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Determining the validity of the Nintendo Wii balance board as an assessment tool for balance

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DETERMINING THE VALIDITY OF THE NINTENDO WII BALANCE BOARD AS AN ASSESSMENT TOOL FOR BALANCE

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ABSTRACT

DETERMINING THE VALIDITY OF THE NINTENDO WII BALANCE BOARD AS AN ASSESSMENT TOOL FOR BALANCE

By

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Context: Application of the Nintendo Wii-fit balance board and its games have been used in Physical Therapy clinics, showing success in individuals with neurological disorders, and has been recommended as a minimum baseline assessment of a symptoms checklist and standardized cognitive and balance assessments for concussion management by the NCAA. However, it still faces challenges of being considered a reliable and consistent tool for producing normative data in the allied healthcare. Because there is little to no evidence for the Wii-fit balance board as a valid balance assessment tool for clinical and/or research usage, the significance of this study is to provide substantial evidence of whether the Nintendo Wii-fit balance board can be used as a valid balance assessment tool.

Objective: The purpose of this study was to evaluate the validity of the Wii-fit balance board as an assessment tool for balance by comparing it to the Bertec balance check platform and Kistler force platform.

Design: Experimental Study

Setting: UNLV research laboratory

Patients or Other Participants: Twelve apparently healthy, male (n = 5) and female (n=7) subjects between the ages of 18 – 30 years (age = 23 ± 3 yrs.) weighing no more than 1468 N (mass = 69.9 ± 22.6 kg, height = 167.6 ± 3 cm).

Main Outcomes or Measure(s): Subjects completed five trials of the Nintendo Wii-fit game called the "Stillness Body Test" on each of the following instruments: Bertec balance check platform, Kistler force platform, and Nintendo Wii-fit balance board (WBB). Results from the tests were used to compare center of pressure (CoP) maximum excursion range relationships among the three instruments.

Results: The results indicated that there was a significant CoP maximum excursion range positive relationship between the Bertec balance check platform and WBB in both the anterior-posterior (A/P) and medial-lateral (M/L) direction, suggesting measurement validity($r_{A/P} = 0.710$, $p_{A/P} = 0.010$, $r_{M/L} = 0.759$, $p_{M/L} = 0.004$). However, there was only a significant positive relationship between the Kistler force platform and WBB in the medial-lateral direction (M/L) but not in the anterior-posterior (A/P) direction, suggesting comparative validity only in the medial-lateral direction (M/L) ($r_{A/P} = 0.465$, $p_{A/P} = 0.128$, $r_{M/L} = 0.579$, $p_{M/L} = 0.049$). Additional results indicated that the A/P CoP total excursion and total excursion velocity averages between the Kistler and Bertec were found to be significantly different ($t_{A/P} = -2.841$, $p_{excursion} = 0.016$

$t_{A/P} = -2.964$, $p_{velocity} = 0.013$). However, the M/L CoP total excursion and total excursion velocity averages between the Kistler force platform and Bertec were not significantly different ($t_{M/L} = -1.754$, $p_{excursion} = 0.107$

$t_{M/L} = -1.349$, $p_{velocity} = 0.204$).

Conclusions: The WBB was found to be a statistically valid tool for producing CoP maximum excursion range data relative to the Kistler force platform in the M/L direction, and in the A/P and M/L direction for the Bertec balance system. However, future research should examine its effectiveness as a rehabilitation tool for balance in the patient population, and continue to investigate a final conclusion on the reliability and concurrent validity of the WBB.

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CHAPTER 1

INTRODUCTION

Recent success in the video gaming industry may be due to its ability to create an interactive environment that simulates real life experiences. This advancement in technology allows the gamer to transcend their actions to an onscreen avatar. For example, video game consoles such as Xbox Kinect ™, PlayStation 3 Move ™, and the Nintendo Wii ™ were developed to simulate real life actions by incorporating the use of human movements applicable to the field of kinesiology.

The idea of using video games in the allied healthcare field was first introduced in the 1970s by Myron Krueger who looked at video capture technology (Weiss et al., 2004). The research investigated a platform that allowed people to interact with graphics via the use of their limbs and body, and was used to explore a variety of virtual art forms. Since that time, there have been numerous studies conducted as early as the mid-1990s that have explored early versions of videogames, termed virtual reality (VR), and how it has been beneficial in the allied sciences and healthcare for rehabilitation (Weiss et al., 2004). Studies have examined the effects that video games have on improving motor, cognitive or metacognitive abilities that help with functional ability and balance in subjects ranging from those with cerebral palsy, post stroke victims, cerebral tumor, and moderate spastic quadriplegia (Betker et al., 2006; Deustch et al., 2009; Shih et al., 2009; Weiss et al., 2004). Weiss et al. (2004) cited several studies and the usage of VR in rehabilitation with video game platforms such as PlayStation II Eye Toy ™, which showed that VR improves motor and balance ability.

In today's society, the Nintendo Wii ™ gaming system has been the focus of new research involving VR and rehabilitation. The Nintendo game console system first became available in North America in 1985 and since then it has been through four generations of video game systems (Nintendo ™, Super Nintendo ™, Nintendo 64 ™, and Nintendo GameCube ™). To add to its success, Nintendo Wii ™ along with Wii Sports ™ was released in 2006. In the fall of 2008, the game Wii-fit with the Nintendo Wii-fit balance board was released and exposed gamers to a healthier aspect of gaming by featuring a fitness platform that incorporates activities such as strength training, cardio, yoga, and balance training. This innate appeal helped the Nintendo Wii cross over into the healthcare field in hospitals and physical therapy clinics across the nation as a means of intervention forum (Coyne, 2008).

The present research focuses on the Wii-fit balance board which electronically senses one's shifting weight to accomplish certain moves within the game via motion sensors at the bottom of the board. The Wii-fit gaming package utilizes the Wii-fit balance board and its various training activities to help improve physical fitness by tracking one's progression through various training programs. The balance assessment feature of the Wii-fit is of particular interest because scores based on results from the body test (balance assessment) are used to determine one's overall health and is the drive behind what training activities a gamer will utilize to achieve optimal health and balance (i.e. improve their balance score).

PURPOSE OF THE STUDY

The purpose of this study was to evaluate the validity of the Wii-fit balance board as an assessment tool for balance by comparing it to the Bertec balance check platform and Kistler force platform.

RESEARCH HYPOTHESIS

The Nintendo Wii-fit balance board is a valid to for tracking center of pressure (CoP).

DEFINITION OF TERMS

Balance (postural stability) –the ability to maintain center of mass (CoM) within the limits of the base of support (Shumway-Cook & Woollacott, 2001).

Base of support –the area underneath the feet in standing posture defined by each foot and a line connecting the toes and heels.

Center of gravity (CoG) - the mean location of gravitational force acting on the body.

Center of mass (CoM) – the mean location of all the mass in the system in 3 dimensions.

Center of pressure (CoP) - center of distributed total force applied to supporting surface (Jancova, 2008).

Postural control –the ability to maintain equilibrium in a gravitational field by keeping or returning the CoM over its base of support (Horak, 1987).

VARIABLES

Independent variables – Balance was evaluated while standing on one leg on each of the three balance measurement systems. The independent variables were each of the balance systems and included the: 1) Nintendo Wii-fit balance board (WBB), 2) Kistler force platform, and 3) Bertec balance check platform.

Dependent variables – dependent variables included 1) maximal A/P (anterior-posterior) CoP excursion range, 2) maximal M/L medial-lateral CoP excursion range, 3) total A/P CoP excursion, 4) total M/L CoP excursion, 5) A/P CoP excursion velocity, and 6) M/L CoP excursion velocity.

LIMTATIONS AND DELIMITATIONS

The study involved five experimental trials that used the Nintendo Wii-fit balance board (WBB), Bertec balance platform, and Kistler force platform to asses one's balance limited the study. Balance measurements can be assessed for anyone in the population; however, this research was limited to the segment of the population who were healthy students between the ages of 18 – 30 years who attend the University of Nevada, Las Vegas. Delimitations of the study include the testing process where subjects completed the "Stillness Body Test" on the Nintendo Wii-fit system a total of five times. Once exposed to the test numerous of times, CoP measurements may have been influenced due to muscle fatigue and/or familiarity with the testing that could have affected the results.

CHAPTER 2

REVIEW OF RELATED LITERATURE

A. Balance

I. Synergies and Strategies for Balance

Balance is a vital part of everyday life relating to both activities of daily living and physical activity. It is a highly integrative system that involves the communication among multiple neurological pathways. When discussing the way in which one maintains balance, the postural control system describes the interaction among at least three sources of sensory information: somatosensory system (proprioception, kinesthesia), vestibular system, and the visual cortex (Prentice, 2004).

Each component has its role in how balance is controlled. The visual cortex has proprioceptive function in maintaining balance similar to those located in the muscles and ligaments (Lee and Arnson et al, 1974; Winter et al., 1990). It plays the important role of inputting information from objects in the environment via the eyes and head so that one can adapt to changes around us unconsciously (reflexively) including tactile sensations (Diener et al., 1986; Prentice, 2004). The somatosensory system consists of signals that provide information regarding the location of the body in relation to surfaces and other body parts (Emery, 2006; Prentice, 2004). Finally, the vestibular system monitors the movement of speed (angular and linear acceleration) in relation to the head (Prentice, 2004). As a result, the interaction among each system allows one to maintain center of gravity within the body's base of support in response to perturbations within the environment.

The process of balance begins with sensory input detected from receptors located in the joints, and the visual cortex, and is sent to the central nervous system (CNS). These signals are then relayed back to the muscles that then activate strategies and synergies specifically associated with balance (Nashner, 1977). The differences between postural synergies and strategies have been distinguished in numerous studies. Synergies are defined as functional coupling of groups of muscles that act together as a unit to simplify the control demands from the CNS (Shumway-Cook, & Woollacott, 2001). Nashner (1977) identified these preprogrammed muscle groups working synergistically showing fixed activated patterns when adjusting to perturbations. They are classified as being centrally organized patterns of muscle activity that are related to initial conditions, which are reflexive responses to perturbation, and are sometimes based on prior experiences.

Postural strategies can be defined as the sensorimotor system that provides solutions to joint mechanics and movement patterns characterized by different muscle synergies that control posture (Horak et al, 1997). Horak and Nashner (1986) identified two different strategies that are activated when balancing, the ankle strategy and hip strategy. They showed how change in surface influences the activation of each strategy. In the ankle strategy, muscles are activated in a distal to proximal pattern and provide adjustment to small perturbations in the anterior-posterior direction. In the hip strategy muscles are activated from proximal hip and trunk muscles, and adjust to large perturbations in the medial-lateral direction (Horak and Nashner, 1986). These synergies and strategies are located throughout the body and utilize specific muscles associated with joints of the body such as, the trunk, knee, hip and ankle.

An understanding of both the synergies and strategies demonstrates how balance is a well-organized reflexive process. This is important because when problems arise in balance there is a disruption in one of the areas of the system that prohibits one from accurately being able to adjust to perturbations and maintain balance.

II. Deficits in Balance

The most common term associated with balance is proprioception, a portion of the somatosensory system that pertains to one's ability to tell where one's body is in space and adjust to perturbation (Hiller et al., 2004). It is accomplished through neural inputs from various mechanoreceptors that surround joint capsules, tendons, ligaments, muscles, and skin (Holmes et al, 2009). Deficits in balance are affected by interruptions in the input signals from the components of the sensory system to the CNS as a result of 1) trauma (injury), 2) neurological disorders, and/or 3) age. As a result of these deficiencies, an increase in one's postural sway may be present (Akbari et al., 2006; Hiller et al., 2004; Leanderson et al.,1993; Lephart et al., 1997).

