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# A Comparison Of Performance On The Wii Basic Balance Test Between Concussed And Non-Concussed Collegiate Students

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A COMPARISON OF PERFORMANCE ON THE WII BASIC BALANCE TEST  
BETWEEN CONCUSSED AND NON-CONCUSSED  
COLLEGIATE STUDENTS

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by  
Vanessa E. Fernandez-Vivar  
2013

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VANESSA E. FERNANDEZ-VIVAR

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Vanessa E. Fernandez-Vivar

## Abstract

The Wii Board Basic Balance Test has served as a useful tool for assessing balance in concussion management. In the event that an athlete is concussed, baseline data will be useful when managing a concussion. In cases where baseline data is not available, having normative data is useful to refer to in order to make appropriate return-to-play decisions. To date, normative data on the Wii Board Basic Balance Test is not available. *Purpose:* This study will compare the performance of concussed and nonconcussed individuals on the Wii Basic Balance Test. *Method:* A between subject design between the two groups of participants is used. The nonconcussed sample group consisted of 84 college students, 53 females and 31 males. The second group consists of 20 concussed participants, 12 males and 8 females. A parametric Univariate Analysis (1 way ANOVA) and a non-parametric Chi-Square test were used to compare between group performances. *Results:* Statistically significant differences were found between the number of trials completed between groups ( $F(1,102)=6.475, p=.012, \eta^2=.060$ ) and the difference, in time, required to complete trial 1 on the Wii Basic Balance Test ( $p<.001$ ). The nonconcussed or normative group completed more trials, in less time than the concussed individuals. Results suggest that normative data on the Wii Basic Balance Test will contribute to the diagnosis and return-to-play decisions for concussed collegiate athletes. Differences found in performance between concussed individuals at Post Concussion test 1(PCI) and the nonconcussed -group may be beneficial Wwhen interpreting the results of concussed collegiate athletes at PCI on the Wii Basic Balance Test

**KEY WORDS:** Concussion, mTBI, balance, dizziness, Wii Balance Board Basic Balance Test

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## **Chapter 1: Introduction**

The virtual reality game system, known as the Nintendo Wii, has progressed from being exclusively an entertainment system to a system used more and more frequently in the rehabilitation setting. This economic, entertaining and commercially available gaming system has become a practical tool in concussion management. Unfortunately normative data does not exist for this game. This study (1) collected data on the performance of a large sample of nonconcussed individuals, and (2) compared the performance of the nonconcussed/normative sample to a sample of concussed athletes.

### ***1.1 Concussion***

The term concussion is often used interchangeably with the term mTBI. A concussion can be defined as “a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces” (McCroy, Meeuwisse, Johnston, Dvorak, Aubrey, et al., 2009). A concussion may occur after a hit to the head, face, neck, or anywhere on the body that forces the head to shake violently. The violent shaking of the head causes the brain to shift abruptly, striking the skull, which may in turn result in neurological damage.

### ***1.2 Balance and Concussions***

As identified by the literature concerning concussions, symptoms reported immediately after a concussion include: headache, dizziness, sensitivity to light, and a combination of cognitive symptoms (feeling mentally slowed down, mental foggy, poor concentration, and memory difficulties) (McCrea, & Academy, 2007). Within the identified list of symptoms, dizziness is recorded second to headaches as an indicator of concussions (McCrea, & Academy, 2007). Athletes who report feeling dizzy after suffering a concussion are ultimately having difficulties maintaining their balance. Balance is, for the most part, an unconscious

process in a healthy individual. Balance is possible through the integration of information from the vestibular system, visual system and the proprioceptive system as well as mechanoreceptors present on the skin (Damijan et al., 2011). The information gathered from these three systems is collected in the central nervous system (CNS). The CNS is responsible for determining the body's orientation in space and sends neural messages to the motor system to activate movements that will maintain the body's equilibrium. A concussion affects this complex system resulting in the common reported symptom of dizziness on concussed patients.

