Gait & Posture 41 (2015) 535–539

Contents lists available at ScienceDirect

Gait & Posture

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

Full length Article

Reliability and validity of an accelerometry based measure of static and dynamic postural stability in healthy and active individuals

Nicholas R. Heebner [a], Jonathan S. Akins [b], Scott M. Lephart [a], Timothy C. Sell [a,*]

[a] Neuromuscular Research Laboratory, University of Pittsburgh, Pittsburgh, PA 15203, United States
[b] Department of Rehabilitation Science and Technology, University of Pittsburgh, Pittsburgh, PA, United States

ARTICLE INFO

Article history:
Received 27 May 2014
Received in revised form 6 October 2014
Accepted 5 December 2014

Keywords:
Accelerometer
Postural stability
Balance
DPSI
Active population

ABSTRACT

Postural stability is an important measure in both research and clinical practice. A portable, easy to use device that can provide higher resolution than current clinical tests may allow for better identification of patients or athletes with postural stability deficits. The purpose of this study was to evaluate the ability of a tri-axial accelerometer to quantify postural stability in a healthy athletic population. Ten subjects were recruited to determine the reliability of the accelerometer to measure dynamic postural stability and thirteen were recruited to compare the accelerometer measures across tasks of varying difficulty. Subjects were asked to complete four static postural stability tasks with eyes open and eyes closed and two dynamic postural stability tasks for a total of ten tasks. During each task postural stability was measured using a tri-axial accelerometer and force platform. Differences between postural stability scores between tasks and the correlation between the two measures were assessed. The accelerometer demonstrated moderate to good test–retest reliability (ICC = 0.732 to 0.899). Only the medial–lateral axis of the accelerometer showed significant differences between static tasks but all directions were able to show significant differences between static and dynamic tasks. Additionally, Spearman's ranked correlations showed little to no correlation between the accelerometer and force platform scores. Accelerometers are a reliability tool for postural stability that measure low difficulty tasks best in the medial–lateral direction. Low correlation between the accelerometer and force platform suggest that these two methods are not measuring the same components of postural stability.

1. Introduction

Postural stability has been defined as the ability to maintain and control one's center of gravity, or maintain equilibrium within the limits of stability, over a base of support [1]. The success of this process is the result of coordination and synergy between the vestibular, visual, and somatosensory systems [1–3]. Decrements in postural stability have been shown to have a relationship with a history of musculoskeletal and/or neurological injury [4–6] and have been able to predict lower extremity injury [2,7]. However, the complex nature of postural stability, specifically dynamic postural stability, has made it difficult to measure in a clinical setting. Current clinical methods and instrumentation for measuring dynamic postural stability do exist; however, they have limitations [8]. Instrumentation and methods that offer portability and ease of use but also provides the necessary resolution and discriminatory ability for quantifying dynamic postural stability would be beneficial to both clinicians and researchers.

Postural stability can be categorized into static and dynamic postural stability. Static postural stability has been referred to as a person's ability to maintain a steady standing posture over a static base of support [9]. Conversely, dynamic postural stability can be defined as the ability to transfer and control the projection of one's center of mass over a base of support while transitioning from a dynamic to static state [9,10]. Previous research has demonstrated no relationship between different static and dynamic measures of postural stability, suggesting that static and dynamic tasks may be targeting different afferent and efferent pathways [11,12]. For this reason it is important to use both static and dynamic assessments when evaluating possible deficits in postural stability.

Force platforms are frequently used to assess and quantify static postural stability using a broad range of algorithms [13]. In an athletic population, static postural stability is commonly evaluated by measuring the excursion of the center of pressure (COP) [9,14] or the standard deviations of ground reaction forces (GRFs)

* Corresponding author. Tel.: +1 412 246 0460.
E-mail addresses: NRH13@pitt.edu (N.R. Heebner), Jon.akins@gmail.com (J.S. Akins), lephart@pitt.edu (S.M. Lephart), TCS15@pitt.edu (T.C. Sell).

http://dx.doi.org/10.1016/j.gaitpost.2014.12.009
0966-6362/

[9,10,12,15]. Dynamic postural stability has been evaluated by measuring time to stabilization (TTS) [15–18] or calculating the dynamic postural stability index (DPSI) based on force platform data [4,10,19]. Although these measures are reliable and valid, force platform systems are expensive and reduce researchers' ability to test outside of laboratory settings [9,10].

Other methods of evaluating postural control that are more portable and simple to use have been validated and are currently used in clinical practice. Two commonly used postural stability tests that have been shown to be reliable and are used in sports medicine practice are the balance error scoring system (BESS) [20,21] and the star excursion balance test (SEBT) [8,22]. The BESS test uses a single-leg balance task and counts the number of corrective actions occurring which is scored as an ordinal rather than a continuous variable. The SEBT also uses a single-leg stance but measures the cumulative reach distance of the opposite foot in three directions [22]. This task does provide a continuous measure, offering increased measure resolution, and has been proposed to be a dynamic measure of postural stability. However, it does not necessarily simulate athletic tasks and can be limited by factors that may not be directly related to postural control systems such as available ankle dorsiflexion range of motion. Although some dynamic tests have been validated in a clinical population, it may not provide enough resolution or discriminatory capabilities to identify risk of injury in healthy or athletic populations. There appears to be a need for technology or assessment tools capable of quantifying dynamic postural stability that are portable, easy to use, and quick. Accelerometers may be an appropriate instrument to meet these demands.