Trauma to ligaments usually comes from external forces that stretch or tear the structures causing substantial damage to the receptors. Ligamentous injuries to the knee and ankle are among the common injury sites and have a major impact on balance. However, among the general and athletic population, ankle sprains (lateral ankle sprains) are the most common. This injury to the ankle involves stretching or tearing of one or all of the three stability ligaments: the anterior talofibular ligament, calcaneofibular ligament, and the posterior talofibular ligament, which ultimately leads to an increase in postural sway. Any type of damage to ligaments results in deafferentation, a delayed signal resulting from interruption in the afferent neuron because of inadequate feedback from the injured limb (Lephart, et al., 1997). As a result, there are impairments to sensorimotor control and mechanoreceptors that surround the joints of the body (Hiller, et al., 2004; Hubbard, et al., 2008).

Hiller et al. (2004), measured dancers with functional ankle instability, and determined the amount of time it takes for a person to correct the ankle back to equilibrium after sudden perturbation. The test was given under four conditions: 1) single leg silent standing flat foot, 2) sudden inversion at 15° single leg standing flat foot, 3) single leg demi-pointe 5 seconds, and 4) sudden inversion at 7.5° single leg demi-pointe. The results indicated that perturbation times were longer in dancers with functional ankle instability than in those who had never sustained an ankle injury. This is important because it indicates impairment in proprioception, the component of the balance system that is most important in the reflexive process of adjusting to perturbations.

Akbari et al. (2006) studied 26 male athletes who had sustained a grade I or II level ankle sprain sway index measuring Limits of Stability via the Biodex Balance System, Functional Reach Test (FRT), and the SEBT (Star Excursion Balance Test) for bilateral and unilateral stance. Results showed body sway scores were significantly lower for FRT when comparing bilateral versus unilateral standing. The SEBT identified significant differences in injured versus uninjured legs for unilateral stance. Finally, significantly lower scores during limits of stability when comparing eyes open versus eyes closed showed that balance problems after traumatic injury occur because of deficits in reflexive proprioception. Both Hiller et al. (2004) and Akbari et al. (2006) indicated the important role that proprioception plays in static balance, and how it affects one's ability to sense or detect these changes and accurately adapt.

Besides trauma, postural sway is attributed to balance deficits that are neurological disorders that affect motor ability of the balance control system. This may then affect efficient communication in the neurological system in determining which balance strategy to activate. In a review of postural perturbations, Horak (1997) discussed how those with disorders such as cerebral palsy, Parkinson's disease, and advanced age showed a reversal in patterns of postural activation from proximal to distal.

Ferdallagh et al. (2002) conducted a study that made a comparison between balance strategies utilized by individuals with balance problems and healthy individuals. The study concluded that children with cerebral palsy activated more hip strategy to stay balanced than ankle strategy, while healthy individuals used a hip strategy primarily for quick adjustments to perturbations. One can surmise that the postural strategies and synergies appeared to be disorganized where activation of muscles occurred from proximal to distal instead of distal to proximal. This disorganized pattern of muscle activation has also been recognized in the older populations (Armidis et al., 2003, Woollacott et al., 1986). Armidis et al. (2003) compared young versus old and muscle activation; EMG patterns showed higher activation of mixed hip activation than those of normal ankle activation. Thus, abnormal coordination of these synergies likely results from problems among abnormal sensorimotor or biomechanical constraints (Horak, 1997).

Overall, balance is a complex system involving vestibular, visual, and somatosensory systems to achieve movement goals in activities of daily living and sports activity. Research suggests that there are many factors that contribute to achieving optimal balance such as muscle activity and communication within the CNS to maintain it. Understanding how balance is achieved and controlled can help with understating how balance is assessed through several balance tools.

B. Balance Assessment Tools

I. Assessment Tools for Balance

Balance assessment is an extensive process of manipulating interactions in the sensorimotor system through perturbations. Assessment of balance uses a variety of instruments that are classified into two main categories, research and clinical (Akbari et al., 2006; Goldie et al., 1989). Even though both are used in different settings, they both share the common goal of detecting abnormalities or deficiencies for balance. The most common instruments in a research setting are strain gauge and piezoelectric force platforms, such as the Bertec and Kistler platforms, respectively. Other research instruments include the NeuroCom system and posturographs which are commonly used in Physical Therapy clinics for the purpose of providing quantitative data generally through three aspects of postural control: steadiness, symmetry, and dynamic stability (Gras et al., 2010; Prentice, 2004). Clinical assessment tools for balance are measured more with observation and subjective scoring with tests such as Balance Error Scoring System (BESS) and SEBT with the purpose of qualitatively measuring progress for a balance intervention and to assess whether or not a patient has a balance problem (Goldie et al., 1989; Mancini & Horak, 2010; Prentice, 2004).

When assessing balance, evaluation of reaction times to perturbations on different surfaces or dropping the surface from underneath subjects, timing of how long one can maintain balance stance, and recording EMG activity of the muscles during balanced stance to detect changes are some common techniques. The basic balance assessment protocol encompasses several tasks that are used to create a non-equilibrium environment over an elapsed period of time. One of the reasons to induce this state is that some of the tasks, such as double leg stance do not provide enough information to determine any type of balance problems. Thus, more complex tasks such as incorporating disruption in visual senses and using single leg stance are commonly used because they provide more of a functional challenge especially in healthy individuals.

Studies have shown that in a healthy individual and those with functional ankle instability, single leg balance tasks may indicate problems with balance. In healthy individuals, single leg balance task requires the use of the ankle strategy to maintain balance (Tropp et al., 1988), whereas in the injured, a single leg balance task is indicative of impaired postural control caused by inadequate ankle function to correct perturbations at the ankle (Clifford and Holder-Powell, 2010). As mentioned previously, the ankle strategy is responsible for maintaining posture in small and low frequency perturbation, which are displayed in a static single leg balance task.

Another reason to combine several balance tasks is to identify a subject's abnormality by separating each postural control component. In a review by Horak (1987) for developing measurement tools for assessing postural stability, there are 3 basic components for the postural system that are assessed: 1) biomechanical component (muscle weakness and joint ROM), 2) motor coordination component (postural synergies and strategies), and 3) sensory organization component (somatosensory, visual, and vestibular system). By addressing each component, it serves as an experimental manipulation to detect any type of balance abnormality by testing it's responses to different tasks. For example, eyes closed takes away the visual system having the person rely more on the vestibular and somatosensory cortex (Emery, 2003). In contrast, double leg and single leg standing on different surfaces focuses more on the aspect of motor coordination (Emery, 2003; Horak, 1987). Balance tests and procedures are typically repeated and are dependent on what the researcher or clinician wants to measure.

II. Variables Describing Balance

When measuring balance, the most commonly utilized descriptors are center of pressure (CoP) and force in relation to center of mass (CoM) or center of gravity (CoG) (Goldie, 1989; Jancova, 2008). Within each of the measurement classes there are variables or parameters, including the duration of the sample collected and sampling frequency that are used to obtain data. Of the two, CoP has been the most commonly used measurement when assessing balance because of its relation to CoG or CoM (Doyle, 2007). The relationship between CoG and CoP has been related to the inverted pendulum idea that the human body uses to maintain balance. This idea was mentioned in a review by Winter et al. (1990), when describing concepts about balance control tasks in humans and assessment techniques. As the body sways anteriorly and posteriorly to remain erect during standing, pressure and forces are distributed and the lower limbs adjust to perturbations. The magnitude and location of forces are under control of the muscles associated with balance acting around the ankle. There is a constant shift between CoP and CoG location.

Early research on CoP has provided thoughts of why it is not a reliable measurement for balance (Goldie et al., 1989). Goldie et al. (1989) looked at the reliability and validity of CoP, and its correlation to force for assessing postural steadiness. Subjects performed 14 different balance tasks, while force and CoP data were recorded and analyzed via a force platform. The tests included variations between eyes open and eyes closed, and dominant and non-dominant standing in various positions such as double leg, tandem, and single legged, for 15s. The results identified that force values were able to produce more significant results for postural steadiness than CoP values, and that CoP and force values for balance are not correlated. However, recent literature has reexamined this idea and has countered this conclusion.

Doyle et al. (2007) focused on only CoP measurement of 15 subjects tested using ten 90s balance trials of eyes open followed by eyes closed at a sampling rate of 100 Hz. The study calculated CoP standard deviation, velocity, and 95% ellipse area across trial length at the first 30s, the first 60s, and then the entire 90s. The study concluded that 30s of eyes closed produced reliable results for all 3 parameters, however, when eyes were open, CoP velocity produced acceptable results. LeClair et al. (1996) came to a similar conclusion when testing CoP at 10, 20, 30, 45, and 60s intervals at a sampling frequency of 50 Hz. It was concluded that 10s trials produced least reliable results, and 30s or more produced better results.

Despite different arguments about CoP measurement, Doyle (2007) and LeClair (1996) have shown that trial lengths of 30s or more with data collected between 50 Hz (LeClair et al. 1996) to 100 Hz (Doyle et al. 2007) respectively, and the number of repeated trials of at least five or more, provide reliable results. Parameters such as mean displacement/excursion and mean velocity also seem to provide reliable results (Raymakers et al., 2003).

In conclusion, CoP is a commonly used measurement when evaluating balance with force platforms; considered one of the gold-standard tools in research. It has been shown that one is able to gather reliable values for balance tasks being measured when assessing balance with the usage of these instruments and parameters.

C. **Videogames/ Virtual Technology in the Allied Healthcare**

I. Nintendo Wii-fit Balance Board Usage

The Nintendo Wii has only been available since 2008 and the Wii-fit since 2009; yet, it has already been incorporated by clinics to measure and track balance. Recent research conducted using the Wii balance board on balance-challenged populations show similar results of improving balance, cognition, and motor abilities (Deustch et al., 2008; Shih et al., 2009). The study by Deustch et al. (2008) with cerebral palsy patients showed improvements in postural control, visual perception processing, and functional mobility. In a similar study (Shih et al., 2009) using adolescent subjects with spastic quadriplegia showed that the usage of Wii-fit balance board improved levels of responding to motor demands and stimulation control independently.

In addition to the previous research, the Wii-fit balance board is being used in PT clinics and has adopted the name "Wii habilitation" for the success seen in individuals with neurological disorders (Painter, 2009). Besides its success in the PT clinics, it has been used for rehabilitation of musculoskeletal injuries, which is another aspect of research that has been newly examined with the Wii-fit board (Middlemas et al., 2009).

Brummels et al (2008) compared the effects of Dance Dance Revolution (DDR) and Nintendo Wii-fit balance board (WBB) training to traditional rehabilitation techniques for improving balance. In the experiment, a traditionally trained group and the DDR and Wii group completed a four week training session on their assigned intervention. Results showed that balance was improved in the experimental group (DDR and Wii) and in some cases improvements were better that the traditional group.

In conclusion, the Nintendo Wii is on the rise for being used clinically but presents questions of validity and reliability. Previous studies have used it as a tool for rehabilitation for injuries or disorders via the games rather than as an assessment portion of balance. Research involving this feature of the game has been limited or non-existent.

II. Potential Shortcomings Associated with Nintendo Wii-fit Balance Board

Besides its claimed success in helping with neurological disorders, injuries, and patient competence, researchers have recently started investigating issues surrounding reliability and validity of the Wii on its balance measurement capabilities. In the game, participants complete a balance assessment test called Center of Balance (CoB), a stability test, before being exposed to other platforms (exercises or activities) of the game. The participant stands on the Wii-fit balance board with eyes open and a traced outline is provided on a video screen showing one's balance capabilities as they attempt to stand as still as possible for 20s. Afterwards, a score is given on how well they maintained postural control through right-left symmetry, and CoB scores, followed by a series of games to analyze one's balance even further.

