Gait & Posture 62 (2018) 291–296

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length article

Self-reported sleep duration affects tandem gait, but not steady-state gait outcomes among healthy collegiate athletes

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ARTICLE INFO

Keywords:
Sleep
Gait
Tandem gait
Concussion
Mild traumatic brain injury
Locomotion

ABSTRACT

Background: Sleep deficits are associated with motor and cognitive function deficits, even in the absence of a recent concussion.
Research question: Does the amount of self-reported sleep prior to pre-season concussion testing affect single-task and dual-task instrumented steady-state gait and timed tandem gait test performance?
Methods: One hundred and fourteen healthy collegiate athletes (mean age 18.8 ± 0.7 years; 60% female) reported the amount of sleep they received during the prior night and completed a timed tandem gait test and an instrumented assessment of steady-state gait in both single-task and dual-task conditions. Outcome variables included spatio-temporal gait parameters during steady-state gait, best and mean tandem gait times, and cognitive test accuracy.
Results: Participants who reported sleeping < 7 h of sleep during the night prior to testing (n = 62) had significantly longer tandem gait times in single-task and dual-task conditions (11.1 ± 2.2 vs. 10.1 ± 2.0 s and 14.5 ± 4.3 vs. 12.3 ± 2.6 s, respectively; $p = .009$) compared to those who reported sleeping ≥7 h (n = 52). No significant differences between groups were observed for spatio-temporal steady-state gait variables or for cognitive test accuracy.
Significance: Self-reported sleep duration may be associated with baseline testing tandem gait performance. Thus, as sleep can play a role in motor abilities, clinicians may consider interpreting tandem gait performance in light of sleep duration during the night prior to testing.

1. Introduction

The management of sport-related concussion often relies on comparison to pre-injury assessments [1]. Pre-injury tests, frequently called baseline tests, are commonly administered in athletic settings to identify post-concussion deficits. Specifically, symptom checklists, computerized neurocognitive evaluations, and the sport concussion assessment tool (SCAT) are frequently used by clinicians as baseline and post-injury management tests [2]. While recommended for athletes at risk for concussion [1], baseline tests can be affected by many factors. The duration of sleep prior to testing is one factor documented to affect cognitive abilities [3]. While it is recommended that young adults get 7–9 h of sleep per night [4], college students sleep approximately 7 h per night, with 25% receiving less than 6.5 h [5]. As the consequences of sleep deprivation often include physical and mental impairments [5], the lack of sleep among collegiate student athletes may affect test performance.

The effect of sleep on neurocognitive function has been reported

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https://doi.org/10.1016/j.gaitpost.2018.03.038
Received 16 January 2017; Received in revised form 13 March 2018; Accepted 23 March 2018

[3,6], but few investigations have observed how sleep affects physical abilities commonly measured during concussion recovery. Associations between sleep deprivation and cognitive and/or gait abnormalities have previously been identified [7,8], while lack of sleep may negatively affect novel functional motor task learning [9]. In contrast, postural stability was not previously associated with sleep quality or quantity [6]. The relationship between sleep duration and cognitive and motor abilities when executed simultaneously among uninjured collegiate athletes, however, remains unknown. As baseline concussion examinations are typically performed soon after a student-athlete arrives at an institution [2], lifestyle adjustments may also lead to altered sleep patterns prior to undergoing baseline tests.

Among the many tests available for clinicians to use on baseline and post-concussion examinations, the tandem gait test is included as a part of the Sport Concussion Assessment Tool-Third Edition (SCAT-3) and Fifth Edition (SCAT-5) [10–12], and has been identified as a useful component in post-concussion deficit identification [13,14]. Furthermore, instrumented steady-state gait tests have been used to identify altered gait characteristics in those with a concussion compared with controls [15–17]. Dual-tasks that pair a gait and concurrent cognitive test can provide a sensitive method for clinicians to observe attentional deficits resulting from a concussion [15,18].

An improved understanding of the influence of sleep on simultaneous cognitive and motor task execution may help in post-concussion clinical test interpretation. Differences in the amount of sleep before pre-injury or post-injury tests may confound post-concussion test interpretation, particularly as sleep disturbances are common after a concussion [19]. Therefore, the purpose of this study was to examine how self-reported sleep duration during the night prior to baseline concussion testing affects single-task and dual-task abilities during an instrumented gait examination and a timed tandem gait test. We hypothesized that individuals who self-reported fewer than 7 h of sleep would demonstrate altered gait performance relative to those who reported 7 or more hours of sleep.

