PIPSS

A Portable Instrument Postural Stability System to Assess Dynamic Postural Stability

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Abstract: The most common method to assess postural stability involves the use of a force plate to measure changes in center of pressure (COP)(Duarte et al 2010). The high cost of this technology limits practicality and accessibility for widespread use outside of major clinical centers. There is an emerging trend toward video game use as a means of increasing patient engagement in rehabilitation interventions. This trend is primarily driven by the newest generation of consumer console systems which use motion-based controls (e.g. Nintendo Wii and WiiFit). We have developed and tested PIPSS, a system that utilizes the Nintendo Wii balance board to quantify COP during simple static and more complex dynamic balance tasks. This low cost, accessible postural stability assessment system could be easily deployed in clinics, sport and athletic centers, training rooms, schools or elderly care facilities to provide a quantitative metric of postural control. Such information would allow for more timely assessment and intervention, improved return to play guidelines in athletes, or balance and fall interventions in care centers for the elderly. Current work includes analyses and interpretation of the PIPSS testing protocols with existing balance measures in children and adults with Cerebral Palsy, and concussion.

1 INTRODUCTION

The widespread use and societal acceptance of video games within households, clinics, care and rehabilitation centers, provides an exceptional opportunity to quantitatively assess and monitor balance training programs on a daily basis. The capability to provide patient-specific therapeutic programs using such devices, and simultaneous data collection from these devices, supports efforts in tele-rehabilitation. The ability to monitor clients at home, obtaining frequent objective measures as well as updating the intervention programs over the internet extends the potential to provide such health care services within a variety of settings.

In the past decade, there has been a recent focus of attention towards concussion management in athletes. The impact of concussion on health status relies on a multifactorial approach that include self-reported symptoms, neurocognition, and postural control. Self-reported symptoms are typically unreliable due to under-reporting and neurocognitive testing has demonstrated good reliability. The most effective and most common method to assess postural stability involves the use of a force plate to measure changes in center of pressure (COP) (Duarte et al, 2010). The high cost of this technology limits practicality and accessibility for clinicians. A low technology alternative that is commonly used to assess postural stability is the Balance Error Scoring System (BESS). Although the BESS test is commonly and easily used by clinicians, it exhibits only moderate reliability (Finoff 2009, Bell 2011) with a lack of normative data to assess minimal detectable changes within the population to determine indication of return to play.

1.1 Background

TheraWii was a software application developed as an Engineering Senior Design Project at Drexel University during the 2008-2009 academic year. TheraWii can generate quantitative balance and reaching assessments and interventions using the Wii balance board, hand controllers, and a laptop computer. In addition to the TheraWii software,

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Excel and blue tooth capability on the laptop are the primary requirements for data collection. TheraWii software incldued a set of generic balance activities that can be linked together to form balance or reaching assessments or interventions. Patient- and session-specific data, as well as the balance and acceleration signals from the Wii devices during sessions, were exported using Bluetooth technology to a data file that could be analyzed and used to quantify posture and movement. The software was designed to record and display models of physical motion using the Wii Remote and Balance Board motion capturing interfaces as input.

The Portable Instrumented Postural Stability System (PIPSS) extends the original TheraWii project with enhanced testing and training protocols as well as a web-based interface.

1.2 Clinical Significance

PIPSS provides the technology of a force plate with a mass-produced, low cost device that demonstrates good validity and reliability in assessing postural stability via COP measures (Clark et al). TheraWii can provide quantitative measures of balance and acceleration in a software platform that is economical, easily accessible for home and clinic use. TheraWii is open-source software released under the GNU General Public License Version 3 (GPLv3), and the copyright is retained by the original TheraWii project personnel. A detailed software guide, project description and User manual are available, and the intention is to provide the TheraWii system as an open-source platform for clinical, non-profit applications. The use of TheraWii as an objective measure that can be used to objectively capture in movement and posture outside of a laboratory environment on a frequent basis is unparalleled, particularly coupled with existing videogame technology.

2 METHODS

2.1 Subjects

The data from a sample of convenience of ten participants (6 female, height=162.3cm±17.0, weight=67.8kg±23.6, leg length=86.2cm±5.4, ages 25±2.5 collected as part of a study are used to demonstrate the PIPSS as a dynamic balance measure for this report. All subjects had no history of concussion or neuromusculoskeletal issues within 6 months of testing.