### ***1.3 Balance Assessments in Concussion Management***

Traditionally, two assessments have been used frequently to assess balance. These commonly used assessment tools consist of the Romberg's test and the Balance Error Scoring System (BESS). The Romberg test was named after the German neurologist, Moritz Heinrich Romberg, in 1853. (Diamantopoulos, Clifford & Birchall, 2003) This test has been used by a number of doctors in a neurological examination and is now being used to test for drunken driving. The notion behind this exam is that an individual requires two of three senses to maintain his/her balance while standing. The three systems responsible for these senses are proprioception, sensation, and vision. The Romberg test requires a patient to stand straight with both feet together placed side-by-side. The patient is then asked to lift both arms straight in front of him/her with the palms of the hands parallel to the ceiling. Once the patient is in this position, he/she is asked to close his/her eyes. The client is then provided with a push towards the front, back and sides. A loss of balance and/or swaying is interpreted as a Romberg positive; whereas, no loss of balance would be interpreted as a Romberg negative. One essential observation made

in this assessment is that a patient's balance becomes more unsteady when his/her eyes are closed.

The Romberg test is possibly the most commonly used test to assess postural stability (Diamantopoulos, Clifford & Birchall, 2003). Regardless of its commonality among clinicians and Department of Public Safety, a large number of differences are seen in the manner that this assessment is administered. One of the main limitations is that the Romberg Balance test is not a standardized test. Some patients are not instructed to raise their arms, while other patient's results differ given the difference in strength used when pushing the patient while his/her eyes are closed. The Romberg test has demonstrated to have low test-retest reliability values and should therefore be used with caution. (Steffen & Seney, 2012) Furthermore, this assessment lacks in quantitative data given the pass or fail nature of this assessment.

Another frequently used assessment for static postural and stability is the BESS. The BESS requires two testing surfaces, the ground and a foam pad for the purpose of creating an unstable surface and a more challenging balance task. The BESS also requires the use of a stop watch, spotter, BESS testing protocol, and a BESS score card. This assessment consists of six twenty-second tests with three different stances on the two different surfaces. The stances include the double leg stance where two feet are placed together, the hands are on the hips and the eyes are closed. Stability is required to be maintained for twenty seconds. The second stance is the single leg stance in which the patient is asked to stand on the non-dominant foot and the dominant leg is held approximately 30 degrees of hip flexion and 45 degrees of knee flexion. The patient is asked to close his/her eyes and maintain stability for 20 seconds. The third stance is referred to as the tandem stance. The patient is asked to stand heel-to-toe with the non-dominant foot placed in the back. The patient is then asked to place their hands on their hips and

close his/her eyes. Again, they should try to maintain stability for 20 seconds. Each of these stances are repeated on the foam pad. The BESS is scored by counting the accumulated errors or deviations from the proper stance. The following are considered errors and are counted against the patient: moving the hands off of the iliac crest, opening the eyes, step stumble or fall, abduction or flexion of the hip beyond 30 degrees, lifting the forefoot or heel off of the testing surface, and remaining out of the proper testing position for greater than five seconds. The maximum number of errors for any single condition is ten (Wilkins, et. al., 2004).

This assessment was developed to assess the effects a concussion has on balance. Because of this test's portability, it has been used to make sideline evaluations or anywhere other than outside the laboratory. Some of the advantages of the BESS are that it can be used for sideline application, is less expensive, and requires less training for effective administration. (Wilkins, Valovich McLeod, Perrin & Gansneder, 2004) Fatigue has demonstrated to play a factor in posture stability. With regards to the BESS, a decrease in performance has been observed after a patient experiences fatigue, resulting in an increase in the patient's total error score (Wilkins, Valovich McLeod, Perrin & Gansneder, 2004). Another observation that has been made on the BESS is that during the course of repeated testing, a significant practice effect has been found (Valovich, Perrin & Gansneder, 2003).