In the end, the game provides a Wii-fit age, and identifies strength and weakness followed by a recommendation of exercises to help improve one's score. In summary, the Wii-fit balance portion utilizes components of commonly used balance tasks, and provides qualitative and quantitative values that describe one's postural control. However, the major challenge is understanding how these values are determined, and if they are reliable and valid when compared with commonly used balance assessment tools.

In 2010, the Washington Post presented an article on Nintendo Wii-fit balance board where it argued views about it being a useful tool in the allied healthcare, as well as a counter-argument of lacking evidence or research to justify its ability to produce reliable, and consistent normative data (Yanda, 2010). In addition, the NCAA Committee on Competitive Safeguards and Medical Aspects of Sports (2010) has classified the Wii-fit as an acceptable concussion management assessment tool to be used for assessing baseline measurements of balance (Yanda, 2010). However, recent literature presents opposing views in regards to its ability to produce valid and reliable data when compared with other balance assessment tools.

Clark et al. (2010) evaluated the validity and reliability and compared total CoP path length data collected from a laboratory force platform (AMTI Model ORG-5) at a sampling rate of 40Hz. Each subject completed four balance tasks: single leg (dominant leg) with eyes open, single leg with eyes closed, double leg with eyes open, and double leg with eyes closed. The subjects were instructed to stand still for 10s single leg stance and 30s for double legged stance. To obtain data from the WBB, researchers created a custom software program. After testing, results showed excellent retest reliability, with the exception of the double leg stance on the WBB failing because it did not reach a criterion value of SE mean of 0.75 for the ICC. It also showed there was little difference between the two devices in CoP path length values. The study concluded that the WBB provided comparable data to a force platform when assessing CoP path lengths.

Gras et al. (2009) tested the reliability and concurrent validity of the Nintendo Wii balance board and concluded otherwise. In this study, the Nintendo WBB was compared to the NeuroCom Equi Test, a highly respected balance instrument used in clinical physical therapy. Participants were instructed to complete the center of balance body test on the Nintendo Wii system followed by the NeuroCom Equi-Test that was manipulated to mimic the Nintendo Wii symmetry test. The study concluded that the results for measuring CoG and left-right symmetry provided were neither accurate nor consistent when compared to the NeuroCom Equitest. Only the left-right symmetry from the WBB provided comparable correlation data to the Equitest but was not concluded to be reliable. The CoG measurement of the WBB was not correlated with or considered reliable to the Equitest. Limiting factors to the results of this study were that both instruments are designed differently to accurately measure different balance conditions, where the Equitest is designed for dynamic measurements in balance and the WBB designed to assess static balance.

Even with the existence of the previously mentioned studies, there seem to be different views of what the Wii fit does and its measuring capabilities. The WBB has been considered to be an innovative tool for balance and rehabilitation in the allied healthcare profession. However, mixed outcomes and limited research providing consistent and accurate results have slowed individuals from making that leap of incorporating it into the allied healthcare field until its reliability and validity are established.

Summary

The Nintendo Wii-fit games possess balance tasks and activities that are capable of challenging one's postural control system and producing results that may indicate postural deficits. Games or activities range from 10 – 30s tests involving shifting of one's weight with single and double leg test, reaction time, and targeting visual acuity through various platforms of the game that are fun, challenging, and engaging for participants; rather than a simple conventional balance test or tasks that are commonly used. This is important because it provides arguable reasons for why clinicians would use it for patient competence, besides it affordability and portability.

CHAPTER 3

METHODS

The purpose of this study was to evaluate the validity of the Wii-fit balance board as an assessment tool for balance by comparing it to the Bertec balance check platform and Kistler force platform. The information obtained from this study can provide evidence about how effective the WBB is in detecting one's balance capabilities when compared to other validated balance instruments.

SUBJECT CHARACTERISTICS

Twelve apparently healthy, male (n = 5) and female (n=7) subjects between the ages of 18 – 30 years (age = 23 ± 3 yrs) were recruited from the UNLV campus to voluntarily participate in this study. Subjects were constrained to weigh no more than 1468 N due to weight constraints of 330lbs. on the Nintendo Wii balance board (mass = 69.9 ± 22.6 kg, height = 167.6 ± 3 cm), and were to be free of any lower extremity injuries and the following confounding medical conditions: ear infections, medications, neurological disorders, and/or visual disorders.

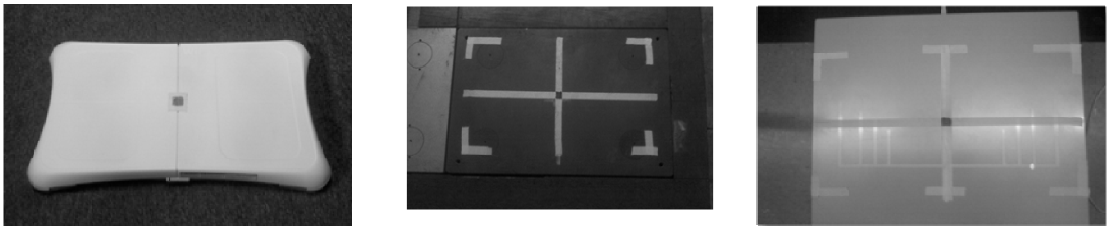
INSTRUMENTATION

Three systems were used to measure balance including the Nintendo Wii-fit balance board (Nintendo of America, Inc., Redmond, WA, USA), the Kistler force platform (Model 9218C), and the Bertec balance platform (Model BP5050). In addition, the Pinnacle Dazzle video capturing card (Dazzle DVD Reorder Plus) and Debut video capturing software (NCH software) were used to capture the Nintendo Wii-fit game play during testing, and used later to quantify center of pressure (CoP) motion. Bioware and Acquire data acquisition software were used to capture CoP motion for the Kistler and Bertec systems, respectively.

COLLECTION OF DATA

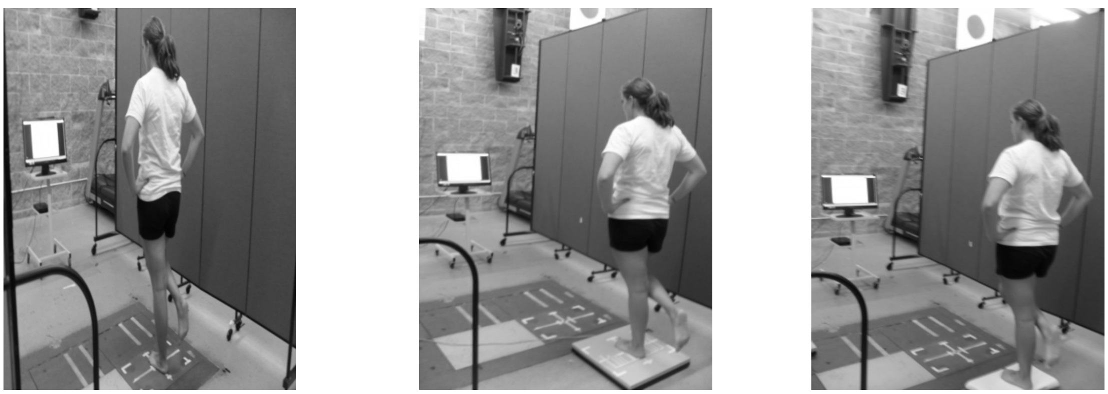
Upon giving written informed consent, subjects participated in the study for a total of 2 days. On the first day of testing, subjects completed a questionnaire that ruled out any of the previously mentioned confounding medical conditions and signed the institutionally approved consent form. After a briefing of the test protocol, subjects had height and weight taken without wearing footwear using a height-weight scale. Subjects then created an anonymous Mii character profile on the Nintendo Wii-fit game and completed each of the Wii-fit "Body Tests" in a randomized order until the specified "Stillness Body Test" was unlocked. After unlocking the desired "Body Test", subjects completed one balance practice trial on each platform.

During day 2 of testing, occurring between 1 – 2 days after, subjects completed five 30s balance trials via a pre-recorded version of the "Stillness Body Test", without any real-time feedback of CoP movement, on each platform in a randomized order using a Latin Squares design. Before each trial began, subjects stood on their preferred/dominant leg, defined as the leg used to kick a ball, and were instructed to place their foot on the center of each platform, indicated by a point marker (*Figure 1a-1c*). As subjects stood in unipedal stance both hands were placed on their hips, and the opposite limb in knee flexion for 30s with eyes open (*Figure 2a – 2c*). After proper stance conditions were met, subjects focused on a fixed point located on a 20 inch monitor that was placed 167.6 cm from each instrument, and completed the 30s "Stillness Body Test" (*Figure 3*). After each trial test, subjects stood in a relaxed or bipedal position for at least 1 minute until the next trial began.



A **B** **C**

Figure 1. (A) The Nintendo Wii-fit balance board (WBB) with the dimensions of 0.511m x 0.316m x 0.0536m. (B) The Kistler force platform with the dimensions of the Nintendo Wii-fit balance board indicated by tape outline. (C) The Bertec balance platform with the dimensions of the Nintendo Wii-fit balance board indicated by tape outline.



A **B** **C**

Figure 2. Subject performing the “Stillness Body test” on (A) the Kistler force platform, (B) the Bertec balance check platform, and (C) the Nintendo Wii-fit balance board (WBB).

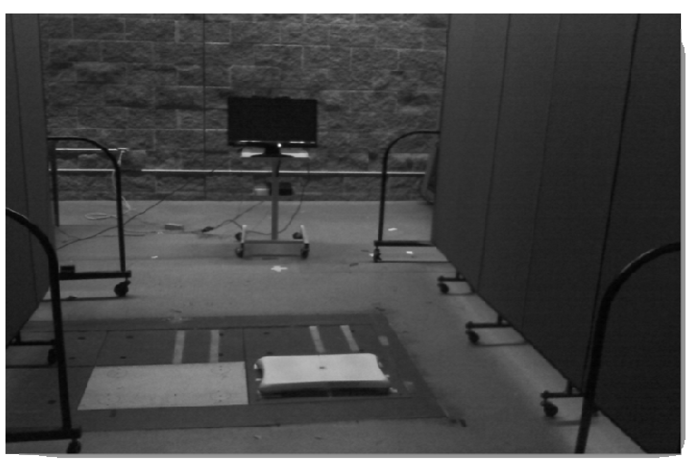


Figure 3. General set up for the balance task.

DATA REDUCTION

CoP data from the Kistler force platform and the Bertec were both obtained at a sampling rate of 100 Hz. The Kistler force platform data was extracted using Bioware software (version 3.0), while data from the Bertec was extracted using Digital Acquire (version 4.0.10) software. The WBB CoP data was obtained at a sampling rate of 64 Hz (Pagnacco et al., Iwata) from the recorded game play produced by the Debut software. After the gameplay was recorded, the screen capture function on the keyboard was used to capture the results from the “Stillness Body Test” and edited using the Windows Vista program, Paint. In the Paint program, the picture was cropped so that only the CoP graph results were shown, and pasted to an Excel graph containing the dimensions of the WBB (0.511m x 0.316m x 0.0536m).

CoP maximum excursion ranges for the WBB were determined by computing the difference between the most positive and most negative values. The maximum CoP value was obtained by measuring the distance from the center of the axis to the maximum value, while the minimum CoP value was obtained by measuring the distance from the center of the axis to the minimum value (*Figure 4*) for each trial. This process of data extraction was done in the 1) anterior-posterior (A/P) direction and the 2) medial-lateral (M/L) direction, and the five-trial average computed for later analysis.

