight periods of walking. Numbers of identified turns and strides did not differ between single- and dual-task conditions.

Compared to the entire FPHS cohort, the TeamStudy sub-sample was similar in age, height, and body mass, but had a greater proportion of white participants (Table 1). The TeamStudy sub-sample was similar to the FPHS cohort in age at first exposure to organized ASF, number of NFL seasons played, and proportion of lineman to non-lineman. As compared to the FPHS cohort, TeamStudy participants reported greater symptomatic head trauma scores and were more likely to report depression as a medical condition. On the other hand, the TeamStudy and FPHS cohorts reported approximately similar PROMIS physical and mental health scores.

The range of symptomatic head trauma score was broad (4-75) across participants. This score was not related to participant age, number of NFL seasons played, or the PROMIS physical health score ($r^2 < 0.02$; $p = 0.30-0.65$). TeamStudy participants who reported greater symptomatic head trauma score reported worse PROMIS mental health score ($r^2 = 0.09$, $p = 0.01$).

Effects of self-reported head trauma on gait performance

We examined relationships between gait outcomes and self-reported burden of hits followed by concussion-related symptoms by separating TeamStudy participants into quartiles of symptomatic head trauma score (Table 2). An effect of quartile was observed for the dual task cost to stride time variability ($F = 6.9$; $p = 0.005$). This effect was independent of age, BMI, the number of NFL seasons, and the number of reported musculoskeletal surgeries ($F = 6.0$; $p = 0.001$). Tukey's post-hoc testing of the adjusted model indicated that those in the highest burden quartile exhibited greater dual task costs to stride time variability than the two quartiles with lowest burden (see Table 2). The dual task cost to stride time variability in the highest quartile was 9.8 (95% CI (3.5, 27.9)) times higher than in the first quartile and 4.4 (95% CI (2.0, 9.4)) times

higher than in the second quartile. A significant effect of quartile was also present for stride time variability specifically within the dual task walking condition (unadjusted: $F=4.6$; $p=0.03$; adjusted: $F=4.2$; $p=0.03$). The highest three burden quartiles exhibited greater dual task stride time variability than the lowest burden quartile by 1.3 (1.1, 1.6), 1.4 (1.2, 1.7), and 1.8 (1.5, 2.2) times, respectively. Symptomatic head trauma quartile was not associated with the dual task cost to stride time, stride time within the dual task walking condition, or either gait metric within the single task walking condition.

Linear regression analysis similarly revealed that participants with higher symptomatic head trauma scores exhibited greater dual task costs to stride time variability (Figure 2). This relationship remained significant when models were adjusted for age, BMI, the number of NFL seasons, and the number of reported musculoskeletal surgeries ($r^2=0.20$; $p=0.003$). Relationships between higher symptomatic head trauma score and greater stride time variability specifically within the dual task walking condition trended towards significance in both unadjusted ($r^2=0.09$; $p=0.09$) and adjusted ($r^2=0.06$; $p=0.10$) regression models. The symptomatic head trauma score was not associated with the dual task cost to stride time or stride time within the dual task walking condition. Neither stride time nor its variability during the single task walking condition was related to self-reported symptomatic head trauma.

Self-report of experiencing hits to the head or neck specifically followed by loss of consciousness was also associated with worse gait performance. Participants who reported experiencing at least one hit followed by loss of consciousness had 2.5 times (95% CI (1.6, 3.9)) greater dual task cost to stride time variability than those who did not report loss of consciousness (unadjusted: $F=4.3$, $p=0.007$; adjusted: $F=4.5$, $p=0.001$) (Table 2). Self-reported loss of consciousness did not have a significant effect on any other gait outcome.

