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Clinical Utility of the Sport Concussion Assessment Tool 3 (SCAT3) Tandem-Gait Test in High School Athletes

Ashley Santo, PhD, ATC*; Robert C. Lynall, PhD, ATC†; Kevin M. Guskiewicz, PhD, ATC, FNATA, FACSM‡; Jason P. Mihalik, PhD, CAT(C), ATC‡

*Department of Kinesiology, Towson University, Maryland; †Department of Kinesiology, University of Georgia, Athens; ‡Exercise and Sport Science, University of North Carolina, Chapel Hill

Context: Dynamic balance during functional movement may provide important clinical information after concussion. The Sport Concussion Assessment Tool, version 3 (SCAT3), includes a timed tandem-gait test (heel-to-toe walking) administered with a pass-fail scoring system. Minimal evidence supports inclusion of the tandem-gait test in the SCAT3, especially in high school athletes.

Objective: To determine (1) the percentage of healthy high school athletes who passed (best trial $\leq$14 seconds) the tandem-gait test at baseline, (2) the association between sex and test performance (pass versus fail), and (3) the relationships among sex, age, height, and tandem-gait test score.

Design: Cross-sectional study.

Setting: High school sports medicine center.

Patients or Other Participants: Two hundred athletes from 4 high schools (age = 15.8 $\pm$ 1.2 years, height = 170.3 $\pm$ 10.3 cm, weight = 64.8 $\pm$ 14.5 kg).

Main Outcome Measure(s): Healthy participants completed 4 trials of the SCAT3 tandem-gait test and a demographic questionnaire. Outcome measures were passing rate at baseline on the tandem-gait test and tandem-gait test score (time).

Results: Overall, 24.5% (49/200) of participants passed the test. Sex and performance were associated ($\chi^2 = 15.15$, $P < .001$), with a passing rate of 38.6% (32/83) for males and 14.5% (17/117) for females. The regression model including predictor variables of sex and height, with the outcome variable of tandem-gait test score and time, was significant ($R^2 = 0.20$, $P < .01$).

Conclusions: Our findings suggest that the tandem-gait test had a high false-positive rate in high school athletes. Given that more than 75% of healthy participants failed the tandem-gait test, the 14-second cutoff appears to have limited clinical utility in the adolescent population. Functional movement deficits after concussion need to be accounted for, but the 14-second cutoff for the SCAT3 tandem-gait test does not appear to be an ideal way to assess these deficits in high school athletes.

Key Words: traumatic brain injuries, dynamic balance, adolescents, functional movement

Key Points

- Males performed better than females on the tandem-gait test at baseline.
- The 14-second cutoff for the tandem-gait test in high school athletes may result in a high false-positive rate.

Concussion assessment and management continue to evolve. With the large number of objective tools now available,[1–5] clinicians may find it challenging to select the most effective assessments for their setting. Several consensus statements[1,6,7] detailing proper concussion-assessment and -management recommendations have been published. One such international collaboration, the Concussion in Sport Group (CISG), has produced several consensus statements to inform concussion management.[1] In the latest iteration,[1] the CISG recommended the use of a sideline assessment tool known as the Sport Concussion Assessment Tool, version 3 (SCAT3). The SCAT3 is designed to function as a standardized tool for evaluating injured athletes over the age of 13 for concussion. The SCAT3 combines several commonly used assessment tools, including the Glasgow Coma Scale, Maddocks Score,[8] symptom evaluation, Standardized Assessment of Concussion,[2] and modified Balance Error Scoring System.[9] Scores are generated for each test. The CISG[1] stated that comparing postinjury scores with preseason baseline scores can be helpful for interpreting postinjury test results and for informing postinjury management strategies.

In addition to the aforementioned validated concussion-assessment tools included in the SCAT3, the CISG proposed a tandem-gait test to act as an added dynamic-balance measure.[1] The tandem-gait test assesses "locomotion, dynamic balance, and lower limb coordination."[10] During the tandem-gait test, participants are instructed to walk forward along a 3-m line, turn, and return to the starting point as quickly as possible without losing their balance. This task became part of the SCAT3 in the absence of empirical data showing how concussion actually affects tandem gait. However, emerging evidence supports the use of dynamic-stability testing[11–13] and tandem-gait walking in concussion assessment.[14] Dynamic-balance deficits have been demonstrated in patients who have returned to normal static-balance function[15,16] and have recovered on all traditional assessments (eg, symptoms, mental status).[17,18]