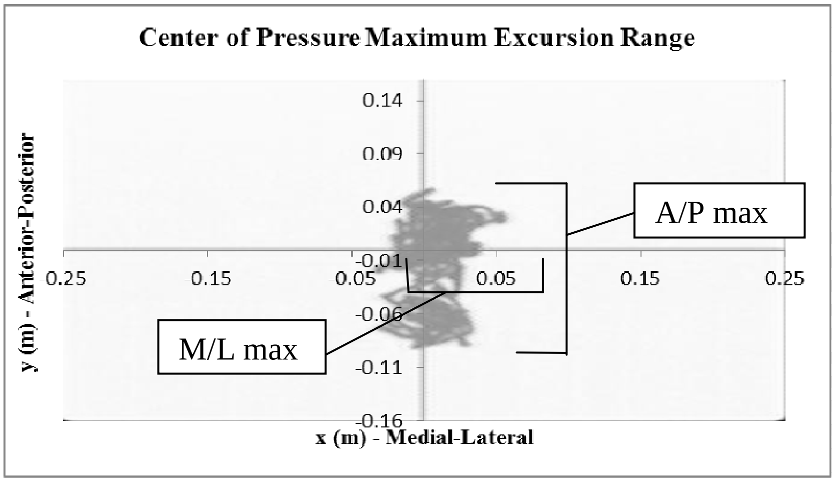


Figure 4. Center of pressure (CoP) maximum excursion range for the Nintendo Wii-fit balance board (WBB) for an exemplar subject-trial.

The CoP ranges for the Bertec and the Kistler were determined by locating the most positive and most negative values within the dataset, and computing the differences, using Excel, for each trial. This was done in the 1) anterior-posterior (A/P) direction and the 2) medial-lateral (M/L) direction and the five-trial average computed for later analysis.

Additional measurements of A/P and M/L CoP total excursion, and A/P and M/L CoP total excursion velocity were measured from only the Kistler and the Bertec platforms, and were recorded in a data table for the purpose of assessing participant balance consistency. The total CoP excursion was calculated as the net sum of all directional changes over the entire 30s of measurement (*Figure 5*). The total excursion velocity was calculated by dividing the total CoP excursion by the total length of time, 30s. Each measurement of CoP was then averaged over five trials and used for data analysis.

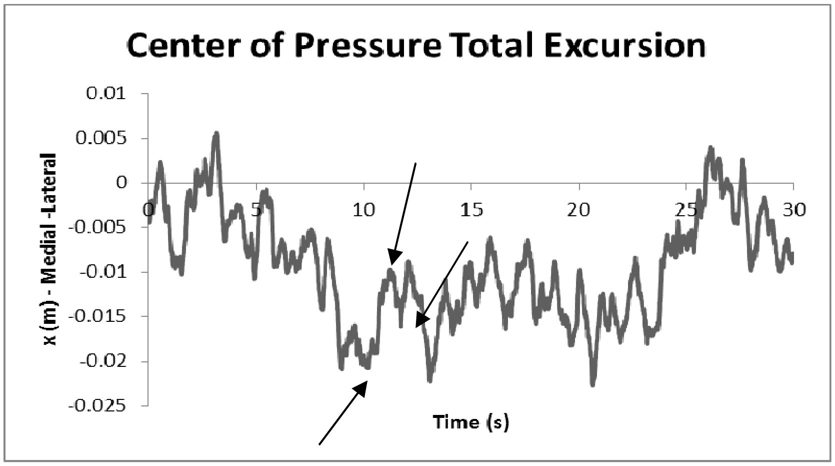


Figure 5. Center of pressure total excursion for the Kistler force platform for an exemplar subject-trial. Arrows indicate directional change.

DATA ANALYSIS

Statistical tests were conducted using Predictive Analytics SoftWare (PASW), formerly SPSS (version18.0). Five trial average values were used to represent performance for each subject/experimental condition. Values for A/P CoP maximal excursion range and M/L CoP maximal excursion range among the three instruments were analyzed using Pearson's Correlation Coefficient (r) to assess validity of the interval data. Two One-Way Repeated Measures Analysis of Variances (ANOVAs) were used to test the equality of means among the three instruments.

The first one way repeated ANOVA was used to assess A/P CoP maximal excursion range and the second ANOVA was used to assess the M/L CoP maximal excursion range. Significance was established at $\alpha = 0.05$. In the case of a significant omnibus F, *a priori* comparisons were conducted for WBB vs. Kistler, and the WBB vs. Bertec ($\alpha = 0.05$). Four additional dependent t-tests were conducted between the Bertec and the Kistler force platform to assess internal consistency in balance capabilities relative to participant performance. The dependent t-tests conducted were as follows: 1)

A/P CoP total excursion, 2) M/L CoP total excursion, 3) A/P CoP total excursion velocity, and 4) M/L total excursion velocity. Significance was established at $\alpha = 0.05$.

CHAPTER 4

RESULTS

The purpose of the study was to evaluate the validity of the Nintendo Wii-fit balance board (WBB) as an assessment tool for balance. This was done by evaluating the center of pressure (CoP) of twelve student volunteers who completed a 30s single leg balance test on three platform systems. CoP maximum excursion range relationships were analyzed between the WBB and two validated instruments, the Bertec balance system (*Figure 6*), and the Kistler force platform (*Figure 7*). Other CoP measurements, total excursion and total excursion velocity, were analyzed to compare the means between the Bertec and Kistler systems as a measure of internal balance consistency of the subjects.

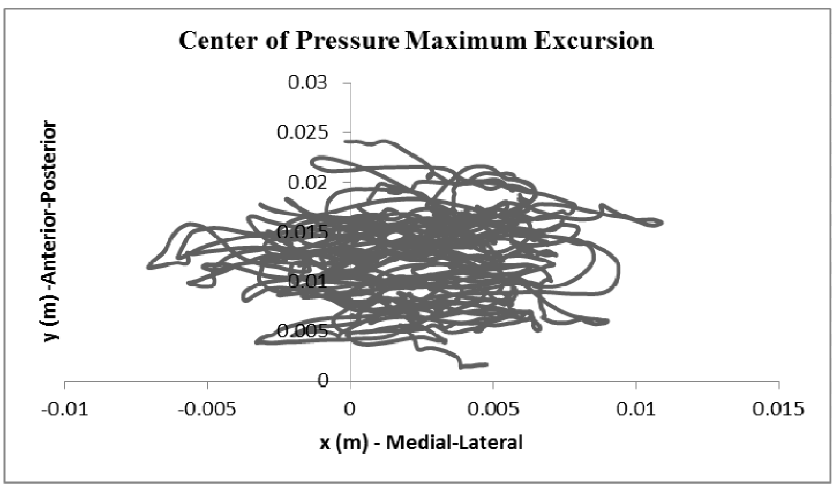


Figure 6. Center of pressure (CoP) maximum excursion range for the Bertec balance platform for an exemplar subject-trial.

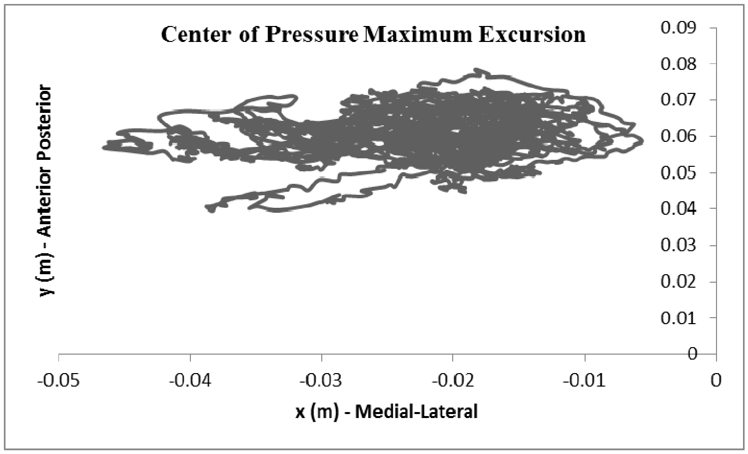


Figure 7. Center of pressure (CoP) maximum excursion range for the Kistler force platform for an exemplar subject-trial.

Center of Pressure (CoP) Maximum Excursion Range

Descriptive data for A/P CoP and M/L CoP are given in Table 1. Pearson product-moment correlation coefficients were computed to test validity of the WBB vs. the Bertec and Kistler systems. The WBB A/P CoP maximum excursion range and M/L CoP maximum excursion range were found to be related to the Bertec ($r_{A/P} = 0.710$, $p_{A/P} = 0.010$, $r_{M/L} = 0.759$, $p_{M/L} = 0.004$; Table 2-3*; Figure 8-9*), and the Kistler ($r_{A/P} = 0.465$, $p_{A/P} = 0.128$, $r_{M/L} = 0.579$, $p_{M/L} = 0.049$; Table 2-3; *Figure 10-11*). This indicated that there is a significant CoP maximum excursion range relationship between the Bertec balance check platform and WBB in both the anterior-posterior (A/P) and medial-lateral (M/L) direction, suggesting measurement validity. However, there is only a significant relationship between the Kistler force platform and WBB in the medial-lateral direction (M/L) but not in the anterior-posterior (A/P) direction, suggesting comparative validity only in the medial-lateral direction (M/L).

Table 1. Mean and Standard Deviations for A/P CoP maximum excursion ranges and M/L CoP maximum excursion ranges (m).

Instrument	Mean $_{A/P}$	Std. Deviation $_{A/P}$	Mean $_{M/L}$	Std. Deviation $_{M/L}$
Bertec	0.039	0.010	0.029	0.011
Kistler	0.038	0.019	0.044	0.019
WBB	0.161	0.026	0.104	0.019

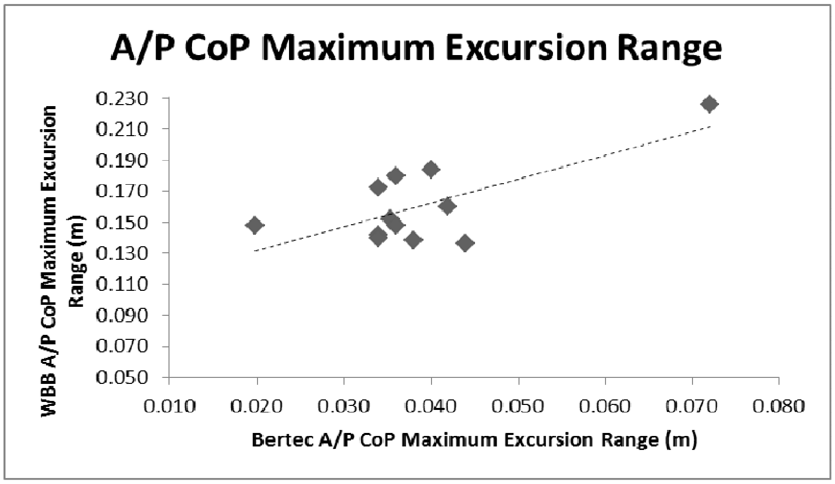


Figure 8. Anterior-Posterior Center of Pressure (CoP) Maximum Excursion Range correlation graphs with regression line for the WBB vs. the Bertec balance check.

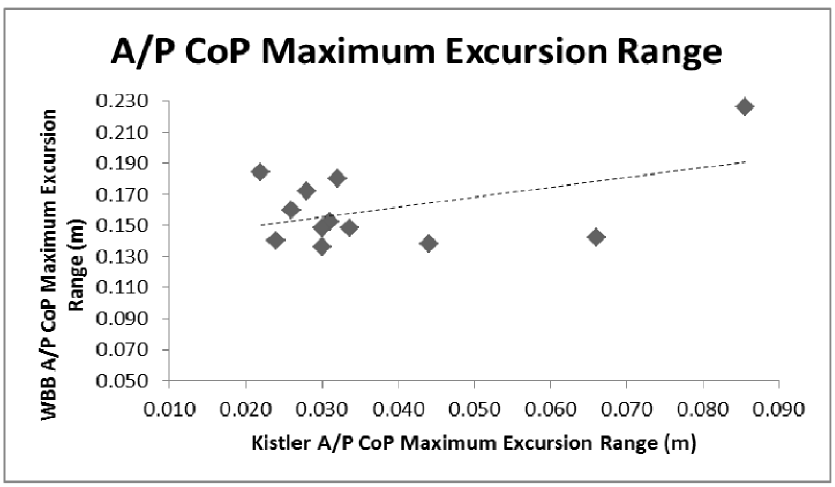


Figure 9. Anterior-Posterior Center of Pressure (CoP) Maximum Excursion Range correlation graphs with regression line for the WBB vs. the Kistler force platform.

