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Gait and Quiet-Stance Performance Among Adolescents After Concussion-Symptom Resolution

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Context: Concussions affect a large number of US athletes each year. Returning an athlete to activity once self-reported symptoms have resolved can be problematic if unrecognized neurocognitive and balance deficits persist. Pairing cognitive and motor tasks or cognitive and quiet-stance tasks may allow clinicians to detect and monitor these changes postconcussion.

Objective: To prospectively examine adolescent athletes' gait and quiet-stance performance while concurrently completing a cognitive task acutely after concussion and after symptom resolution.

Design: Case-control study.

Setting: Sport concussion clinic.

Patients or Other Participants: Thirty-seven athletes (age = 16.2 ± 3.1 years; 54% female) were diagnosed with a concussion, and their performance was compared with that of a group of 44 uninjured control participants (age = 15.0 ± 2.0 years; 57% female).

Intervention: Participants diagnosed with a concussion completed a symptom inventory and single- and dual-task gait and quiet-stance evaluations within 21 days of injury and then again after symptom resolution. Gait and postural-control measurements were quantified using an inertial sensor system and analyzed using multivariate analyses of covariance.

Main Outcome Measure(s): Post-Concussion Symptom Scale, single-task and dual-task gait measures, quiet-stance measures, and cognitive task performance.

Results: At the initial postinjury examination, single-task gait stride length (1.16 ± 0.14 versus 1.25 ± 0.13 m, $P = .003$) and dual-task gait stride length (1.02 ± 0.13 m versus 1.10 ± 0.13 m, $P = .011$) for the concussion group compared with the control group, respectively, were shorter. After symptom resolution, no single-task gait differences were found, but the concussion group demonstrated slower gait velocity (0.78 ± 0.15 m/s versus 0.92 ± 0.14 m/s, $P = .005$), lower cadence (92.5 ± 12.2 steps/min versus 99.3 ± 7.8 steps/min, $P < .001$), and a shorter stride length (0.99 ± 0.15 m versus 1.10 ± 0.13 m, $P = .003$) during dual-task gait than the control group. No between-groups differences were detected during quiet stance at either time point.

Conclusions: Acutely after concussion, single-task and dual-task stride-length alterations were present among youth athletes compared with a control group. Although single-task gait alterations were not detected after symptom resolution, dual-task gait differences persisted, suggesting that dual-task gait alterations may persist longer after concussion than single-task gait or objective quiet-stance alterations. Dual-task gait assessments may, therefore, be a useful component in monitoring concussion recovery after symptom resolution.

Key Words: concussion, dual-task gait, symptom recovery

Key Points

- After reporting their concussion symptoms had resolved, youth athletes walked with altered dual-task gait compared with control participants.
- No quiet-stance differences were found between groups, regardless of whether they were simultaneously completing a cognitive task.
- Dual-task gait impairments may outlast quiet-stance task and symptom-recovery alterations when youth athletes recover from concussion.

An estimated 1.6 to 3.8 million sport-related traumatic brain injuries occur annually in the United States,[1] with the vast majority being concussions. Despite this high prevalence, the clinical management of concussion remains difficult and controversial.[2] The heterogeneity of concussion contributes to the complexity of clinical management, and the lack of prospective evidence has resulted in a reliance on expert opinion as the basis for return-to-play guidelines. Postconcussion management decisions typically rely on assessments of self-reported symptoms, neurocognition, and balance.[2] Although these measures are helpful in quantifying and determining the type of injury, there are limitations to using symptom inventories alone to manage patients with concussions and make return-to-play decisions.[2,3] Furthermore, previous authors[4] have observed persistent neurocognitive impairments after patients no longer reported concussion-related symptoms, highlighting the need for objective measures other than symptom inventories in concussion-management paradigms.

Concussion results in balance impairments; thus, researchers and clinicians have emphasized the use of balance assessments to measure concussion-related impairments. Specifically, balance impairments after concussion have been quantified using postural-control (ie, quiet-stance–based tasks) or gait (ie, gait-analysis) measurement techniques.[5,6] Gait assessments, in particular, are an objective and repeatable method for quantifying functional abilities in the context of concussion management.[7,8] The complexity required by a dynamic motor task, such as gait, may allow concussion-related deficits to be detected for a longer period of time after injury than do symptom inventories.[6,9,10] Therefore, concussion evaluations that include gait analysis may allow clinicians to recognize deficits not readily identifiable through symptom inventories.