#### ***1.4 Wii Balance Board Basic Balance Test in Concussion Management***

The idea of using video games in the healthcare field was first introduced in the 1970's by Myron Krueger, who was interested in video capture technology (Weiss et al., 2004). Since this time, studies have investigated the use and benefits of using videogames, termed virtual reality (VR), in the allied sciences and healthcare for rehabilitation purposes (Weiss et al., 2004). The Nintendo Wii has not been available to the public for an extended amount of time. The

Nintendo Wii was made available in 2008 and the Wii-fit since 2009. After the release of the Nintendo Wii and the Wii-fit, clinics quickly incorporated the Wii in order to measure and track balance in a short period of time. (Deans, 2011) Furthermore, the NCAA Committee on Competitive Safeguards and Medical Aspects of Sports (2010) has classified the Wii-fit as an acceptable concussion management assessment tool for assessing baseline measures of balance (Yanda 2010). However, the Nintendo Wii Balance Board has had mixed research outcomes and limited research preventing it from being fully incorporated into allied healthcare. That is, until its validity and reliability are established. (Deans, 2011)

The Wii Balance Board's Basic Balance Test is used to test the balance of athletes during baseline testing and at post-concussion. The Wii Balance Board Basic Balance Test has become a useful tool in concussion management. This balance test is administered to athletes who are participating in contact sports. It is ideal for an athlete to have pre-season baseline testing in order to have data on how the athlete functions without any head injury. In the event that the athlete is concussed, this data will be useful when managing a concussion. Baseline data will help the clinician in recognizing when the athlete's brain has healed from the concussion, since it will return to the capabilities it had at baseline testing. Unfortunately, baseline data is not always available on every athlete. In cases like this, having normative data is practical to compare the results of the concussed athlete.

Normative data is not available for the Wii Basic Balance Test. This balance test has been one of the many useful tools used for managing a concussion. Having normative data available will make this test even more effective. Although other balance tests, such as the Balance Error Scoring System (BESS) and Romberg's test are accepted for testing balance,

they do not offer the practical and appealing 3-dimensional computer experience that the Wii Basic Balance Test offers benefiting the athlete and the clinician.

### ***1.5 Purpose***

The purpose of this study was to gather normative data for the Wii Balance Board's Basic Balance Test and to compare the results of concussed patients on the Wii Balance Test to the normative data collected. The collection of this normative data will be used as a clinical guide when managing a concussion. This normative data will serve as a clinical tool used when making return-to-play decisions on athletes without baseline testing who have suffered a concussion.

## **Chapter 2: Method**

### ***2.1 Participants***

84 nonconcussed students (53 females and 31 males) attending the University of Texas at El Paso (UTEP) were recruited for this study to represent the normative sample. The results of 20 concussed participants (12 males and 8 females) on the Wii Board Basic Balance Test were collected from a pre-existing database based on their composite scores on the Immediate Post-Concussion Assessment and Cognitive Test (ImPACT). The participation for this study was strictly voluntary. Testing for the normative sample was conducted at the UTEP Concussion Management Clinic (CMC). Participants in both groups were required to fall within the ages of 18-25 years. Normative sample participants were required to have a history of sport involvement, and with no history of mTBI/concussions, meningitis, Hydrocephalus, Hydranencephaly, balance disorders, Seizures, and/or any form of attention deficit disorders. Patients cannot exceed the Wii Balance Board's weight limit of 150kg or 330 lbs.

Recruitment for the normative sample was done by randomly approaching students who attend UTEP. If the student accepted to participate, they were asked to complete a brief questionnaire to determine if they meet the basic criteria for his study. This questionnaire consisted of a list of disorders and asked the participant if they have ever been diagnosed with any of these. If the criteria was met, the participant was scheduled to attend the CMC to complete the Wii Fit Basic Balance Test.

The sample of 20 concussed participants in this study consisted of collegiate athletes between the ages of 18-25 years who completed the Wii balance test and the neurocognitive test, The Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) in the UTEP CMC. The participant's Wii Balance Test and ImPACT results were derived from a pre-

existing post-concussion database in the CMC. This database contains results from a battery of tests given to concussed patients seen in the clinic. Concussed participants were selected from the database if any of their ImPACT composite score(s) fell at two standard deviations or more below the mean, reflecting a group of severely impaired concussed participants. The Wii Balance Test results completed on the first post-concussion assessment were analyzed and compared to the nonconcussed/normative sample performance.