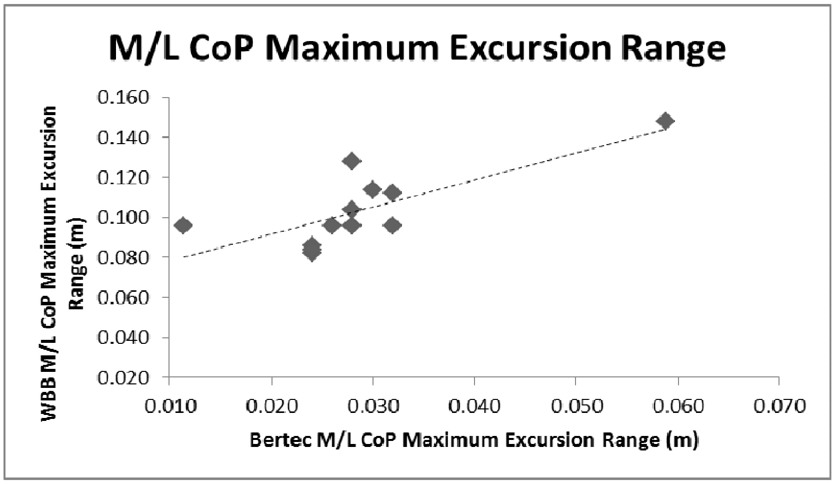


Figure 10. Medial-Lateral Center of Pressure (CoP) Maximum Excursion Range correlation graphs with regression line for the WBB vs. the Bertec balance check.

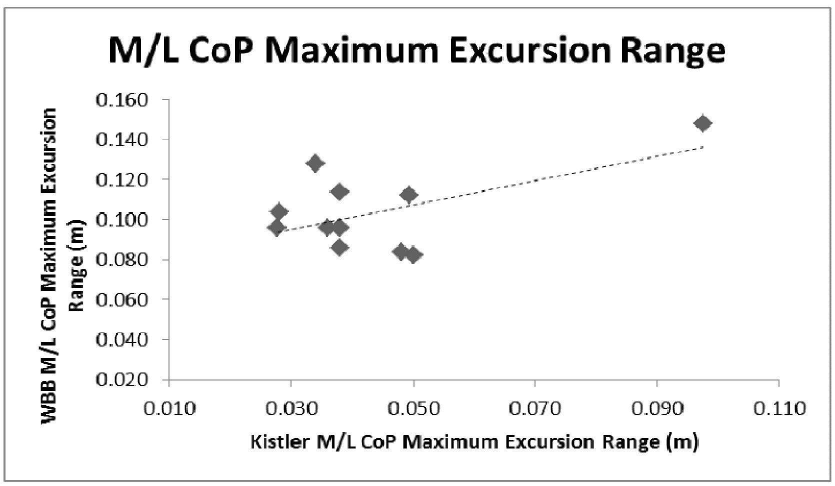


Figure 11. Medial-Lateral Center of Pressure (CoP) Maximum Excursion Range correlation graphs with regression line for the WBB vs. the Kistler force platform.

The Wii-fit balance board A/P CoP maximum excursion range and M/L CoP maximum excursion range averages across five trials was found to be significantly different from the Bertec ($F_{A/P\ (1.761)} = 299.495$, $p_{A/P} < 0.001$; $F_{M/L\ (1.710)} = 189.438$, $p_{M/L} < 0.001$; Table 4-5, *Appendix 1*), and the Kistler ($F_{A/P\ (1.761)} = 299.495$, $p_{A/P} < 0.001$; $F_{M/L\ (1.710)} = 189.438$, $p_{M/L} < 0.001$; Table 4-5, *Appendix 1*). The mean differences between the WBB vs. Bertec, and WBB vs. Kistler were at least 2 to 3 times higher in both the A/P and M/L direction (*Figures 12-13*). Despite significant correlations, this indicates that the CoP mean values produced by the WBB are significantly different from the other two instruments. This observation is supported by the nominal magnitude of explained variance observed (Bertec, $R^2_{A/P} = 0.504$, $R^2_{M/L} = 0.576$; Kistler, $R^2_{A/P} = 0.216$, $R^2_{M/L} = 0.335$).

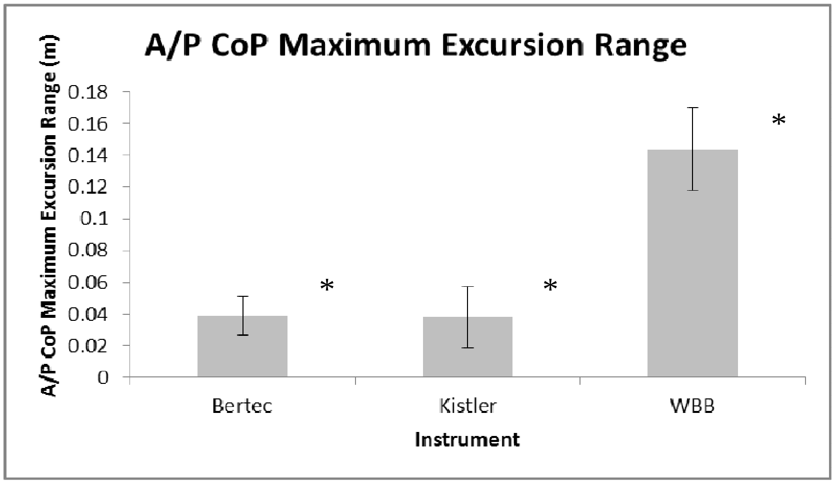


Figure 12. Anterior-Posterior (A/P) Center of Pressure (CoP) maximum excursion range ANOVA of the Bertec, Kistler, and WBB. Asterisk indicates significant difference compared to the WBB at $p < 0.05$.

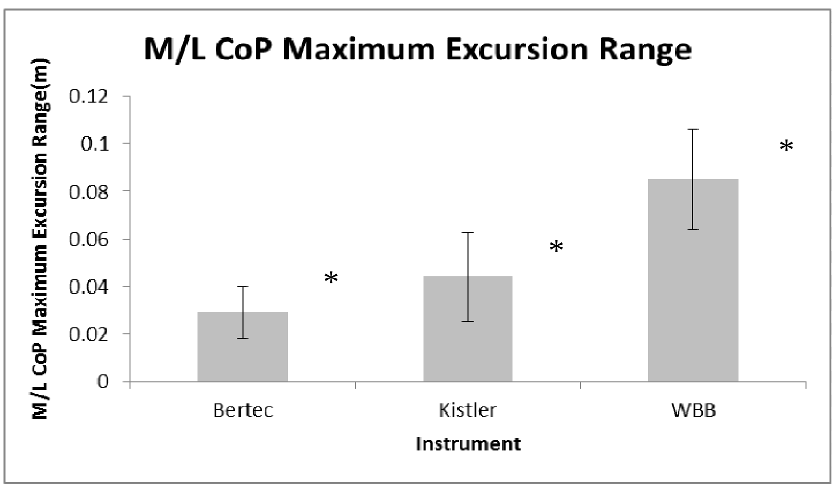


Figure 13. Medial-Lateral (M/L) Center of Pressure (CoP) maximum excursion range ANOVA of the Bertec, Kistler, and WBB. Asterisk indicates significant difference compared to the WBB at $p < 0.05$.

Center of Pressure (CoP) Total Excursion

The average CoP total excursion was calculated as the net sum of all directional changes over the entire 30s measurement between the Kistler force platform and Bertec balance system. The A/P CoP total excursion averages between the Kistler and Bertec were found to be significantly different ($t_{A/P} = -2.841$, $p_{excursion} = 0.016$; *Figure 14;* Table 6, *Appendix 1*). However, the M/L CoP total excursion averages between the Kistler force platform and Bertec were not significantly different ($t_{M/L} = -1.754$, $p_{excursion} = 0.107$; *Figure 15;* Table 6, *Appendix 1*). Considerable variability was observed the Kistler and the Bertec.

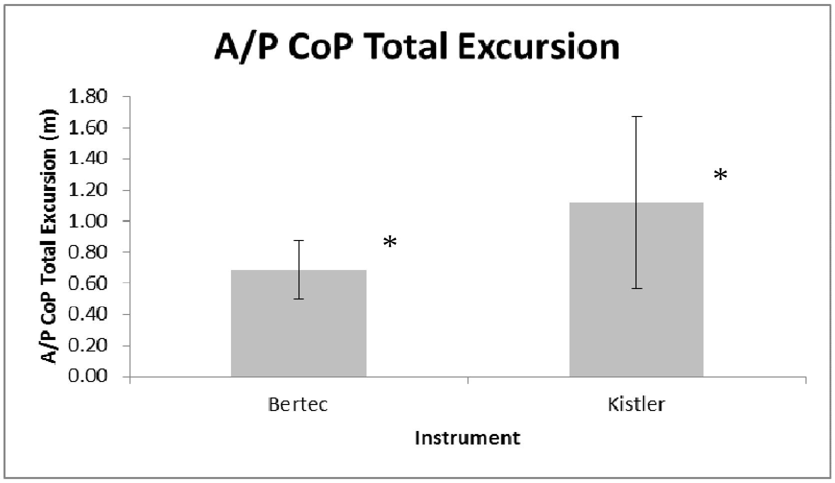


Figure 14. Anterior-Posterior (A/P) Center of Pressure (CoP) total excursion between the Bertec vs. the Kistler. Asterisk indicates significant difference at $p < 0.05$.

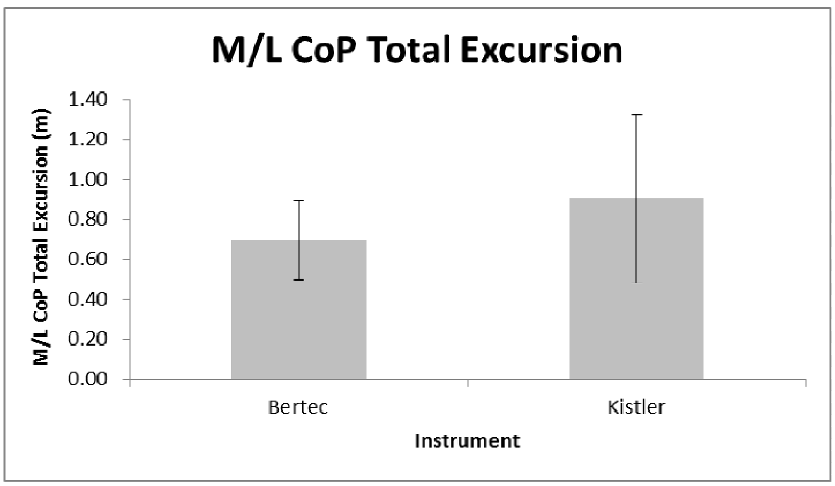


Figure 15. Medial-Lateral (M/L) Center of Pressure (CoP) total excursion between the Bertec vs. the Kistler.

Center of Pressure (CoP) Total Excursion Velocity

The A/P CoP total excursion velocity between the Kistler force platform and Bertec balance system were found to be significantly different ($t_{A/P} = -2.964$, $p_{velocity} =$

0.013; *Figure 16;* Table 6, *Appendix 1*). However, the M/L CoP total excursion velocity between the Kistler force platform and Bertec were not significantly different ($t_{M/L} = -1.349$, $p_{velocity} = 0.204$; *Figure 17;* Table 6, *Appendix 1*), consistent with observed total excursion results.

