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Examining the diagnostic accuracy of dynamic postural stability measures in differentiating among ankle instability status

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ABSTRACT

Background: Dynamic postural stability is defined as the ability to transition from a dynamic movement to a stable condition over one's base of support. Measures of dynamic stability have been used extensively to classify ankle instability status and assist clinicians with ankle injury interventions. Therefore, the purpose of this study was to determine if current methods of quantifying dynamic stability are accurate in differentiating among healthy, coper, and unstable ankles.

Methods: One hundred ninety four Division-I collegiate athletes (football, volleyball, field hockey, men's/women's soccer, men's/women's lacrosse, men's/women's basketball) volunteered for this study. Participants were categorized into healthy, coper, and stable groups by a self-reported questionnaire and previous history of ankle injuries. Dynamic postural stability was assessed using the Multi-Directional Dynamic Stability Protocol by jumping and landing single-legged onto a force platform from four different directions. Receiver operator curves were used to analyze the accuracy of current techniques of calculating dynamic stability among groups.

Findings: None of the existing methods were found to be accurate in differentiating ankle instability status in any of the jump landings.

Interpretation: Researchers have commonly used these existing methods to quantify dynamic postural stability. None of the current calculation techniques worked with our jump landing protocol. Researchers need to pay attention to the protocol and calculation technique pairings in that using inaccurate measures of dynamic postural stability makes any findings of that research ineffective. Therefore, this challenges researchers to develop a more accurate calculation to quantify dynamic postural stability, or develop a jump landing protocol that exposes sensorimotor deficits in the more able-bodied population.

1. Introduction

Postural control is the ability to maintain and control balance in quiet standing (Prieto et al., 1996). Postural control is an important aspect of injury prevention because it has been shown that a more stable body results in a reduced incidence of recurrent lower extremity injuries (Bahr et al., 1997; Verhagen et al., 2004). Dynamic postural stability is defined as the ability to maintain balance while transitioning from a dynamic movement to a static state over the base of support (Goldie et al., 1989; Gribble and Robinson, 2009). The ankle is the single most frequently injured joint of the body, especially among the active population (Hootman et al., 2007). Since landing from a jump has been identified as the most common mechanism for an ankle sprain (Dufek and Bates, 1991), researchers commonly use a jump landing protocol to measure dynamic postural stability.

Dynamic postural stability is quantified by applying a mathematical formula to solve for time-to-stabilization (TTS) or stability index (SI). Researchers have developed numerous methods to calculate dynamic postural stability. One of the most common and simple methods to calculate TTS was first presented by McKinley and Pedotti (1992). McKinley and Pedotti (1992) quantified TTS by analyzing the vertical component of the ground reaction force (GRF) generated from a jump landing onto a force platform. Another common measure of TTS was presented by Colby et al. (1999), by separately assessing a sequential average for all three orthogonal components of GRF in the anterior-posterior (AP), medial-lateral (ML), and vertical directions. Ross and colleagues incorporated a line fitting method to the AP and ML components of the GRF with the assumption that when the GRF is at its smallest point, stabilization has been met. (Ross and Guskiewicz,

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2003; Ross et al., 2005). Alternatively, Wikstrom et al. quantified stability with SIs (Wikstrom et al., 2005, 2010). An integration of all three directional GRF was used to create the dynamic postural stability index (DPSI). In addition, a SI was calculated for each of the three orthogonal directions of the force platform. Therefore, Wikstrom et al. (2010) created a total of four different SIs: anteroposterior stability index (APSI), mediolateral stability index (MLSI), vertical stability index (VSI), and DPSI, where lower SI scores indicate better stability. With so many different methods to calculate dynamic postural stability, a standardized assessment for dynamic postural stability is lacking in the current literature.

Additionally, researchers of dynamic postural stability often neglect the lateral motion. Since lateral motions are a mechanism of ankle sprains, it is important to understand multi-directional stability tasks. The typical protocol of dynamic postural stability research involves a forward and upward propulsion of the body by having subjects jump to 50% of the maximal jump height, land on one foot, and stabilize as quickly as possible (Ross and Guskiewicz, 2003; Wikstrom et al., 2005). Because dynamic postural stability calculations are based on orthogonal components of the GRF vector, it would seem that jump direction would influence the assessment. Very few studies have examined the influence of different jump directions on dynamic postural stability (Brown et al., 2010; Gerbino et al., 2007; Liu and Heise, in press; Wikstrom et al., 2008). With contradictory results among these studies, the influence of jump direction on these measures of dynamic postural stability has still yet to be determined.