Specifically, by concurrently pairing cognitive and motor tasks, dual-task gait assessments have been used to identify concussion-related impairments for up to 2 months after concussions in adolescent athletes.[6] Additionally, pairing a cognitive and a quiet-stance task may provide a more sensitive way to detect subtle changes than a single-task assessment of quiet-stance performance.[11] Thus, objective instrumented tests of dual-task gait and quiet stance may provide additional information not typically obtained from traditional clinical examinations.

Complex and real-life tasks such as divided-attention gait may allow clinicians to identify deficits not detectable with standard clinical evaluations. Hence, determining if gait or postural-control deficits persist once symptoms have resolved may be an important aspect of determining readiness to return to sport safely after a concussion. The purpose of our study was to examine the postural control of youth athletes while symptomatic after concussion and again after self-reported symptom resolution using single-task gait, dual-task gait, and quiet stance. We hypothesized that dual-task gait deficits would exist at the initial postconcussion examination and persist after self-reported symptom resolution.

METHODS

Participants

All study participants completed an instrumented gait and postural-control examination. Patients who sustained a concussion were seen at a single sport concussion clinic of a tertiary care regional hospital. There they were diagnosed by a Board-certified sports medicine physician within 21 days of injury and subsequently identified and recruited for potential study enrollment. Healthy control participants were eligible if they completed an evaluation at an injury-prevention center, underwent testing at that time, and reported no previous concussions. The injury-prevention evaluation consisted of the medical history and measurements of biomechanical, neuromuscular, anatomical, and physiological function and has been described previously.[12] All concussion participants were tested during their regularly scheduled clinic visits in a hallway adjacent to their examination room. Control participants were also tested in a hallway adjacent to an examination room after their injury-prevention evaluation.

Patients were eligible to participate in the study if they reported to the sports medicine clinic after being injured during sport or by a mechanism similar to sport (eg, falling from the ground level or being injured during recreational activities), were diagnosed with a concussion that occurred within the previous 21 days, and were experiencing concussion symptoms at the time of the clinical examination. Therefore, patients who reported to the clinic within this timeframe but were asymptomatic were not included in the study. Consistent with prior work,[13] we set the postinjury assessment time of 21 days as the cutoff for study inclusion because if symptoms persist beyond this time, the management strategy may change. Patients with more severe injury mechanisms, such as falling from a height or motor vehicle collisions, were excluded. Also excluded from the study were any recruits who reported an existing lower extremity injury at the time of testing that may have affected normal gait or balance control, a history of permanent memory loss, learning disability, Down syndrome, or a developmental disability. Before the study, the institutional review board approved the study protocol. All participants and the parents or guardians of those younger than 18 years provided written informed consent to participate in the study before enrollment.

Testing Timeline

Participants in the concussion group were tested at 2 postinjury time points: (1) during their initial examination, which occurred within 21 days of injury while they were still symptomatic, and (2) subsequently during the postinjury examination after they reported no longer experiencing concussion-related symptoms. Participants in the control group were tested once as part of a sport injury-prevention evaluation. As single-task and dual-task gait have recently been identified[7] as highly consistent measures across time among uninjured participants, control-group values were used for comparison with the concussion group at both postinjury time points. All study participants were recruited, screened for eligibility, and administered the study protocol by a single certified athletic trainer.

Experimental Protocol

To assess gait and postural control, we asked participants to complete testing under 4 conditions: (1) quiet standing, (2) quiet standing while completing a cognitive test, (3) single-task walking, and (4) dual-task walking. During both quiet-standing conditions, participants stood without shoes as still as possible for 30 seconds with their eyes open and hands on their hips. During both walking conditions, participants walked without shoes at a self-selected, comfortable speed toward a target placed 8 m in front of them, walked around it, and returned to the original position. For cognitive-test trials, the participant was cued by an auditory beep from a computer to perform a cognitive test before the walking or quiet-standing condition. The cognitive test took 3 forms: (1) spelling a 5-letter word backward, (2) subtracting by 6 or 7 from a randomly presented 2-digit number, or (3) reciting the months in reverse order starting from a randomly chosen month. High test-retest consistency[7] and normative values among