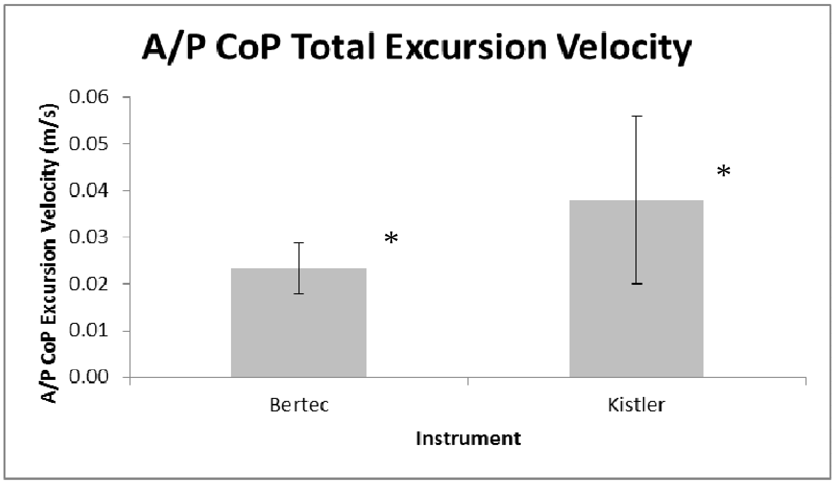


Figure 16. Anterior-Posterior (A/P) Center of Pressure (CoP) total excursion velocity between the Bertec and the Kistler. Asterisk indicates significant difference at $p < 0.05$.

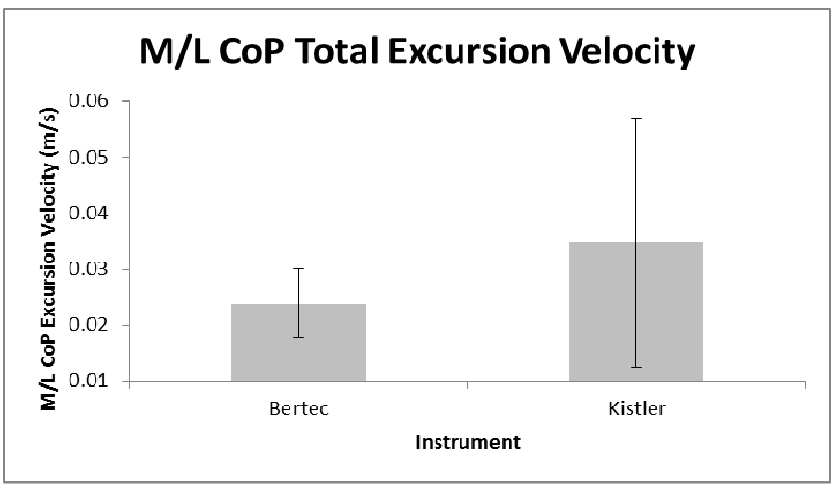


Figure 17. Medial-Lateral (M/L)) Center of Pressure (CoP) total excursion velocity between the Bertec and the Kistler.

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

DISCUSSION OF RESULTS

The purpose of the study was to evaluate the validity of the Nintendo Wii-fit balance board (WBB) as an assessment tool for balance. This was done by having subjects complete five trials of the Nintendo Wii-fit game called the "Stillness Body Test" on each instrument and comparing their relationships. Based on the correlation results, there was a positive relationship between the data extracted from the WBB when compared to the other two validated instruments, the Kistler and the Bertec, suggesting comparative validity expect in the anterior-posterior (A/P) direction for the Kistler. The information used supports the hypothesis that the WBB is capable of producing relatively comparable data, which is in contrast to opinions of how the WBB is incapable of producing comparable data for analyzing or measuring balance (Yanda, 2010; Gras et al., 2009).

Similar to a bathroom scale, the WBB senses shifts in weight (only vertical forces) via four strain gauge sensors position at the corners of the board (Clark et al., 2010; Gras et al., 2009; Iwata 2011; Pagnacco et al., 2011). Strain gauges are used in force platforms such as the Bertec, and are usually used for static balance measurements. With this similarity in devices, it would be reasonable to expect that results between the WBB and Bertec to be related (Table 2-3, *Appendix 1*). Unlike the WBB and the Bertec, the Kistler is a piezoelectric platform that contains crystal transducers to measure forces, and it is used for measuring dynamic movements. With these differences in devices, it would be reasonable to assume that results between the WBB and Kistler may show dissimilar relationships.

In this study the WBB was capable of obtaining information about one's balance capabilities using a novel method. For example, if a subject produced higher CoP values on one of the validated instruments, the WBB produced a relative result (Table 7-8, *Appendix 1*). The correlations between the WBB and the Bertec showed Pearson's coefficient (r) value of 0.710 in the A/P direction (Table 2, *Appendix 1)*, and an (r) value of 0.759 in M/L direction for CoP maximum excursion ranges (Table 3, *Appendix 1)*. The correlation between the WBB and the Kistler showed a Pearson's coefficient (r) value of 0.465 in A/P direction, and an (r) value of 0.579 in the M/L direction. This indicates that there was a greater and significant relationship in data production between the WBB and Bertec rather than the WBB and Kistler, which suggest similarity between the device's ability to detect balance. Similar results were seen in the study by Clark et al (2010) indicating that the WBB provides comparable data to a force platform (AMTI Model OR6-5) when assessing CoP path length during standing balance trials. The AMTI, similar to Bertec, is also a strain gauge instrument.

The behavior in how each subject performed on each device is exhibited in Tables 9-14 (*Appendix 1*). Of all the three instruments, the Bertec values showed the smallest variability which is indicated by the standard deviation values. This could explain why the relationship between the data had a higher Pearson's (r) coefficient. On the other hand, the values for the Kistler had slightly higher standard deviation. This may be due to the fluctuations exhibited in individual trial data on the Kistler in some of the subjects (e.g. S1, S8, S11; Table 10, *Appendix 1*).

For example, subject 1 had an average CoP range in the A/P direction of 0.066 m which was a difference of 0.028 m from the total group mean, and approximately 0.032 m difference from the testing performance on the Bertec. This may have been because the fluctuations in the individual trials. The highest range was 0.18 m in the A/P direction, and 0.11 m in the M/L direction. The other trial ranges were an average of 0.038 m in the A/P direction, and 0.035 m in the M/L direction (Table 10 and 13, *Appendix 1*). As a result, this produced greater averages that were not related to the averages produced by the WBB, and may have contributed to a Pearson's (r) coefficient were slightly lower between the WBB and Kistler.

To further investigate the relationships among the instruments, the study examined the mean difference values between each instrument. The difference in CoP averages produced between the WBB and Bertec were at least 4 times higher in the A/P direction, and 3 times higher in the M/L direction, while the averages between the WBB and Kistler were at least 4 times higher in the A/P direction, and 2 times higher in the M/L direction (Tables 7-8, *Appendix 1*). This can be supported by evaluating the scaling with a static object.

A 15 pound object was placed on the WBB at specified distance, 0.045 m (anterior-posterior), and 0.095m (medial-lateral). The distance was measured from the center of the WBB to the end of the object. After measuring the known distance, the static object was placed in the center and then moved to the specified marker on the balance to ensure that the WBB measured the pressure of the object at the specified marker. As performed in the study protocol, the end results of the WBB "Stillness Test" were captured and scaled to the dimensions of the WBB to obtain the CoP data. Results showed an approximate 1:2 ratio between the known distance measured on the WBB, and the distance done by the subjective approach. This *post* hoc scaling measure suggests that that there is at least a 2 times difference in scaling between the WBB and the other measures.

The differences in the study CoP averages produced between the other two instruments and the WBB are also supported by the Pearson's coefficient (r) squared, the magnitude of explained variance observed. Only 22% of the WBB variation is related in the A/P direction, and 34% of the variation in the M/L direction for the Kistler. For the Bertec, when (r) values are squared only 50% of the variation is related in the A/P direction, and 58% of the variation is related in the M/L direction. This is also indicated by the correlation plots of the maximum excursion range (*Figure 10-11*). If the outliers contributing to the linear relationship were taken removed from the dataset, there would be no linear relationship, supporting the R^2 values.

These results may be related to the subjects losing balance, and the differences in the design of each instrument, agreeing with several studies (Clark et al, 2010; Gras et al. 2009; Pagnacco et al., 2011). For example, there may be differences in physical constraints of each instrument. When subjects stood on the Kistler, it is embedded in the ground creating greater stability and stiffness. However, when standing on the WBB and Bertec, the height changes because of the legs positioned at each corner of the platform may influence the level of stability and subject's performance capability on the platform.

The differences in the numerical data can also be seen when comparing the means for the Bertec and the Kistler variables of total excursion, and total excursion velocity (Tables 15-18, *Appendix 1*). This was used specifically to assess internal consistency in balance capabilities relative to participant performance. Based on the results, the total excursion and excursion velocity in A/P direction showed significant differences, whereas the total excursion and excursion velocity in the M/L direction did not show any significant difference. This indicated that subject balance performance was consistent in the M/L but may have varied in the A/P direction. If this was true across all measurement systems, there may be cause to temper the observed results.

The significant difference between the devices may be due to the Bertec and the Kistler ability to measure horizontal and vertical forces, which are important in how CoP data are computed (Clark et al. 2010; Gras et al. 2009; Pagnacco et al., 2011). Unfortunately, a limitation to the WBB is that it does not provide individual data points for horizontal and vertical forces, over an elapsed time like the other two laboratory platforms. The only type of data it provides are vertical forces in a form of a trajectory graph due to shift in weight. Thus, the process used to extract and quantify data from the WBB may have introduced inconsistencies among instruments.

In a study by Pagnacco et al. (2011), it was concluded that graphical and numerical CoP data produced by the WBB are different compared to the balance instrument used, CAPS ™ Lite force platform. The WBB and the CAPS ™ Lite force platform were both were sampled at 60 Hz. In this current study, the Bertec and Kistler were set to a sampling rate of 100Hz. Despite setting the instruments to the same sampling rate as done by Pagnacco et al. (2011), or different sampling rates, results produced by the WBB were still different numerically and graphically, indicating the differences in the way data were produced. This led to an important issue of how the influence of noise is a factor in causing overestimation of data collected by the WBB.

Each instrument is sensitive to the noise produced that can significantly affect the data produced. To eliminate noise with force platforms, filters are used to exclude points within a data set that may not be a part of the true data. However, in this study a filter was not used for the data produced by the Bertec or Kistler. This is an important factor because it can lead to an assumption that another explanation for the significant differences may be that the graphical representation produced a lower than desirable signal: noise ratio.

When extracting data from the WBB, researchers have used different techniques. One way this has been done is to directly access the internal electronics of the WBB through custom software (Clark et al., 2010). The other way this has been done is through extracting data from visual feedback produced by the Wii-fit game software itself, which was subjective (Gras et al., 2009). The current study used a novel approach for gathering data which included capturing the graphical image produced and quantifying it. As a result, this conclusion can only be generalized to the data extracted from the present study.

The Nintendo Wii-fit balance board is capable of producing statistically comparable data to other balance instruments reflecting one’s balance capabilities using the method described in this study. However, the study also provides important information that there is a unique difference in the way its data are produced, which was indicated in the study by the ANOVA and the R squared results, and exhibited in the study by Pagnacco et al. (2011). The information from this study can add to literature regarding the WBB capabilities as a scientific device, and used as pilot data for future research to continue to investigate a final conclusion on the reliability and concurrent validity of the WBB.

CONCLUSIONS AND RECOMMENDATIONS

The WBB was found to be a statistically valid tool for producing CoP maximum excursion range data relative to the Kistler force platform in the M/L direction, and in the A/P and M/L direction for the Bertec balance system. The significance of this study is to provide concrete evidence regarding its capabilities for providing data that can be compared to commonly used research instruments that assess balance. These conclusions can provide opportunities for researchers to decide on usefulness of the WBB as a research or clinical tool in allied healthcare.