2.1.2 Procedures

All subjects completed the BESS test and the Random Positioning Test on the PIPSS as well as clinical measures of postural stability. The BESS was performed on the TheraWii balance board to ensure coincident COP and BESS scores for each condition. The BESS consists of 6 conditions performed for 20sec with eyes closed: 1) double leg standing, 2) non-dominant single leg standing, 3) tandem stance, 4) double leg standing on foam (AIREX Balance Pad Elite, Power Systems Inc, Knoxville, TN), 5) non-dominant single leg standing on foam, and 6) tandem standing on foam (4). The investigator scored the BESS based on the following criteria: 1) moving hands off iliac crests, 2) opening the eyes, a step, 3) stumble or fall, 4) abduction or flexion of the hip beyond 30 degrees, 5) lifting the forefoot or heel off the testing surface or 6) remaining out of the testing position for greater than five seconds. Each error counted as 1 point with a maximum score of 10 points per condition. Anterior-Posterior (A-P) and medial-lateral (M-L) COP data was acquired at 30Hz from the Wii balance board. Custom Matlab programs were written to analyze the data. COP was averaged across A-P and M-L values and log transformed for the purpose of this report

The Random Positioning Test is a test where subjects stand barefoot (standardized foot position) and look straight ahead at a screen on which a red dot representing their real-time COP is visible. A target shape appears on the screen in a random position (position specifications controlled by the software) and the subjects are instructed to move their COP within the target and maintain it there for 2 seconds. After 2 seconds in the target, the target moves to a new random position, and the subject again moves as fast as possible to that target. This process is repeated for a total of 10 random target positions. Hence the total trail length varies depending on how fast and accurate the individual is in moving to the target and remaining in the target. Though many performance metrics are available in the PIPSS software, for the purposes of this report we have focused only on the COP trajectory and average path efficiency.

3 RESULTS

Quantitative measures for each BESS score showed appropriate directionality (Table 1) with a BESS score of 1 having a mean COP path efficiency of

.04cm±.02 and a BESS score of 10 having a mean COP path efficiency of .01cm±.01. Average COP range and path efficiency for each BESS score had overlapping ranges across scores (Figure 1). A score of zero on the BESS varied in average COP from 0.13 to 0.58cm for range with path efficiency spread from 0.016 to 0.11cm. A BESS score of five also had high variation for range (0.51-3.7cm) where a BESS score of eight had a high path efficiency variation (0.01-0.44cm). The BESS score of ten had the highest variation in both range and path efficiency (0.51-8.1cm, 0.01-0.02cm), respectively.

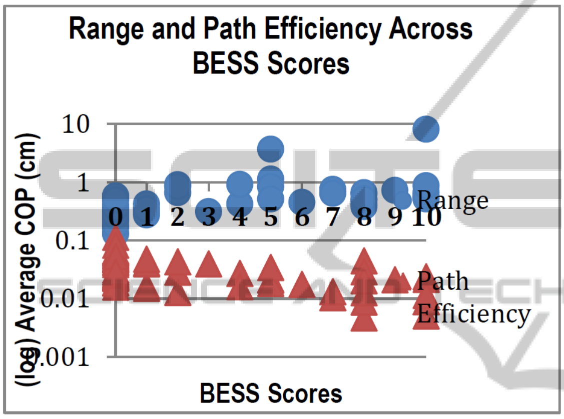

Figure 1: BESS COP measures of range and path efficiency.

Table 1: Range and Path Efficiency Across BESS Scores, mean (SD). BESS Scores represent the min and max values awarded for each condition.

BESS Scores						
Condition	**0**	**1**	**2**	**3**	**4**	
Range	.32(.13)	.33(.06)	.80(.13)	.31(.)	.67(.35)	
Path	.04(.02)	.03(.02)	.03(.02)	.04(.)	.02(.01)	
Condition	**5**	**6**	**7**	**8**	**9**	**10**
Range	1.3(1.45)	.45(.)	.70(.07)	.51(.11)	.72(.)	1.9(3.0)
Path	.02(.01)	.02(.)	.01(.01)	.02(.01)	.02(.)	.01(.01)

The PIPSS random positioning test was completed by all subjects with an average time for completion of 32.2+14.3 (range 35.6 – 84.1 seconds). Examples of 2 COP relative to target positions are displayed in Figures 1 & 2. of (range for simply.