All procedures, benefits and risk related to this research study were comprehensively explained to each normative sample participant prior to completing the initial questionnaire at the scheduled appointment date before initiating the Basic Balance Test. Participants were repeatedly assured that their participation in this study was entirely voluntarily and of their right to withdraw from this study at any time. Each participant was asked to read and sign the written consent. The opportunity for any questions regarding the study was encouraged.

The participant's decision to take part in this study will be kept confidential. All results have been reported without disclosing any identifiable information that may reveal the identification of the participant. The data was analyzed and entered into a dataset for analytical purposes. A hard copy of consent forms, questionnaires and test results were filed in a file cabinet and will be kept locked. The file cabinets are located in the CMC laboratory at UTEP which is always locked, when not in use. The dataset has been saved into one of the computers found in the CMC. These computers require a password that only the test administrator and advisor have for accessing purposes.

All of the participant's information was held confidential. This information was used to gather normative data for the Wii Basic Balance Test, but does contain identifiable information

disclosing the participant. The participant's file includes signed consent forms, questionnaire and Wii Basic Balance Test results. At no time, was this study audio or video recorded.

## ***2.2 Statistical Analysis***

This study was a between subject design between the two groups of participants. Parametric statistical analyses are reported for the comparison of performance on the Wii Board Basic Balance Test between the concussed and normative sample groups. To compare the two groups, a parametric Univariate Analysis (1 way ANOVA) and a non-parametric Chi-Square test were used. Furthermore, descriptive statistics were used in order to further evaluate differences between trials found between non-concussed and concussed participants on the Wii Board Basic Balance Test. The dependent variable in this study is the number to total trials completed within 30 seconds and the total amount of time to complete the first trial in the game. The independent variable is the age of the participants, education level, medical history, and history of sport involvement.

## ***2.3 Study Interventions***

### ***2.3.1 Description of Wii Gaming Technology***

Nintendo has created the Wii Fit Basic Balance Test along with the Wii Balance Board. The Wii Balance board comes with a number of different games. The only task that was used to assess a patient's balance was the Basic Balance test. In this test, the participant's gender, date of birth, height and weight of the clothing (options consist of light, heavy or none) were required to proceed with the testing. After an explanation concerning center of balance was displayed on the television screen, the participant was asked to step on the Wii Balance Board. While standing on the balance board the participant was asked to relax the shoulders and to place the arms to the

side of the body. The participant was then required to stand still for the balance board to detect the patient's center of balance. If the center of balance was not appropriately centered, the participant was asked to first be aware of his/her center of balance by shifting his/her weight and manipulating a blue dot on the screen by asking the participant to place this blue dot inside a pink circular area and keep this there for three seconds. Once the participant completed this task, the Wii Balance Board presented with instructions on the computer screen regarding the Wii Balance Test. The Wii Balance Test offered a practice session which consists of two practice trials allowing the participant to become familiar with the task and practice the task. The test consists of five test trials and allows the participant thirty seconds to complete all trials. The level of complexity increases with each trial. The first trial offers a large target requiring the participant to place a marker in this target area by shifting their body weight and maintaining their position for three seconds. The target in the fifth trial is significantly smaller, making it much more difficult to position and hold the manipulated marker in place. The results of the test demonstrated the time in seconds that it took for the participant to complete each of the five trials. The results also offered the total time, in seconds, that it took to the participant to complete the five trials. In the event that the participant did not complete the five trials in thirty seconds, the incomplete rounds were presented with a horizontal line instead of time. The maximum time allowed to complete five test trials for any participant was thirty seconds.

### ***2.3.2 Description of ImPACT Assessment Instrument***

The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT, Applications, Inc., Pittsburgh, PA) is a computer-based testing instrument designed specifically for assessing and managing sports-related concussions. The battery is divided into three sections:

Demographic information, Self-Reported Symptom Inventory, and six neurocognitive test modules. Multiple aspects of cognitive functioning that ImPACT measures includes: attention span, working memory, sustained and selective attention time, response variability, non-verbal problem solving, and reaction time. There are five ImPACT composite test scores calculated from this neuropsychological test, which include: verbal memory composite, visual memory composite, reaction time composite, impulse control composite and total symptom score composite. The battery is available in 21 different languages taking 30 to 40 minutes to complete.

