Reliability of a Novel iPhone App on Testing Proprioception of the Lower Extremities

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Abstract

The term "proprioception" has been used to describe a variety of different mechanisms and systems related to motor control and the sensorimotor system. Stability is an important outcome of proprioception and can be measured through a variety of balance tests. Through measuring stability, an individual's relative proprioception can be determined. One common balance test is the Balance Error Scoring System (BESS). There are few studies that involve the use of a cellular device, such as an iPhone, to test balance and stability. iPhones are versatile machines with components capable of measuring changes in movement. We aim to create an application that is easy to use, readily accessible, and affordable for users. This project investigated the reliability of a student-designed iPhone app to measure balance on the mildly unstable platform of a rehabilitation device. Results suggest that these methods were a successful pilot study for the internal reliability of the app. Further studies should aim to increase the statistical power and significance of these methods.

Introduction

The term "proprioception" has been used to describe a variety of different mechanisms and systems related to motor control and the sensorimotor system. "Proprioception" was extensively used to oversimplify the complex neuromotor and neurosensory processes. Proprioception was derived from a series of inferences made from Sherrington's work in 1906 regarding the "proprioceptive system" (Lephart & Fu, 2000). These peripheral sensory receptors send afferent signals to be processed by the central nervous system and create an appropriate muscular response. Proprioception's afferent signals for motor control can be categorized into feedback or feedforward mechanisms. The body appears to use feedback mechanisms for posture and slow movement, while the feedforward mechanism is critical for anticipatory loads or movements and joint stabilization. The presence of these two mechanisms and their interactions with each other suggest that they do not operate independently of each other (Swanik et al., 1997).

For these reasons, proprioception has garnered a significant amount of interest in the arena of sports medicine. In sports, the human body can be required to make a variety of anticipatory movements within a short time span. In addition, the body may be subjected to blunt forces (in the cases of contact sports) in which the body must make an instantaneous adjustment to prevent injury. Similarly, it is clear that a strong sense of proprioception is essential for the kinesthesia and joint stabilization required in strenuous physical activities such as team sports. Likewise, sports injuries are a major burden on public health in most of the developed countries around the world (Hubscher et al., 2010). Therefore, it is understandable why sports medicine is interested in increasing proprioception. The relative strengths of proprioception and kinesthesia are linked to likelihood and frequency of sports injury and the recovery prognosis in injury recovery. With appropriate training techniques, increased proprioception can help decrease the probability of injury.

Stability is an important result of proprioception and can be measured through a variety of balance tests. Through measuring stability, an individual's relative proprioception can be determined. One common balance test is the Balance Error Scoring System (BESS). The BESS was developed to measure postural instability without the need for expensive equipment. The BESS is particularly effective for testing postural instability in cases of mild head injury when sophisticated balance equipment is unavailable (Reimann & Guskiewicz, 2000). A more recent balance test involves the use of an accelerometer. The National Institute of Health's Balance Accelerometer Measure (BAM) is easily administered as a means of assessing balance across a wide age range (Furman et al., 2013). The BAM compared to the BESS showed that the BESS is more effective at differentiating between concussed and healthy individuals. However, if a baseline measure were taken with the BAM, it could be compared to the experimental measure to show a difference in sway.

Previous studies looking at mechanical measures of balance and stability included concussed and non-concussed individuals (Corwin et al., 2020). However, there are few studies that involve the use of a cellular device, such as an iPhone, to test balance and stability. iPhones are versatile machines with components capable of measuring changes in movement. Consequently, prior studies have shown that an iPhone application can be both valid and reliable at measuring changes in direction (Balsalobre-Fernández et al., 2019).

The Shuttle Balance is used for rehabilitation with injured patients. See Fig. 1. The Shuttle Balance challenges users by creating an uneven surface through the horizontal plane that safely challenges balance and proprioception. An app could utilize the accelerometer in the iPhone to track the path length and determine the farthest distance of sway during testing sessions. Essentially, these methods combine the BAM and BESS tests to create an application that is easy to use, readily accessible, and more affordable for users through the App Store.