The WBB capabilities are limited by the manufacturer's design of the WBB such as the size of the board (limiting foot size), and weight limitations, which limit its usage to only a specific population. The most important conclusion one can gather from this study is that the WBB produced data that was based on what it is designed to do, to provide awareness of balance. This was established in the current study showing the capabilities of detecting forces or pressure applied rather than correcting horizontal forces which are important in CoP data thus, explaining why there may be an overestimation in values produced that are significantly different from what would be expected from other balance instruments. Despite its significantly moderate correlation values, there are structural component differences that have a significant impact on the usefulness of the WBB in the allied healthcare field as a reliable and possibly valid research or assessment tool for balance.

Future research should continue to examine the effects of using the WBB games as a rehabilitation tool for improving awareness of balance through proprioception and other factors, which is the goal stated within the game itself, and not its usefulness for extracting data. Studies should target its effectiveness in larger patient populations as a way to track progression of balance capabilities, and analyze or assess one's improvement of balance with other reliable and valid balance tests or instruments.

APPENDIX 1

STATISTICAL TABLES
AND
INDIVIDUAL SUBJECT DATA

STATISTICAL TABLES

Table 2. Correlation test summary for A/P CoP Maximum Excursion Ranges.

	Bertec vs. WBB	**Kistler vs. WBB**
r	0.710**	0.465
p	0.010	0.128

* Correlations is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Table 3. Correlation test summary for M/L CoP Maximum Excursion Ranges.

	Bertec vs. WBB	**Kistler vs. WBB**
r	0.759**	0.579*
p	0.004	0.049

* Correlations is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Table 4. Repeated ANOVA summary for A/P CoP Maximum Excursion Ranges.

	Bertec vs. WBB	**Kistler vs. WBB**
F	299.495	299.495
p	< 0.001*	< 0.001*

*significance difference at p < 0.05

Table 5. Repeated ANOVA summary for M/L CoP Maximum Excursion Ranges.

	Bertec vs. WBB	**Kistler vs. WBB**
F	189.438	189.438
p	< 0.001*	< 0.001*

*significance difference at p < 0.05

Table 6. The Bertec and Kistler A/P CoP total excursion and total excursion velocity, and M/L COP total excursion and total excursion velocity.

	p-value $_{A/P}$	**p-value $_{M/L}$**
Total Excursion	0.016*	0.107
Total Excursion Velocity	0.013*	0.204

* Significant difference at p < 0.05

Table 7. Overall and individual subject mean and standard deviations for A/P CoP maximum excursion ranges (m) across five trials.

Subject	Bertec	Kistler	WBB
1	0.034 ± 0.005	0.066 ± 0.064	0.142 ± 0.016
2	0.020 ± 0.000	0.034 ± 0.007	0.148 ± 0.032
3	0.034 ± 0.009	0.024 ± 0.005	0.140 ± 0.022
4	0.042 ± 0.008	0.026 ± 0.005	0.160 ± 0.045
5	0.044 ± 0.011	0.030 ± 0.000	0.136 ± 0.029
6	0.034 ± 0.011	0.028 ± 0.008	0.172 ± 0.055
7	0.036 ± 0.009	0.032 ± 0.004	0.180 ± 0.027
8	0.072 ± 0.037	0.086 ± 0.071	0.226 ± 0.047
9	0.035 ± 0.007	0.031 ± 0.002	0.152 ± 0.033
10	0.036 ± 0.005	0.030 ± 0.000	0.148 ± 0.020
11	0.038 ± 0.008	0.044 ± 0.021	0.138 ± 0.026
12	0.040 ± 0.012	0.022 ± 0.004	0.184 ± 0.024
Overall Average	0.039	0.038	0.161
Overall Std. Dev.	0.010	0.019	0.026

Table 8. Overall and individual subject mean and standard deviations for M/L CoP maximum excursion ranges (m) across five trials.

Subject	Bertec	Kistler	WBB
1	0.024 ± 0.005	0.050 ± 0.037	0.082 ± 0.008
2	0.011 ± 0.002	0.028 ± 0.008	0.096 ± 0.009
3	0.024 ± 0.005	0.038 ± 0.008	0.086 ± 0.009
4	0.028 ± 0.008	0.034 ± 0.005	0.128 ± 0.011
5	0.030 ± 0.007	0.038 ± 0.004	0.114 ± 0.005
6	0.028 ± 0.004	0.028 ± 0.004	0.104 ± 0.015
7	0.028 ± 0.008	0.036 ± 0.009	0.096 ± 0.005
8	0.059 ± 0.043	0.098 ± 0.055	0.148 ± 0.076
9	0.032 ± 0.004	0.049 ± 0.008	0.112 ± 0.013
10	0.032 ± 0.004	0.038 ± 0.008	0.096 ± 0.013
11	0.024 ± 0.005	0.048 ± 0.025	0.084 ± 0.011
12	0.026 ± 0.005	0.038 ± 0.008	0.096 ± 0.021
Overall Average	0.029	0.044	0.104
Overall Std. Dev.	0.011	0.019	0.019

Table 9. Individual trials of A/P CoP maximum excursion range (m) for the Bertec.

Subject	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
1	0.030	0.040	0.030	0.030	0.040	0.034
2	0.020	0.020	0.020	0.020	0.019	0.020
3	0.030	0.050	0.030	0.030	0.030	0.034
4	0.040	0.030	0.040	0.050	0.050	0.042
5	0.040	0.030	0.040	0.060	0.050	0.044
6	0.040	0.050	0.020	0.030	0.030	0.034
7	0.030	0.050	0.030	0.030	0.040	0.036
8	0.048	0.050	0.040	0.123	0.099	0.072
9	0.028	0.032	0.046	0.035	0.036	0.035
10	0.040	0.040	0.030	0.040	0.030	0.036
11	0.050	0.030	0.040	0.030	0.040	0.038
12	0.040	0.040	0.060	0.030	0.030	0.040

Table 10. Individual trials of A/P CoP maximum excursion range (m) for the Kistler.

Subject	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
1	0.180	0.040	0.030	0.030	0.050	0.066
2	0.039	0.036	0.038	0.032	0.023	0.034
3	0.020	0.020	0.030	0.020	0.030	0.024
4	0.030	0.030	0.020	0.020	0.030	0.026
5	0.030	0.030	0.030	0.030	0.030	0.030
6	0.040	0.030	0.030	0.020	0.020	0.028
7	0.030	0.040	0.030	0.030	0.030	0.032
8	0.033	0.077	0.209	0.041	0.068	0.086
9	0.030	0.034	0.031	0.030	0.030	0.031
10	0.030	0.030	0.030	0.030	0.030	0.030
11	0.040	0.030	0.040	0.030	0.080	0.044
12	0.020	0.020	0.020	0.020	0.030	0.022

Table 11. Individual trials of A/P maximum excursion range (m) for the WBB.

Subject	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
1	0.130	0.160	0.130	0.130	0.160	0.142
2	0.170	0.100	0.170	0.170	0.130	0.148
3	0.140	0.110	0.130	0.170	0.150	0.140
4	0.150	0.230	0.170	0.110	0.140	0.160
5	0.110	0.150	0.160	0.160	0.100	0.136
6	0.180	0.150	0.110	0.160	0.260	0.172
7	0.210	0.210	0.160	0.160	0.160	0.180
8	0.170	0.270	0.280	0.200	0.210	0.226
9	0.190	0.170	0.150	0.150	0.100	0.152

10	0.170	0.130	0.140	0.130	0.170	0.148
11	0.110	0.120	0.130	0.160	0.170	0.138
12	0.190	0.210	0.200	0.170	0.150	0.184

Table 12. Individual trials of M/L CoP maximum excursion range (m) for the Bertec.

Subject	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
1	0.030	0.030	0.020	0.020	0.020	0.024
2	0.010	0.010	0.012	0.010	0.015	0.011
3	0.020	0.020	0.030	0.030	0.020	0.024
4	0.020	0.030	0.020	0.030	0.040	0.028
5	0.030	0.020	0.030	0.040	0.030	0.030
6	0.020	0.030	0.030	0.030	0.030	0.028
7	0.030	0.040	0.020	0.020	0.030	0.028
8	0.091	0.026	0.024	0.117	0.036	0.059
9	0.032	0.031	0.036	0.035	0.026	0.032
10	0.030	0.030	0.030	0.040	0.030	0.032
11	0.030	0.020	0.030	0.020	0.020	0.024
12	0.020	0.030	0.030	0.020	0.030	0.026

Table 13. Individual trials of M/L CoP maximum excursion range (m) for the Kistler.

Subject	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
1	0.110	0.030	0.020	0.030	0.060	0.050
2	0.040	0.028	0.025	0.019	0.026	0.028
3	0.050	0.030	0.030	0.040	0.040	0.038
4	0.040	0.030	0.040	0.030	0.030	0.034
5	0.030	0.040	0.040	0.040	0.040	0.038
6	0.030	0.030	0.020	0.030	0.030	0.028
7	0.040	0.030	0.050	0.030	0.030	0.036
8	0.064	0.087	0.189	0.049	0.099	0.098
9	0.041	0.049	0.051	0.044	0.062	0.049
10	0.040	0.030	0.030	0.050	0.040	0.038
11	0.050	0.040	0.030	0.030	0.090	0.048
12	0.040	0.030	0.040	0.030	0.050	0.038

Table 14. Individual trials of M/L CoP maximum excursion range (m) for the WBB.

Subject	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
1	0.080	0.070	0.080	0.090	0.090	0.082
2	0.100	0.100	0.100	0.100	0.080	0.096
3	0.080	0.090	0.080	0.100	0.080	0.086
4	0.140	0.140	0.120	0.120	0.120	0.128
5	0.110	0.120	0.120	0.110	0.110	0.114
6	0.100	0.080	0.110	0.120	0.110	0.104

7	0.100	0.090	0.090	0.100	0.100	0.096
8	0.280	0.110	0.090	0.140	0.120	0.148
9	0.100	0.130	0.100	0.120	0.110	0.112
10	0.090	0.080	0.110	0.090	0.110	0.096
11	0.090	0.080	0.100	0.070	0.080	0.084
12	0.120	0.080	0.110	0.070	0.100	0.096

Table 15. Overall and individual subject mean and standard deviations for A/P CoP total excursion (m) across five trials.

Subject	**Bertec**	**Kistler**
1	0.74 ± 0.02	2.71 ± 02.83
2	0.52 ± 0.02	1.28 ± 0.08
3	0.77 ± 0.08	0.86 ± 0.06
4	0.58 ± 0.18	0.60 ± 0.07
5	0.87 ± 0.12	1.34 ± 0.17
6	0.53 ± 0.03	0.76 ± 0.13
7	0.61 ± 0.10	0.98 ± 0.09
8	1.17 ± 0.35	1.32 ± 0.36
9	0.57 ± 0.05	1.03 ± 0.24
10	0.59 ± 0.08	0.86 ± 0.02
11	0.60 ± 0.11	1.00 ± 0.10
12	0.73 ± 0.05	0.75 ± 0.03
Overall Average	0.699	1.124
Overall Std. Dev.	0.186	0.552

*Table 16.*Overall and individual subject mean and standard deviations for M/L CoP total excursion (m) across five trials.

