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Validity and reliability of the Balance Tracking System during feet together stance

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A R T I C L E I N F O

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A B S T R A C T

Laboratory and clinical measures of postural control are commonly used in the diagnosis of concussion. A novel instrument, the Balance Tracking System (BTrackS), has similar instrumentation to a force platform (FP), with greater portability and reduced cost. The purpose was to evaluate the concurrent validity of derived center of pressure (CoP) excursion and mean velocity for the raw CoP coordinates produced by the BTrackS and FP during feet together quiet upright stance. Participants stood on the BTrackS and FP at two time points. The BTrackS excursion values were significantly lower than the FP values at both time points but the devices CoP excursion values were strongly related at both time points and in all conditions. For mean velocity data, there were no significant differences between the devices at any time point. The BTrackS had excellent test–retest reliability over time in all conditions for both the excursion and mean velocity data.

1. Introduction

Postural control is a cardinal sign of sport-related concussion (SRC) and can be assessed with a range of clinical and laboratory based methodology [1–3]. The most common clinical measure of postural control used in the detection of SRC is the Balance Error Scoring System (BESS) [4], wherein trained raters subjectively detect balance errors during numerous stances. The BESS has previously been found to be reliable and valid, however, it has limited interrater reliability and has difficulty detecting postural instability after day 7 post-SRC [2,4,5]. Laboratory measures of postural control commonly involve quantitative assessments of upright stance using a force platform to measure the changes in the amount of applied force via transduction [6]. These changes are further quantified to determine various center of pressure (CoP) metrics such as excursion, velocity, and entropy [1,6,7]. Force platform assessments of postural control are both valid and reliable, as well as having the ability to detect postural impairments beyond 30 days in post-SRC populations [1,8–10]. However, force platforms are not widely used in clinical settings due to high cost and immobility. As such, less expensive mobile force platform technology has been developed as a potential clinical tool to quantitatively measure postural control following a SRC.

One device in particular, the Balance Tracking System (BTrackS), uses technology similar to a laboratory grade strain gauge force platform to measure postural control via the calculation of the point-to-point summation of the CoP changes [11,12]. A strain gauge force platform typically has a minimum of four sensors located in the corners of the platform that are connected to a Wheatstone bridge circuit. When pressure is applied to the platform, it causes structural and geometric changes in resistors that alter their electrical resistance. The electric potentiation has a linear relationship to the applied force. The overall voltage change is measured, converted, and amplified into raw CoP coordinates, which are in turn used to calculate numerous CoP postural metrics [13]. Standard force platforms are expensive (approximately $5000–$100,000 US) and are typically mounted in the ground or floor [11,13]. As such, portable platforms such as the BTrackS (approximately $800 US) may be more cost effective in clinical settings [11].

The BTrackS has been validated (intraclass correlation coefficient [ICC] > 0.99) using a mechanical inverted pendulum model [11] and in a non-impaired older adult populations (Pearson product correlation > 0.90) [14] when compared to the gold standard laboratory grade strain gauge force platform. Additionally, the BTrackS has been noted to have excellent test–retest reliability in healthy young adults (ICC = 0.92) when measured from day 1 to 15 [15], and in older non-impaired adults from day 1 to 3 when dichotomized in the eyes open (ICC = 0.83) and eyes closed (ICC = 0.83) conditions [14]. Furthermore, it has been noted to be twice as sensitive (64%) as the BESS for SRC diagnosis when compared to the gold standard physicians diagnosis [1,16]. Given the excellent validity and reliability of the BTrackS, it is possible that this mobile postural control assessment tool could be

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Fig. 1. BTrackS testing procedure setup.

used to approximate accurate measures of CoP within healthy, older, and SRC populations.

To date all research found involving human participants on the BTrackS were assessed while placing their feet shoulder width apart [11,12,14,15]. In neurological populations such as SRC, it is common practice to measure participants with their feet together (medial malleoli to medial malleoli) [1,2,7,9,17,18]. The reduced base of support produces a more challenging task and evokes greater postural sway in human participants [6]. For example, research comparing feet shoulder width apart to feet together stance has reported an average increase of 10–20 cm in the CoP excursion metrics in healthy, impaired, and neurological populations [6,8,9,19]. The increased postural sway in a narrow base of support closely mimics the inverted pendulum and will naturally elicit greater sway magnitude as a result of internal perturbations (i.e. respiration and heart rate) [6]. Greater amounts of postural sway are often associated with postural control system decline due to aging and/or disease [20,21]. Increased postural sway allows for easier detection of postural instabilities in mild neurological disorders, such as SRC [1]. Furthermore, the feet together stance is widely used in SRC due to the increased difficulty of the task without compromising participant safety, which is advantageous over the highly unstable single leg stance positions [1,2,7,9,17,18]. As such, further research is needed to evaluate the validity and reliability of the BTrackS while in the feet together stance during an upright quiet stance position in a non-impaired population.

The purpose of this study was to examine the concurrent validity of derived CoP excursion and mean velocity in the anteroposterior (AP) and mediolateral (ML) directions from the raw CoP coordinates produced by the BTrackS and compare them to the gold standard laboratory grade force platform during feet together quiet upright stance in a healthy collegiate non-athletic population. We hypothesized that AP and ML CoP excursion and mean velocity derived from the raw CoP coordinates of the BTrackS would be strongly correlated and not different than the force platform. A secondary purpose of our study was to examine the test-retest reliability of the derived CoP excursion and mean velocity in the AP and ML directions from the BTrackS raw CoP coordinates between two time points, separated by 48–72 h. We hypothesized that the derived CoP excursion and mean velocity in the AP and ML directions from the BTrackS would be reliable over time.

2. Methods

2.1. Study design

A cross-sectional sample of healthy collegiate aged students were recruited to participate in this study. Concurrent validity was established by collecting CoP data from the BTrackS simultaneously with an in-ground strain gauge force platform (AMTI OR6 Series, Watertown, MA, USA). Test-retest reliability of the BTrackS was established by comparing CoP data collected between Time Point 1 (T1) and Time Point 2 (T2), which were separated by 48–72 h.

2.2. Participants

51 healthy collegiate volunteers (22 ± 3 years) who met the inclusion/exclusion participated in this investigation. A medical history questionnaire and informed consent were completed prior to the first testing session. All participants were free of a current musculoskeletal and/or neuromuscular injury, Attention Deficit Hyperactivity Disorder diagnosis, a learning disorder diagnosis, and/or seizures and had no documented concussion within the past 6 months as determined by self-report. Research procedures were approved by the University's Institutional Review Board (protocol number H17022) prior to testing.

2.3. Protocol

Participants were instructed to stand quietly with hands at their sides, feet together (medial malleolus to medial malleolus) on the BTrackS (Balance Tracking System Inc. San Diego, CA, USA, 20 Hz) which was positioned on top of a 0.40 m × 0.60 m AMTI force platform (OR6 Series, Watertown, MA, USA, 1000 Hz) for 4 eyes open (EO) and 4 eyes closed (EC) trials (20 s each), while ground reaction force data were collected from both devices simultaneously (Fig. 1). During data collection, two researchers initiated and terminated data collection for each device independently on two separate computers. This was due to the BTrackS not having an external trigger port to attach a synchronization cable or unit to the AMTI force platform. A single familiarization trial was provided at the beginning of each set of 4 trials in which no data were collected. At the beginning and end of a trial, an auditory tone provided by the BTrackS would occur. Each trial was separated by 10 s of rest, based upon the recommendation of BTrackS. The protocol was repeated 48–72 h later on the same sample.