Relationships between gait performance and participant demographics, ASF exposure, and health and wellness

Older participants tended to have longer stride times when walking in both single-task ($r^2=0.30$, $p=0.04$) and dual task ($r^2=0.32$, $p=0.03$) conditions. Those who reported at least one

surgery to the neck, back, hips, knees or ankles also tended to have longer stride times in both walking conditions (single-task: $r^2=0.25$, $p=0.02$; dual-task: $r^2=0.18$, $p=0.05$). Age and history of musculoskeletal surgery did not significantly correlate with stride time variability or dual task cost metrics. Gait metrics were not significantly correlated with participant BMI, race, age at first exposure to organized football, number of NFL seasons played, or primary position played within the NFL. Participants who reported worse PROMIS global physical health walked with longer stride times in the single task condition ($r^2=0.19$, $p=0.05$), but not during dual task walking. Gait metrics were not sensitive to general pain severity or PROMIS global mental health.

DISCUSSION

This cross-sectional study utilized a validated smartphone App to remotely assess dual task walking performance in former professional ASF players participating with the FPHS at Harvard University. Participants who reported relatively high burden of hits followed by concussion-related symptoms during their professional playing careers exhibited significantly greater stride time variability when dual tasking, as well as greater dual task cost to this metric of gait performance. Those who reported suffering at least one hit to the head or neck followed by loss of consciousness also exhibited greater dual task costs to stride time variability. As each of these results were independent of participant age, BMI, NFL career duration, and reported history of musculoskeletal surgery, this preliminary evidence indicates that remote assessments of dual task walking may be particularly sensitive to chronic brain dysfunction associated with repetitive sports-related head trauma.

Performance decrements associated with dual tasking are theorized to arise as the two tasks compete for shared brain resources.²⁰ The observation that participants who reported greater total symptomatic head trauma, or at least one hit followed by loss of consciousness, also exhibited greater dual task costs suggests that these individuals possessed diminished capacity to differentially recruit the required brain networks or enlist the alternative cognitive strategies

needed to maintain performance in both tasks.²¹ While symptomatic head trauma was linked to worse gait performance specifically during dual task walking, it was not correlated with gait performance during single-task walking—a task that, as compared to dual-tasking, is less cognitively demanding and associated with relatively lower levels of cortical brain activation.²² The results of this study therefore suggest the possibility that the accumulation of biomechanical head trauma severe enough to induce concussion-like symptoms may manifest in later life as diminished “cognitive reserve.”²¹ Still, future studies that assess and control for serial subtraction performance are needed. Such work should also consider capturing common proxies of cognitive reserve such as education,²³ examine compensatory strategies that may enable some individuals to maintain function in the presence of brain pathology, and consider the possible beneficial protective impact of cognitive remediation, physical exercise, and/or other interventions aimed at promoting cognitive reserve into senescence.²⁴

Although walking entails repetitive cyclical movements, no two gait cycles are exactly the same. In the current study, self-reported symptomatic head trauma did not influence single- or dual-task average stride time, a metric closely related to walking speed. However, participants within the three highest quartiles of symptomatic head trauma score, as compared to the lowest quartile, walked with elevated dual task stride time variability. Mounting evidence indicates that dual task stride time variability may be a sensitive predictor of even subtle changes in cognitive function.^{9,13,25} Beauchet et al¹³ for example, reported in a sample of 56 non-demented older adults, that those with greater dual task stride time variability at baseline were more likely to experience global cognitive decline as measured by the Mini-Mental State Examination over a five-year follow-up period. Recently, Lo et al¹⁹ provided resting-state functional MRI evidence from a small sample of older adults that greater stride time variability correlated with weaker functional connectivity *between* two large-scale brain networks; namely, the dorsal attention and default networks. Intriguingly, the functional connectivity between these two networks has separately been linked to sustained attention defined as the capacity to maintain performance on a continuous cognitive task over time.²⁶ The observed link between symptomatic head trauma

and stride time variability in the current study is thus supported by reports that retired NFL players who report a history of concussion, as compared to those who do not, tend to have difficulties in attentional control,²⁷ structural abnormalities within fronto-parietal tracts and the corpus callosum,²⁸ and reduced global resting-state functional connectivity.²⁹ Still, reported links between sports-related head trauma, brain structure, brain function, and/or and health outcomes have been derived largely from cross-sectional studies and/or comparisons to suboptimal control groups. Longitudinal studies that include multi-modal mobile imaging of numerous aspects of dual task gait performance³⁰ and/or habitual physical activity coupled with physiologic, biomarker, and neuro-cognitive testing are thus needed to establish if a history of sports-related head trauma alters the time-course of changes in brain health, and whether such changes underline reductions in gait and other cognitive-motor functions over time.

