CRITERION VALIDITY OF SELECTED WII FIT™ GAMES FOR BALANCE ASSESSMENT

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To the Dean of the Graduate School:

I am submitting herewith a dissertation written by Vanessa Fiaud entitled "Criterion Validity of Selected Wii Fit™ Games for Balance Assessment". I have examined this dissertation for form and content and recommend that it is accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy with a major in Kinesiology.

David Nichols, Ph. D., Major Professor

We have read this dissertation and recommend its acceptance:

Barney Sanborn, Ph. D, Department Chair

Accepted:

Dean of the Graduate School

DEDICATION

I dedicate this dissertation to my family and especially…

To Janet for being so patient, supporting, and understanding;

To my mom and dad for instilling the importance of hard work and higher education;

To my grandmother, Rachel Machère, who endured my absence with pride and patience;

To Dr. Ishee, the most significant mentor I have had in the United States.

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ABSTRACT

VANESSA FIAUD

CRITERION VALIDITY OF SELECTED WII FIT™ GAMES
FOR BALANCE ASSESSMENT

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The purpose of this study was to examine the criterion validity of selected Wii Fit™ games for balance assessment. One hundred and eleven participants (n_{men} = 67, n_{women} = 4) completed the testing protocol and were included in the analysis. The protocol included assessment of balance using both the Basic Balance Master® and Wii Fit™ games using the balance board. The Wii Fit™ games selected included the Center of Balance, the Body of Control-Agility, the Body of Control-Basic Stance, Soccer Heading, and Ski Slalom. The Basic Balance Master® variables included the Weight Bearing Symmetry, Limit of Stability-directional control, Limit of Stability-maximum excursion, Rhythmic Weight Shift-directional control lateral, and Rhythmic Weight Shift-directional control antero-posterior. The data were analyzed using a canonical correlation. The canonical analysis revealed a statistically significant canonical correlation between the two canonical variates ($F [25, 376.70] = 10.763$, $p < .001$; Wilks' $\lambda = .135$). Tests of dimensionality for the canonical correlation analysis indicated that two of the five canonical functions were statistically significant ($\alpha = .05$). The first function explained 81.8% of variance within its function and the second function explained 15.9%

of the remaining variance. The strongest contributors to the relationship between the canonical variates were the Wii Fit™ Center of balance (r_s = .992) and the Balance Master® Weight Bearing Symmetry (r_s = .989). In conclusion, the Wii Fit™ Balance Board selected exercises showed excellent criterion validity for measuring balance as compared to the more established Balance Master®. All selected Wii Fit™ games seemed to provide a rather accurate depiction of balance ability.

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CHAPTER I

INTRODUCTION

An increasing number of falls among the elderly has been observed in the United States (U.S.). According to the Centers for Disease Control (CDC, 2010b), one third of man and women 65 and older fall at least once each year. In addition, the death toll among elderly who fall has risen dramatically in the past decade. Many of the injured elderly need to go to the emergency room or even check in for an extended stay in the hospital. This increase in hospitalizations has amplified the cost associated with falls. Stevens, Corso, Finkelstein, and Miller (2006) reported that, in 2000, direct medical costs resulting from falls amounted to slightly over $19 billion with a breakdown of $179 million for fatal falls and $19 billion for nonfatal fall injuries. The CDC has published a number of communications and encouraged many research initiatives regarding the implementation of programs to reduce the number of falls in the elderly population (CDC, 2010a). As the medical community starts to focus on fall prevention rather than consequences of falls, the importance of providing the elderly population with physical activities to curve the expenses of the problem becomes heightened. Essential to the evaluation of efficacy of such programs is the use of valid instrumentation to measure balance, an important component in determining risk of fall (Johnson Hilliard, Martinez, Janssen, Edwards, Mille, Zhang, & Rogers, 2008).

Aside from the elderly population, it has been reported that obesity could also be a factor in balance impairments (Xiang, Smith, Wilkins, Chen, Hostetler, & Stallones, 2005). Although the consequences included mostly nonfatal injuries, it was nevertheless an issue that deserved to be noted as the rate of obesity in the U.S. has been increasing steadily for the past two decades (CDC, 2011). Vartanian and Shaprow (2008) reported decreased involvement in physical activity in overweight children and adolescents as a result of weight stigma. The recommendation for creating less threatening exercise environments was mentioned. In this case, the ability to perform exercise in their own home, without peers or strangers around possibly reinforcing that weight stigma, could be construed as a possible venue for that population to achieve a minimal amount of exercise.

In both cases, the elderly or the excessive obese, the ability to remain in equilibrium has been compromised. The aptitude to control the movement of our own body and to perform the desired motions is an important concept. The decrease in the ability to safely and effectively move has been shown to be detrimental to the elderly population (Yumin, Simsek, Sertel, Ozturk, & Yumin, 2011). Thus, it appears to be critical to examine the concept of balance and the various ways it can be improved.

With the growing development of technology, companies have had to constantly find new ways to market their new products. As the economy changes and the buying power shifts to various age groups, the companies have been developing products that could serve several purposes, targeting a wide variety of consumers. As the *Generation Y* grows into adulthood and embraces technology at a higher rate than any previous

generation, the demand for technologically advanced games rather than traditional games has been growing as well. Additionally, the younger generation, denominated as *Generation Z* (also known as the internet generation), has become dependent on technology. Indeed electronic devices have been incorporated in every aspect of their lives. Jones, Jo, and Martin (2007) described the Generation Z as technologically savvy individuals who use the internet for research or school work, stay in touch through short message service (SMS), instant messaging, have dedicated computers for gaming, and generally prefer the internet to communicate rather than the phone. In an attempt to reach new markets, several companies have launched extensive research regarding the development of virtual reality games. The Wii Fit™ system developed by Nintendo managed to catch the attention of many by suggesting that you would be involved physically in the game rather than being passive. This new technology was especially appealing to the people who saw in it a possibility to curve the already alarming situation with obesity in the U.S. Such a game would allow an increased level of activity, most likely generated by the desire of the child, with little necessary supervision. As the technology expanded, other companies, such as Sony and its Kinect product, joined the movement. One feature that Nintendo has kept unique so far is the use of the "*balance board*", which is nothing less than a force plate with four sensors, as an integrated part of some games. Even though the range of available games is rather restricted, the popularity of the product was enhanced by the disturbing obesity situation in the U.S. Many people saw that piece of equipment as a potential quick fix. Natterson (2009), a pediatrician, advocated for the Wii as a substitute for outside activity when constraints such as bad

weather or lack of supervision are present. She went on to mention that her claims were based entirely on observation only and not on empirically derived research findings; consequently she mentioned not being aware of any existing studies that substantiated or disapproved her assertions.

As the piece of equipment was named “Balance Board”, several ideas started to emerge in some health care professionals as they were dealing with balance issues with particular populations; elderly were identified by the research as particularly at risk for decreased balance abilities. As a result, around the nation, some health care professionals started investigating the potentials of using this new piece of equipment as a rehabilitation aid. Across the country, signs such as “Wiihab” started appearing on advertising billboards. The Wii Fit™ has been used with various populations in an attempt to better their balance ability (Allen, 2009; McCain, 2010; Pluchino, 2010; Vuong, 2010).

Problems with range, flexibility and strength in the lower limbs (Ramsey, Miszko, & Horvat, 2004) and trunk, together with movement control impairments will impact speed, center of gravity (COG) position and control during the sit to stand task (Inkster & Eng, 2004). The loss of balance stability is a great concern in our society as it is related to the increase in falls, feeling of fear of falling, and reoccurrence of falls, as well as fear of immobilization (Bloem, van Vugt, & Beckley, 2001; Cumming, Salkeld, Thomas, & Szonyi, 2000; King & Tinetti, 1995; Stel, Smit, Pluijm, & Lips, 2003). The loss of stability is closely related to a diminished quality of life for some part of the population,

especially the elderly. Thus the ability to correctly, easily, and repeatedly assess balance capabilities could be construed as critical.

In an editorial, Ceravolo (2010) addressed significant questions about balance assessment; the article revolved around four core questions: who, when, why, and how should balance assessment be conducted. The author suggested that patients older than 65 years should be carefully screened regarding postural control by the physician and refereed to further testing if necessary. Ceravolo argued that the best approach is preventative measures and thus, assessments if necessary should be done on a routine basis and should not be invasive, difficult to administer, or costly. Even though it does not seem that a consensus has been reached on what should be the best way to assess posturography, there was a definite need to include active balance control in posturography assessment (Ceravolo, 2010).

Balance issues are critical in both elderly and overweight populations. The ability to assess balance aptitude in a regular and easy manner would provide professionals with important information to better serve those populations. The Wii Fit™ Balance Board is a portable, cheap, and entertaining device that could potentially serve that purpose.

The purpose of this study was to determine the criterion validity of selected games of the Nintendo Wii Fit™ system with the balance board as being used as an instrument to assess balance capabilities and limitations in the general population. Specifically, this study examined special balance features and two games for the Wii Fit™ and their relationship with a more established measure of balance assessment, the Balance Master®.

Problem Statement

The purpose of this study is to examine the criterion validity of selected Wii Fit™ games and activities based on to balance scores of an able-bodied person on the Basic Balance Master® piece of equipment.

Research Questions

Do selected Wii Fit™ games meet criterion validity as a valid measure of balance?

Which Wii Fit™ measurements or combination of measurements are the most appropriate in evaluating postural balance?

Definitions

Anteroposterior (AP): Refers to the sway or movement of the body from the front to back.

Balance: Refers to the ability to maintain the body's center of gravity over its base of support with minimal sway and maximal steadiness (Emery, 2003). For the purposes of this study, balance will be defined as the ability to maintain the body's COG over its base of support and to respond to external challenges and regain quiet stance with minimal sway and maximal steadiness and measured using the Balance Master. Balance is an important concept that often defines whether a person can live an independent life or not. Several intricate systems from the body have to properly perform to maximize a balance achievement. Musculoskeletal, movement control, and balance impairments are all factors which affect everyday movements such as gait. The accurate control of the Center of Pressure (COP) position in relation to the Center of Mass (COM) is important as it allows a controlled transfer and aids in the maintenance of postural stability.

Center of Gravity (COG): An imaginary point representing the balance point of an object. It represents the point around which the mass of an object is equally distributed.

Center of Mass (COM): Synonymous to Center of Gravity.

Center of Pressure (COP): The point around which the contact force with a support surface is equally divided.

Directional Control (DCL): A measure aimed at evaluating the quality of the movement and expressed as a percentage of movement toward the intended target versus the amount of extraneous movement. For this study, Directional Control will be measured using the Limits of Stability test on the Basic Balance Master®.

Equilibrium: The state of a system that is not under the influence of acceleration (Nigg et al., 2000).

Limits of Stability (LOS): Maximum distance that an individual can lean in a given direction without losing balance. It is measured as angular distance from the vertical axis.

Mediolateral (ML): Refers to the sway or movement of the body from one side to the other.

Mii: A virtual representation of the player in the Wii™ gaming system. The player can customize the Mii with various features.

Maximum Excursion (MXE): A measure aimed at evaluating the quality of the movement and expressed as the distance an individual can move their center of gravity as a percentage of the theoretical limit. For this study, Maximum Excursion will be measured using the Limits of Stability test on the Basic Balance Master®.

Postural stability: The visible arrangement of the body segments to maintain a position.

Posturography: The science of recordings changes in the body movement as a means to quantify postural sway.

Stability: The ability of an object to maintain equilibrium or resume its original, position after displacement.

Virtual Reality: A realistic simulation of an environment by a computer system using interactive software and hardware.

Assumptions

- The participants will be free of any underlying medical conditions that would affect balance at the time of the test.
- The vision of the participants will be sufficient as not to interfere with balance abilities.
- The Balance Master® is a valid and reliable instrument to assess balance.
- The participants will complete the tests to the best of their ability.

Limitations

- The study was limited to two games from the Wii Fit™.
- The study was limited to the examination of only three tests on the Balance Master®.
- The study was limited to the assumptions of the statistical tests used.

Significance of the Study

As the population continues to grow and live longer, an increasing number of people might encounter balance challenges and require additional health care. Many physical therapists and occupational therapists have sought to find more affordable and more easily administered methods to assess clients' balance abilities. The emergence of virtual reality games has prompted physical therapists and occupational therapists to attempt to incorporate them into their rehabilitation protocols. To date, the validity of those virtual reality tools has not been demonstrated. They have just been utilized as training instruments to facilitate improvement in balance. This study initiated the validation process of the Wii Fit™ system as a tool for continuous balance assessment.

CHAPTER II

REVIEW OF LITERATURE

Balance

Balance is defined as "the ability to maintain a position within the limits of stability or base of support" (Shumway-Cook & Horak, 1986) and the ability to respond to perturbations to keep the body's center of gravity over the base of support (Emery, 2003). Additionally, Winter (1995) defined balance in biomechanical terms as the maintenance of upright posture with minimal deviation from the center of gravity and vertical axis. The ability to maintain a position is critical to sustaining quality daily living. Many components are involved in the ability to control balance. The elderly and people with pathologies have been the primary populations affected by the degeneration of balance control (Winter, 1995). Sturnieks, St George, and Lord (2008) reported that balance impairments in elderly people often resulted in a deficiency in one or more of the following systems, sensory, motor, and/or central processing. The authors further identified key components affecting balance in the sensory and central processing systems: vision, vestibular sense, proprioception, and sensory integration (Sturnieks et al., 2008). Horak (1997) organized the postural stability in slightly different terms but they included the same components.

As a common occurrence, vision often begins to deteriorate after the age of 50 (Gitting & Fozard, 1986). This includes visual acuity, contrast sensitivity, glare

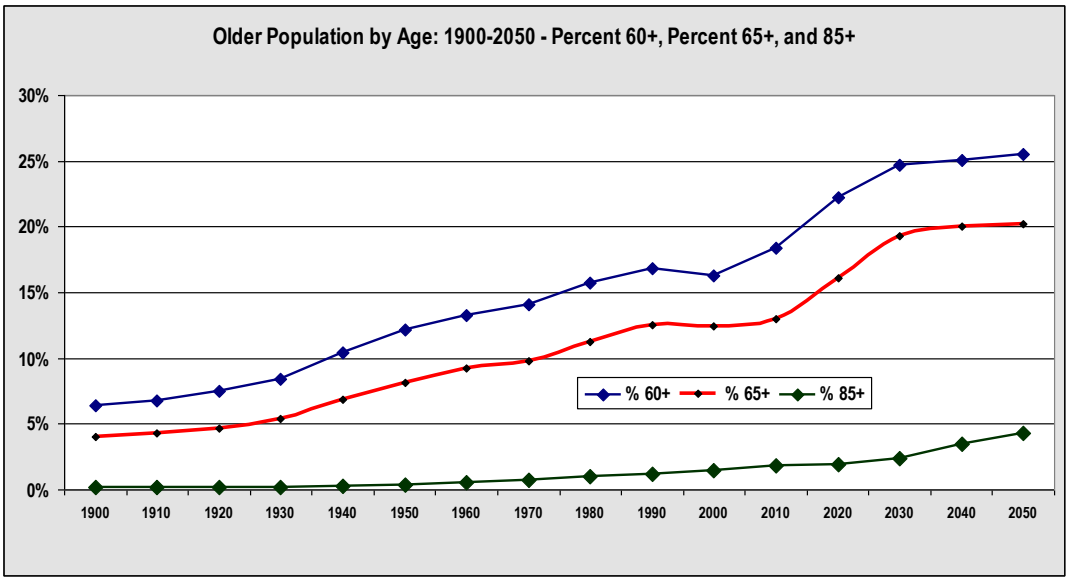
sensitivity, dark adaptation, and accommodation and depth perception. In addition to those normal age-related declines, elderly are more susceptible to develop eye-related pathologies such as cataracts and macular degeneration, as well as glaucoma. Furthermore, elderly who already have been suffering from diabetes and hypertension have a higher risk of developing pathologies associated with retinopathies. The American Diabetes Association (ADA) released its 2011 National Diabetes Fact Sheet indicating that 8% of the total population has been diagnosed with a form of diabetes, including more alarming numbers such as 11.3% for people age 20 and older, and 26.9% in the 65 and older age category. Visual aptitudes have a direct effect on the ability to interpret spatial information such as obstacle clearance and balance control (Lord, 2001).

Impairments in balance were often the expression of underlying causes that affect the biomechanical, motor coordination, and sensory organizations of the individual (Horak, 1997). In each of those categories, subcomponents can be identified and evaluated with specific tests. Horak gave the example of an individual compensating for weakness in ankle strength by adopting a strategy that required excessive movements at the hip and trunk to maintain postural equilibrium. The above case illustrated the importance of appropriate interpretation of the results.

The movements of the head are detected by the vestibular system to contribute to the postural control (Sturnieks et al., 2008). It appeared that degeneration of that system occurs naturally as a function of age although additional pathologies such as migraine, cerebellar ataxia, direct trauma, and some autoimmune diseases can increase the system's impairment (Sturnieks et al., 2008).