The tandem-gait test is an example of a dynamic-balance assessment. The CISG cited 2 published manuscripts that investigated the tandem-gait task. One publication detailed normative values for a sample with a mean age of approximately 22 years,[19] and the other detailed the effect of footwear and sport surface on the outcome.[10] The current SCAT3 tandem-gait task assesses only time to task completion. It is unclear how a cutoff score of 14 seconds was determined. Also, sex-specific maturational gait changes have been identified, which suggests that both age and sex may affect tandem-gait test performance.[20] Furthermore, height has been correlated with performance on a walking test.[21] Therefore, the purpose of our study was to investigate the current SCAT3 tandem-gait task in healthy high school-aged male and female athletes. Understanding how healthy young athletes perform on the SCAT3 tandem-gait task is a critical first step in assessing its value in this population. Specifically, we investigated the baseline pass rate, association between sex and tandem-gait test performance (pass versus fail), and the relationships among sex, age, height, and tandem-gait test score.

METHODS

Participants

Athletes at 4 high schools were approached about participation in this study before concussion baseline testing. Athletes who were 18 years old and wished to participate in the study provided informed consent, and athletes who were younger than 18 years provided assent after their parents or legal guardians provided informed consent; the written informed consent and assent forms were approved by the university's institutional review board, which also approved the study. A total of 204 participants completed informed consent or assent forms. Volunteers were eligible for the study if they met the following inclusion criteria: eligibility and clearance to participate in baseball, basketball, cheerleading, field hockey, football, lacrosse, soccer, softball, or volleyball at 1 of the 4 public high schools. Volunteers were excluded if they self-reported (1) more than 3 diagnosed concussions in their lifetime or (2) an orthopaedic or neurologic condition that could affect balance. Four participants were excluded for a recent lower extremity injury, leaving 200 participants in the study.

Participants reported for routine baseline concussion testing at their high school and were administered a number of assessments (CNS Vital Signs, the SCAT3 symptom checklist, the Standardized Assessment of Concussion, Balance Error Scoring System, King-Devick test, near-point convergence, and SCAT3 tandem-gait test) in a random order. Participants also completed a demographic form, which assessed the following self-reported information: age; height; weight; sport; history of epilepsy, brain surgery, seizures, attention-deficit/hyperactivity disorder, or learning disability; treatment for drug or alcohol abuse; or a psychiatric condition. Concussion history was also self-reported as a response to the following question: "How many times have you been diagnosed with a concussion by a medical professional?" We only used information from the tandem-gait test and the demographic form for this study.

Table 1. Demographic Information, Passing Rate, and χ^2 Analysis

Characteristic	Mean ± SD Overall (n = 200)	Males (n = 83)	Females (n = 117)	χ^2 (P Value)
Age, y	15.8 ± 1.2	16.2 ± 1.3	15.6 ± 1.2	
Height, cm	170.3 ± 10.3	177.2 ± 9.3	165.5 ± 7.9	
Weight, kg	64.8 ± 14.5	73.8 ± 15.5	58.5 ± 9.6	
Best trial	17.16 ± 4.18	15.35 ± 3.46	18.45 ± 4.18	15.15 (<.001)
Passers, % (No.)[a]	24.5 (49)	38.6 (32)	14.5 (17)	

[a] Passers = percentage of participants with a time of 14 seconds or less as their best trial on the tandem-gait test.

We followed the instructions listed in the SCAT3 for the tandem-gait test.[1] Participants were instructed to remove their shoes and stand with their feet together behind a starting line. When ready, participants walked forward using an alternating-foot heel-to-toe gait along a line 38-mm wide and 3-m long, ensuring that their heel and toe touched on each step. Once the participant crossed the end of the 3-m line, he or she turned 180° and returned to the starting position using a tandem gait. Participants were encouraged to complete the task as quickly as possible and free of error. Participants failed the trial if they stepped off the line, had a separation between their heel and toe at any time, or touched or grabbed the examiner or an object. For failed trials, the time was not recorded, and the participant completed the trial again. Short rest intervals were given between trials. Participants completed a total of 4 trials. The best time was recorded as the score for the tandem-gait test.

Data Analysis

We computed descriptive statistics for the following variables: age, height, and weight (Table 1). We also calculated the percentage of participants who passed the tandem-gait test (Table 1). For the purposes of this study, *pass* was defined as completing the tandem-gait test in 14 seconds or less, adhering to the published SCAT3 guidelines that "athletes should complete the test in 14 seconds."[1] We used χ^2 analysis to determine the association between sex and performance on the tandem-gait test (pass versus fail). Finally, we performed linear regressions to determine whether sex, age, or height predicted tandem-gait test score. We established an a priori removal level of $P >$ .05 for all predictor variables in the model. We computed variance inflation factors (VIF) to assess for collinearity of the predictor variables, for which we set an acceptable value of VIF < 4. All data were analyzed using SPSS (version 19.0; IBM Corp, Armonk, NY). An a priori α level of significance was set at $P < .05$ for all analyses.