Metrics of gait performance were obtained via smartphone assessment without supervision from trained personnel in non-laboratory environments that undoubtedly varied from participant to participant. While it is thus impossible to confirm whether participants completed the assessment correctly in the absence of environment perturbations, only those steps identified from periods meeting specific validated criteria were included in analysis. Moreover, we observed that participant age, history of musculoskeletal surgery, and self-report of worse physical function were each correlated with longer average stride times under both single and dual task walking conditions. The presence of these relationships, which were expected and corroborated by several previous reports in other populations,^{15,31} provides additional support that gait assessments were completed successfully as directed.

Symptomatic head trauma scores were derived from self-report of events that occurred quite remote in time for many participants. The accuracy of such recall may have also been influenced by multiple factors including participant age, NFL career duration, and current health status. Sampling biases may have also been present; for example, older players who were willing and able to participate in the study despite relatively high symptomatic head trauma scores may not be representative of all players of similar age and self-reported burden. Nevertheless, results

of adjusted analyses focused on symptomatic head trauma score quartiles—together with corroborating results of models focused on self-report of suffering at least one hit followed by loss of consciousness—provide preliminary evidence that suffering relatively large amounts of symptomatic head trauma during one’s professional playing career is associated with worse gait performance in later life. We therefore believe that a remote smartphone-based assessment of dual task walking may provide important information for the evaluation of present and incipient dysfunction in former professional ASF players and possibly others exposed to high-risk repetitive head trauma.

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Author Contributions

B.M., R.Z., and A.P.L. contributed to study concept and design. B.M., J.Z., O.L., H.Z., W.Y., and T.G.T. contributed to data acquisition and analysis. B.M., J.Z., O.L., H.Z., R.Z., L.A.L., T.G.T., and A.P.L. contributed to manuscript and figure preparation.

Conflict of Interests

All authors have nothing to disclose.

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FIGURE LEGEND

FIGURE 1: Stride times derived from remote smartphone-based dual task gait assessment for two retired NFL players. Symptomatic head trauma score was defined as the number of self-reported hits to the head or neck followed by one of eleven queried symptoms related to concussion (See Methods). Each data point represents a validated stride time derived from consecutive heel strikes of the phone-side leg during all non-turning periods of walking within

each 45-second trial. The dual task cost to stride time variability, as defined by the change (i.e., percent increase) from single- to dual-task walking conditions, was noticeably higher in the player who reported higher symptomatic head trauma.

FIGURE 2: The relationship between self-reported symptomatic head trauma and the dual task cost to stride time variability. The symptomatic head trauma score was defined as the number of self-reported hits to the head or neck followed by one of eleven queried symptoms related to concussion (See Methods). The dual task cost was calculated as the percent change in the coefficient of variation (COV) in mean stride time from single to dual task walking conditions.

Table 1: Self-reported demographic, health, and football-related characteristics of the TeamStudy sub-sample compared to the total population of the Football Players Health Study at Harvard University (FPHS)