Reliability is a critical concept for healthcare providers to understand if they want to accurately assess a patient. The reliability of an instrument is crucial to understanding if a patient's condition has changed over time. All measurements have some source of error. Reliability refers to the magnitude of error in a measurement. If the error is below an acceptable value, the form of measurement in question may be proven reliable (Reimann & Lininger, 2018). With this novel iPhone app, we will look to determine the app is reliable at measuring changes in movement in the lower extremities.

This project investigated the reliability of a student-designed iPhone app to measure balance on the mildly unstable platform of a rehabilitation device (Shuttle Balance). If this app is shown to be reliable, then additional projects will be designed to see if the app is valid for a variety of conditions to include lower extremity injuries (knee and ankle) and concussions. In addition, if the app is shown to also be reliable and valid, then the app measurements can be used to assess progress in recovery and rehabilitation. In conjunction with the Shuttle Balance system, this novel iPhone app may provide an inexpensive and convenient way of providing proprioception tests for the high school and collegiate athlete.

Materials and Methods

Subjects

This project recruited 20-22 year olds as a convenience sample from the Florida Southern College campus and Lakeland community. Recruitment was through word of mouth and approved flyers distributed across campus. The exclusion criterion was any musculoskeletal injury in the previous 30 days.

Study Protocol

All subjects were given instructions and familiarized with the procedures before the study. Each subject was involved for 20-30 minutes on 3 separate occasions, each separated by 24-48 hours. The subjects balance on a mildly unstable platform (Shuttle Balance - http://www.shuttlesystems.com/products/shuttle-balance). The Shuttle Balance has safety side rails and the subjects were supervised during testing.

During the first session, height, weight and gender were recorded. Then safe entry onto the platform of the rehabilitation device was demonstrated. Subjects then stepped onto the platform. Three lower extremity balancing tasks were done during data collection. These tasks are portions of the Balance Error Scoring Scale (BESS) which is a standard test used in the evaluation of concussions. The BESS is done on a foam pad which provides a slightly unstable surface. We utilized a somewhat more unstable platform (Shuttle Balance, Shuttle Systems, Bellingham WA, USA, https://www.shuttlesystems.com/products/shuttle-balance). This is considered a minor risk which is slightly increased for non-athletes. The iPhone with the app was placed on a magnet on the edge of the balancing platform. The subjects did not have any contact with the app or the iPhone during testing sessions. The app used touch buttons to enter subject info, select the test stance and begin the timer. The subjects were asked to accomplish three tasks of 20 seconds each. The iPhone was programmed for the timing of the test. The supporting chains of the balance platform were set at a mid-level of difficulty. The first task was standing with both feet on the balance platform with hands on hips and eyes closed (See Figure 1). The second task involved standing on the balance platform on the non-dominant leg (the leg not used when kicking, or the stance leg) for 20 seconds with hands on hips and eyes open (See Figure 2). The third task is a tandem stance in the cardinal direction (vertical of the balance platform) with the non-dominant foot forward and toes of the dominant foot placed immediately behind, with hands on hips and eyes open for 20 seconds (See Figure 3). Data was recorded by hand and entered into Google Sheets for subsequent statistical analysis.

Figure 1: Visual demonstration of the two feet stance on the Shuttle Balance

Figure 2: Visual demonstration of the one foot stance on the Shuttle Balance

Figure 3: Visual demonstration of the tandem stance on the Shuttle Balance

Results

Data analysis was conducted using Cronbach's Alpha measure for internal reliability. Cronbach's Alpha was calculated for each stance including: two feet, one foot and tandem. Additionally, the results for each subject over the course of three trials were graphed to visually represent these reliability measures. Internal reliability measured with Cronbach's Alpha suggests that the app displayed excellent consistency when measuring proprioception on two feet, acceptable consistency for the tandem stance and questionable consistency for the one foot stance. Spaghetti plots were created to visualize the internal consistency of the trials. Each color represents the same subject over the course of each trial and each stance.