Table 1. Demographic and Injury Information

Characteristic	Group		P Value
	Concussion (n = 37)	Control (n = 44)	
Female sex, n (%)	20 (54)	25 (57)	.82
	Mean ± SD		
Age, y	16.2 ± 3.1	15.0 ± 2.0	.3
Height, cm	167.0 ± 10.1	166.9 ± 12.6	.98
Mass, kg	62.8 ± 15.9	61.4 ± 15.2	.70
Body mass index[a]	22.3 ± 4.3	21.8 ± 3.4	.53
Initial examination			
Time since injury, d	9.5 ± 5.2		
Post-Concussion Symptom Scale score	28.4 ± 16.5		
Total symptoms endorsed	12.0 ± 5.7		
Examination after symptom resolution			
Time since injury, d	28.7 ± 22.3		
Post-Concussion Symptom Scale score	0.8 ± 3.0		
Total symptoms endorsed	0.2 ± 0.4		

[a] Calculated as kg/m^2.

healthy collegiate athletes[8] have been identified using these cognitive tasks during dual-task gait; the tasks have also been used to distinguish between adolescents with and those without a concussion.[9] Consistent with these studies, we randomly selected the test form for each trial to avoid learning effects from 1 trial to the next, and no duplicate cues were used.

During the initial and follow-up clinical visits, patients filled out a clinical intake form that asked for the number of concussions they had experienced before the current one. If necessary, parents were available to assist in completing the form. Additionally, patients completed the Post-Concussion Symptom Scale (PCSS), outlined in the Standardized Concussion Assessment Tool, version 3 (SCAT3), to describe the severity of each concussion symptom they had experienced within the 24 hours before the clinic visit. This scale uses a range of scores from 0 (*asymptomatic*) to 6 (*maximum severity*) for 22 symptoms of a concussion. Thus, the severity of concussion symptoms, ranging from a minimum score of 0 to a maximum of 132, is quantified, and the total number of symptoms endorsed, ranging from 0 to 22, is reported. If they were no longer experiencing any symptoms related to their concussion during the follow-up examination, participants were asked to document the date of their last symptom. The time between the dates of injury and symptom resolution was then calculated to provide the symptom-duration time.

Outcome Variables

Gait and quiet-stance outcome variables were measured using an inertial sensor system (Opal Sensor; APDM Inc, Portland, OR) that has previously been identified as a valid and reliable system to characterize gait and postural control.[14] The sensors were attached at the lumbosacral junction level of the spine and on the dorsum of each foot with an elastic strap. Sensor data were obtained at a sampling frequency of 128 Hz, synchronized, and wirelessly transmitted to a laptop computer during each trial. Spatiotemporal gait and postural-control measures were calculated using Mobility Lab software (version 2.0; APDM Inc); prior researchers[8] have used this system to identify clinical reference ranges among healthy collegiate athletes. Gait outcome variables were average gait speed, cadence, stride length, and double-support time. Postural-control variables were root mean square (RMS) sway, 95% sway ellipse, coronal-plane RMS sway, and sagittal-plane RMS sway. Cognitive test performance was evaluated by calculating the total number of correct answers, the total number of task items provided, and the corresponding accuracy rate in the standing and walking conditions.

Statistical Analysis

Continuous variables are presented as mean ± standard deviation; categorical variables are presented as numbers included (n) or percentage of the total. We used a series of multivariate analyses of covariance (MANCOVAs) to identify outcome variable differences for each condition (single-task gait, dual-task gait, quiet standing, quiet standing with cognitive test, and cognitive test performance during standing and walking) between the concussion group and the control group at both time points. Potential confounding variables that may have affected gait (age, sex, height, and weight) were compared using 1-way analyses of variance. Those variables that appeared different between groups ($P < .20$) were included as covariates in the MANCOVA model. Before analysis, we assessed multicollinearity; if 2 dependent variables demonstrated a correlation of $r > 0.90$, then 1 was removed from the model. Statistical significance was set at $\alpha < .05$. Follow-up comparisons were performed using the Bonferroni procedure to control for family-wise type I error. For significant MANCOVA models, between-groups differences were evaluated with a statistical significance cutoff value set at $\alpha < .0125$ to adjust for the 4 comparisons made. Statistical analyses were performed using SPSS (version 23; IBM Corp, Armonk, NY).

RESULTS

A total of 81 participants were included in the study, 37 who reported after a sport-related concussion and 44 uninjured controls. Of the concussion participants, 24 (65%) returned to the clinic after symptom resolution and were able to complete the study protocol. Participants in the postconcussion group were older than participants in the control group (Table 1). Thus, age was included as a covariate in subsequent MANCOVA analyses. The most common sports in which concussions occurred were soccer (19%, n = 7), football (14%, n = 5), ice hockey (11%, n = 4), and volleyball (8%, n = 3). The majority of study participants completed testing during the summer and fall months (n = 30 [81%] of the postconcussion group, n = 35 [80%] of the control group).