Motor systems that affect balance are mainly strength and reaction time. As muscle mass decreases with age, the ability to maintain balance and adapt to the environment could be compromised (Lexell, Taylor, & Sjostrom, 1988). Significant deficiencies in lower limb strength have been associated with poor performance on balance tests (Lord, Clark, & Webster, 1991). Reaction time increased by 25% between the age of 20 and 60 on average (Fozard, Vercryssen, Reynolds, Hancock, & Quilter, 1994). This increase was more pronounced when the person needed to perform cognitive tasks or more demanding movement such as stepping.

As the elderly population is growing at a rapid rate, as illustrated in Figure 1, the necessity to find inexpensive and efficient ways to assess balance has become urgent.



[1]*Figure 1*: Projected elderly population in the USA

[1] Projections for 2010 through 2050 by Department of Health and Human Services. Administration on aging. Projected future growth of older population: by age: 1900-2050: older population as a percentage of the total population (May 2011).

Assessments of Balance

An assessment is defined as quantifying a variable or placing a value on something (Guide to Physical Therapist Practice, 2001). The quantification of balance abilities is critical for populations in which a deficit in such abilities could result in loss of individual freedom.

An impressive number of tools have been developed to assess balance abilities. Most of those instruments, however, have been designed for research purposes and are not necessarily practical for general use with clinical populations. It does not appear that there is a consensus on what instrument or tool is consistently used by health care professionals. Many variations could be due to the great diversity in time, monetary funds, and/or expertise of the professionals (Grimmer, Bialocerkowski, & Kumar, 2004).

Instruments

Several tests are currently being used in assessing balance in a health care setting. Additionally there are several approaches to balance assessment, including a functional approach, systems approach, or quantitative posturography.

In the functional approach, tests usually rate the performance of the patient or client using a three to five point scale or a stopwatch to time the ability of the individual to maintain a determined position. The individual is challenged by performing tasks to explore their limits of stability or in response to a destabilizing force (Tyson & Connell, 2009). One of the most commonly used functional assessment tools is the Performance-Oriented Assessment of Mobility by Tinnetti (1986). The Tinnetti test has excellent inter-rater reliability (85%) and good sensitivity (93%) as reported in Topper, Maki, and

Holliday (1993). Another popular balance assessment is the Berg Balance test which consists of 14 tasks evaluated on a five-point scale. This test is designed to increase the difficulty of the tasks by reducing the size of the base of support and to evaluate the time it takes for the individual to complete the tasks. The Berg Balance test, as the Tinnetti test, shows high inter-rater reliability (98%) but has poor sensitivity (53% of prediction accuracy) as reported in Horak (1997). The Berg Balance test does not correlate well with platform-based sway exercises (r = .55) or with exercises in response to perturbations (r =.38) (Bogel, Thorbahn, & Newton, 1996).

Tyson and Connell (2009) categorized functional performance tests into 3 types: timed tests, reaching, and stepping tests. The authors included tests which last between 15 to 60 s and required the individual to maintain positions with various stances, whether it is two feet, in tandem, on one foot, adding to that eyes closed or open (Tyson & Connell, 2009). The reaching tests included the sitting arm raise, standing arm raise, and standing forward reach test as examples (Tyson & Connell, 2009). The Stepping task tests included stepping on and off a block, the tap test, and the weight shift in tandem stance (Tyson & Connell, 2009). The Functional Reach test has been a common test used by physical therapists to assess dynamic balance. However, Wernick-Robinson, Krebs, and Giorgetti (1999) concluded that the Functional Reach test did not assess dynamic balance.

The most common tests used in research for balance assessment for elderly populations in physical therapy seemed to be the Berg Balance Scale (BBS) and the Time up and Go (TUG) as reported by Langley and Mackintosh (2007). Both tests were

reported to be valid, reliable and practical. Two other assessments met the same criteria, the Balance Screening Tool (BST) and the Fullerton Advanced Balance Scale (FAB). The BST is a newly developed assessment that requires less time than the BBS for administration. It is shown to have excellent intra-rater reliability (r = .89) as well as inter-rater reliability (r = .89) as reported in Mackintosh, Datson, and Fryer (2006). A low score in the BST test indicates a good balance performance while a high score in the BBS test indicates a high balance performance. The criterion validity was also demonstrated to be excellent (r = -.92, Mackintosh et al., 2006). The FAB assessment does not require as much time as the BBS for evaluation but does require more equipment. It is a reliable test (r = .93 to .99) and has good concurrent validity (r = .75) with the BBS (Rose, Lucchese, & Wiersma, 2006). Further research is needed for both tests (Langley & Mackintosh, 2007).

Decision Making

The clinician's choice of an assessment instrument or tool is a critical decision and depends on a variety of factors. It is especially important for therapists who base the development of a plan of care on the results of such observations. The American Physical Therapy Association (APTA) has identified the Evidence-based practice (EBP) as a key component to deliver appropriate services to patients or clients (American Physical Therapy Association, 2011). Appropriate test choice is one of the elements of EBP. The reliability and validity of the chosen instrument should match the client's need and condition. According to McGinnis, Hack, Nixon-Cave, and Michlovitz (2009), the determination of the chosen assessment depends on five components: "the therapist

knowledge (Jones, 1992), the patient factors, potential constraints, the therapists' intended use of the data, and the available options for assessment of potential balance deficits" (p. 234). The decision model developed by McGinnis, Hack, Nixon-Cave, & Michlovitz (2009) is illustrated in Figure 2.

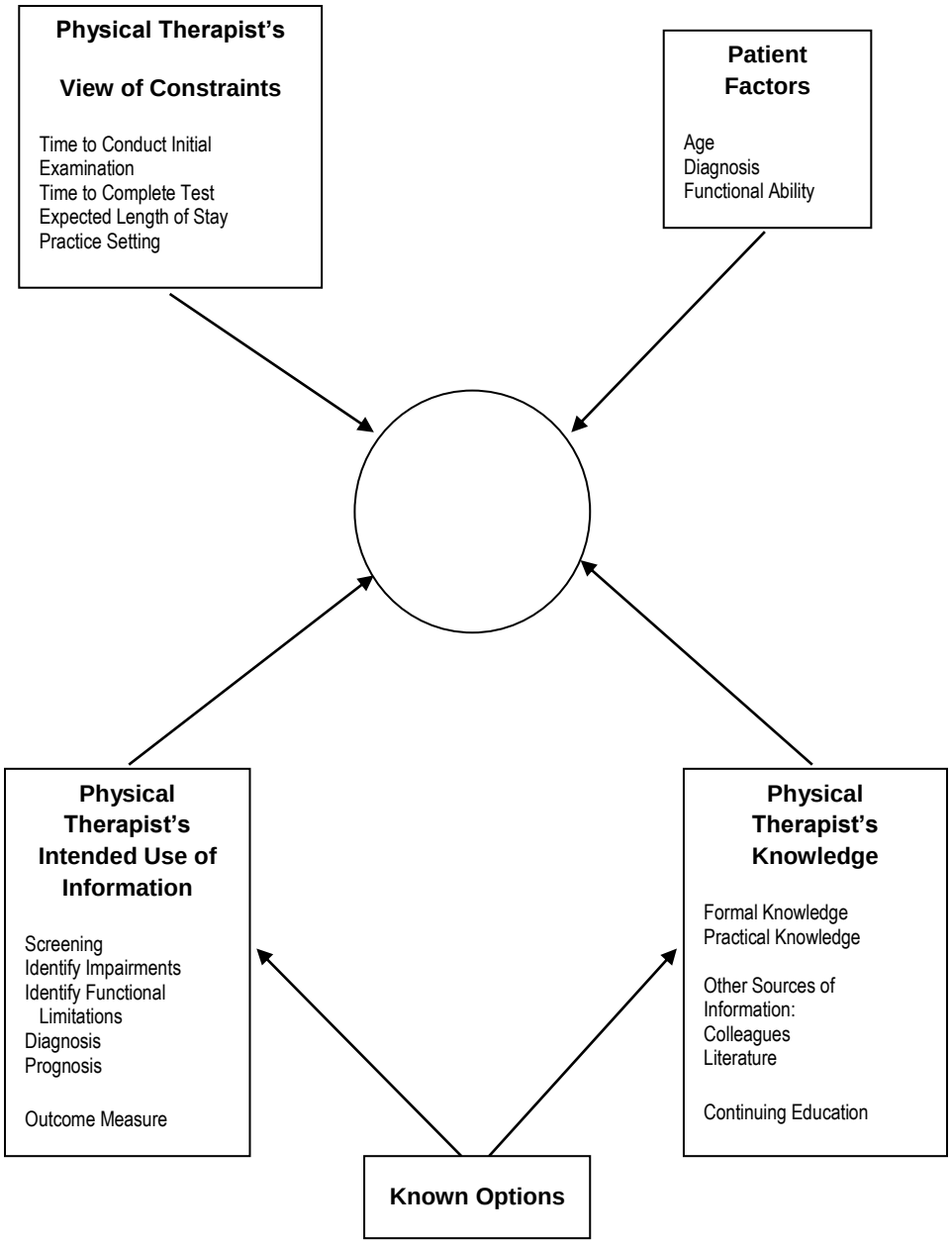


Figure 2: Decision model. by McGinnis, Hack, Nixon-Cave, & Michlovitz (2009)

Jones (1992) emphasizes the importance of knowledge as the therapist would proceed to the physical examination of the patient. The initial subjective examination should be supplemented with more specific tests to attain a sound diagnostic (Jones, 1992). The diagnostic would then lead to a plan of treatment and alterations in the treatment would be envisioned in case of insufficient progress in the patient's recovery. The reexamination of the data collected and possibly the recollection of the data using a different instrument would then be discussed. VanSwearingen and Brach (2001), as part of their practicality model, addressed the necessity for the therapist to be knowledgeable of proper test administration practices. The authors acknowledged that certain assessments such as the Functional Reach Test, the Time Up and Go (TUG), the gait speed, and the chair rise time do not require as much expertise to complete an accurate evaluation of balance. Others, such as the Berg Balance Scale and the Modified Gait Abnormality Rating Scale (GARS-M), require more expertise in interpreting the performances and thus, making appropriate judgments relative to clinical standards (VanSwearingen & Brach, 2001). Thus the knowledge of the therapist would be an essential element for the determination of the proper tests to be administered.

Jette, Grover, & Keck (2003) discuss the elements from the patient factors that influence the therapist's clinical reasoning to reach a decision on whether or not to discharge a patient. The decision model developed by Jette, Grover, & Keck (2003) is illustrated in Figure 1. The therapist makes a decision after collecting data and analyzing it to create an overall picture of the problem. It is suggested that the more experienced the therapist, the more accurate the diagnosis especially with regard to length of treatment

(Jette et al., 2003). It is also noted that more experienced therapists tended to be more confident about their evaluation than younger, less experienced therapists. This seemed to be due to the ability to recall past experiences and draw some similarities in the situation (Jette et al., 2003). Physical therapists and occupational therapists used a similar decision making process with regard to balance assessment (Jette et al., 2003).

The third critical component necessary for optimal choice of an assessment tool was attending to potential constraints (McGinnis et al., 2009). Jette et al. (2003) indicated that time was one of the constraints. VanSwearingen and Brach (2001) identified time as part of a broader element, practicality, when deciding on an assessment. The initial ability of the patient or client should be taken into consideration in order to maximize the utility of the results. A test that would be too long could create fatigue in some patients resulting in inaccurate results and evaluation (VanSwearingen & Brach, 2001). The authors suggest that clinicians attend to practicality when choosing an assessment protocol (VanSwearingen & Brach, 2001). Practicality is divided into seven components as follows: (1) the time needed to administer the test, (2) the experience needed by the person administering the test (eg, professional or technical), (3) whether administering the test requires prior experience or formal training, (4) the equipment needed, (5) the format of the test (self-report or performance-based), (6) the method of scoring (eg, manually or computer-assisted), and (7) the format of the resulting measurements (VanSwearingen & Brach, 2001). It is sometimes necessary to have specific training and experience to achieve an acceptable level of accuracy in collecting the measurement. VanSwearingen and Brach (2001) suggest that the Berg Balance Test

and the GARS-M would be good examples of the necessity for the administrator of the test to be trained to increase the rater reliability and validity. In contrast, the authors specified that the seated step tests did not require additional expertise or training other than the ability to record vital signs (VanSwearingen & Brach, 2001). Constraints directly related to the pieces of equipment were also addressed (VanSwearingen & Brach, 2001). The cost of equipment can range from a few dollars to several hundred thousands of dollars. In addition, the time required to install the equipment and train the personnel on novel equipment could be significant. The availability of space was also a concern when determining which assessment to use. VanSwearingen and Brach (2001) added the growing need for portable equipment to better serve some populations, especially in rural areas, free-standing outpatient clinics, or when providing home care. Ideally, the use of portable equipment should not result in less accurate measures. The concept of "format of the test" mentioned by VanSwearingen and Brach (2001) includes two major categories, Performance-based or Self-Report.

Guralnik, Branch, Cummings, and Curb (1989) discussed the advantages and disadvantages of performance-based and self-reported measures for elderly populations. A major disadvantage of the performance-based measurements was that the environment in which it was collected often did not mimic the abilities of the person in their home environment or in daily activities. Self-reported measures although often perceived as a better reflection of daily activities, have been identified as a person's usual opinion of their ability to perform the assessed tasks rather than an objective assessment (Kane & Kane, 1981; Tager, Swanson, & Satariano, 1998). Reuben, Valle, Hays, and Siu (1995)

reported that self-report measurements were correlated to performance-based measurements for elderly populations and that both sets of information were complementary. The additional details that each set would provide allowed a better analysis of cases and, in the event that no staff was available to direct a performance-based test, self-reported data was critical in the evaluation of the case.

The concept of "methods of scoring" mentioned by VanSwearingen and Brach (2001) aligned with an important theme identified by McGinnis et al. (2009). In a time where accountability has been increasingly expected and where professionals have been constantly threatened by lawsuits, the necessity for accurate and clear documentation of the assessments has been recognized as an essential component of competent practice. The presence of quantitative data assisted in redefining specific treatment plans and outcomes (McGinnis et al., 2009). However McGinnis et al. (2009) reported that some therapists indicated that some of those data were not essential to the treatment but rather to documentation.

> But honestly, a lot of this stuff is necessary for paperwork purposes and not so much for my treatment. I could treat this guy perfectly fine without doing any Berg balance assessment, but then later I have nothing objectively to compare it back to (McGinnis et al., 2009, p.238).

VanSwearingen and Brach (2001) also argued that although many tests have reports that contained single composite scores, it was often more useful to analyze the subscales. As McGinnis et al. (2009) reported in their study, standardized balance tests that were recommended in the literature were widely used by physical therapists.

In conclusion, the decision making process contained several components which were varying tremendously between settings and individuals. Although the main components remain common to physical therapists, and occupational therapists, the choice of various assessment tools to use would depend on the participant's ability, desired outcomes, equipment availability and therapist's training among other factors.

Introduction on Wii

Sales and Availability on the Market

According to Ascraft (2009), the total number of sold consoles for Wii Fit™ surged to 3.6 million units during the period April – June 2009 which brought the total number of units sold to 21.82 million since its introduction to the market in 2006. The total number of units sold in America is reported at 32 million for the entire 2009 year (CVG, 2010). In addition, the report of the Wii Sports sales recorded, in the same period, 1.91 million copies of the software which brought the total number of copies sold since its creation to 47.62 million (Ashcraft, 2009). The same reports for the year 2008, considering the exact same time period indicate Wii Fit™ sales at 3.42 million units and Wii Sports sales at 4.76 million copies. These numbers clearly show the interest for the Wii Fit™ video games. In 2010, CVG (2010) reports that Wii Fit™ Plus, the upgraded software for the Wii Fit™ had recorded 10.16 million copies sold; that number is truly remarkable as the software had only been on the market for a few months.

As the number of Wii Fit™ units making their way into the public's homes is drastically increasing, mainly for the purpose of entertainment, it is only natural that its popularity may attract other uses. Rauscher (2008), in an interview with a professor of

athletic training, presented the case for the use of the Wii Fit™ as a rehabilitation device for postoperative patients. As the professor emphasized the difficulty in rehabilitation often relying in the "tedious and repetitive" nature of the exercises, she professed that the entertainment value of the video games may help change the perception of rehabilitation and may even improve the outcomes. She also stressed the potential use in assisted living facilities for improvement of fitness and range of motion. All these encouragements for introduction of the Wii Fit™ into new environments were followed by a warning that improper supervision of those activities may result in injuries and that other forms of physical activity remain a necessity. Occupational and physical therapy clinics have started to incorporate the Wii Fit™ as an alternative means of rehabilitation (Wadsley, 2009). The primary reason seems to be the enjoyable nature of the game, once again contrasting with the monotonous nature of the task to rehabilitate. As Wadsley (2009) mentions, the research supporting the numerous anecdotes is rather slim. One of the reasons to increase the body of research regarding the effects of the Wii Fit™ video games on health would be its recognition at an administrative level which could possibly lead to the classification of such costs as medical expenses.