	FPHS	TeamStudy Subsample
Sample size	3506	64
Age, years, mean (SD)	52.8 (14.2)	52.7 (12.4)
Height, inches, mean (SD)	74.3 (2.5)	74.9 (2.7)
Body mass, lbs, mean (SD)	239.6 (42.0)	240.7 (41.3)
Race, n (%) white	2053 (58.6)	47 (73.4)
Age, first organized football, mean (SD)	11.8 (3.1)	11.7 (3.0)
# of professional seasons, mean (SD)	6.8 (3.8)	6.5 (4.5)
Primary position played, n (%)		
Linemen	1248 (35.6)	28 (43.8)
Non-linemen	2258 (64.4)	36 (56.2)
Concussion-related symptoms		
Symptomatic head trauma score ¹ , mean (SD)	32.0 (29.2)	21.9 (14.8)
Loss of consciousness ² , n (%)	1763 (50.2)	31 (48.4)
Physician-Diagnosed Medical Conditions, n (%)		
Hypertension	1325 (37.8)	23 (35.9)
Diabetes	313 (8.9)	2 (3.1)
Parkinson's disease	24 (0.7)	1 (1.6)
Stroke	99 (2.8)	2 (3.1)
Arthritis	1785 (50.9)	30 (46.9)
Dementia	125 (3.6)	0 (0.0)
Depression	312 (8.9)	1 (1.6)
History of musculoskeletal surgery³, n (%)	2115 (60.3)	42 (65.6)

Global pain,⁴ mean (SD)	4.8 (2.5)	3.75 (2.3)
PROMIS physical health,⁵ mean (SD)	48.4 (8.1)	51.8 (6.8)
PROMIS mental health,⁵ mean (SD)	43.4 (11.3)	49.4 (9.5)

¹Symptomatic head trauma score: Sum of reported number of hits to the head or neck followed by one of 11 concussion-related symptoms; ²Loss of consciousness: Report of at least one hit to the head or neck followed by loss of consciousness; ³Musculoskeletal surgery: at least one reported surgery for the neck, spine, hips, knees, or ankles; ⁴Global pain: Response on the question “In the past seven days, how would you rate your pain on average on a scale of 0 (no pain) to 10 (worst pain imaginable); ⁵PROMIS global physical and mental health were T-scored using standard procedures.

Table 2: Relationship between self-reported symptomatic head trauma quartile and remotely-assessed walking performance in retired NFL players

	Symptomatic head trauma score (quartile thresholds)				P value
	<11	11 – 19	20 – 28	>28	
Sample, n	16	16	16	16	
Stride time, sec					
Single task	1.1 (0.1)	1.2 (0.1)	1.2 (0.1)	1.2 (0.1)	0.89
Dual task	1.2 (0.1)	1.2 (0.1)	1.3 (0.1)	1.3 (0.1)	0.87
Stride variability, COV					
Single task	2.6 (0.8)	3.4 (1.2)	3.2 (1.1)	3.1 (1.7)	0.06
Dual task	2.7 (0.6)^A	3.6 (1.2)^B	3.8 (1.2)^B	4.9 (1.3)^B	0.03
Dual task cost, %					
Stride time	1.7 (4.6)	3.2 (4.2)	4.4 (6.2)	3.8 (5.1)	0.19
Stride variability	3.3 (6.8)^A	7.4 (10.9)^{AB}	22.9 (13.4)^{BC}	32.4 (17.6)^C	0.003

All values reflect group means (SD); p values reflect one-way ANOVAs adjusted for age, BMI, the number of NFL seasons, and the number of reported musculoskeletal surgeries; Within each row, quartile means with different superscript letters were significant different from one another based on Tukey's post hoc testing of adjusted models.

Table 3: Relationship between self-reports loss of consciousness following a hit to the head or neck and remotely-assessed walking performance in retired NFL players

	Loss of consciousness		P value
	No	Yes	
Sample, n	32	32	
Stride time, sec			
Single task	1.2 (0.1)	1.2 (0.1)	0.80
Dual task	1.2 (0.1)	1.2 (0.1)	0.68
Stride variability, COV			
Single task	3.2 (1.1)	3.0 (1.1)	0.83
Dual task	3.5 (1.1)	3.7 (1.2)	0.41
Dual task cost, %			
Stride time	2.9 (5.7)	2.9 (5.4)	0.94
Stride variability	8.6 (10.2)	21.4 (12.7)	0.007

All values reflect group means (SD); p values reflect one-way ANOVAs adjusted for age, BMI, the number of NFL seasons, and the number of reported musculoskeletal surgeries;