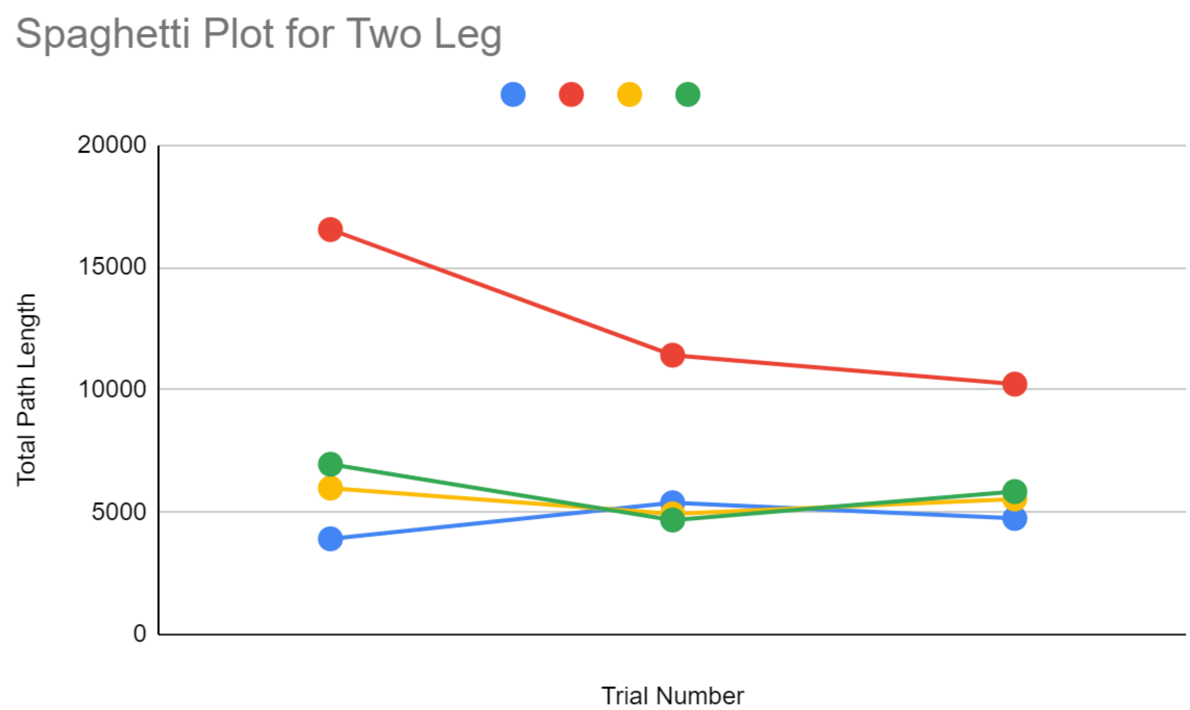

Figure 4: Spaghetti Plot for Two Leg demonstrating the relative reliability for measuring proprioception using the two leg stance. Each dot represents a separate trial. Each color represents an individual subject over the course of the study.