Reliability and Validity of the Wii Fit™

The reliability and validity of the Wii Fit™ Balance Board has been assessed by Clark et al. (2010). They compared the data of an AMTI force plate to the retrieved data of the Wii Fit™ Balance Board. The population tested was injury free and did not report any pathology. It contrasted with the majority of earlier research studies which had involved populations with specific limitations. Thirty participants of both genders were

asked to perform 4 different tasks; the first task was quiet standing on both legs eyes open, the second task was quiet standing on both legs eyes closed, then quiet standing on the dominant leg eyes open, and finally quiet standing on the dominant leg eyes closed. The team repeated the experiment 24 hr later for all data set but it is interesting to notice that as they encountered difficulties with the completion of three successful trials in the single dominant leg eyes closed condition the first day, only data from the second day are included in the analysis. The variable measure was the center of pressure path length in each condition. The test-retest statistical analysis was performed. All ICC values exceeded the pre-determined value of .75 except for the double-limb standing with eyes open which generated an ICC = .66. This result is not excellent but still very acceptable. The use of the Bland-Altman plots for the COP showed a small difference in the COP path length values between the force plate and the Wii balance board, with the balance board reporting slightly higher means. However, the authors reported that the differences were consistent between the various testing sessions and thus would not likely affect measurements to compare patients on the same device. Clark et al. (2010) speculated that the differences may be due to factors that would be difficult to control such as the sensitivity of the sensors or the variability in surface texture. The authors also measured concurrent validity and reported excellent values across testing sessions and balance tasks (ICC = .77 to .89). The minimum detectable change (MDC) values showed better results than the force plate data in all conditions except the single limb eye closed (MDC range for force plate = 14.5 - 34.7%; MDC range for Wii = 24.5 – 29.4%). The authors concluded that the Wii balance board is a valid tool for assessing standing balance. As a

limitation, the authors acknowledged that the necessity to create a computer program to retrieve the data from the Wii balance board is not a skill most clinicians possess. The authors were positive though about the potential of the Wii balance board to provide additional, less noticeable information regarding balance, not always available in subjective visual testing, that could further improve evidence-based clinical practice.

Research Integrating the Wii Fit™

Allen (2009) investigated the effects of a Wii Fit™ exercise program on balance in a female elderly population. The author used five games, the Balance Bubble, Ski Slalom, Table Tilt, Hula Hooping, and the Tightrope walk as a training device. The Berg Balance test was used in a pre-post design to assess the progress of the three participants of the study. The Balance Berg scores did not significantly increase over the 8-week period of training. Allen (2009) used a paired sample t-test to analyze the Balance Berg scores and reported no significant differences. The author observed a significant improvement in the Wii Fit™ age (p = .012). However that improvement in the Wii Fit™ age (mean change = - 38.75%) appears to be more than the improvement in the Berg Balance test (mean change = 4.175%). The variability of the components that determined the Wii Fit™ age data was not controlled or reported. Allen (2009) concluded that the Wii Fit™ did not appear to be an adequate measure for determining balance improvements. As an additional challenge, one of the participants was not able to complete the study leaving only two participants. It appears that the significance of Allen's study remained questionable as a result of such a small sample size and attrition. Furthermore, the author did not appear to fully control the determinants of one of his

major variables (Wii Fit™ age) as the various components that determined that variables were not reported. Allen (2009) noted that the participants seemed to have enjoyed their participation in the study. One participant expressed an interest in acquiring a Wii Fit™ for personal use.

McCain (2010) evaluated the effectiveness of the Wii Fit™ as part of pediatric rehabilitation services. The author used a pre-post design with the Bruininks-Oseretsky Test of Motor Proficiency 2nd Ed. (BOT-2) to assess the changes in fine and gross motor skills. The study did not show any significant differences between the experimental and the control groups in the BOT-2 overall score (McCain, 2010). A closer examination of the scores revealed an increase in fine manual control, agility, and strength for all participants. The detailed data were not reported, only figures using the 90% confidence interval to report significant skill gains. As with the previous study, McCain (2010) noted that the participants enjoyed the use of the games as part of their program. In her conclusion, the author stated that incorporating virtual reality games into rehabilitation programs may have some potential although additional research would be needed to strengthen the Evidence –Based Practice argument (McCain, 2010). Similarly to Allen's study (2009), the small sample size (n = 4) puts in question the significance of the study.

In a case study, Brown, Sugarman, and Burstin (2009) reported an increased enjoyment in participation in rehabilitation exercises as well as an increase in functional balance assessment scores. The outcome measures used to evaluate included the Berg Balance test, the Functional Reach and Lateral Reach tests, the Timed Up and Go test, and a Computerized Posturography test (Brown et al., 2009). In addition to those

functional tests, the authors used a Short Feedback Questionnaire to assess the feeling of enjoyment derived from the game usage. The comments stated a perception that the treatment was "up-to-date" (Brown et al., 2009, p.S110). It needed to be noted that the patient benefited from concurrent standard physical therapy exercises along with Wii Fit™ training; this might have skewed some of the results as the increase in functional balance scores may partially due to the standard rehabilitation practices (Brown et al., 2009).

Pigford and Andrews (2010) conducted a clinical study involving an elderly patient with a history of falls. The case study examined the effect of a 2-week program using the Wii Fit™ platform as a training device along with standard therapeutic rehabilitation treatment on dynamic balance. The design was a pre-post test with an intervention. The selected outcome measures were collected using the Berg Balance Scale, the Time Up and Go, Gait speed, and the Activities-specific Balance Confidence Scale (Pigford & Andrews, 2010). The patient participated in five 60-min rehabilitation sessions for 2 weeks. The amount of time spent on the Wii Fit™ platform varied from 15 to 25 min during each session. The selected games for the Wii were the Ski Slalom, the Table Tilt, and Deep Breathing which is part of Yoga. The Table Tilt game is not typically part of the initial package but was made available for this study prior to reaching the level of mastery normally required. The rest of the time was dedicated to a more traditional approach of therapy. The author reported that all outcome measures indicated positive improvements in balance. The Berg Balance Test score almost doubled, going from 13/56 in the preintervention assessment to 25/56 in the

postintervention assessment. The Time Up and Go test score decreased by approximately 24%, albeit remaining in the at risk category by more than 30 s (Pigford & Andrews, 2010). The Gait speed score progressed by approximately 62%, increasing the speed from 0.24 to 0.39 m/s. Although the improvements recorded in the Berg Balance Test and the Time Up and Go test were significant, the patient remained in the at-risk of fall category. The other two tests reported improvements but the author determined that those improvements did not meet the "Minimal Detectable Change" (MDC) criteria. Pigford and Andrews (2010) also noted that the patient reported increased satisfaction and had increased his participation in the exercises resulting in an increased amount of time spent on the Wii Fit™.

The report in increased satisfaction was similar to other studies involving virtual reality or gaming experiences (Allen, 2009; Brown et al., 2009; McCain, 2010; Reid & Hirji, 2003). It was reported that the patient, 6 weeks following the end of the intervention, did not experience any falls and had retained independence and benefits from the program while ambulating in an indoor environment. Pigford and Andrews (2010) identified a number of advantages in utilizing a piece of equipment such as the Wii Fit™ console, including the presence of visual biofeedback which seemed to enhance the goal-oriented center of pressure shifts. Furthermore, each recorded score provided increased motivation to better one's performance. The author also identified the cost as an advantage citing that some balance assessment equipment could cost up to $100,000 compared to a mere $100 for a Wii™ console. The portability and ease of use of the equipment completed the array of advantages (Pigford & Andrews, 2010). As an

additional possibility for increasing the levels of difficulty, Pigford and Andrews (2010) suggested surface modifications applied to the Wii Fit™ platform, such as various densities or heights.

Bainbridge, Bevans, Keeley, and Oriel (2011) explored the effects of the Nintendo Wii Fit™ on community-dwelling older adults with perceived balance deficits. Using a pre-post test design, eight participants (M_{age} = 75 ± 9.7 years) were asked to participate in a 6-week long study, meeting 30 min twice a week to perform some Wii Fit™ games (Bainbridge et al., 2011). Each session included yoga games as warm-up and cool-down, and balance games such as soccer heading, ski slalom, ski jump, tightrope walk, penguin slide, and table tilt. Each game was timed for exactly 5 min. The authors use four outcomes to measure balance, confidence, and limits of stability (Bainbridge et al., 2011). The assessment included the Berg Balance Test (BBS), the Activities-Specific Balance Confidence Scale (ABC), the Multi-Directional Reach Test (MDRT), and the center of pressure (COP) excursion measurements. None of the findings were statistically significant (Bainbridge et al., 2011). The improvements in balance (4 out of 6 participants) in the BBS were not sufficient to generate statistical significance when compared to the minimum detectable change score (MDC). According to the graphical representation of the results, the BBS mean scores improved from approximately 56 to 58 pts. The change in scores (CS) for the BBS should be greater than 5 pts to be significant. Although 3 of 6 of the participants improved in balance in the ABC assessment, the results were not statistically significant (CS < 18%). According to the graphical representation of the results, the ABC means decreased by approximately

15%. The MDRT test was decomposed into 4 directional components. Forward bending (FB), backward bending (BB), right sidebending (RB), and left sidebending (LB) did not generate any significant differences between the pretest and the posttest. The authors did not report the data but a graphical representation was included. MDRT FB appeared to remain constant around a mean of 10 cm ($CS_{FB} < 9$ cm). Backward bending, RB, and LB decreased slightly but remained around 5, 6, and 8 cm respectively ($CS_{BB} < 7$ cm; no minimal detectable change scores established for the sidebending tests). None of the participants reached the minimal detectable change scores (MDC) established in the literature. The COP excursion assessment did not show any statistically significant differences between the pretest and the posttest remaining around 8 cm. Bainbridge et al. (2011) reported that their findings were consistent with several case studies where some improvement was noticed but the amplitude of the improvement was not necessarily sufficient to generate statistical significance (Bainbridge et al., 2011). The authors further inquired about the movement strategy utilized by the participants and noticed the extensive use of the hip strategy compared to the ankle strategy to perform the tasks. The authors are hypothesizing that a lack of ability to use the ankle strategy, due to decreased ankle range of motion, may have affected the participants in successfully performing at the Wii Fit™ games (Bainbridge et al., 2011). The study was limited by its small sample with 2 participants withdrawing from the study (n = 8) and the lack of sufficient representation of both genders ($n_{male} = 1$ & $n_{female} = 7$). In addition, the absence of a control group made it difficult to isolate the effect of the Wii Fit™ intervention (Bainbridge et al., 2011). Although the Wii Fit™ games appeared to be an effective tool

for reducing balance deficits in elderly, further research is necessary (Bainbridge et al., 2011).

Brumels, Blasius, Cortright, Oumedian, and Solberg (2008) investigated the efficacy of two video games integrated into a balance program compared to a traditional approach. The authors used randomly assigned groups, one control group and three experimental groups; the first group (Dyna) was prescribed a traditional approach to balance training using DynaDisc®, with eyes open and with eyes closed. The second group used Dance Dance Revolution (DDR) and incorporated activities performed on a single leg in all directions (anterior, posterior, medial, and lateral). The third group used the Wii Fit™ by Nintendo. Using the balance board, the participants were instructed to play the Ski Slalom, the Table Tilt, and the Balance Bubble games. The participants were required to move in all directions (anterior, posterior, medial, and lateral) to be successful. Each session, for all groups, consisted of 12 to 15 min, 3 days a week for a period of 4 weeks. All training sessions were supervised by a research team member. Brumels et al (2008) collected a qualitative questionnaire pertaining to the difficulty of the program, the engagement of the participant, and the enjoyment. In addition to the qualitative questionnaire, the participants were tested using a pre-post design with the Star Excursion Balance Test (SEBT) and a single leg balancing exercise on a force plate (AMTI AccuSway^{PLUS} Balance Platform). The Wii Fit™ group generated significant improvement in the average deviation of their center of pressure from the centroid y axis of their base of support for the pre-post test (p = .043, Brumels et al., 2008). The DDR group improved its average deviation as well (p = .031) and the Dyna group improved in

the medial direction (p = .004) and the lateral direction (p = .027). All improvements were noticed while the participants were in the eyes open condition (Brumels et al., 2008). Significant differences were noted regarding the average deviation of their center of pressure from the centroid y axis of their base of support. The DDR and the Wii Fit™ groups demonstrated significant improvement over the Dyna group (p = .014 and p = .028 respectively). The qualitative analysis reported significant differences between the groups on difficulty (p = .016) and enjoyment (p = .003). The perceived level of difficulty was not significantly different between the DDR and the Wii Fit™. The Wii Fit™ program was perceived to be "not very" to "mildly difficult" compared to the traditional approach (p = .014). The participants seemed to enjoy the programs that incorporated the video games more than the traditional approach (DDR, p = .007, Wii Fit™, p = .006). The level of engagement did not show any significant differences between the 3 experimental groups (Brumels et al., 2008). The authors noted that only the video game training resulted in the reduction of the postural sway in the sagittal plane (Brumels et al., 2008). In addition to the similar improvements to the traditional training method, the video games demonstrated a much higher level of enjoyment (Dyna, M = 2.1 ± 1.4, DDR, M = 4.1 ± .6, Wii Fit™, M = 4.4 ± .5). The authors recommended the integration of video games based training programs as it appears to generate more enjoyment and are perceived as being easier (Brumels et al., 2008). The authors do caution that there was no evidence as to whether the video game based exercise were actually easier (Brumels et al., 2008).

Williams, Soiza, Jenkinson, and Stewart (2010) investigated the effect of a Wii Fit™ program (M_{age} = 76.8 ± 5.2 years, n = 15) for elderly community dwelling fallers compared to a traditional exercise combined with education program (M_{age} = 76.5 ± 4.8, n = 6) during a 12-week period. All sessions were supervised. The study included three assessments at Weeks 0, 4, and 12 using the Berg Balance Scale (BBS), the Tinetti Balance Assessment Tool, and the Falls Efficacy Scale (FES-I). In addition to the psychomotor tests, the participants were asked to complete the Attitude to Falls-Related Intervention Scale (AFRIS) to evaluate the degree of positivity toward the intervention (Williams et al., 2010). The AFRIS score did not show any significant differences between the 2 groups. This led the investigators to conclude that both groups, at the completion of the study, had a positive attitude towards the efficacy of the program (Williams et al., 2010). The authors reported that 92% of the participants communicated a strong desire to engage in the Wii Fit™ program in the future and when asked their preference, 61% decided on the Wii Fit™ while only 8% chose the traditional program. The FES-I scores of the intervention group did not increase significantly between the baseline and the completion of the study (p = .6) while significant for the standard group (p = .09, Williams et al., 2010). The Wii Fit™ age was recorded at Weeks 0 and 12 and significantly decreased (p = .03). The mean of the Wii Fit™ age baseline was 72.2 years at Week 0 and decreased to 57.3 years at Week 12. Williams et al. (2010) warn that the standard group appeared to be frailer than the intervention group with significant differences in weight (p = .03), number of co-morbidities (p = .01), and abbreviated mental test (p = .04) thus possibly affecting their ability to perform the activities. In

addition, the high level of dropout rate in the standard group, going from 6 to 4 participants, may affect the comparison between the groups (Williams et al., 2010). As a conclusion, the authors supported the acceptability of the Wii Fit™ addition to a falls intervention program for a community dwelling elderly population (Williams et al., 2010).

Nitz, Kuys, Isles, and Fu (2010) examined the feasibility of Wii Fit™ in improving balance, strength, flexibility and fitness for healthy women aged between 30 and 60 years. Ten women were recruited to participate to a 10-week intervention program where the participants exercised twice a week for 30 min (Nitz et al., 2010). The intervention program consisted of yoga, balance, aerobic and strength options from the Wii Fit™. The participants were encouraged to improve their performance and challenge themselves at increasing levels of difficulty (Nitz et al., 2010). A pre-post test design included assessments using the 6-min walk, the Time Up and Go (TUG), timed Up & Go cognitive (TUGcog), and the step test (ST right and left). Balance assessment was performed using the modified Clinical Test for Sensory Integration of Balance (mCTSIB) using the item (foam, eyes-closed), unilateral stance, eyes-open (right and left) and the limits of stability (LOS) programs of the Basic Balance Master™ (Nitz et al., 2010). The authors reported improvements in unilateral stance for both limbs ($p < .05$) as well as lower limb strength ($p < .02$). The unilateral stance stability values, with eyes open decreased by 14.1% for the right limb and 17.7% for the left limb. The lower limb strength is composed of quadriceps, hip abductors and hip adductors strength measurements. For all measurements, both limbs were tested and the quadriceps strength

increased on average by 18.3%, the hip abductors by 41.8%, and the hip adductors by 28.4%. The authors concluded that, following the Wii Fit™ intervention, balance and strength abilities have significantly improved and reaction time and flexibility did not result in significant improvement although showing positive trends (Nitz et al., 2010). The authors expressed concerns that the power of the study was insufficient due to a small number of participants (10 versus 61 participants required), an insufficient number of training sessions, and the short duration of the sessions (Nitz et al., 2010).