During the initial clinical examination, postconcussion participants exhibited shorter single-task stride lengths than control participants (Table 2), but no single-task gait differences were detected between groups after the symptom-resolution time point. For dual-task gait at the initial examination, the postconcussion group walked with shorter stride lengths than the control group (Table 2). At the follow-up examination after symptom resolution, postconcussion participants demonstrated slower average

Table 2. Single-Task and Dual-Task Gait Performance

Gait Variable	Group: Concussion: Initial Examination	Group: Concussion: After Symptom Resolution[a]	Group: Control	P Value: Concussion Versus Control: Initial	P Value: Concussion Versus Control: After Symptom Resolution
Single-task gait				(Wilks λ = .87) .03	(Wilks λ = .88) .08
	Mean (95% Confidence Interval)				
Average gait speed, m/s	1.10 (1.04, 1.15)	1.09 (1.03, 1.16)	1.18 (1.13, 1.23)	.03	N/A
Cadence, steps/min	112.2 (109.2, 115.1)	112.6 (109.2, 115.9)	112.1 (109.4, 114.8)	.98	N/A
Stride length, m	1.16 (1.11, 1.20)[b]	1.16 (1.11, 1.21)	1.25 (1.21, 1.29)	.003	N/A
Double support time, % gait cycle	34.7 (33.5, 35.7)	34.6 (33.4, 35.8)	34.8 (33.9, 35.7)	.87	N/A
Dual-task gait				(Wilks λ = .88) .04	(Wilks λ = .778) .003
Average gait speed, m/s	0.84 (0.79, 0.89)	0.78 (0.72, 0.83)[b]	0.92 (0.88, 0.97)	.60	.005
Cadence, steps/min	98.0 (94.5, 101.5)	92.5 (88.7, 96.3)[b]	99.3 (96.1, 102.5)	.027	<.001
Stride length, m	1.02 (0.98, 1.06)[b]	0.99 (0.94, 1.05)[b]	1.10 (1.06, 1.14)	.011	.003
Double-support time, % gait cycle	38.1 (36.9, 39.3)	39.2 (37.9, 40.5)	38.3 (37.2, 39.4)	.86	.22

Abbreviation: N/A, not applicable due to lack of omnibus test significance.

[a] Due to patients lost to follow-up, data from 24 participants were available for the examination after symptom resolution.

[b] During the initial postinjury evaluation, concussion participants walked with shorter stride lengths than controls during single-task (Cohen d = 0.68) and dual-task (Cohen d = 0.54) gait. After symptom resolution, concussion participants walked with slower average gait speed (Cohen d = 1.04), lower cadence (Cohen d = 0.79), and shorter stride length (Cohen d = 0.74) than controls.

gait speeds, smaller cadences, and shorter stride lengths than control participants during dual-task gait (Table 2).

No differences were observed between groups at either testing time point during quiet stance or during quiet stance while completing the cognitive test (Table 3). Cognitive test performance was not different between the groups during quiet stance at either time point. At the initial examination of dual-task walking, postconcussion participants were less accurate than control participants on the cognitive test, but this difference was no longer detected after the symptom-resolution time point (Table 4).

DISCUSSION

Dual-task gait impairments persisted after concussion symptoms had resolved. Additionally, cognitive performance deficits were observed initially after injury during gait but resolved in a manner similar to symptoms. These findings indicate that dual-task gait deficits may continue to persist after the patient no longer reports experiencing concussion symptoms. Thus, dual-task gait evaluations using portable sensors may help clinicians objectively quantify concussion recovery.

Dual-task gait deficits, including decreased gait speed, cadence, and stride length, were present in the postconcussion group compared with the control group during the clinical examination after symptom resolution was reported. This supports previous observations[6,10] of lingering gait deficits in patients after concussion-symptom resolution. Adolescents, in particular, displayed greater dual-task gait deficits than young adults,[15] whereas male adolescent athletes performed worse than male collegiate athletes on the Balance Error Scoring System.[16] Although the specific variables differed between studies, the collective data indicate that postconcussion gait and balance impairments persisted beyond the first week after concussion among