The use of trunk accelerations to measure static postural stability has been shown to be reliable [23,24] and has been previously used to quantify postural stability [25–27]. Most recently, Dalton et al. [26] determined that an accelerometer-based sensor is capable of distinguishing differences in static postural stability between manifest and pre-manifest Huntington's disease groups and healthy control. In order to use this technology in a different population, such as athletes, similar studies using athletic individuals are necessary. Additionally, athletic individuals may require more challenging and sport-specific tasks, such as balancing upon landing, to better discern those with poor postural stability. The ability of an accelerometer-based sensor to measure such dynamic postural stability is still unknown.

A portable, easy to use device that can provide higher resolution than current clinical tests of postural stability may allow for better identification of patients or athletes with dynamic postural stability deficits. Therefore, the purpose of this study was to evaluate the ability of a tri-axial accelerometer to quantify postural stability in a healthy and athletic population. The first aim of this study was to determine if an accelerometry-based measure of dynamic postural stability is reliable. The second aim of this study is to assess the validity of data collected by an accelerometer placed at the approximate center of mass (COM) by assessing its ability to distinguish between balance tasks of varying difficulty. Validity was further assessed by measuring the relationship between postural stability concurrently collected with the tri-axial accelerometer and a force platform. It was hypothesized that the dynamic measure of postural stability with the accelerometer will demonstrate good to excellent test–retest reliability. It was also hypothesized that the accelerometer measures would be able detect differences in postural stability scores between tasks of varying difficulty and the accelerometer and force platform postural stability scores would display good correlation coefficients [28]. If the hypotheses of the current study are correct then researchers will have a tool capable of quantifying postural stability in an athletic population and increase the ability to conduct testing outside of the laboratory setting.

2. Methods

2.1. Subjects

Subjects for this study were recruited from a recreationally active population defined as participating in physical activity a minimum of 3 days per week for at least 30 min each session. Any subject who reported a history of lower extremity fracture or surgery to their dominant leg, lower extremity injury within the last six months, or sustained a concussion within the last three months was excluded. For the reliability aim of this study ten healthy male subjects were recruited. Previous research has demonstrated ICC values of 0.74 for RMS calculations at the center of mass using an accelerometer [24]. Based on sample size estimation tables from Walter et al. [29] at least 10 subjects will be needed to fins significant ICC values of 0.7 with two testing sessions [29]. For the validity portion of aim of this study thirteen healthy males were recruited. All subjects completed a written informed consent prior to participation in accordance with the Institutional Review Board. Demographics for each group are shown in Table 1.

2.2. Materials

Ground reaction force data were collected using a force platform (Type 9286BA, 60 cm × 40 cm platform; Kistler Instrument Corp., Amherst, NY) with an onboard amplifier. The analog signal from the force platform was converted to a digital signal and acquired using Nexus software (Vicon Motion Systems, Centennial, CO) at 1000 Hz. The force platform was mounted flush with the surrounding custom-built flooring from which the subjects were asked to jump from during the dynamic postural control tasks.

Center of mass accelerations were measured using a wireless, custom-built accelerometer (ZeroPoint Technologies, Johannesburg, South Africa). The device weighs approximately 31 g and is 4.2 × 3.9 × 1.2 cm in size. This tri-axial accelerometer sensor node consists of three orthogonal ($\pm 16 \times g$) uni-axial microelectromechanical system (MEMS) accelerometers (Model: ADXL78; Analog Devices Inc., Norwood, MA), a buffer, amplification unit, and microcontroller. An on-board SD-card gives the accelerometer the capability of storing up to 2 h of continuous data. Acceleration data was also collected at 1000 Hz. The accelerometer was attached to the subject using a Neoprene belt and positioned over L5 so the vertical axis was in-line with the spine and the horizontal axes (anterior–posterior and medial–lateral) aligned in the transverse plane of the pelvis.

2.3. Procedure

Previous research as already established the reliability of force platform measures of static and dynamic postural stability [9,12]. Goldie et al. [9] determined that the reliability of static postural stability tasks used in the current study have test–retest interclass correlation coefficients (ICC) of 0.31–0.85. Sell et al. [12] determined that the reliability of anterior–posterior (AP) and medial–lateral (ML) DPSI using force platforms have ICC values of 0.86 and 0.90, respectively, with a SEM of 0.01 [12]. Additionally,

Table 1
Subject demographics.

	Age (years)	Height (cm)	Weight (kg)
	Mean (SD)	Mean (SD)	Mean (SD)
Reliability group ($n = 10$)	24.3 (4.2)	176.7 (4.8)	76.2 (9.7)
Validity group ($n = 13$)	24.1 (3.1)	180.4 (3.8)	81.2 (8.8)

Mean and standard deviation (SD) values by group.