Williams, Doherty, Bender, Mattox, and Tibbs (2011) examined the effect of the Nintendo Wii on balance in an occupational therapy setting for the well elderly. Twenty-two participants (M_{age} = 83.86 ± 5.47 years) volunteered to participate to a 4-week program with three 20-min sessions per week of balance and aerobic games with the Wii Fit™. The authors followed a pre-posttest design using the Berg Balance Scale (BBS). The results showed a significant improvement in balance (M = 25.03% of improvement). Williams et al. (2011) noted that the results of this study are consistent with similar studies where the Wii Fit™ was used as an instrument to improve balance. In addition to improvement in balance, the authors noted that the participants reported having enjoyed the activity (Williams et al., 2011). Two of the participants even went as far as buying their own Wii Fit™ to pursue their routine at home. As limitations, the authors identified the use of a reduced sample of convenience as well as the absence of a control group to make the study truly experimental. Williams et al. (2011) also noted the possibility of rater bias as the study was not a blind design. In summary, the authors were positive

about the potential use of the Wii Fit™ balance board as a therapeutic agent in occupational therapy settings (Williams et al., 2011).

Bell et al. (2011) investigated the effects of the Nintendo Wii on quality of life, social relationships, and confidence to prevent falls in an elderly population from assisted living facilities. Twenty-one participants were randomly assigned to 3 groups; the 1st group received fall education as well as participated in Nintendo Bowling game, the 2nd group only played the Wii Bowling game, and the 3rd group was the control group (Bell et al., 2011). The intervention consisted of an 8-week program. The number of sessions per week was not disclosed by the authors. A pre-posttest design allowed the authors to collect information using the Control, Autonomy, Self-Realization, Pleasure-19 (CASP-19) assessment, the Social Provisions Scale (SPA), and the Modified Falls Efficacy Scale (M-FES, Bell et al., 2011). The authors additionally conducted qualitative observations where they recorded verbal and nonverbal actions of the participants during the sessions. The authors noted that the participants came early to their appointment and were eager to start their session while it was common for the staff to have to "corral" the residents to participate in other activities (Bell et al., 2011). The authors noted some quotes from the participants who stated that "'the activity' was fun, 'they' would not mind having one of those at home" (Bell et al., 2011, p. 218).

Basic Balance Master®

The Neurocom system, Computerized Dynamic Posturography (CDP), has been shown to comply with the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) and the American Academy of Neurology (AAN) and has been

established as a valid method to evaluate postural and balance control (Roller, Boismier, & Krzak, 2009). It received its FDA clearance in 1986.

The Limits of Stability test (LOS) is one assessment available in the Basic Balance Master. The reliability of the LOS measures has been examined with various populations. Geldhof et al. (2006) recorded the LOS reliability (Intraclass correlation coefficient [ICC] = .81) of the Balance Master measurements for pediatrics (9-10 years old children). Hageman, Leibowitz, and Blanke (1995) have examined normal adults and their study recorded the limit of stability directional control (BMLOSdc) intraclass reliability (ICC) of .83. The 12 participants were tested twice 1 week apart. For the same variable (BMLOSdc), Tsang and Hui-Chan (2003) recorded a reliability of ICC = .83 in healthy older adults.

Brouwer, Culham, Liston, and Grant (1998) reported a reliability ranging from .88 to .93 for the Maximum Excursion (BMLOSmxe) indicator in youth. In a study examining healthy older adults, Tsang and Hui-Chan (2003) reported the reliability at ICC = .93 while for the older adult at risk of falling, Clark and Rose (2001) reported a reliability of ICC = .87. The authors collected data from 32 adults over a period of four consecutive days.

In the LOS assessment, it was noted that the MXE composite score reflected the highest sensitivity to identify fallers as compared to the performance tests. (Trueblood, Hodson-Chennault, McCubbin, & YoungClarke, 2001). The LOS results were reported as moderately correlating (r = .602) with the Berg Balance test in a mixed population

study by Alonte, Grosch, and Brenneman (1995). The authors used 30 patients with various diagnoses, including multiple sclerosis, amputation, and vestibular disorders.

Liston and Brouwer (1996) attempted to determine the validity and reliability of measures obtained from stroke patients using the Balance Master®. To establish the reliability of the measurements, the authors collected data on three occasions, with each data collection separated by 1 week. The validity was evaluated by comparing results to the Berg Balance test as well as preferred gait speed (Liston & Brouwer, 1996). Although the sample group contained both right hemiparesis and left hemiparesis in an equal number, a between-group analysis revealed no statistical differences, protecting the homogeneity of the entire sample. The reliability on the Balance Master revealed no significant differences in the overall data over the three sessions (p = .27). A more detailed evaluation exposed that only the movement time and movement path in the randomly selected Limits of Stability generated strong reliability (ICC2,1 = .88; 95% confidence limits: .58, .99 and ICC2,1 = .84; 95% confidence limits: .52, .98 respectively, Liston & Brouwer, 1996). Duncan and Badke (1989) cautioned against the testing of patients beyond their capability as it would generate uncharacteristic responses which, in turn, would challenge the reliability of the data (as cited in Liston & Brouwer, 1996). As a result Liston and Brouwer (1996) concluded that the weight shift test, at 2 and 3 s was too challenging for the tested population with hemiplegia. The measures from the Balance Master all correlated with the Berg Balance test and similarly all but one correlated with the gait velocity test (Liston & Brouwer, 1996). A high correlation was observed between the center of gravity movement during the randomly assigned

Limits of Stability test and the Berg Balance and gait velocity tests (Liston & Brouwer, 1996).

Home Exercise Programs

The Otago Exercise Program (OEP) consisting of strength training, balance exercises, and a walking program was developed to allow patients to perform those in a home-based setting. In this study, two physiotherapists delivered the program by visiting the home of the patients. The program was evaluated using community-dwelling elderly and generated a decrease of fall-related injuries when applied to a population of 80 years and older (Liu-Ambrose et al., 2008). Although the adherence in the program was sparse, 25% for 3 or more times per week, 57% for 2 or more times per week, and 68% for at least once a week, the authors concluded that the Otago program significantly improved the response inhibition by 12.8% (p = .05) while the control group declined by 10.2%.. The response inhibition is responsible for the participant to suppress automatic responses in favor of planned behaviors (Liu-Ambrose et al., 2008).

In a case report, Flynn, Palma, and Bender (2007) have tested the use of the Sony PlayStation 2 for the rehabilitation of an individual poststroke. A 76-year-old woman who had sustained a stroke followed a 20-session protocol using the virtual reality PlayStation 2 Eye Toy (VR2 Eye Toy) and was tested following the pre-post design with a 6-month retention test after completion of the program. The participant was asked to complete daily logs of the use of the equipment. The individual participated in a wide array of games including Bubblepop, Goal Attack, Monkey Bars, colors, Air Guitar, Do It Yourself, Drummin', Homerun, Knockout, Kung 2, Mr. Chef, Pool, Secret Agent,

Solar System, and Table Tennis. The participant expressed that the use of games for rehabilitation was enjoyable and "very motivating" (Flynn et al., 2007, p.182). The various games challenged the dynamic balance, upper extremity range of motion, speed, cognition, reaction time, and many of them were target-based exercises. The authors collected data on additional 12 standardized assessments as a measure of improvement. The Beck Depression Inventory and the Time Up and Go test scores decreased between the pretest and the posttest by 66.66 and 8.25% respectively (Flynn et al., 2007). Those results indicated a decrease in the presence of depressive symptoms and an increase in ability related to functional mobility. The authors further indicated that the improvement of both scales continued at the 6-month follow-up (Flynn et al., 2007). The participant managed to achieve a maximum score in 5 assessments at the 6-month follow-up assessment. All measurements showed some improvement, whether minimal or more substantial. The authors mentioned the improvements were minimal for some assessments as a ceiling effect may have been present (Flynn et al., 2007). The participant already scored well in the Berg Balance Scale, the Time Up and Go, the 6 min Walk test, the Motor Activity Log – actual amount of use, the Modified Ashworth Scale, and the Functional Reach test thus leaving very little room for further improvement. The authors noted that balance was the only component of the Fugl-Meyer Assessment that did not show improvement going from a score of 11/12 to 10/12 (Flynn et al., 2007). The greatest change was observed in the sensory function where the participant improved by 11 points surpassing the clinically relevant 10-point increase (Flynn et al., 2007). Overall, this study indicated a positive outcome of the use of virtual reality equipment for

rehabilitation purposes. In addition, the authors reported no account of increased pain or falls during the program. Although an anticipated challenge was the nonfamiliarity with electronic and computerized devices, the participant reported that after a few days of practice in navigating the device, it did not interfere with her ability to choose the games. After completion of the program, the participant went on expressing the desire to purchase such a device to continue the exercises (Flynn et al., 2007). The authors cautioned that the Sony Eye Toy device had not been designed for rehabilitation purposes and thus, its yielded benefits in this particular study may or may not be equal to a similar training program using other types of equipment. Flynn et al. (2007) however reiterated that the main purpose of that study was to explore the motivational factors associated with a gaming-based exercise program. This study emphasized the positive outcomes of a Virtual Reality system used as a rehabilitation device. The authors were careful to state that this type of device was not to replace traditional exercises but rather as a complementary inexpensive piece of equipment which could, in time, lead to decrease in health care costs (Flynn et al., 2007).

Summary

In summary, there are currently several tests used to identify balance deficiencies but most of them require some professional training or specific equipment to perform the task. With a growing aging population, the need to provide a means of evaluating balance both in and outside of clinical settings is becoming an increasingly important issue. Virtual games have entered homes as entertainment devices but have since been used as training devices to increase balance abilities, particularly in physical therapy

settings. It has been reported, throughout the literature, that people experienced a high level of enjoyment when engaging in virtual games activities. Virtual games utilizing the Wii Fit™ with the balance board provide an inexpensive means to exercise and improve balance. Those virtual games have been primarily used as training devices with balance assessments using established protocols. The establishment of the criterion validity of the Wii Fit™ balance board would allow professionals to include them in their arsenal of tests and possibly allow the patients to keep valuable records of their progress.

CHAPTER III

METHODS

Research Design

The purpose of this study was to measure the criterion validity of the Wii Fit™ compared with the Basic Balance Master with regards to balance. The research design for this study was a correlational research study, in which the analysis of the relationship between data generated by selected Wii Fit™ Balance Board games and selected Balance Master tests were examined.

Sample Selection

Sample Size

The sample size was determined by the existing literature and the recommendation by Tabachnick and Fidell (2007). It was estimated 10 participants per variable thus summing to a total of a minimum of 100 participants as five variables from the Wii Fit™ Balance Board and five variables from the Balance Master were collected. It was hypothesized that these numbers were adequate to address the research question.

Participant Recruitment

The subjects were recruited by a sample of convenience. Participants were recruited from a midsized state-funded university in the Southwest, and through advertising for participants in the surrounding communities. For Participants recruited through advertisement, the flyer stated the eligibility for participation. Their eligibility

was confirmed by discussing the information in the "purpose and aims of the study" section in the consent form. (Appendix I)

Inclusion and Exclusion Criteria

As the main purpose of the study was to validate the use of a piece of equipment, very few limitations were implemented on the participant recruitment criteria. No gender restrictions were imposed. No ethnicity restrictions were imposed. The participant should be at least 18 years of age for consent purposes. No upper limit of age was imposed as long as the participant met the health and ambulatory criteria. The ambulatory criteria were composed of the ability of the participant to stand for 10 s and then walk 25 m without the use of assisting devices and/or without losing their balance.

Exclusion Criteria for all Participants

The presence of any musculoskeletal or cardiorespiratory problems that would affect ambulation, or any diagnosed neurological problems resulted in the exclusion of the participant from the study. The participants attested to no use of prescription medication for high blood pressure or other balance disorders to remain eligible.

Initial Intake Information

Total testing time took approximately 1 hr. During this time, the initial process involved explaining the project, obtaining informed consent and descriptive data, and performing the Balance Master and the Wii tests. The age, height, weight, hip and waist circumferences were recorded. The hip and waist circumferences will be measured using a tape measure. The procedure will be repeated 3 times for accuracy and the median of the three measures will be used to determine the waist to hip ratio of the participant. This

ration will be utilized in the descriptive analysis of the data set. Testing was done in a single laboratory visit to the Biomechanics laboratory at West Texas A&M University in Canyon, TX.

Consent Form and Personal Information

Prior to testing, subjects were asked to read an information letter for the study and sign a consent form (Appendix I) in accordance with the Institutional Review Boards of West Texas A&M University and Texas Woman's University.

After reading and signing the information letter and consent form, measurements (Appendix II) were taken and the participant answered general information, such as familiarity with the Nintendo game device, familiarity with the Wii Fit™ Balance Board games, and general level of activity with the Tegner Activity Level Scale.

Instrumentation

Basic Balance Master®

The Basic Balance Master® system (Neurocom, Clackamas, OR, USA, 1993) is used to record balance measurements using three different tests. This system is composed of a portable force platform connected to a computer that is used to compute the center of pressure movement from the force platform sensors. The software is included in the computer and computes estimation of the position and displacement of the center of gravity sampled at 100Hz from the center of pressure data.

Nintendo Wii Fit™ Balance Board

The Nintendo Wii system first appeared in 2006 using wireless motion-sensitive remote controllers. The maximum capacity of the board is 330 lbs (150 kg). The

Balance Board is a component of the popular Wii Fit™ game. It is composed of four sensors which are used to assess force distribution on the board and thus allows the computation of the resultant movement of the center of pressure.

Description of the Wii Fit™ Tests and Games

The first measure was defined as the Body Test. The approximate weight of the participant's clothes was entered as to modify the measured weight from the platform. The height of the participant was also entered. The participant was asked to stand still and try to keep their balance. This test is named the "Center of Balance" test. The force plate calculated their weight at this time and recorded the amount of force exerted by each leg on the force platform. The output was a percentage of weight distribution on each leg. The ideal amount was recorded as 50% for the right leg and 50% for the left leg. A sample screenshot of the test is illustrated in Figure 3.

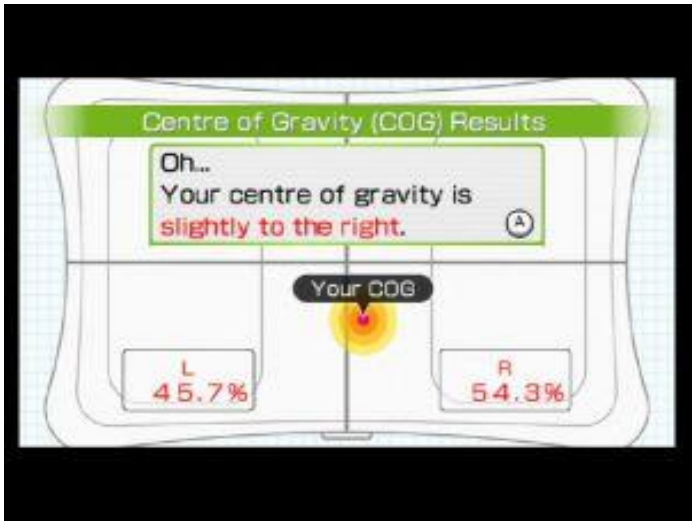


Figure 3: Screenshot center of balance test

The system then displayed the BMI of the participant. The BMI data from the Wii Fit™ Balance Board test was recorded but not used in the study. Following the BMI display, the participant was then given two of three tests, randomly selected by the Wii system. These tests were recorded under the "Body Control" criteria for the Wii Fit™. The tests were the Basic Balance Test, the Agility Test, or the Steadiness Test. The interest of the researcher remained in the collection of the data from the Agility test and the Basic Balance test. In the event that the Steadiness test was randomly selected by the computer, the test was skipped.

The Basic Balance Test (Figure 4) required the participant to place two red bars, each representing the center of force of each leg, in blue areas and maintain it there for 3 s. As the participant progressed, the blue areas became smaller. The blue areas were symmetrical for both legs. The test lasted for 30 s.

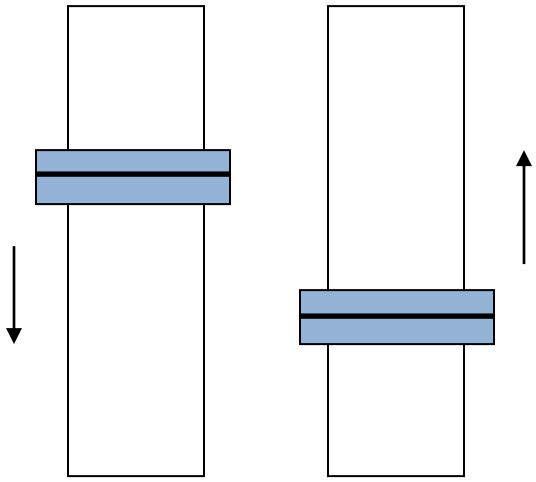


Figure 4: Basic balance test

The Agility Test lasted for 30 s. The participant was asked to shift their weight in various directions, anterior, posterior, medial, lateral, and a combination of all to place

the center of pressure in blue boxes. Each time the center of pressure reached a blue box, the latter disappeared and another box appeared somewhere else. As the test progressed, more boxes of various sizes appeared. The goal was to make the most amounts of boxes disappear. Figure 5 was a representation of the Agility test.