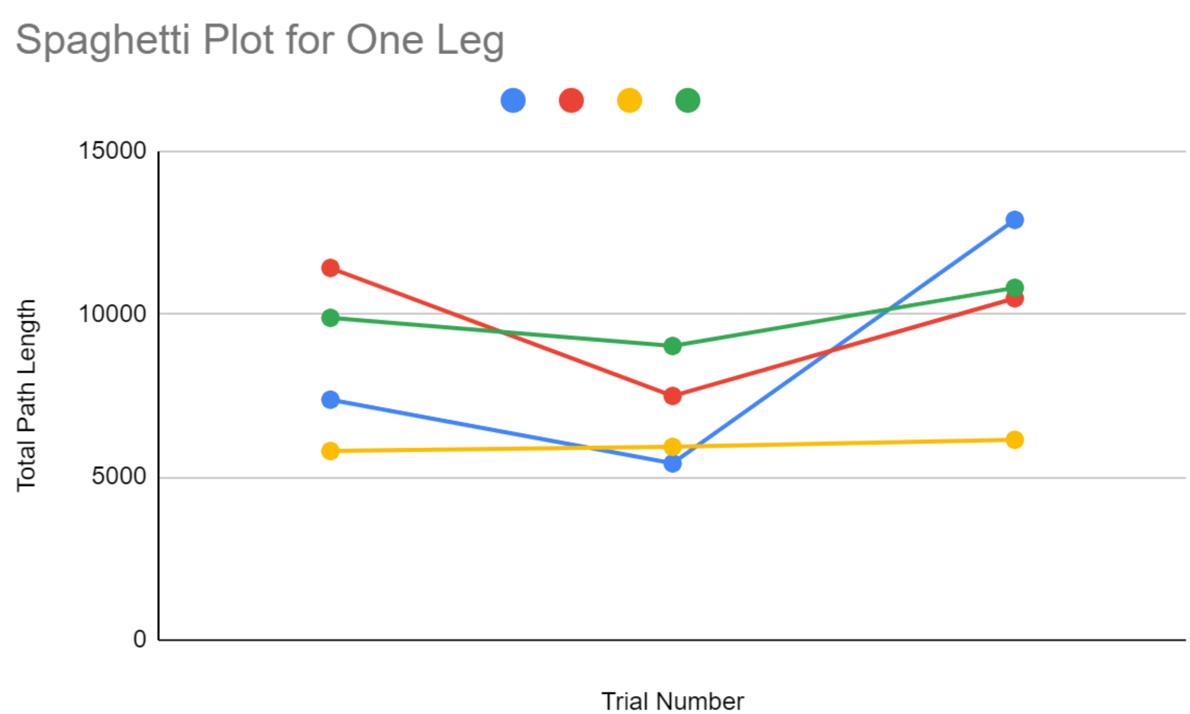

Figure 5: Spaghetti Plot for One Leg demonstrating the relative reliability for measuring proprioception using the one leg stance. Each dot represents a separate trial. Each color represents an individual subject over the course of the study.