A common complaint of those who suffer from chronic ankle instability (CAI) is the sensation of “giving way”, or repeated ankle sprains under seemingly low risk conditions (Freeman, 1965). For example, Yeung et al. (1994) reported a 70% re-injury rate at the ankle joint. Research involving ankle instability often groups subjects into those with and without CAI. This grouping leaves out those who have suffered an ankle sprain but do not experience residual symptoms or recurrent injuries. Therefore, the subgroup of “copers” is neglected in ankle instability research. The term “copers” is a common expression that is used in anterior cruciate ligament (ACL) literature. In ACL research, copers refer to those that are ACL deficient, but display no signs of instability (Rudolph et al., 2000). Only recently have copers emerged in ankle instability research. In general, ankle copers refer to those that have suffered an ankle sprain but have not experienced a subsequent sprain (Hertel and Kaminski, 2005). Understanding the copers could help decrease the rate of recurrent injuries at the ankle.

When considering the several different mathematical formulas to calculate dynamic postural stability, the lack of a homogenous assessment hinders research in dynamic postural stability from advancing. In addition, the diagnostic accuracy of all of these calculations in differentiating among the healthy, coper, and unstable groups has not been examined. Therefore, the purpose of this study is to determine the accuracy of existing methods to quantify dynamic postural stability in differentiating those with healthy, coper, and unstable ankles in multi-directional jumps.

2. Methods

2.1. Participants

A total of 194 NCAA Division-I collegiate athletes (112 males, 82 females, mean height = 178.8 (SD 10.9) cm, mean mass = 80.2 (SD 19.1) kg, mean age = 18.3 (SD 0.9) years) participated in this study. Participants were excluded if they had a previous lower extremity fracture, an existing neurological condition, or an ankle sprain within 6 months of data collection. All participants read and signed the informed consent approved by the university's institutional review board (UD IRB# 131714-3). All participants completed the Cumberland Ankle Instability Tool (CAIT) for each ankle, as well as, reported the number of previous ankle sprains experienced by each ankle.

2.2. Grouping

A randomly selected ankle from each subject was classified into the healthy, coper, and unstable groups, separated by their CAIT scores and their ankle injury history. Self-reported questionnaires offer clinicians insight to the patient's struggles and disabilities that cannot be measured by objective functional outcomes. The CAIT is a valid and reliable questionnaire used to determine ankle instability by self-reported symptoms (Hiller et al., 2006). Based on a 30-point system, a score of 26 and above is considered healthy while a score of 25 and below is considered functionally unstable (Wright et al., 2011).

Therefore, the healthy ankles were classified as those with no history of ankle sprain and a score of 26 and above on the CAIT. The coper ankles consisted of those that: (1) experienced a single previous sprain at least 12 months ago, (2) returned to the pre-injury level of activity, (3) a score of ≥26 on the CAIT, and (4) no episodes of re-injury (Brown et al., 2008; Wikstrom et al., 2009). The unstable ankles consisted of the ankles that score ≤25 on the CAIT regardless of the number of previous ankle sprains (detailed demographic data for grouped subjects are displayed in Table 1). The investigator was blinded as to which group the subjects were in during data collection and analysis.

2.3. Procedures

Prior to testing, subjects were allowed a five minute warm up on a stationary bike followed by a five minute period for stretching of lower extremity musculature. Each participant performed various hopping tasks onto a force platform (Advanced Mechanical Technology Inc., Watertown, MA). All hopping tasks were performed barefoot to avoid stability assistance from a shoe. The Multi-Directional Dynamic Stability (MDDS) Protocol was used for the hopping tasks of: backward hop, forward hop, lateral hop, and a medial hop (Liu and Heise, in press). Force platform data were collected at a sampling rate of 100 Hz for a duration of 5 seconds. Sampling rates as low as 60 Hz and durations as low as 3 seconds have been found to be sensitive for dynamic postural stability (Ross and Guskiewicz, 2003; Wikstrom et al., 2005).

For the forward hop, participants were asked to complete a “step, step, hop” protocol. This protocol required participants to take two comfortable steps before hopping and landing single legged on the test leg. Participants hopped over a 15 cm hurdle placed at a distance of 100% of the leg length from the center of the force platform (Fig. 1). Medial, lateral, and backward described the direction of the hop with respect to the participant; for example, a lateral hop for the right leg would be towards the right, and a medial hop for the right leg would be towards the left. For these hop directions, participants were instructed to stand single-legged on the test leg, hop over a 5 cm hurdle placed directly next to the force platform, and land single-legged on the force platform with the test leg (Figs. 2–4). Hurdles were placed for all landing directions to normalize a minimal hop height among participants. All participants were instructed to land in the middle of

Table 1
Detailed demographic data of each group.

	Healthy	Coper	Unstable
N	65	64	65
Gender	F: 28, M: 37	F: 25, M: 39	F: 29, M: 36
Height (cm)	178.0 (SD 11.1)	178.8 (SD 10.3)	179.5 (SD 11.3)
Mass (kg)	80.3 (SD 19.9)	78.5 (SD 17.0)	81.8 (SD 20.4)
Age (years)	18.5 (SD 1.2)	18.3 (SD 0.8)	18.2 (SD 0.7)
CAIT score	28.8 (SD 1.3)	28.1 (SD 1.9)	21.9 (SD 3.8)
No. of sprains	0.0 (SD 0.0)	1.0 (SD 0.0)	2.1 (SD 1.5)