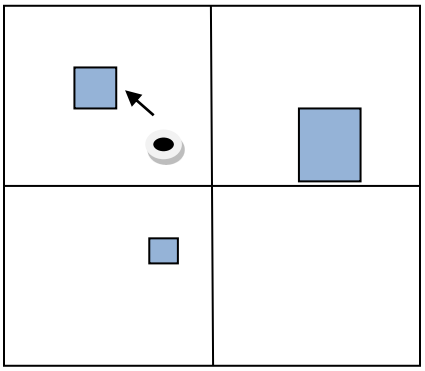


Figure 5: Agility test

The Nintendo Wii system came with a basic package of balance games but allowed the participant to unlock additional games or levels. The selected basic games Ski Slalom (beginner's level) and Soccer Heading (beginner's level) were used in this study. The participant was represented in the games as a Mii, a digital avatar designed by Nintendo and was intended to be used as the virtual extension of the player.

The soccer heading game entailed 80 soccer balls being kicked in the direction of the participant. As the participant moved on the platform to position themselves in the path of the kicked ball, each contact between the head and the ball resulted in points. As the game progressed, additional objects were kicked and the participant was expected to discriminate between the objects and only head the soccer balls. When one ball was headed, one point was scored. As the participant built a streak, the scoring became one point for the heading and the number of points for the streak. For example, if a

participant had headed three balls without heading another object, the amount of points gained was one point plus three points, thus a total of four points. After the 80 balls were kicked, the total of points became the data output. The maximum number of points possible at the beginner level was 763 points. Each time another object (a shoe or a panda head) was headed, there was a decrease in points; when a soccer ball was missed, the points count restarted at one. As the game progressed, the delivery speed of the ball increased, thus forcing the participant to decrease their reaction time to be successful. To successfully move the Mii on the screen, the participant was required to shift their body weight laterally. A sample screenshot (Figure 6) of the Wii Fit Soccer game illustrated what the participants saw.

Figure 6: Screenshot soccer heading

The ski slalom required the participant to shift their weight laterally unto the balance board to downhill ski on the slalom course and successfully go through the gates. The participant could increase their speed by leaning forward to place their center of gravity in the blue area on the screen. The participant received constant feedback on the

screen regarding the position of their center of gravity. For the beginner's level, there were a total of 19 gates. The gates were color-coded blue and red to help the participant as they had to alternate the colors. The score was calculated with the time that it took the participant to complete the course and the number of errors. If the participant missed a gate, a penalty of 7 s was added to their overall time.

Figure 7: Screenshot Wii Fit Ski Slalom

The upper right hand box indicated the position of the center of gravity of the participant in relation to the balance board (Figure 7). In this case, the participant was attempting to shift their weight to the left, thus the position of the red dot on the left side of the balance board reproduction. In addition, the left dot was placed on the inferior part of the drawing, indicating that the participant was attempting to slow down the Mii. The blue area represented the ideal placement of the center of gravity to maximize the speed. The data generated was displayed in seconds with the number of missed gates.

Description of the Balance Master® Tests

The Basic Balance Master® is a piece of equipment which aims at exploring the balance issues of patients. It aims at providing an "objective assessment […] of the sensory and voluntary motor control of balance with visual biofeedback" (http://resourcesonbalance.com/neurocom/products/BasicBalanceMaster.aspx). The equipment assesses three types of components: sensory dysfunction, voluntary motor impairments, and functional limitations. In this study, only the voluntary motor impairments tests will be utilized and compared to the Nintendo Wii games.

The Limit of Stability Test (LOS) quantifies the maximum distance a person can intentionally displace their center of gravity (COG). The measured parameters are reaction time, COG movement velocity, directional control (BMLOSdc), end point excursion, and maximum excursion (BMLOSmxe).

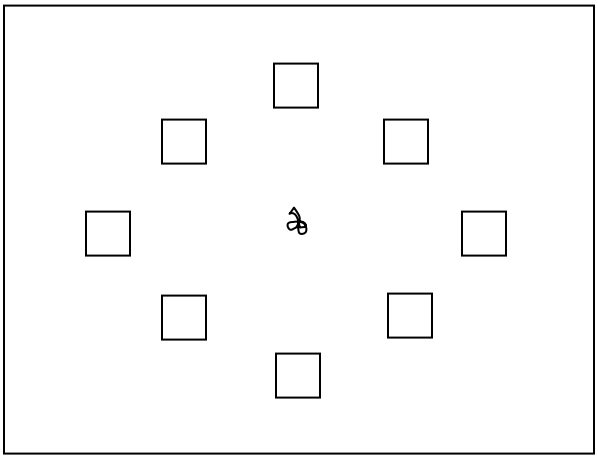


Figure 8: LOS set-up

Figure 8 illustrated the positioning of the various targets the participant had to reach. For this study, although all data will be recorded, only the directional control and the maximum excursion were analyzed.

The Directional Control data reports the quality of movement control by comparing the amount of movement conducted by the participant in the intended direction that is toward the target versus the amount of extraneous movement away from the target. It is reported as a percentage and compared to age-matched normative data.

The excursion measure, Maximum Excursion (BMLOSmxe), is an indicator of the ability of the participant to shift their center of gravity toward the theoretical limit (100%) in each of the eight directions. The BMLOSmxe measures the distance the participant is moving toward the target, regardless of the attempts. The BMLOSmxe is expressed in percentage of the theoretical limit of 100%.

The Rhythmic Weight Shift (BMRWl) test quantifies the ability of the participant to move their COG in a predefined velocity over a defined distance. The participant is expected to attempt to follow the speed of a moving cue. The ability of the participant to increase the COG velocity to maintain the speed and to decrease the COG velocity to change direction is challenged. The dexter/sinister as well as anterior/posterior movements are tested. Each movement is tested at three different speeds; the slow speed is 3 s for the cue to travel the distance before changing direction, the medium speed is 2 s, and the fast speed is 1 s. In addition to the various speeds information, the data also breaks down into Directional Control (DC_{RWS}) and the On-Axis Velocity. The DC_{RWS} once again records the amount of movement along the desired plane versus the amount of

extraneous movement (Figure 9). The ideal DC_{RWS} would be 100%. For this study, the Directional Control will be utilized and broken down into the antero-posterior and dexter-sinister axes. Both sets of data will be used. The On-Axis Velocity refers to the speed of the COG movement in the intended direction, expressed in degrees per second. This data was collected but not included in the analysis.

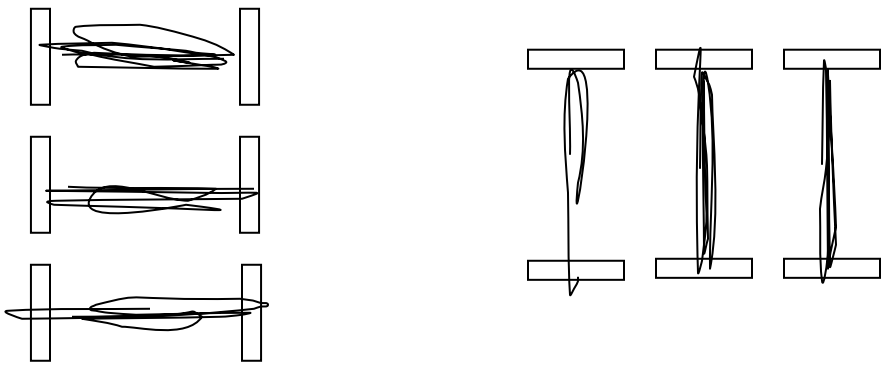


Figure 9: Rhythmic weight shift

The Weight Bearing Squat (BMWBR) test records the distribution of body weight on each leg for four conditions of knee flexion (knees fully extended which is 0°, knees flexed at 30°, 60°, and 90°). Normal body weight distribution should remain within 15% variation in normal adults. The data is expressed in percentage of total body weight. In this study, although all data were recorded, only the Weight Bearing Squat at 0° angle will be analyzed.

Pilot Study

To familiarize the investigator with the data collection instruments and procedures and to determine the intraclass reliability (ICC), a pilot study was conducted. Thirty five participants (n_{men} = 29, n_{women} = 6) were tested on the Wii Fit™ and the Balance Master®. The participants were asked to participate in two sessions with at least one week apart.

Table 1

Descriptive Data

	Age (yrs and months)	Height (cm)
Gender	*M (SD)*	*M (SD)*
Overall	22.9 (4.2)	175.3 (10.7)
Women	20.8 (1.2)	160.9 (11.4)
Men	23.3 (4.5)	178.3 (7.9)

Wii Fit™

The Center of Balance (WiiCOB) was measured twice per session, randomly concentrating on the placement of the left foot and the right foot. Only 34 participants completed data collection. One participant exceeded the maximal recommended weight of 300 lbs for the Wii Fit™. The 1st test from session 1 was analyzed with the 1st test from session 2 in an attempt to control threats to internal validity. The intraclass correlations were ICC = .925, 95% CI [.855, .962] and ICC = .938, 95% CI [.879, .968].

Balance Master®

The 0° and 30° Weight Bearing were analyzed. Thirty two participants completed the study while 3 participants' data were removed. One participant incurred a concussion between the two sessions and the data was clearly affected, one participant had a leg injury that impaired her balance for the 2nd session, and one participant was sick and was not able to reschedule. The intraclass correlations were ICC = .802, 95% CI [.632, .898] and ICC = .799, 95% CI [.628, .897].

Procedure for Recording the Data

Data Collection

The Wii Fit™ system and the Basic Balance Master require visual feedback. The distance between the participant and the screens will be determined by the participant's comfort to see the screens. The distance will be recorded for each participant. The order of the tests will be randomized to minimize the learning effect; however the participant will conduct the Wii games as a group and the balance master test as another group. The order for the test, Wii or Balance Master® will be randomized as well. The order of the individual tests will be recorded.

In the Balance Master® test data collection, the protocols used are the ones suggested by the manufacturer. Appropriate placement of the feet and clear and concise instructions to the participants are important. In order to maximize reliability, all tests will be performed once prior to data collection. For the LOS, the participant is instructed to "keep the cursor in the center target. When the blue circle appears in the yellow outer target, move as quickly and accurately as you can towards the yellow target and hold

steady there" (Neurocom® Clinical Operation Guide, 2008, pp.30). The participant is also instructed to not "bend at the waist or arch your back, bend your knees, or lift your feet during testing" (Neurocom® Clinical Operation Guide, 2008, pp.30). For the BMRWl, the participant will be provided one practice trial. The participant is instructed to follow the pace of the "sun" and remain between the two bars. The test will start when the participant has reached a steady speed and will last 10 s. For the BMWBR, the feet will be positioned in a parallel manner, without any splay. The malleoli are positioned over the wide horizontal line with the calcaneus bisected by the 'M' line. A careful check of the feet placement is required for the reliability of the test. A goniometer is used to check the knee joint angles and ensure proper flexion. The participants are given one practice trial.

For the Wii Fit™ tests, the Center of Balance test, two Body Control tests, and three games have been selected. Each recorded test will preceded by a practice trial. The Center of Balance test will be repeated twice and the average of both data points will be used. For the Body Control tests, the Nintendo Wii Fit™ randomizes the tests; as such, the body control test will be repeated three times to make sure that two sets of data are collected from two tests, the agility test and the basic balance test. Those trials will then be averaged and used as a single data point. The ski slalom test and the soccer heading game are repeated 3 times. The researcher will use the median of the scores as data to analyze.

Statistical Analysis

A canonical analysis (CCA) is a multivariate technique that allows the assessment of two sets of multiple variables (Sherry & Henson, 2005). The presence of a high number of variables is a threat to type I error and this statistical method reduces the probability of an increased type I error (Pedhazur, 1982). Therefore a canonical correlation was an appropriate analysis to answer the research questions as there are multiple criterion variables (10). An alpha level of .05 was used to identify significance.

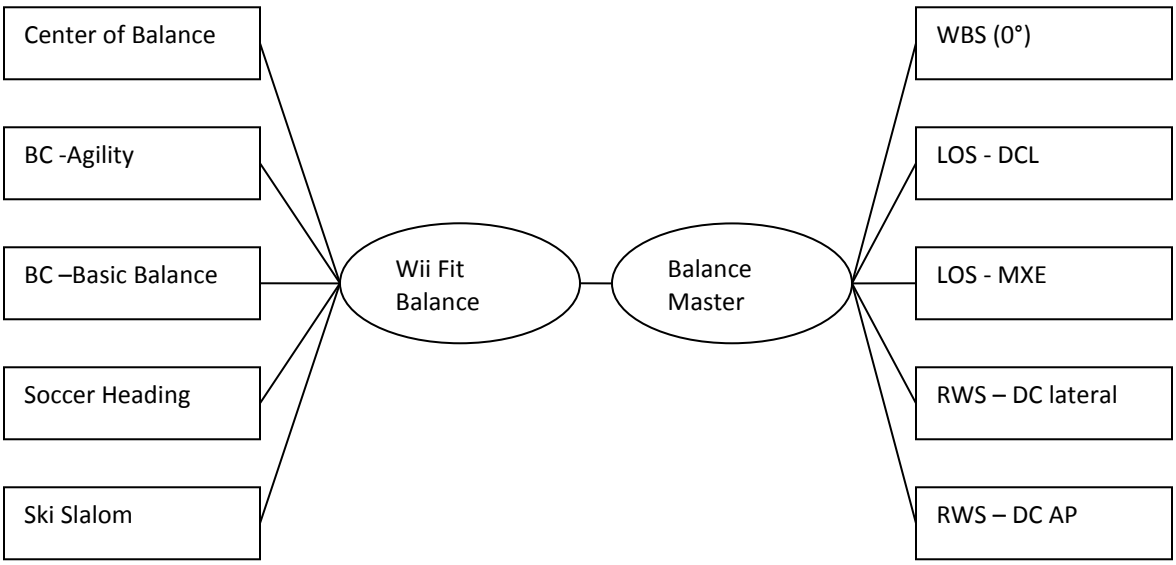


Figure 10: Canonical structure

The canonical set I is composed of the following variables: Center of balance (WiiCOBR), Body of Control Agility (WiiAgil), Body of Control Basic Stance (WiiBB), Soccer score (WiiSoc), and Skiing score (WiiSki). The canonical set II is composed of the following variables: Weight Bearing Squat at 0 ° angle (BMWBR), Limit of Stability Directional Control (BMLOSdc), Limits of Stability Maximum Excursion (BMLOSmxe),

Rhythmic Weight Shift Directional Control Lateral (BMRWl), and Rhythmic Weight Shift Directional Control Antero-Posterior (BMRWap). The structure of the correlation is illustrated in Figure 10.

The significant canonical functions were identified. The canonical correlation coefficient and the canonical loadings were reported. Bland-Altman plots Analyses were added to assess the level of agreement of paired variables to compare the use of Wii Fit™ selected games to the Balance Master® exercises when assessing balance ability in a healthy population.

CHAPTER IV

PRESENTATION OF FINDINGS

The purpose of this study was to determine the criterion validity of selected Wii Fit™ games when measuring balance. The research design for this study was a correlational research study, in which the relationship between data generated by the selected Wii Fit™ Balance Board games and selected Balance Master® tests were examined.

Descriptive Statistics

A total of 114 participants were recruited and 112 participants completed the data collection process. Data from 111 participants (n_{men} = 67, n_{women} = 44) were used in the statistical analysis; one person's data was excluded as it was an extreme outlier, thus threatening some of the preliminary assumptions. The majority of the participants were young college-age active people (M_{age} = 22.8 yrs ± 5.71). The breakdown of participants' ethnicities was as follows: 59.46% of the participants were Caucasian (n = 66), 31.53% were Hispanic (n = 35), and 9.01% were African-American (n = 10). All participants denied having any back pain or current injury. Amount and types of reported injuries are described in Table 2. A total of 82.88% (n = 92) of the participants reported no injuries and 17.12% (n = 19) of the participants reported having sustained an injury over one year prior to the data collection. None of those injuries occurred in the year preceding the data

collection and the participants had resumed regular activity, including sports participation.

Table 2

Past Injuries Reported

Injuries	# of participants	% of participants
Hip	1	5.26
Knee	10	52.63
Ankle	8	42.11

To determine whether a practice effect was present and, subsequently, needed to be controlled for, participants were asked about their familiarity with the Wii Fit™ console and games. The distinction was made between the participants who were familiar with the Wii console including the balance board and the participants who were familiar with the console but had not used the balance board. The results are reported in Table 3. Given that 92% reported being unfamiliar, this did not seem to be a potential confounding variable.

Table 3

Wii Familiarity

Wii	# of participants	% of participants
Not familiar	102	91.89
Wii familiar	5	4.50
Wii Fit games familiar	4	3.60

The Tegner Activity scale (Appendix A) was used to record the level of activity of participants. Traditionally, this scale is used for patients in knee surgery recovery. Many participants had been active in their earlier years and reported old injuries. According to the participants, those past injuries did not interfere with their ability to perform the tests. As the majority of the participants were students, the most common levels of reported activity were 5-6, corresponding to a moderate level as shown in Table 4. Most participants were students and engaged, on campus, in some recreational activities involving exercise.

Table 4

Participants Level of Activity

Tegner Scale	0	1-2	3-4	5-6	7-8	9-10
% of participants	0	5.4	20.7	39.6	14.4	19.8

The assumptions of the canonical correlation analysis (CCA) were evaluated. The assumptions of linearity, multicollinearity, homoscedasticity, and normality were checked. The test of normality using the Shapiro-Wilk test was performed and was not significant ($W = .388$ for the Balance Master composite score, $W = .490$ for the Wii Fit™ composite score). None of the assumptions were violated after the removal of one participant identified as an outlier (2 SDs beyond the mean). The required minimum sample size of 100 was achieved.