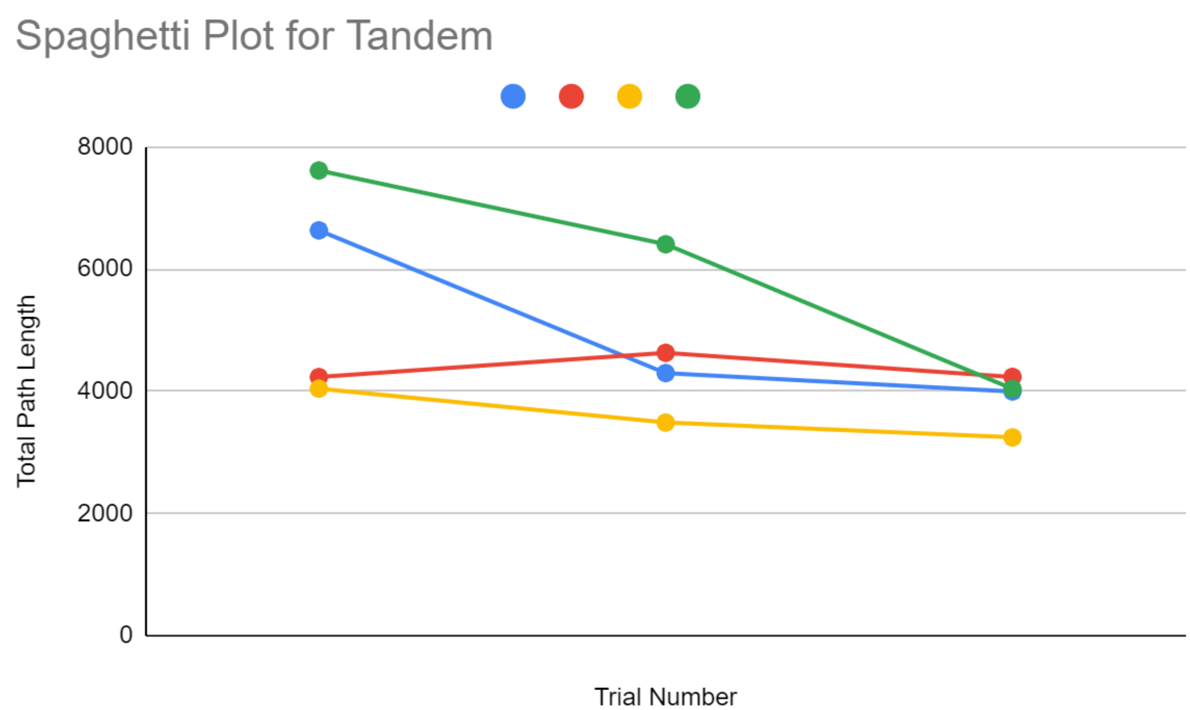

Figure 6: Spaghetti Plot for Tandem demonstrating the relative reliability for measuring proprioception using the tandem stance. Each dot represents a separate trial. Each color represents an individual subject over the course of the study.

Stance	Cronbach's Alpha Values	Internal Consistency
Two Feet	0.9258083357	Excellent
One Foot	0.6597352388	Questionable
Tandem	0.7317763978	Acceptable

Figure 7: Calculated values for internal reliability using Cronbach's Alpha. The left column represents the given stance. The center column notes the calculated value for Cronbach's Alpha. The right column states the internal consistency of the system when compared to known values.

Discussion

Sherrington outlined a mechanism in which “proprio-ceptors” in the “proprio-ceptive field” led to the conscious muscle movements, joint stability and posture with which proprioception was commonly associated. However, Sherrington’s descriptions of the “proprioceptive system” created difficulty for future researchers who tried to decipher his writings. This provides an explanation for the confusion surrounding the mechanisms behind proprioception and its physiological consequences. Prior studies indicate that proprioception originates from peripheral sensory receptors in muscles, joints, and cutaneous tissues (Lephart & Fu, 2000).

Therefore, prior research was conducted without a categorical definition of proprioception leading to inaccurate use of the term and inappropriate research methods (Lephart & Fu, 2000). This compounded the need for a clear understanding of proprioception and its relationship with the nervous and musculoskeletal systems. Subsequently, many theories arose to explain proprioception’s role in anatomical and physiological mechanisms with no clear consensus within the scientific community.

As the understanding of proprioception has increased, so has its role in sports therapy. More specifically, the relationship between proprioception and its role in balance and kinesthesia attracted considerable interest. The contemporary definition of proprioception has been summarized as the conscious and unconscious appreciation of joint position while kinesthesia refers to joint motion or acceleration (Swanik et al., 1997). Balance is the maintenance of one’s center of gravity within the body’s base of support (Lephart & Fu, 2000). When the center of gravity moves uniformly with minimal sway around the body’s equilibrium point, postural equilibrium is achieved. If the center of gravity sways too far, a fall will result unless appropriate adjustments are made, for example, taking a step forward or adjusting their hips, ankles, etc. Increasing proprioception through balance control has become a point of interest in sports injury research. Prior studies suggest that proprioceptive training through balance exercises reduces injuries (Malliou et al., 2004). The objective of balance training is to increase the neuromuscular control of the target area. More specifically, in controlled movements which place the knee in positions of vulnerability, neuromuscular adaptations should occur that help strengthen proprioception (Swanik et al., 1997). In addition, balance disorder was associated with an increase in all-cause mortality (Cao et al., 2021). This highlights the importance of maintaining balance throughout an individual’s lifespan.

This study indicated that these methods may be useful for measuring proprioception of the lower extremities; however, due to the small sample size no firm conclusions can be drawn from these results alone. Cronbach’s alpha is the most common test score for measuring internal consistency (Tavakol & Dennick, 2011). The internal reliability of the system was determined after calculating Cronbach’s alpha and comparing them to commonly accepted values (See Figure 7).

This study proved to be a promising pilot for further research involving a larger subject pool. All subjects who participated also completed the trials suggesting a high feasibility. A number of measures should be taken to improve these methods. We suggest including a larger population in the statistical analyzes. Similarly, a more diverse population including athletes, females, and a larger age range would lend credence to the app’s reliability. Further analyzes on statistical power and significance are necessary after accumulating a large enough sample size. If the app is shown to be reliable, then the appropriate measurements should be made to determine validity as well. Future studies should include a concussed population to determine if any significant differences in proprioception can be discerned using this app.

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