2. Materials and methods

2.1. Participants

We conducted a cross-sectional investigation of intercollegiate varsity athletes at a National Collegiate Athletic Association Division I institution that completed a comprehensive pre-season testing battery. All participants were 18 years of age or older and provided written informed consent to participate in the study as approved by the institutional review board. Participants were included in the study if they were active members of a varsity athletic team and excluded if they were under the age of 18, had an existing neurological disorder or lower extremity injury which may have affected gait abilities, a currently active psychiatric condition, or any medical condition which prohibited them from participating in their sport. All testing took place prior to the start of the athletic season and academic school year, during the morning or afternoon hours.

2.2. Testing protocol

All study participants first responded to the following question: “approximately how much sleep did you get last night (hours)” and were given adequate time to recall when they fell asleep and woke up. Answers were provided to the nearest half hour as the difference in time between falling asleep and waking up. Although we recognize the limitation of reliance on recall of sleep duration as a measurement technique, moderate correlations between self-reported and objectively-measured sleep duration have been reported [20]. Furthermore, as most clinical settings do not provide objective sleep monitors after concussion, such a self-reported measurement may reflect a way to assess sleep duration in a clinically-feasible manner.

Participants completed two forms of gait testing: a steady-state gait examination [21] and a tandem gait test [11,13]. During the steady-state gait examination, participants were asked to walk under two conditions: without a cognitive test (single-task steady-state gait) and while concurrently completing a cognitive test (dual-task steady-state gait). During steady-state gait trials, participants walked barefoot or while wearing socks at a self-selected, comfortable speed. They were instructed to walk in a normal manner toward a target placed 10 m in front of them, walk around it, and return to the original position, completing 5 trials per condition. During dual-task trials, when cued by a verbal instruction from the test administrator, participants began walking and completing a cognitive test (described below) for the duration of the trial. During steady-state gait trials, participants wore an inertial measurement unit (Opal Sensor, APDM Inc., Portland, OR) attached with an elastic strap on the lumbar spine (at the level of the lumbosacral junction) and on the dorsal surface of the feet. This valid and reliable system has been previously used to evaluate gait and postural deficits following sport-related concussion [15,22]. Data were obtained at sampling frequency of 128 Hz, synchronized, and transmitted to a laptop computer wirelessly during each trial. No instructions were given to prioritize the motor or cognitive task; rather, participants were instructed to continue walking while accurately responding to the test. Outcome variables from the steady-state gait examination included average gait speed, stride length, and cadence, selected a-priori and calculated using Mobility Lab software [22].

Participants completed four trials of the tandem gait test in single-task and dual-task conditions while barefoot. Consistent with the instructions provided by the SCAT-3 and SCAT-5 [11,12], participants were instructed to walk forward along a 3 m long piece of sports tape 38 mm wide with an alternate heel-to-toe gait, where the heel and toe were approximated on each step. Once they crossed beyond the end of the 3 m piece of tape, they were instructed to turn and return to the original starting point with the same gait pattern and to complete the trial as fast as possible without stepping off of the line, having a separation between the heel and toe, or touching the test administrator. The test administrator used a standard stopwatch to measure test completion time to the nearest hundredth of a second. Based on small mean error, and high intraclass correlations, using hand-held stopwatches to obtain results is a viable alternative to electronic timing systems [23] and suitable for our investigative purposes. Results from failed trials (separation of heel and toe, stepping off the tape, or touching the test administrator) were not included in further analysis. A subset (78%) of participants completed this component of the protocol. Outcome variables included the fastest time of the four trials in both conditions and the mean time from the four trials, calculated separately for single-task and dual-task conditions. In previous work, researchers have noted a high (0.97) intra-rater reliability [24] and an inter-rater minimal detectable change score of 0.38 s [14] for the tandem gait test.

With the release of the SCAT5 in 2017, the tandem gait instructions were updated to no longer specifically record test completion times [12]. Instead, clinicians identify if the patient can perform the tandem gait test normally. The test criteria consist of stepping off the line, having a separation between their heel and toe, or touching or grabbing the examiner or an object. We chose to include the time to completion as our primary outcome variable consistent with several recent publications observing that timed tandem gait is a useful method for post-concussion postural control assessments [14], a viable proxy measure for instrumented average walking speed [25], able to detect post-concussion deficits in dual-task conditions [13], and a clinically useful dynamic balance assessment with need to further identify clinically relevant pass/fail thresholds [10,25].

Participants completed a cognitive test previously used to evaluate the effects of concussion on dual-task gait [15–17]. They completed the test in three separate conditions: while standing still for 30 s, during dual-task steady-state gait trials, and during dual-task tandem gait trials. The cognitive test included 3 different forms: 1) spelling a five-