Table 5

Variables Descriptive Statistics

Variable	Range	Minimum	Maximum	Mean (SD)
WiiCOBR (%)	17.9	41.1	59.0	50.86 (± .32)
WiiBB (s)	26.03	21.97	48.00	32.36 (± .60)
WiiAgil (pts)	9.6	9.0	18.6	13.34 (± .19)
WiiSoc (pts)	457	10	467	137.35 (± 8.58)
WiiSki (s)	78.95	34.76	113.71	61.82 (± 1.73)
BMWBR (%)	22	41	63	51.21 (± .38)
BMRWl (%)	14	79	93	88.78 (± .23)
BMRWap (%)	30	63	93	83.53 (± .57)
BMLOSmxe (%)	30	79	109	97.09 (± .52)
BMLOSdc (%)	36	56	92	80.12 (± .57)

(n=111)

Wii Fit™ abbreviations: WiiCOBR was the center of balance, WiiBB was the basic balance, WiiAgil was the agility exercise, WiiSoc was the soccer heading game, and WiiSki was the Ski Slalom game.
Balance Master®: BMWBS was the weight bearing exercise, BMRWl was the rhythmic weight shift in lateral motion, BMRWap was the rhythmic weight shift in lantero-posterior motion, BMLOSmxe was the limits of stability maximum excursion, and BMLOSdc was the limits of stability directional control.

The descriptive statistics are presented in Table 5. The data for each variable was found to be normally distributed. The data was converted into z-scores for analysis purposes.

Bland-Altman plots were created to assess the level of agreement between the paired variables. A range of agreement was defined as mean bias ± 2SD. The following Figures 11-13, illustrated the level of agreement as less than 5% of the data was outside the 95% confidence interval.

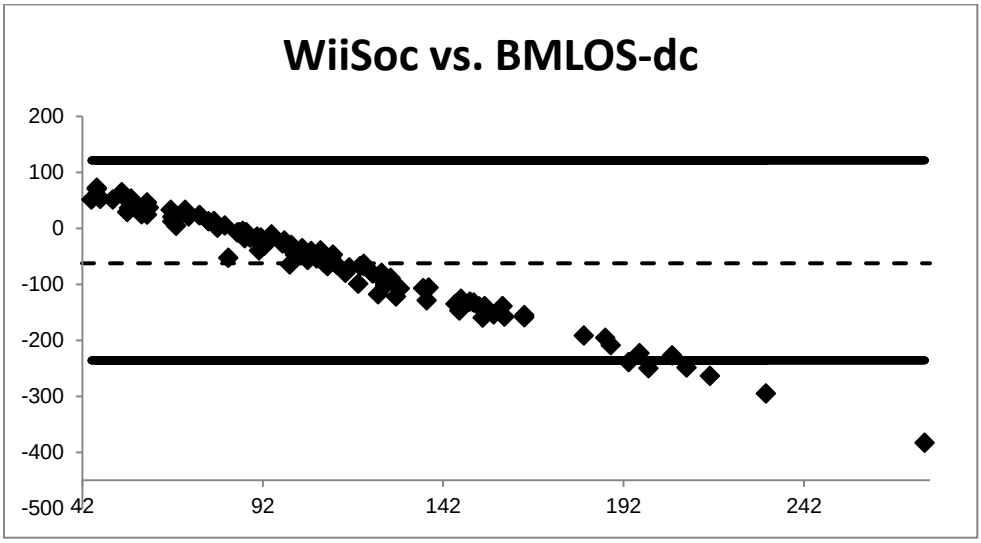


Figure 11: Bland-Altman plot of Wii Fit™ soccer and Balance Master® limits of stability directional control.

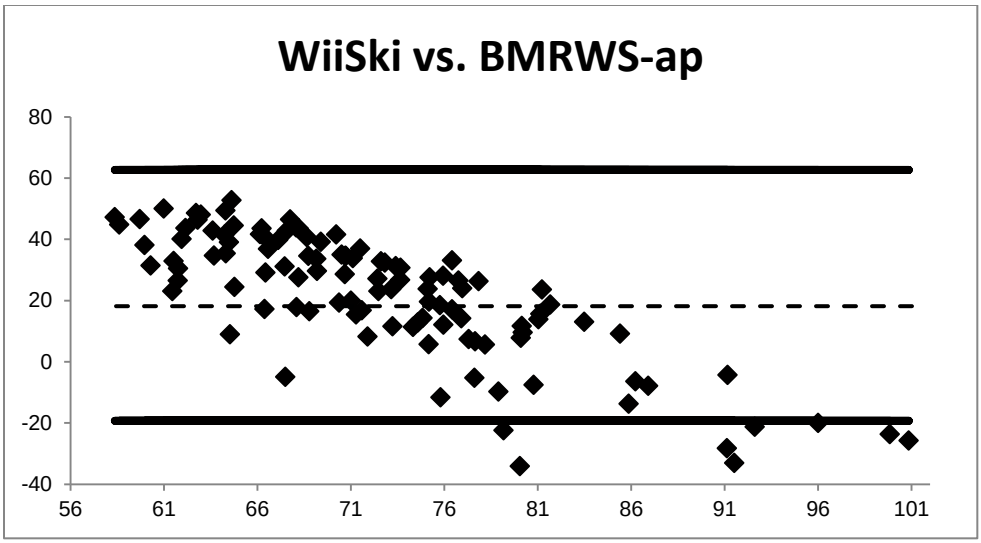


Figure 12: Bland-Altman plot of Wii Fit™ ski and Balance Master® rhythmic weight shift antero-posterior.

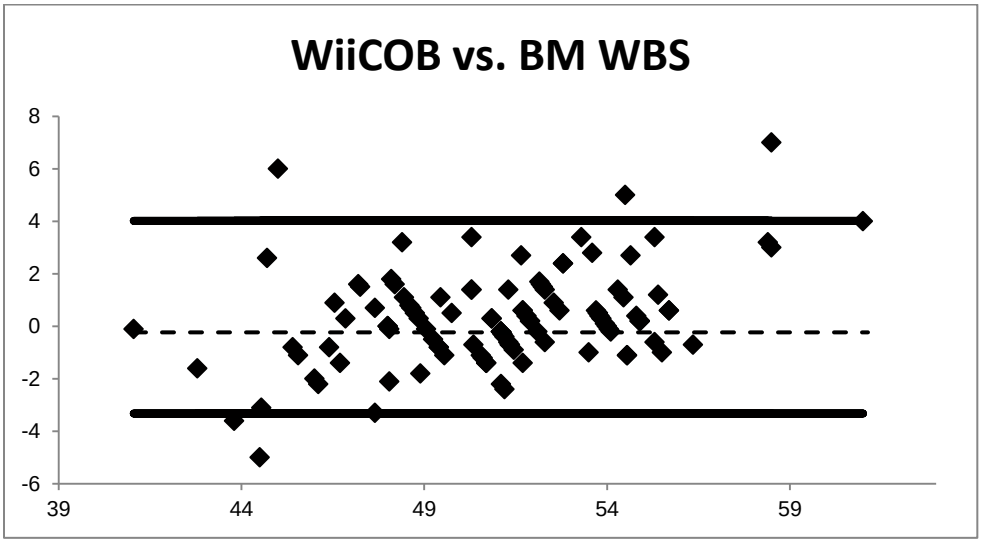


Figure 13: Bland-Altman plot of Wii Fit™ center of balance and Balance Master weight bearing shift.

Canonical Correlation Analysis

Results

A canonical correlation was performed using five Wii Fit™ variables as predictors of the five Balance Master® variables to evaluate the shared variance between the two sets of variables. The Wii Fit™ variables were the Center of Balance (WiiCOBR), the Agility Test (WiiAgil), the Basic Balance Tests (WiiBB), the Soccer Heading game (WiiSoc), and the Ski Slalom game (WiiSki). The Balance Master® variables were the Weight Bearing Test (BMWBR), the Limits of Stability Directional control (BMLOSdc), the Limits of Stability Maximum Excursion (BMLOSmxe), the Rhythmic Weight Shift Directional Control Lateral (BMWl), and the Rhythmic Weight Shift Anterior Posterior (BMWap). The canonical analysis revealed a statistically significant canonical correlation between the two canonical variates (F [25, 376.70] = 10.763, $p < .001$; Wilks' $\lambda = .135$) as shown in Table 6. In addition, the $1-\lambda$ value was .865, which indicated that approximately 86.5% of the variance in the Balance Master® canonical variate was explained by the Wii Fit™ canonical variate. It was concluded that a large effect size was found for the full model ($R^2_c = 0.865$).

Table 6

Full Canonical Correlation Model Significance

Test Name	Value	Approximate F	Error DF	*p*
Pillais's	1.097	5.899	525.00	<.001
Hotelling's	4.810	19.126	497.00	<.001

Continued

Cont'd

Wilks λ	.135	10.763	376.70	<.001
Roy's	.818			

Tests of dimensionality for the canonical correlation analysis, shown in Table 7, indicated that two of the five canonical functions were statistically significant at the .05 level. The analysis of each canonical function gave us information on the shared variance between the two of canonical variates. All five canonical functions are reported in Table 7.

Table 7

Dimension Reduction Analysis

Canonical Function	Wilks λ	F	Error DF	*p*
1 to 5	.135	10.763	376.70	<.001
2 to 5	.741	2.013	312.25	.012
3 to 5	.880	1.496	250.83	.150
4 to 5	.994	.163	208.00	.957
5 to 5	.999	.108	105.00	.743

As shown in Table 8, the first function explained 81.8% of variance within its function and the second function explained 15.9% of the remaining variance. Although the third function explained close to 10% of variance within its function (R^2_c = .114), it was not identified as significant by the dimension reduction analysis and therefore, was

not analyzed. The last two functions were sufficiently weak, explaining less than 1% of the variance in their function (0.5% and 0.1%, respectively). The first canonical function had a canonical correlation of 0.904 between the sets of canonical variates, while the second canonical function had a much lower but still significant correlation at 0.398.

Table 8

Eigenvalues and Canonical Correlations

Canonical Function	Eigenvalue	%	Cumul. %	Can. Corr.	Squared Corr.
1	4.487	93.277	93.277	.904	.818
2	.188	3.918	97.195	.398	.159
3	.129	2.674	99.869	.338	.114
4	.005	.109	99.978	.072	.005
5	.001	.022	100.00	.032	.001

The standardized canonical coefficients (Beta Weights) were computed and reflected the relative contribution of each variable to the canonical variate taking into consideration the contribution of other variables. The structure coefficients reflected the direct contribution of the variable to the canonical variate independently of other variables. Both sets of coefficients are reported in Tables 9 and 10.

Table 9

Beta Weights (β), Structure Coefficients (r_s), and Squared Structure Coefficients (r_s^2) for the Balance Master® Variables

	Function 1			Function 2		
Variable	β	r_s	r^2_s	β	r_s	r^2_s
WBS	-.983	-.989	.978	-.098	-.048	.002
LOS - DCL	.059	-.039	.002	.059	.717	.514
LOS - MXE	-.008	-.051	.003	.262	.498	.248
RWS – DC lat	-.125	-.200	.040	.095	.320	.102
RWS – DC AP	-.050	-.078	.006	.683	.918	.843

NOTE: Balance Master®: BMWBS was the weight bearing exercise, BMRWl was the rhythmic weight shift in lateral motion, BMRWap was the rhythmic weight shift in lantero-posterior motion, BMLOSmxe was the limits of stability maximum excursion, and BMLOSdc was the limits of stability directional control.

Looking at Function 1, Center of Balance (WiiCOBR) and the weight Bearing Squat (BMWBS) were the main relevant contributing variable for their respective canonical variate (the Wii Fit™ variate and the Balance Master® variate). When analyzing function 2, the most relevant contributors for the Balance Master® variate were the LOS – DCL and the RWS – DC AP. On the Wii Fit™ variate side, Function 2 seemed to be relying on the BC – Basic Balance and the Ski Slalom game variables. It was indicated that better dynamic balance (i.e., smaller scores in the Basic Balance and the Ski Slalom games and larger scores in the Agility and Soccer games was associated

with the Wii Fit™ canonical variate). The two functions were graphically represented in Figures 14 and 15.

Table 10

Beta Weights (β), Structure Coefficients (r_s), and Squared Structure Coefficients (r_s^2) for the Wii Fit™ Variables

	Function 1			Function 2		
Variable	β	r_s	r^2_s	β	r_s	r^2_s
WiiCOBR	-1.002	.992	.984	-.048	-.033	.001
WiiAgil	.068	.073	.005	-.114	.332	.110
WiiBB	.037	.050	.003	-.761	-.878	.771
WiiSoc	.096	-.010	< . 001	.089	.499	.249
WiiSki	.102	.002	< . 001	-.458	-.706	.498

NOTE: Wii Fit™ abbreviations: WiiCOBR was the center of balance, WiiBB was the basic balance, WiiAgil was the agility exercise, WiiSoc was the soccer heading game, and WiiSki was the Ski Slalom game.

The correlation matrix was reported in Table 11.

Table 11

Pearson Correlation between the Wii Fit™ Variables and the Balance Master® Variables

Pearson Correlation

	WiiCOBR	WiiBB	WiiAgil	WiiSoc	WiiSki	BMWBR	BMRWl	BMRWap	BMLOSmxe	BMLOSdc
WiiCOBR	1									
WiiBB	-.042	1								
WiiAgil	-.016	-.423**	1							
WiiSoc	.067	-.317**	.272**	1						
WiiSki	.054	.304**	-.218*	-.442**	1					
BMWBR	.891**	-.019	-.042	.022	-.006	1				
BMRWl	.160	-.179	-.136	-.078	.021	.066	1			
BMRWap	.058	-.334**	.115	.180	-.244**	.024	.265**	1		
BMLOSmxe	.034	-.158	.001	.097	-.155	.034	.104	.228*	1	
BMLOSdc	.035	-.225*	.216*	.209*	-.267**	.061	.078	.528**	.254**	1