Table 3. Quiet-Stance Performance

Stance Variable	Group: Concussion: Initial Examination	Group: Concussion: After Symptom Resolution	Group: Control	P Value: Concussion Versus Control: Initial	P Value: Concussion Versus Control: After Symptom Resolution
Quiet stance				(Wilks λ = .98) .88	(Wilks λ = .97) .70
	Mean (95% Confidence Interval)				
RMS sway, m/s²	0.18 (0.13, 0.23)	0.24 (0.16, 0.32)	0.20 (0.16, 0.25)	N/A	N/A
95% Ellipse sway area, degrees²	10.3 (3.9, 16.7)	20.6 (9.46, 31.8)	12.5 (6.8, 18.2)	N/A	N/A
Coronal-plane RMS sway, °	0.94 (0.68, 1.20)	1.23 (0.79, 1.68)	1.04 (0.81, 1.26)	N/A	N/A
Sagittal-plane RMS sway, °	0.46 (0.32, 0.60)	0.61 (0.42, 0.79)	0.54 (0.42, 0.66)	N/A	N/A
Quiet stance + cognitive task				(Wilks λ = .96) .49	(Wilks λ = .94) .41
RMS sway, m/s²	0.24 (0.20, 0.28)	0.28 (0.22, 0.34)	0.26 (0.22, 0.30)	N/A	N/A
95% Ellipse sway area, degrees²	15.2 (8.1, 22.4)	25.7 (14.7, 36.7)	22.3 (15.8, 28.7)	N/A	N/A
Coronal-plane RMS sway, °	1.22 (1.01, 1.43)	1.40 (1.12, 1.67)	1.26 (1.07, 1.45)	N/A	N/A
Sagittal-plane RMS sway, °	0.59 (0.44, 0.73)	0.76 (0.56, 0.97)	0.74 (0.61, 0.87)	N/A	N/A

Abbreviations: N/A, not applicable due to lack of omnibus test significance; RMS, root mean square.

Table 4. Cognitive-Task Performance

Cognitive-Task Variable	Group: Concussion, Initial Examination	Group: Concussion, After Symptom Resolution	Group: Control	P Value: Concussion Versus Control, Initial	P Value: Concussion Versus Control, After Symptom Resolution
Standing cognitive-task performance				(Wilks λ = .98) .63	(Wilks λ = .93) .17
	Mean (95% Confidence Interval)				
Total No. of correct answers	27.7 (23.8, 31.6)	32.3 (26.9, 37.7)	29.4 (25.9, 33.0)	N/A	N/A
Total No. of task items provided	29.4 (25.7, 33.2)	34.5 (29.3, 39.8)	31.0 (27.6, 34.4)	N/A	N/A
Overall accuracy rate	0.92 (0.89, 0.95)	0.92 (0.89, 0.95)	0.94 (0.92, 0.96)	N/A	N/A
Walking cognitive-task performance				(Wilks λ = .89) .03	(Wilks λ = .99) .83
Total No. of correct answers	18.6 (15.9, 21.2)	21.6 (18.3, 25.0)	21.5 (19.1, 23.9)	.10	N/A
Total No. of task items provided	21.4 (18.9, 23.9)	23.7 (20.4, 26.9)	23.2 (20.9, 25.4)	.30	N/A
Overall accuracy rate	0.83 (0.78, 0.87)[a]	0.90 (0.87, 0.94)	0.92 (0.88, 0.97)	.003[a]	N/A

Abbreviation: N/A, not applicable due to lack of omnibus test significance.

[a] The overall accuracy rate was lower for the concussion group compared with the control group during the initial postinjury evaluation.

adolescent athletes. This suggests that gait measures can monitor recovery more sensitively than subjective assessments (ie, symptom inventories), which can be prone to underestimation or overestimation.[17,18] Specifically, dual-task gait assessments probe abilities that are common in everyday life and can detect subtle neurologic deficits after a concussion, thereby potentially resulting in documentation of a longer duration of postconcussion deficits than that determined from symptom reports.[19] All participants reported that their symptoms had resolved at the symptom-resolution testing time point, yet some participants still endorsed items on the PCSS. This finding supports prior research describing the nonspecific nature of the PCSS as a means to monitor recovery, because individuals may report symptoms in the absence of concussion.[20] Therefore, a combination of clinically feasible yet objective methods of assessment, including both functional and symptom assessments, may allow clinicians to accurately monitor recovery.