Subject	**Bertec**	**Kistler**
1	0.790 ± 0.048	2.092 ± 2.582
2	0.504 ± 0.038	0.958 ± 0.133
3	0.786 ± 0.099	0.732 ± 0.056
4	0.550 ± 0.103	0.544 ± 0.048
5	1.210 ± 0.293	0.944 ± 0.092
6	0.508 ± 0.036	0.584 ± 0.044
7	0.806 ± 0.113	0.648 ± 0.071
8	0.768 ± 0.140	1.246 ± 0.229
9	0.652 ± 0.650	0.902 ± 0.163
10	0.530 ± 0.450	0.750 ± 0.078
11	0.618 ± 0.111	0.762 ± 0.211
12	0.670 ± 0.042	0.722 ± 0.035
Overall Average	0.699	0.907
Overall Std. Dev.	0.197	0.420

Table 17. Overall and individual subject mean and standard deviations for A/P CoP total excursion velocity (m/s) across five trials.

Subject	**Bertec**	**Kistler**
1	0.026 ± 0.005	0.090 ± 0.095
2	0.020 ± 0.000	0.043 ± 0.003
3	0.026 ± 0.005	0.030 ± 0.000
4	0.022 ± 0.004	0.020 ± 0.000
5	0.028 ± 0.004	0.044 ± 0.005
6	0.020 ± 0.000	0.026 ± 0.005
7	0.020 ± 0.000	0.032 ± 0.004
8	0.038 ± 0.012	0.045 ± 0.012
9	0.019 ± 0.002	0.035 ± 0.008
10	0.020 ± 0.000	0.030 ± 0.000
11	0.018 ± 0.004	0.036 ± 0.009
12	0.024 ± 0.005	0.026 ± 0.005
Overall Average	0.023	0.038
Overall Std. Dev.	0.006	0.018

Table 18. Overall and individual subject mean and standard deviations for M/L CoP total excursion velocity (m/s) across five trials.

Subject	**Bertec**	**Kistler**
1	0.03 ± 0.00	0.07 ± 0.08
2	0.02 ± 0.00	0.09 ± 0.13
3	0.03 ± 0.01	0.02 ± 0.00
4	0.02 ± 0.00	0.02 ± 0.00
5	0.04 ± 0.01	0.03 ± 0.00
6	0.02 ± 0.00	0.02 ± 0.00
7	0.03 ± 0.00	0.02 ± 0.00
8	0.03 ± 0.00	0.04 ± 0.01
9	0.02 ± 0.00	0.03 ± 0.01
10	0.02 ± 0.00	0.02 ± 0.01
11	0.02 ± 0.00	0.03 ± 0.01
12	0.02 ± 0.00	0.02 ± 0.00
Overall Average	0.025	0.034
Overall Std. Dev.	0.007	0.023

APPENDIX 2
IRB APPROVALS

UNLV
UNIVERSITY OF NEVADA LAS VEGAS

Biomedical IRB – Expedited Review Approval Notice

NOTICE TO ALL RESEARCHERS:

Please be aware that a protocol violation (e.g., failure to submit a modification for any change) of an IRB approved protocol may result in mandatory remedial education, additional audits, re-consenting subjects, researcher probation, suspension of any research protocol at issue, suspension of additional existing research protocols, invalidation of all research conducted under the research protocol at issue, and further appropriate consequences as determined by the IRB and the Institutional Officer.

DATE:	March 28, 2011
TO:	**Dr. Janet Dufek**, Kinesiology
FROM:	Office of Research Integrity - Human Subjects
RE:	Notification of IRB Action by /Charles Rasmussen/ Dr. Charles Rasmussen, Co-Chair Protocol Title: **Determing the Validity of the Nintendo Wii Balance Board as an Assessment Tool for Balance** Protocol #: 1102-3745 Expiration Date:March 27, 2012

This memorandum is notification that the project referenced above has been reviewed and approved by the UNLV Biomedical Institutional Review Board (IRB) as indicated in Federal regulatory statutes 45 CFR 46 and UNLV Human Research Policies and Procedures.

The protocol is approved for a period of one year and expires March 27, 2012. If the above-referenced project has not been completed by this date you must request renewal by submitting a Continuing Review Request form 30 days before the expiration date.

PLEASE NOTE:

Upon approval, the research team is responsible for conducting the research as stated in the protocol most recently reviewed and approved by the IRB, which shall include using the most recently submitted Informed Consent/Assent forms and recruitment materials. The official versions of these forms are indicated by footer which contains approval and expiration dates.

Should there be *any* change to the protocol, it will be necessary to submit a **Modification Form** through ORI - Human Subjects. No changes may be made to the existing protocol until modifications have been approved by the IRB. Modified versions of protocol materials must be used upon review and approval. Unanticipated problems, deviations to protocols, and adverse events must be reported to the ORI – HS within 10 days of occurrence.

If you have questions or require any assistance, please contact the Office of Research Integrity - Human Subjects at IRB@unlv.edu or call 895-2794.

Office of Research Integrity - Human Subjects
4505 Maryland Parkway • Box 451047 • Las Vegas, Nevada 89154-1047
(702) 895-2794 • FAX: (702) 895-0805

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Biomedical IRB – Expedited Review
Modification Approved

NOTICE TO ALL RESEARCHERS:

Please be aware that a protocol violation (e.g., failure to submit a modification for <u>any</u> change) of an IRB approved protocol may result in mandatory remedial education, additional audits, re-consenting subjects, researcher probation, suspension of any research protocol at issue, suspension of additional existing research protocols, invalidation of all research conducted under the research protocol at issue, and further appropriate consequences as determined by the IRB and the Institutional Officer.

DATE: April 25, 2011

TO: **Dr. Janet Dufek**, Kinesiology

FROM: Office of Research Integrity – Human Subjects

RE: Notification of IRB Action by /Charles Rasmussen/ Dr. Charles Rasmussen, Co-Chair
Protocol Title: **Determining the Validity of the Nintendo Wii Balance Board as an Assessment Tool for Balance**
Protocol #: 1102-3745
Expiration Date:March 27, 2012

The modification of the protocol named above has been reviewed and approved.

Modifications reviewed for this action include:

- Addition of a questionnaire which reflects the inclusion/exclusion criteria stated on the informed consent.
- The informed consent has been modified to include this additional step.

This IRB action will not reset your expiration date for this protocol. The current expiration date for this protocol is March 27, 2012.

PLEASE NOTE:
Upon approval, the research team is responsible for conducting the research as stated in the protocol most recently reviewed and approved by the IRB, which shall include using the most recently submitted Informed Consent/Assent forms and recruitment materials. The official versions of these forms are indicated by footer which contains approval and expiration dates.

Should there be *any* change to the protocol, it will be necessary to submit a **Modification Form** through ORI - Human Subjects. No changes may be made to the existing protocol until modifications have been approved by the IRB. Modified versions of protocol materials must be used upon review and approval. Unanticipated problems, deviations to protocols, and adverse events must be reported to the ORI – HS within 10 days of occurrence.

Should the use of human subjects described in this protocol continue beyond March 27, 2012, it would be necessary to submit a **Continuing Review Request Form** *30 days* before the expiration date.

If you have questions or require any assistance, please contact the Office of Research Integrity - Human Subjects at IRB@unlv.edu or call 895-2794.

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UNIVERSITY OF NEVADA LAS VEGAS

Department of Kinesiology and Nutrition Sciences

INFORMED CONSENT FORM

TITLE OF THE STUDY: DETERMINING THE VALIDITY OF THE NINTENDO WII BALANCE BOARD AS AN ASSESSMENT TOOL FOR BALANCE.

INVESTIGATOR/S: Ms. Sabrina Deans, LAT, ATC; Janet S. Dufek, Ph.D.

RESEARCH ASSISTANTS:

CONTACT INFORMATION: If you have any questions or concerns about the study, please contact Ms. Deans at (510) 407-4399 or smd852003@yahoo.com, or Dr. Dufek at (702)895-0702.

For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted you may contact the **UNLV Office of Research Integrity – Human Subjects Research at (702) 895-2794.**

Purpose

The purpose of the study is to determine the validity of Nintendo Wii balance board as a tool for assessing balance.

Participants

You are being asked to participate in the study because you are from the ages of 18-30 years. For the purpose of the study, you must be free from any lower extremity injuries, and weigh less than 330 lbs. Additional exclusion criteria include ear infection or known neurological disorders and/or vestibular disorders, and currently taking any medications that may affect balance.

Procedure

If you volunteer to participate in the study, you will be asked to report to the SIRC research Lab two times at mutually agreed upon times and informed that your gameplay will be video recorded. During your first visit, your height and weight will be measured, you will be asked to complete a brief questionnaire, and you will be asked to create your own Mii character and unlock all of the tests for the Wii-fit body test. On the second day of testing, you will complete a on each of three platforms including the Wii-balance board (WBB), the Kistler force platform, and the Bertec balance check platform. While completing each test, you will be instructed stand for 30 s on your preferred/dominant leg with hands on your hips, and the opposite limb at 90° of knee flexion. This test will be completed a total of 5 times on each platform.

Risks

This study involves minimal risk to you. Other than performing in an experimental setting, this research study does not require you to engage in any activity that is unusual or unfamiliar.

Initials ______________

Approved by the UNLV IRB. Protocol #1102-3745

Received: 04-18-11 Approved: 04-25-11 Expiration: 03-27-12

Cost/Compensation
There will be no financial cost to you to participate in this study. The study will take two days (30-45 min/day) of your time. You will not be compensated for your time.

Benefits of Participation
There is likely little benefit to you other than you will have the opportunity to play different Nintendo Wii games and be entertained for a short period of time. However, you will come away knowing your height, weight, and balance capabilities. This information will add to our knowledge of how balance measurement of the Nintendo Wii compares to the force platform and Bertec balance platforms.

Voluntary Participation
Your participation in this study is completely voluntary. You may refuse to participate in this study or in any part of this study and you may withdraw at any time without prejudice to your relations with the University. You are encouraged to ask questions about this study prior to the beginning or at any time during the study. You will be given a copy of this form.

Confidentiality
All information gathered in this study will be kept completely confidential and will be referred to by a subject number only. Only those persons who are directly related to this study (i.e.: researchers, data analysts) will have access to your data. No reference will be made in written or oral materials, which could link you to this study. All records will be stored in the laboratory for a period of 3 years. After 3 years, any documentation with identifiable information (e.g., name) will be destroyed. Unidentifiable data will be stored in locked storage indefinitely.

Freedom of Consent
I have read the above information carefully and I am aware of the tests/procedures to be performed. Knowing these risks and having the opportunity to ask questions, I agree (consent) to participate in this study. I understand that I have a right to withdraw from this study at any time without prejudice. I am at least 18 years old and a copy of the informed consent has been given to me.

______________________________ ____________
Signature of the Participant Date

I UNDERSTAND THAT MY GAMING SESSIONS WILL BE VIDEO RECORDED, HOWEVER THEY WILL NOT BE BROADCAST IN ANY WAY, SHAPE, OR FORM.

______________________________ ____________
SIGNATURE OF PARTICIPANT DATE

________________________ ____________
Signature of Witness Date

Initials __________

DETERMINING THE VALIDITY OF THE NINTENDO WII BALANCE BOARD AS AN ASSESSMENT TOOL FOR BALANCE.
Department of Kinesiology and Nutrition Sciences
Ms. Sabrina Deans (510) 407–4399 or smd852003@yahoo.com, Dr. Dufek at (702)895-0702

Approved by the UNLV IRB. Protocol #1102-3745
Received: 04-18-11 Approved: 04-25-11 Expiration: 03-27-12

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Department of Kinesiology and Nutrition Sciences

Participant Survey

Please answer the following questions and place a check mark next to your answer:

1. Are you free from any lower extremity injuries that may affect your balance capabilities (i.e. fracture, sprain, muscle strains, knee injuries, etc.)?

   _____ yes _____ no

2. Do you weigh less than 330 lbs?

   _____ yes _____ no

3. Do you currently suffer from an ear infection?

   _____ yes _____ no

4. Have you been diagnosed with any known neurological or vestibular disorders?

   _____ yes _____ no

5. Are you currently taking any medications that may affect your balance?

   _____ yes _____ no

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