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

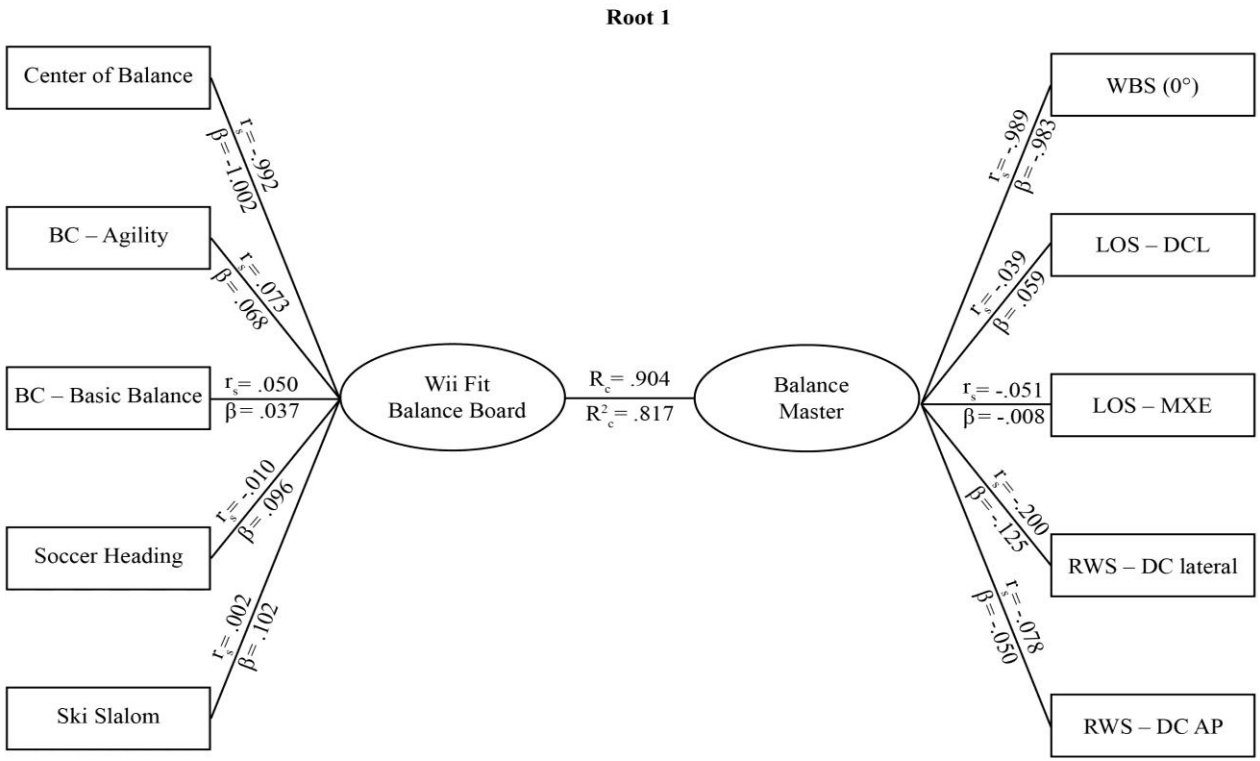


Figure 14: Function 1

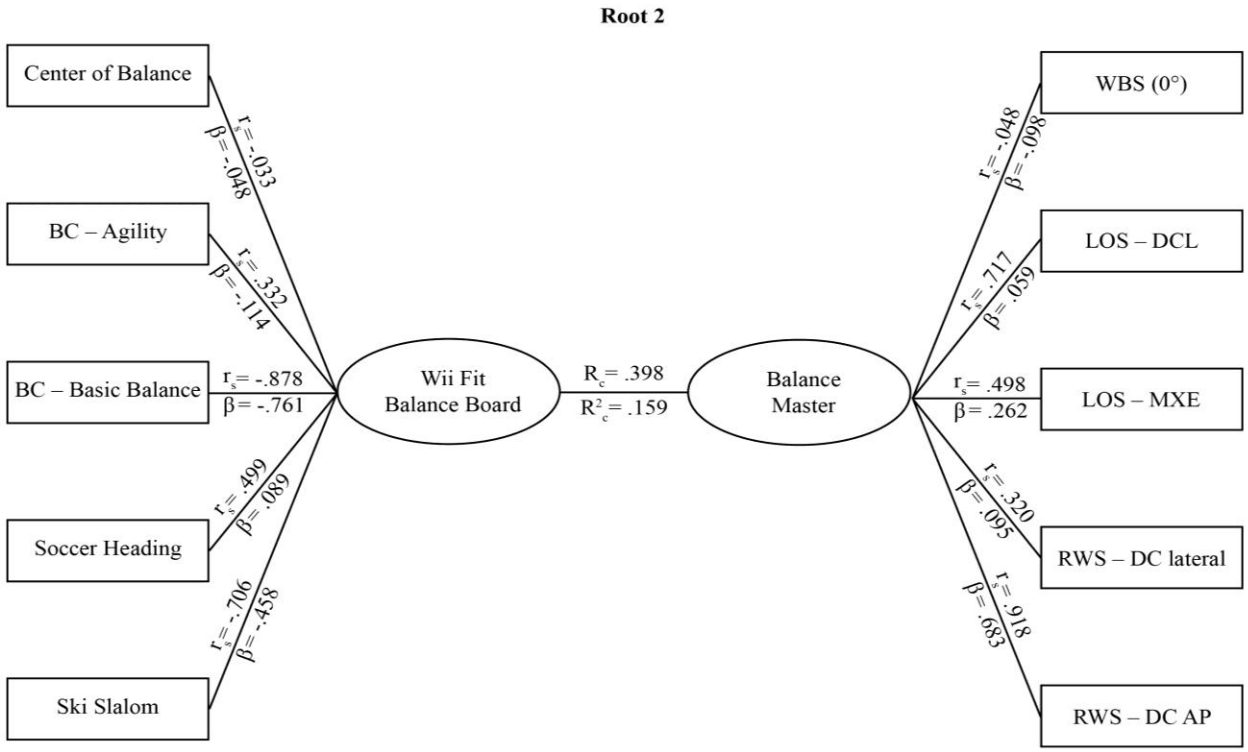


Figure 15: Function 2

CHAPTER V

Summary

The purpose of this study was to examine the criterion validity of Wii Fit™ selected games for balance assessment. In addition to examining criterion validity, the author examined the relationships of each variable with the composite Wii Fit™ variable to identify the best contributors to the overall assessment. A canonical correlation analysis (CCA) was performed to measure the strength of the relationship between the Wii Fit™ combined variables and the Balance Master® combined variables. A significant correlation was identified between the two canonical variates, the Wii Fit™ activities and the Balance Master® exercises. The strongest contributing components were the static balance with a small contribution from a few dynamic balance components.

Discussion

Criterion Validity of the Wii Fit™ Balance Board

Balance is an important component of independent life (Yumin et al., 2011) and is composed of static and dynamic components. Components from both static and dynamic balance were included in the present study. The Center of Balance from the Wii Fit™ and the Weight Bearing Symmetry were identified as the static balance components as the participants were not moving. The other components, Agility, Basic balance, Soccer Heading, and Ski Slalom from the Wii Fit™ and Limits of Stability Directional Control

and Maximum Excursion, and Rhythmic Weight Shift Directional Control lateral movements and antero-posterior movements, were identified as the dynamic components. According to the study's results, there is a strong correlation between the Wii Fit™ Balance Board variate and the Balance Master® variate.

Using standard in the existing literature and the recommendation by Tabachnick and Fidell (2007), an approximate sample size was determined a priori. A power analysis was performed and an estimate of 10 participants per variable was necessary to reach a power of .80. A total of 10 variables were identified in the study, five variables from the Wii Fit™ Balance Board and five variables from the Balance Master®. A minimum of 100 participants were therefore necessary to complete this study. It was hypothesized that these numbers were adequate to address the research question.

While analyzing the various motions, it was possible to identify some common traits between the Wii Fit™ activities and the Balance Master® components. As the various Wii Fit™ activities were chosen with the idea that they would utilize similar motions that were used in the Balance Master®, it was certainly understood that those motions could contain additional variables, not included in this study. The two measures that were most closely associated would be expected to be the center of balance and the weight distribution (r = .891). Both measured static balance and the weight distribution between both feet. As the correlation matrix reported, the two measures were highly correlated and had good agreement as defined by the correlation matrix. The placement of the feet and the direction given for the test on the Balance Master® were very specific and each participant was placed according to their height. The Wii Fit™ did not require

any specific directions but the researcher chose to also give specific directions to the participants, i.e. to place the feet at equal distance from the center line of the balance board. This was an attempt to minimize the possibility of unequal output variable while the participant was still equally distributing one's weight. The canonical correlation determined the weight of each variable in order to maximize the correlation between the two canonical variates. The two static components (center of balance and weight distribution) were highly correlated and thus drew the largest weights to maximize the first canonical correlation R_c. Subsequently, the second function identified by the canonical correlation was determined by maximizing the relationship between the two variates not accounted for by the first function. Each additional function was determined using the residual variance (Hair, Anderson, Tatham, & Black, 1998). The inclusion of these two parameters may have changed the dynamics of the canonical correlation, especially with regards to the interpretation of the first canonical function.

The first canonical function identified that almost all loading for the Wii Fit™ balance board variate was accounted for by the Center of Balance (r_s = .992). Additionally, the Balance Master® balance estimate reported a high loading on the Weight Bearing Symmetry (r_s = .989). It appeared that the measurements of static balance were the principal correlated components. These results confirmed the findings of Clark et al. (2010) that the balance board from the Wii Fit™ was an accurate force plate. The high correlation between the two variables tended to further strengthen the findings of Clark et al. Clark et al. discussed the validity and reliability of the Wii Fit™ balance board and concluded that the measurements were similar to using a regular force

plate. The present study, while assessing static balance using the Wii Fit™ center of balance measure and the Balance Master® body weight distribution reinforced Clark et al.'s findings. Clark et al. mentioned the necessity to develop a computer program to retrieve the data. This extra step would add some difficulty to perform the test and thus, require the person who would conduct and analyze the test to have advanced knowledge in computer programming. This would defeat the benefit of a piece of equipment "*easy*" to operate. According to the present study, if the physician required an accurate positioning of the feet in relation to the whole force plate, a computer program was not necessary to acquire the information regarding the weight bearing symmetry. Practically, the weight distribution symmetry is more valuable than the feet position within the force plate in terms of coordinates. The balance board of the Wii Fit™ was a valid measure of static balance when specific and detailed directions on how to use the piece of equipment were given. It would be appropriate for a professional to instruct a patient on how to use a Wii Fit™ balance board and let the patients report back on their progress. This could be a valuable piece of equipment for patients or elderly people with imbalance issues and the Wii Fit™ balance board would be an inexpensive apparatus for them to work on weight distribution with immediate feedback.

Which Combination of Measurements?

The second canonical function distributed its loadings among the remaining variables. However, the amount of variance explained by these loadings amounted to 15.9%. Thus, each variable's contribution to the overall score of the balance was minimal. The second canonical function appeared to be of more interest as the static

balance variables were not as strongly involved. As the remaining Wii Fit™ variables were examined, it was noted that the canonical weights were more divided between the remaining variables. The variables that required mainly lateral movements appeared to have the highest correlations. The lateral movements on the Wii exercises (e.g., Basic Balance & Ski Slalom) seemed to contribute the most to the second function with respectively 77.1% and 49.8% of the variance of the remaining 15.9%. The multidirectional games such as the Wii agility activity rated the lowest on the contribution to explaining the changes in the overall Wii Fit™ balance variate. The lateral movement component of the Balance Master® recorded the lowest correlation with the canonical variate while the antero-posterior movement variable posted the highest correlation. These results were somewhat surprising since, according to the second canonical function, apart from the static component, the Balance Master® variate was influenced by the antero-posterior and multi-directional movements while the Wii Fit™ variate was influenced by primarily lateral movements.

According to the correlation table (Table 10), the Wii Fit™ Basic Balance exercise is mildly correlated (r = .334 and r = .225 respectively) with the Balance Master® Rhythmic Weight Shift antero-posterior movement and the Balance Master® Limits of Stability Directional Control. These results were unexpected as the Wii Fit™ exercise required the participant to move in a lateral manner while given feedback in an antero-posterior way on the screen. The directional control relationship was slightly more expected as the participant was required to adjust to the amount of movement performed while pressured with time. The Wii Fit™ Agility exercise recorded as well a

mild relationship (r = .216) with the Balance Master® Limits of Stability Directional Control. Both exercises required the participant to evaluate and adjust the path of their movements and minimize extraneous movements. The inability of the participant to perform the movement on the Balance Master® in a straight path resulted in a decreased score. A time limit was present but not visible to the participant, thus not adding pressure on the performance. On the contrary, the Wii Fit™ Agility game was based on time and the participants exhibited very different strategies to achieve high scores. Most participants were not familiar with the Wii Fit™ equipment or the game. While the instructions were specific as to control your Mii and touch as many targets as possible, it was observed that some participants chose to engage in erratic hip strategies, thus resulting in a more "hit or miss" type of movement. The Wii Fit™ soccer game was also related to the Balance Master® Limits of Stability Directional Control (r = .209). The Wii Fit™ Soccer game strictly required the participants to move in a lateral manner. It was observed, however, that the participants had a tendency to "head" the ball with their upper body, thus using precious time to regain their balance prior to the next object coming to them. The amount of movement was variable as five different potential placements of the objects were possible. An adequate control of the amount of movement was necessary to record a high score. The Wii Fit™ Ski slalom game was correlated to both the Balance Master® Rhythmic Weight Shift antero-posterior movement and the Balance Master® Limits of Stability Directional Control (r = .244 and r = .267 respectively). This relationship was expected because the Ski Slalom game required the participant not only to control the amount of movement in order to pass the

gates and not overshoot them but also to be able to control their antero-posterior movement to maximize their speed and thus minimize the time to complete the course.

It was observed that many participants adopted a different attitude when testing on the clinical piece of equipment compared to the video game. They seemed to concentrate more and be more serious. Their demeanor changed when testing on the Wii Fit™. It did not matter what the order was of the testing, the change in behavior was frequently observed. As no supporting data was recorded to that effect, it seemed to be very similar to the reports from several studies (Allen, 2010; Brumels et al., 2008; Pigford et al., 2010) that the participants enjoyed the involvement in the activity. Express cautiousness in interpreting the scores of the game should be used as it was easy to "cheat" and perform a better score without challenging oneself. The investigator had to carefully explain the delimitations of allowed movements, as the necessity to keep the heels in contact with the balance board or the force plate at all times. It was observed that several participants were "caught in the action" and forgot about the rules more often on the Wii Fit™ balance board rather than on the Balance Master® force plate.

Some studies have identified the Wii Fit™ balance board as an adequate tool for training and increasing balance abilities in various populations (Brumels et al., 2008; Williams et al., 2011). The absence of a strong relationship between the games and the Balance Master® measurements indicated that it would be premature to depend on those data to evaluate individual balance abilities. There was no consensus on the benefits of video games utilization for balance training. This study did not attempt to assess the benefits of the Wii Fit™ balance board as a training tool but rather examined the validity

of some games against an established means of balance measurement, the Basic Balance Master®. With the given combination of games and exercises, it appeared that the Wii Fit™ static measurement was valid. The assessment of dynamic balance would require more research.

Conclusions

In conclusion, the Wii Fit™ Balance Board selected exercises showed excellent criterion validity for measuring balance as compared to the more established Balance Master®. All selected Wii Fit™ games seemed to provide a rather accurate depiction of balance ability of each participant. The results from this project, however, were insufficient to recommend the use of the selected Wii Fit™ activities as a clinical assessment tool. Although the Wii Fit™ Balance Board seemed to be an accurate device, it would require much control of the directions given to the patients for a reliable performance. The use of the Wii Fit™ Balance Board was acceptable for assessing static balance and weight distribution however the present study failed to demonstrate a strong validity of dynamic Wii Fit™ games to assess balance. The recommendation for using such a device outside a clinical environment and at home would be premature and require additional data. Supplementary research is needed to strengthen the identified trend.

Recommendations for Further Studies

A larger sample size would be beneficial in future studies. In addition while the sample size was sufficient, it included only individuals without any physical impairments or limitations. The sample was rather homogeneous regarding the familiarity with the Wii Fit™. It might be useful to use a large sample of participants very familiar with the

Wii Fit™ to possibly reduce the learning effect. As the static balance components were so strongly loaded, it would be advisable to remove such components and identify the loadings of the Wii Fit™ games. In the future, adding games to the future studies would be beneficial.

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APPENDIX A

TEGNER ACTIVITY LEVEL SCALE

Activity Level

Tegner Activity Level Scale: _____

Level 10	Competitive sports- soccer, football, rugby (national elite)
Level 9	Competitive sports- soccer, football, rugby (lower divisions), ice hockey, wrestling, gymnastics, basketball
Level 8	Competitive sports- racquetball or bandy, squash or badminton, track and field athletics (jumping, etc.), down-hill skiing
Level 7	Competitive sports- tennis, running, motorcars speedway, handball Recreational sports- soccer, football, rugby, bandy, ice hockey, basketball, squash, racquetball, running
Level 6	Recreational sports- tennis and badminton, handball, racquetball, down-hill skiing, jogging at least 5 times per week
Level 5	Work- heavy labor (construction, etc.) Competitive sports- cycling, cross-country skiing, Recreational sports- jogging on uneven ground at least twice weekly
Level 4	Work- moderately heavy labor (e.g. truck driving, etc.)
Level 3	Work- light labor (nursing, etc.)
Level 2	Work- light labor Walking on uneven ground possible, but impossible to back pack or hike
Level 1	Work- sedentary (secretarial, etc.)
Level 0	Sick leave or disability pension because of knee problems

Tegner and Lysolm (1985).

APPENDIX B

DEMOGRAPHICS, INJURY HISTORY, AND WII FIT™ USE HISTORY

Questionnaire

Demographics

Sex: ☐ Female ☐Male

Ethnicity: ☐Caucasian ☐Hispanic

Age: _____

☐African American

Height: _____

☐Asian/Pacific Islander

Weight: _____

☐Native American

Waist circumference: _____

☐Other: _____

Hip circumference: _____

Injury history

Have you had any injury in lower body joints in the past year?

☐Knee ☐Ankle ☐Hip

Have you had any injury in lower body joints prior to this past year? Please indicate the approximate date for each.

☐Knee_____ ☐Ankle_____ ☐Hip_____

Have you experienced lower back pain in the last year?

☐Yes ☐No

Have you had any other significant impairment to your motor ability in the past year?

☐Yes ☐No

Nintendo Wii Fit™ Use

How often have you used the Wii Fit™ with balance board system in the past month?

_____

Place a check mark if you have played any of the following balance board games in the past month:

☐ Ski Slalom ☐ Soccer Heading ☐ None

APPENDIX C

IRB APPROVAL LETTERS

TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378 FAX 940.898.4416
e-mail: IRB@twu.edu

November 21, 2011

Ms. Vanessa Fiaud
7500 Hillside Rd., Apt. #713
Amarillo, TX 79119

Dear Ms. Fiaud:

Re: Criterion Validity of Selected Wii Fit Games for Balance Assessment (Protocol #: 16873)

The above referenced study has been reviewed by the TWU Institutional Review Board (IRB) and appears to meet our requirements for the protection of individuals' rights.

If applicable, agency approval letters must be submitted to the IRB upon receipt PRIOR to any data collection at that agency. A copy of the annual/final report is enclosed. A final report must be filed with the Institutional Review Board at the completion of the study. Because you do not utilize a signed consent form for your study, the filing of signatures of subjects with the IRB is not required.

This approval is valid one year from November 21, 2011. Any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any unanticipated incidents. If you have any questions, please contact the TWU IRB.

Sincerely,

Kathy DeOrnellas, Ph.D.