RESULTS

Demographic data are presented in Table 1. Overall, only 24.5% (49/200) of participants passed the tandem-gait test. Sex was associated with performance on the tandem-gait test (χ^2 =15.15, $P < .001$), with a passing rate of 38.6%

Table 2. Regression Analysis Modeling Predictive Ability of Sex and Height

Model[a]	Sum of Squares	Degrees of Freedom	Mean Square	*F* Value	*P* Value	
Regression	681.22	2	340.61	23.99	<.001	
Residual	2797.10	197	14.20			
Total	3478.31	199				
	Unstandardized Coefficients		Standardized Coefficients			
Model	B	Standard Error	β	*t* Value	*P* Value	95% Confidence Interval for B
(Constant)	36.87	5.58		6.61	<.001	25.86, 47.87
Sex	1.69	0.65	0.20	2.58	.01	–0.18, –0.06
Height	–0.12	0.03	–0.30	–3.87	<.001	0.40, 2.98

[a] Model: Predictor variables = sex, height. Predicted variable = tandem-gait test score.

(32/83) for males and 14.5% (17/117) for females (Table 1). We conducted a regression model with sex, age, and height as predictor variables and tandem-gait score as the outcome variable. Based on our preestablished removal level ($P < .05$), age ($P = .53$) was removed from the model. The second regression modeled the predictive ability of the remaining 2 independent variables (sex and height) and was statistically significant ($R^2 = 0.20$, $P < .01$; Table 2). Sex was significant ($P = .01$), indicating that males (mean time = 15.35 ± 3.46 seconds) performed better than females (mean time = 18.45 ± 4.18 seconds). Height was significant ($P < .001$), indicating that taller individuals performed better than shorter individuals. All VIF values were <4, reflecting an acceptable level of collinearity.

DISCUSSION

Using a simple pass-fail scoring system, as currently described in the SCAT3, likely has limited clinical utility in assessing tandem gait among concussed high school athletes. More than 75% of healthy high school-aged athletes failed the test at baseline. Even in the absence of concussion, the lack of specificity (or the high number of false-positives) in this sample raises questions about the clinical utility of the recommended clinical cutoff time in high school athletes. A new clinical cutoff score should be established for high school athletes because baseline testing can be time and resource intensive and needs to be conducted frequently enough to control for maturational changes. In establishing this clinical cutoff score, it is important that future researchers include concussed athletes. Until a new clinical cutoff is established, baseline testing for the tandem-gait test in high school athletes may aid in the interpretation of postinjury data.

The difference in findings between our study, which involved a large sample of 200 participants, and previously published normative values is striking. Using the same methods, Schneiders et al[19] reported a mean time-to-task completion of 11.2 seconds. In our sample, only 2% (4/200 of participants) were able to complete even a single trial under 11 seconds. The disparity between reported outcomes could be due to age differences between our samples (Schneiders et al study = 22.2 years, range = 16–37 years; current study = 15.8 years, range = 14–19 years).[19] However, a subset of 18-year-olds to 19-year-olds in our study (n = 10) had a mean time-to-task completion of 15.5 seconds, which was still substantially greater than the mean time reported by Schneiders et al.[19] Although age was not a significant predictor of tandem-gait test scores in this study, previous investigators[22] demonstrated that collegiate athletes had better dynamic balance than did high school athletes. Athletes at various competition levels could pursue different movement strategies[22] as a result of their training, which could explain the differences in dynamic balance. Competition-level differences (high school versus college) could at least partially explain the discrepancy in findings; the mean age of participants in the study by Schneiders et al[19] was closer to the mean age of a collegiate sample, whereas our participants' mean age was closer to that of a high school sample. Given our findings, the pass-fail cutoff score for athletes under the age of 20 should be reconsidered.

In addition to the majority of athletes failing the test at baseline, sex and height influenced performance; males and taller athletes performed better. Previous authors have reported conflicting findings regarding sex differences in dynamic balance. Some studies have shown no difference between males and females in dynamic balance and tandem gait.[23,24] However, our findings were consistent with others showing that females had less dynamic postural control[25] and walked more slowly than males.[26] Potential reasons for sex differences in dynamic balance include differences in muscle strength and the speed of muscle contractions.[27] Women tend to have less functional leg power than men.[28] This is important because lower limb strength and performance on timed walking tasks are highly correlated.[29] Our results are also consistent with those of previous researchers who demonstrated that height played a role in walking intensity[30] and affected dynamic postural control.[31] Height may play a role in the tandem-gait test because height is correlated with foot length[32]; therefore, taller individuals will have to take fewer steps to complete the same task. Unfortunately, we did not record foot length in this study. Future investigators should evaluate the relationship between foot length and performance on the tandem-gait test.