The observed deficits in dual-task gait at each time point suggest that concussion induces motor and cognitive dysfunction, supporting earlier observations.[4,6,10] Specifically, individuals with concussion may adapt to the additional cognitive perturbation induced by a dual task by reducing their forward progression during locomotion.[21] This may be due to a reduction in attentional-allocation ability resulting from the concussion.[22] Alternatively, some healthy individuals may be less able to effectively distribute their attention during sports, making them more likely to sustain a concussion. Mihalik et al[23] indicated that awareness of oncoming impacts may be related to the risk or severity of a concussion. If an athlete is unable to appropriately allocate attention to identify an oncoming impact, he or she may be at a greater risk for a severe head impact. Thus, our results may reflect pre-existing differences in attention distribution. However, our study was not designed to account for such a factor, and future authors should investigate how attention-distribution and dual-task abilities are associated with the risk of concussion.

Similar performance between participants after a concussion and healthy control participants during double-legged, quiet stance on firm ground has been previously documented[24] through the use of an accelerometer placed on the torso. Consistent with this observation, we did not detect between-groups differences in the double-legged, quiet-stance condition, regardless of whether the participant was simultaneously completing a cognitive task or not. However, other researchers have used multiple quiet-stance configurations to assess postural control with accelerometers worn on the body. Specifically, quiet-stance abilities were rated with and without accelerometers during double-legged stance, single-legged stance, and tandem stance; the measurements obtained with an accelerometer were more accurate in diagnosing patients with a concussion,[5] supporting the clinical quantification of postural control with accelerometry. Thus, quiet-standing assessments in double-legged stance on firm ground simply may not be difficult or complex enough to distinguish between individuals in the acute postconcussion stage and uninjured controls. More challenging postural-control tasks, such as standing on a single leg, may be more likely to distinguish between healthy people and injured patients and assist in concussion-management decisions.

Postconcussion neurocognitive impairments have been documented in symptom-free athletes using computerized tests.[4] In contrast, our measure of cognitive performance was different between the groups only at the first time point when individuals walked simultaneously but not after the injured group reported that their concussion symptoms had resolved. The cognitive performance assessment used in our study consisted of 3 specific mental tasks rather than computerized measurements. Although these mental tasks have been used previously in postconcussion evaluations,[9,25] computerized neurocognitive tests provide a more comprehensive evaluation of neurocognitive deficits after concussion.[26] However, 1 advantage to the cognitive performance measures in our study is that they can be administered during motor activities and, thus, provide a realistic examination of sport demands that may be useful in making clinical decisions related to return to participation.

Our findings suggest that dual-task gait deficits may persist beyond detection of symptoms by a symptom inventory. Therefore, athletes with subtle deficits undetectable by traditional clinical examinations may be returned to play under standard clinical guidelines, perhaps before full physiologic recovery. As recent investigators[27–29] have identified an apparent association between concussion and subsequent musculoskeletal injury, neuromuscular-control deficits that outlast traditional clinical signs and symptoms may be at least partially responsible. Hence, it may be worthwhile for postconcussion testing batteries to include components of activities that represent the demands of sports, such as dual tasks, to accurately identify complete recovery from concussion.

LIMITATIONS

Our study was limited due to the participants, who were patients seen for care at a specialty concussion clinic, and therefore, may have had more severe injuries and may be less generalizable to the overall population of athletes who sustain concussions. Additionally, patients who were initially evaluated after concussion were symptomatic at the time of evaluation. Thus, those who may have recovered by the time of the initial evaluation were not included in our study. Similarly, the control group consisted of people who reported for an injury-prevention evaluation and may not be generalizable to all healthy athletes. Although a majority of postconcussion patients had a reliable date of symptom resolution and returned for a clinical examination once symptom free, data from the examination after symptom resolution were not available for all participants. However, no differences were noted in characteristics between those who did and those who did not return for an examination after symptom resolution, potentially mitigating the effects within our data. Additionally, preinjury baseline data were not available for study participants. Such comparisons might have yielded different results from those observed in this investigation. Finally, given the nature of this clinical investigation, a Hawthorne effect may have influenced the results.

CONCLUSIONS

Single-task and dual-task gait-pattern deficits were identified acutely after concussion. These differences persisted after symptom resolution during dual-task gait but not during single-task gait. Furthermore, cognitive impairments were detected initially but resolved in a pattern similar to symptoms. These data suggest that dual-task deficits may persist longer than other forms of impairment. Therefore, including dual-task protocols in the monitoring of concussion recovery may be useful for clinicians as an objective, standard representation of real-life activities.

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