Dr. Kathy DeOrnellas, Chair
Institutional Review Board - Denton

enc.

cc: Dr. Charlotte Sanborn, Department of Kinesiology
Dr. David Nichols, Department of Kinesiology
Graduate School

West Texas A&M University
Institutional Review Board for Human Subjects

October 13, 2011

Vanessa Fiaud
WTAMU Box 60216
Canyon, TX 79016

We are pleased to inform you that your study titled. "Criterion Validity of selected Wii Fit Games for balance assessment" has been approved by the WTAMU IRB. This approval is extended to you for one year. Should data collection proceed past one year, or should you make changes in the methodology as it affects human subjects, you must resubmit the study to the IRB.

Thank you for your cooperation with the IRB and we wish you well with your research project.

Sincerely,

Dr. Angela Spaulding, *ex-officio*
Dean, Graduate School and Research

Dr. Gary Hignam
Chair, WTAMU IRB

Discover the **BUFF** in You.

APPENDIX D

RECRUITMENT FLYER

Sports and Exercise Sciences Department

Come find out your Wii age !!!

Participants Needed

Balance Study with Wii Fit !!!

- One time 1 hr Commitment
- Must be 18 or older
- No recent injuries
- Voluntary Participation

Contact person: Vanessa Fiaud
(806) 651-2677
vfiaud@wtamu.edu
VHAC 230

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APPENDIX E

CONSENT FORM

West Texas A&M University
Consent to Participate in Research

Project Title: Criterion Validity of selected Wii Fit Games for balance assessment.
Principal Investigator: Vanessa Fiaud – 806-651-2677

Introduction:

You are being asked to participate in a research study for Ms. Fiaud at West Texas A&M University. This research is being done for Ms. Fiaud's dissertation as part of her Ph.D. requirements at Texas Woman's University. The purpose of this study is to contribute to knowledge about the possibility of the Nintendo Wii Fit™ system with the balance board being used as an instrument to assess balance capabilities and limitations in the general population. Specifically, this study examines special balance features and two games for the Wii Fit™ and their relationship with a more established measure of balance assessment, the Balance Master®.

Balance is an important concept that often defines whether a person can live an independent life or not. Balance issues are critical in both elderly and overweight populations. The ability to assess balance aptitude in a regular and easy manner would provide professionals with important information to better serve those populations. The Wii Fit™ Balance Board is a portable, cheap, and entertaining device that could potentially serve that purpose.

Research Procedures

For this study, the investigator will collect data including your height, weight, circumference of your waist and hips. This data collection will be done in the Biomechanics Lab at West Texas A&M University. You will be then asked to answer a questionnaire regarding your familiarity with the Wii Fit™ and your perception of physical activity level. You will be then asked to perform a series of games on the Wii Fit™. Using the Balance Master, you will be asked to follow the investigator's instructions to perform 3 exercises: the Limits of Stability, the Rhythmic Weight Shift, and the Weight Bearing Squat. Your maximum total commitment time in the study is estimated to be approximately 1 hour. Upon completion of the tests, you will be free to go.

Potential Risks

Potential risks related to your participation in the study include fatigue and physical or emotional discomfort during your interview. To avoid fatigue, you will have a rest period between the tests of up to 5 minutes. You can choose to stop and leave the study at any time without any consequences. Only the principal investigator will be present for all testing. You may request the presence of additional people for comfort. The data will be kept confidential and will be disclosed to the participant only at their request.

Another possible risk to you is the loss of balance resulting in possible injury. The principal investigator will be positioned on the side of the participant to prevent any fall. If the participant were to fall and hurt themselves, the principal investigator will call 911 for assistance.

_____

Participant initials

Another possible risk to you as a result of your participation in this study is release of confidential information. Confidentiality will be protected to the extent that is allowed by law. All collected data will be coded using participant ID which will not be linked to a specific participant name. Only the informed consent will have the name of the participant and they will not be stored in the same file as the data. During data collection, the data will be kept in a binder with the principal investigator. Only the investigator will have access to the information which will be stored in a cabinet in the principal investigator's office. It is anticipated that the results of this study will be presented at conferences as well as in other research publications. However, no names or other identifying information will be included in any publication. *"Confidentiality will be protected to the extent that is allowed by law."*

"The researcher will try to prevent any problem that could happen because of this research. You should let the researcher know at once if there is a problem and she will help you. However, TWU does not provide medical services or financial assistance for injuries that might happen because you are taking part in this research."

Participation and Benefits

Your involvement in this research study is completely voluntary, and you may discontinue your participation in the study at any time without penalty. The only direct benefit of this study to you is that at the completion of the study you may request the results by contacting the principal investigator through e-mail.*

Questions Regarding the Study

If you have any questions about the research study you may ask the researcher; her phone number are at the top of this form. If you have questions about your rights as a participant in this research or the way this study has been conducted, you may contact the West Texas A&M University Research Compliance Officer at 806-651-2732. You will be given a copy of this signed and dated consent form to keep for your record.

_____ _____

Signature of Participant Date

- **If you would like to receive a summary of the results of this study, contact the Principal Investigator's e-mail address:**

Vanessa Fiaud

*vfiaud@twu.edu

_____

Participant initials

APPENDIX F

ORIGINAL DATA

ID	gender	Ethnic	age	height	weightkg	Tegner	WiiCOBR	WiiBB	WiiAgil	WiiSoc	WiiSki	BMWBR	BMRWl	BMRWap	BMLOSmxe	BMLOSdc
1	0	2	20	156.5	48.18	6	55.4	36	11	42	111.7	56	88	88	109	79
2	0	1	26	159	50.91	6	55.6	24.19	12	467	48.28	55	90	89	102	84
3	1	1	21	190.5	96.36	9	53.5	29.42	12.3	135	80.83	54	90	90	98	88
4	1	2	21	177	77.27	7	48.2	29.63	12	202	92.76	49	92	79	99	73
5	1	2	23	180	93.64	5	48.9	42	15	97	63.56	50	79	79	101	80
6	0	1	23	167.7	71.82	9	54.8	27.56	14	190	59.2	55	91	77	99	68
7	1	1	23	175	81.82	9	57	29.97	13	125	60.75	60	90	80	92	77
8	0	1	20	165	53.64	9	53.4	42	10.6	46	76.21	54	89	84	100	71
9	0	1	24	167.7	70.00	9	52.1	36	15.3	217	38.45	53	91	87	103	84
10	0	2	21	165	95.45	2	51.2	27.65	14.6	118	60.56	51	85	77	103	82
11	1	2	21	172.7	72.73	3	59	30	13	153	67.8	63	88	76	99	85
12	0	1	19	162.5	68.18	6	51.9	36	11	40	61.45	51	87	89	101	76
13	1	2	22	177.8	83.64	7	52.4	26.24	13.6	238	40.3	51	90	84	97	80
14	1	2	24	185.5	102.27	7	47.2	36	11.3	109	90.36	45	84	68	85	56
15	0	2	20	162.5	72.73	3	53.6	30	12.3	19	105.26	55	90	77	95	70
16	0	2	24	152.4	84.09	4	48.7	42	10	37	56.23	49	91	89	95	73
17	0	1	21	162.5	57.73	5	52.4	29.35	12	21	53.03	50	92	90	103	85
19	1	2	22	167.7	63.64	4	51.5	36	12.3	103	44.5	53	93	91	90	85
20	0	2	19	157.5	56.36	6	53.9	42	11	111	60.08	55	89	69	93	71
21	1	2	22	170	69.32	5	49.5	27.67	14.3	128	54.21	50	89	88	103	88
22	1	1	21	183	93.18	9	48.3	26.15	15	63	66.55	49	90	85	103	86
23	1	1	23	177.8	82.73	9	51.8	28.22	15.6	48	51.93	52	90	83	83	72
24	1	1	21	177.8	84.09	7	46.5	36	11	222	45.31	48	89	87	101	82
25	1	1	21	180.3	81.82	9	54.8	28.53	15	223	69.45	55	93	93	98	84
26	1	1	21	180.2	81.82	5	54	25.05	14.6	61	65.38	54	90	85	91	74
27	0	1	22	157.5	57.73	2	55.1	30	13	54	59.85	54	91	93	100	87
28	1	2	22	180	93.18	9	52.2	30.3	13	173	75.4	55	91	85	97	78
29	1	3	21	167.7	66.36	7	51.2	42	11	133	45.06	51	89	78	93	76
30	0	2	21	160	63.64	5	50.7	29.18	14	78	77	50	91	90	100	81
31	1	2	18	176	81.36	7	51.3	32	14	144	60.3	51	90	87	101	76
32	0	2	19	165	68.18	9	54.6	32	13.3	132	46.53	55	91	77	97	67
33	0	1	20	152.4	52.27	7	54.8	36	10.6	29	57.81	55	93	89	109	82
34	0	2	56	165	49.09	6	47	36	15.3	134	84.58	45	86	77	92	80
35	1	2	22	170.1	80.91	7	51.6	36	12	163	61.88	51	88	90	97	82
36	0	1	29	165	56.82	5	51.4	30	14.3	213	53.48	53	92	88	101	78
37	1	1	41	185.4	90.00	1	47.2	36	11.6	43	67.68	49	89	82	102	75
38	0	1	18	165.1	55.00	8	51.8	30	12.3	63	74.3	52	89	81	98	86
39	0	1	39	159	97.27	3	46.1	42	10	100	46.16	47	92	90	98	83
40	0	1	19	180.3	60.91	7	51.4	25.72	13.6	115	42.48	52	90	87	99	85
41	0	2	20	160	56.82	3	54.8	28.41	15	25	61.03	56	90	81	100	76

ID	gender	Ethnic	age	height	weightkg	Tegner	WiiCOBR	WiiBB	WiiAgil	WiiSoc	WiiSki	BMWBR	BMRWl	BMRWap	BMLOSmxe	BMLOSdc
42	1	1	20	190.5	102.27	5	51.1	29.17	14	92	53.41	50	90	88	96	81
43	0	1	21	170	51.82	3	52.2	27.49	13.6	151	51.86	50	85	81	99	81
44	1	1	21	170.1	75.00	6	51.2	26.64	15.3	190	42.21	50	85	85	107	83
45	1	2	22	188	119.55	7	53.6	36	11.3	126	67.48	57	90	79	92	85
46	0	2	23	157.5	42.27	3	56.8	42	11	37	83.81	60	86	74	98	83
48	0	1	19	175	58.18	9	49.1	26.34	16.6	98	63.23	49	90	87	94	83
49	0	1	21	178	70.45	5	52	27.38	12	96	57.78	57	85	75	105	78
50	0	2	20	167.7	84.09	4	46.8	42	12.3	40	70	50	87	65	94	69
51	1	1	19	196.6	99.09	5	49.5	36	13	99	67.85	49	88	85	101	81
52	1	1	20	183	90.91	7	50.7	30	16.6	348	47.23	51	86	87	102	84
53	0	2	20	157.5	58.18	4	51.6	36	12	334	52.33	54	88	86	100	85
54	0	1	20	170	86.82	3	51.3	42	13.6	25	75.36	53	91	81	105	82
55	0	2	30	160	68.18	3	45.8	26.94	16	18	56.36	45	91	85	98	75
56	1	1	21	180.3	74.09	5	52.2	27.59	12.6	79	49.43	52	89	91	97	80
57	0	1	23	167.7	56.14	3	48.5	32	15.3	89	69.93	49	88	82	97	84
58	1	1	22	170.1	77.27	6	52.4	26.94	14.6	183	48.48	53	87	75	93	65
59	1	3	20	174	62.73	10	51.6	48	10.6	42	72.36	54	90	91	96	76
60	1	3	19	180.3	96.82	10	45.6	42	9	61	80.23	42	91	75	90	73
61	1	1	22	193	109.09	5	54.1	29.94	15.3	244	48.16	54	90	85	101	85
62	1	1	20	177.8	65.00	7	53.5	27.34	12.6	191	39.58	54	90	89	94	85
63	0	3	23	172.7	70.45	2	51.7	48	11	57	97.1	51	89	63	98	77
64	0	3	22	165	65.45	2	53.3	32	11.3	61	90.85	56	89	83	102	82
65	1	1	21	188	103.64	4	50.3	22.62	14	379	35.98	53	86	86	94	84
66	1	1	30	177.8	85.00	5	56.7	28.57	15	152	46.43	56	92	90	94	88
67	1	1	21	187.9	93.64	6	46.4	21.97	17.3	79	68.18	48	92	81	100	84
68	1	1	21	187.9	80.00	6	55.1	27.86	15.3	285	54.4	54	92	84	91	89
69	1	1	20	182.8	65.45	9	51.4	36	14.6	109	113.71	50	92	88	93	87
71	1	3	45	180.3	87.73	6	55.4	42	10	36	103.23	56	87	82	79	75
72	0	1	40	157.4	70.45	4	50.7	36	15	184	40.93	51	88	79	105	76
73	0	2	22	162.5	81.36	3	47.3	42	14	10	81.61	48	88	70	87	82
74	1	1	23	172.7	94.09	5	51.4	36	12	113	45.6	50	86	87	102	84
75	0	1	21	167.8	65.45	3	54.2	29.54	13.6	277	51.48	54	88	86	100	85
76	1	1	20	180.3	80.91	4	49.3	25.84	18.6	228	44.96	46	92	84	107	89
77	1	2	23	172.8	75.00	7	53.6	25.81	15.6	319	38.26	54	84	91	99	92
78	0	2	23	152.5	50.00	9	50.6	26.02	16.3	242	44.45	52	89	88	93	87
79	0	2	19	172.6	86.36	3	43.6	29.58	13.6	111	46.18	42	89	89	90	84
80	0	1	21	172.7	61.36	5	51.6	30	12.3	50	69.85	55	88	84	102	83
81	1	3	23	190.5	116.36	9	56	28.6	12	220	68.66	55	92	80	96	73
82	0	1	22	162.5	53.64	3	51.6	25.24	15.6	100	61.33	52	87	85	83	89
83	0	1	20	160	60.91	6	51.7	22.84	14	155	52.55	51	92	77	101	75

ID	gender	Ethnic	age	height	weightkg	Tegner	WiiCOBR	WiiBB	WiiAgil	WiiSoc	WiiSki	BMWBR	BMRWl	BMRWap	BMLOSmxe	BMLOSdc
84	1	1	20	180.3	94.55	5	46.8	26.9	12.6	233	43.5	46	89	85	95	79
85	1	1	20	185.5	104.09	2	47.9	26.6	15.6	138	49.81	49	90	89	98	84
86	1	3	25	182.9	75.00	6	49.6	24.58	12.6	215	73.31	51	90	89	100	84
87	1	1	32	175.3	88.18	5	51.6	36	15	130	58.33	53	85	89	101	87
88	1	2	23	188.9	92.27	9	49.8	30	12	168	64.95	49	87	89	101	69
89	1	1	21	182.9	82.27	6	41.1	29.52	13	72	74.31	41	86	86	102	85
91	0	1	19	150	54.55	6	53.7	22.65	13.3	210	63.51	54	90	90	97	84
92	0	1	19	160	69.09	6	50.1	28.62	12.6	165	56.65	49	89	89	97	85
93	1	1	24	170	95.45	5	49.8	28.59	13.6	58	64.68	49	89	91	101	84
94	1	1	23	187.9	88.64	8	46.1	36	15	172	44.58	43	87	76	94	83
95	1	1	19	180.4	84.09	6	47.4	36	11	293	34.76	46	88	82	99	84
96	1	1	21	172.7	76.36	5	48.1	36	10	145	46.35	48	91	81	97	80
97	1	2	19	180.3	90.00	5	47	36	9.3	21	108.06	42	91	75	90	73
98	1	1	20	185.4	80.00	6	49.8	36	18	313	72.33	48	86	78	96	74
99	1	1	19	177.8	82.27	5	43.4	28.52	17	177	41.9	46	84	82	95	75
100	1	1	20	193	110.00	9	46.7	23.4	10	174	38.95	47	90	87	100	80
101	1	1	29	170.1	73.64	5	42	27.05	13	121	58.86	48	89	86	97	85
102	1	1	19	172.7	76.36	6	47.4	28.67	12.3	108	54.4	49	88	82	98	77
103	1	1	21	167.7	69.09	4	48.6	22.64	13	140	46.63	52	85	82	88	78
104	1	2	24	167.8	70.91	5	51.4	36	13	154	36.43	51	87	83	90	86
105	1	3	36	188	88.18	4	55	48	14	11	36.21	62	85	81	86	81
106	1	2	21	178	87.27	9	48	36	15	324	60.96	48	88	84	89	74
107	1	1	32	170.1	82.73	5	54	26.25	18	66	73.63	53	88	81	92	70
108	1	1	30	182.8	88.64	4	53.9	42	13	233	63.18	54	88	80	97	73
109	0	2	22	155	62.27	7	52.6	36	14	106	106.08	52	85	86	87	78
110	1	1	21	177.9	86.82	6	49.6	36	15	308	39.61	51	87	86	98	85
111	1	1	23	182.9	87.27	6	51.2	29.07	13.6	91	53.01	51	91	88	104	84
112	0	1	22	160	57.27	6	51.4	36	14	71	74.1	52	90	88	94	83
113	1	2	20	172.7	71.82	9	46.1	42	11.6	89	93.31	45	88	89	96	82
114	1	3	20	190.5	91.36	9	49.1	42	16	127	89.45	47	86	83	95	78
115	1	2	23	162.5	69.55	9	48	42	11	89	49.9	48	87	73	101	81