Despite the flaws in the current form of the SCAT3 tandem-gait task, it is becoming increasingly clear that an assessment of functional movement or dynamic balance may add great value to concussion-assessment and -management protocols. Our findings did not suggest that dynamic-balance testing is an inadequate addition to the concussion-management paradigm. In fact, although static-balance tests have performed admirably in identifying acute balance deficits,[3,9] scores typically resolved within 3 days of injury.[3,9] Dynamic-balance deficits can linger beyond symptom resolution and the return of normal cognitive and static-balance function,[15,16] which indicates that the value in dynamic-balance testing may be to inform clinical return-to-activity decisions. Under laboratory conditions, concussed participants had compromised gait stability compared with control participants,[11,33] even after having recovered on all aspects of the traditional clinical-assessment battery[17] and having returned to full activity.[15,16,18] Compromised postural control has also been demonstrated in individuals after concussion while completing dual-task paradigms, characterized by participants simultaneously performing functional movement and cognitive tasks.[33] These dual-task paradigms may more closely resemble the functional demands of sport participation, as most athletic events impose a high cognitive load in conjunction with fast, dynamic movements. However, dynamic-balance deficits after concussion have been observed only under laboratory conditions. An important next step is developing a tool to translate dynamic-balance assessment from the laboratory into evidence-based practice. The SCAT3 tandem-gait task is certainly a step in this direction, but our data showed that the task in its current form does not add any value to clinical decision making.

We believe an important component missing from the SCAT3 tandem-gait task is an assessment of dynamic-balance errors. The current tandem-gait test scoring criteria only account for time-to-task completion. No consideration is given to trunk sway or arm movement aimed at stabilizing the center of mass. An athlete's dynamic-balance deficits may be inadequately masked given that he or she is asked to reattempt test trials in which gross motor errors were committed. Accounting for these dynamic-balance errors, instead of simply discarding the trial, may be a valuable contribution to the evaluation and management of patients with concussion. Additionally, it may be useful to establish separate pass-fail criteria for males and females at the high school level. In our sample, females had an average tandem-gait test score of 18.45 seconds, whereas males had an average score of 15.35 seconds. Having separate cutoff scores for males and females in high school may lead to a lower number of false-positives. Furthermore, height plays a role in performance on the tandem-gait test. To control for this, participants could be asked to complete a certain number of steps within 14 seconds, instead of having to walk 6 m despite differing heights and foot lengths. Importantly, future researchers should aim to develop clinician-friendly means of identifying important dynamic-balance deficits during functional movement. Before this can happen, it is imperative to understand how concussion affects tandem gait in adolescent athletes. This will allow for the creation of more sensitive and specific functional movement assessment tools.

Our study had several limitations. Our results are mostly generalizable to high school-aged athletes. It is possible the SCAT3 tandem-gait scoring criteria may be more effective in other cohorts. Our cross-sectional study design may have introduced bias in our sample. However, we observed athletes at 4 high schools, and ancillary analyses comparing scores across schools revealed no significant differences. We included data from participants who self-reported epilepsy, attention-deficit/hyperactivity disorder, learning disabilities, treatment for substance or alcohol abuse, or a psychiatric condition. Ancillary analyses revealed no differences in the results of any outcomes with the exclusion of individuals who had self-reported conditions; therefore, these participants were included in the final analyses. We did not measure foot length, which may contribute to performance on the tandem-gait test. Future researchers should examine the relationship between foot length and tandem-gait test performance. Additionally, we did not record the number of discarded trials (trials in which participants stepped off the line, had a separation between heel and toe, or touched or grabbed the examiner or an object). Future authors should record the number of discarded trials and explore errors as a possible addition to the test. Finally, we studied only healthy participants. It is possible that the current SCAT3 tandem-gait test may have clinical utility in concussion management when comparing postconcussion times with baseline times as opposed to a global passing standard (14 seconds).

CONCLUSIONS

The clinical cutoff time for the SCAT3 tandem-gait test appears to have limited clinical utility for high school athletes. As the test is currently conducted, more than 75% of healthy high school-aged athletes failed at baseline, males performed better than females, and height could have played a role in performance. Concussed patients have demonstrated compromised gait stability compared with control participants,[11,33] even after returning to full activity.[12,15,16] Therefore, a clinically useful dynamic-balance assessment that is sensitive to the lingering effects of concussion is necessary. Future researchers should aim to develop clinician-friendly means of identifying important dynamic-balance deficits during functional movement.

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Address correspondence to Ashley Santo, PhD, ATC, Department of Kinesiology, Towson University, 8000 York Road, Towson, MD 21252. Address e-mail to asanto@towson.edu.