4 DISCUSSION

PIPSS can be used simply as an input device that quantifies COP during simple static balance tasks, but more importantly as demonstrated in this report, can be used to implement dynamic postural tasks. This low cost, accessible postural stability assessment system could be easily deployed on clinics, sport and athletic centers, training rooms, schools or elderly care facilities to provide a quantitative metric of postural control. Such information would allow for more timely assessment and intervention, improved return to play guidelines in athletes, or balance and fall interventions in care centers for the elderly. Current work includes analyses and interpretation of the PIPSS testing protocols with existing balance measures

Table 2: Center of Pressure (COP) variables during standing eyes open (SEO) baseline trial, Total Time (TT) on the random positioning (RP) test, and BESS firm surface sub-score (out of 30 points).

	S001	S002	S003	S004	S005	S006	S007	S008	S009	S010
RP TT (sec)	43.500	54.100	66.700	59.000	52.200	51.700	84.100	45.500	39.200	35.600
SEO Path Eff	0.052	0.080	0.056	0.096	0.010	0.024	0.081	0.124	0.010	0.100
SEO Range	0.129	0.140	0.128	0.198	0.155	0.210	0.173	0.161	0.105	0.180
BESS (Firm)	1	1	1	18	0	0	13	4	0	4

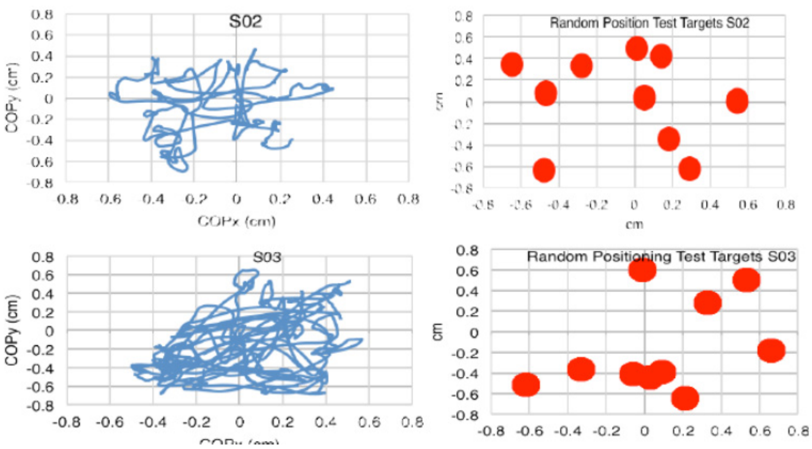

Figure 2: Of the COP and target positions for 2 exemplar subject performing the PIPSS random positioning test.

and improved definition to the relevant PIPSS output variable that are more sensitive to changes in postural control.

5 CONCLUSIONS

The PIPSS provides a portable, instrumented system that captures center of pressure like data that can be used to provide improved quantification of balance and postural stability during quiet and dynamic standing tests. We are currently continuing our validation of the PIPSS measures in children and adults in a variety of conditions including typically developing, individuals post-concussion, and individuals with cerebral palsy.

Our current technological work is focused on the integration of a software design pattern for this new style of PIPSS with Model-View-Controller (MVC) pattern at its core. In order to facilitate interoperability and further system extension a component based MVC should be implemented where raw server API is abstracted and the gathering, validation and conversion of parameters for data models should be made easy and server based.

The emerging concept of the Internet of Things provides a foundation for this relationship with some advanced telemetry methodologies. Until recently, connection of edges of networks has been problematic, particularly if devices are limited in their computation power. The Message QueuingTelemetry Transport protocol alleviates many issues with remote telemetry. With it's publish/subscribe pattern, it is a great candidate for the PIPSS application. We will create a centralized entry point for PIPSS telemetry and simple hardware drivers for computing and mobile devices that will enable device level MQTT communication with the MVC architecture. A standard API along with MQTT will enable further development of drivers for other diagnostic devices to seamlessly enter this ecosystem and support the collection of data. This idea of an openly available API facilitates dissemination of results as well as broadly impacting the field and enable clinicians to make the steps needed for standardizing return-to-sport criteria through collaborative data collection and analytics

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