## ***2.4 Study Procedures***

### ***2.4.1 Randomization***

A sample of convenience was used for the selected participants in the nonconcussed/normative sample. Students attending the University of Texas at El Paso (UTEP) were recruited for this study. Male and female students attending UTEP in the Health Sciences Building were randomly approached and asked if they were interested in participating in a study focused on the collection of normative data for the Wii Balance Board Basic Balance Test. All approached participants were advised that their participation for this study was strictly voluntary. The participants who agreed to take-part in this study were required to complete a questionnaire to determine if they fit the basic criteria set to participate in the study. The questionnaire consisted of yes/no questions along with open ended questions. These questions asked for the participant's age, since they were required to fall within the ages of 18-25 years. Additional questions asked if the student attended UTEP and if they participated in any sports affiliated to the university or during their high school years. The participants are required to have a history of sport involvement. Participants were also asked to document if they had a

history of mTBI/concussions, meningitis, Hydrocephalus, Hydranencephaly, balance disorders, seizures, and/or any form of attention deficit disorders. Any of these diagnoses would automatically disqualify the participant from the study. Participants were also asked to document their weight, given that patients cannot exceed the Wii Balance Board's weight limit of 150kg or 330 lbs. The questionnaires were immediately reviewed upon completion. If the answers fit the set criteria for the study, the participant was scheduled to meet in the UTEP Concussion Management Clinic (CMC) to complete the testing for this study at a later date.

## ***2.5 Testing***

Upon arrival, each participant was, once again, reminded of their strictly voluntary participation in the study. Participants were asked to sign the informed consent form needed to proceed with the study. Participants were, once again, explained the benefits and risks associated with this study and were reminded of their right to discontinue the study at any moment without penalties. The participants were asked to remove their shoes and were asked to step on the Basic Balance Board. An assistant, who acted as a spotter, participated in this research study. The spotter was an individual who assisted the participant in the event that the participant became unstable and/or fell. The spotter's primary focus was the participant and monitored the participant during the entire testing period on the Wii Balance Board. As soon as the participant stood properly on the Wii Balance Board, he/she was introduced to the Wii Fit Basic Balance Test and was walked through a set of oral instructions which were read from a script. The balance test offered two trials for means of adjusting to the equipment and understanding the instructions for the actual test. Immediately after the two practice trials were over, the test began. The test consisted of five balance trials. The participant was given 30 seconds to complete each trial. The balance test became more difficult as each trial advanced to

the next. After 30 seconds, the test was over and the participant's scores were immediately displayed on the television screen. The results describe the amount of time (in seconds) it took for the participant to complete each balance round. If the participant did not complete all five rounds in the 30 seconds, the incomplete rounds appeared with a horizontal line across to represent the incomplete round. The participant was asked to step off the board and to put his/her shoes back on. The scores were immediately recorded. The board was wiped clean and disinfected between each patient use.

The derived scores from the 20 concussed participants gathered from a pre-existing data base were compared to the results of the normative sample. The PC1 Wii Balance Board Basic Balance Test results of each of the 20 concussed participants were selected from the CMC Post-Concussion database based on any ImPACT composite score(s) which fell below two standard deviations below the mean, as a marker for the severity of their concussion.

### **Chapter 3: Results**

A parametric analysis was conducted using a Univariate Analysis (1 way ANOVA) to compare the number of trials completed on the Wii Basic Balance Test between the normative sample and the concussed group at post-concussion one (PC1). PC1 testing is typically done between 24-48 hours after a concussion. When conducting within and between group comparisons, no statistical significant differences were found in the performance on the Wii Basic Balance Test between females and males, in either group. Furthermore, initial analysis consisted of comparing the Wii Basic Balance Test performance of the nonconcussed/normative group to the entire group of concussed individuals found in the CMC database (N=78). The entire sample of PC1 individuals consisted of collegiate athletes within the ages of 18-25 years. No statistical significant difference ( $p=.123$ ) was found when using a parametric Univariate Analysis (1 way ANOVA) to compare Wii Basic Balance Test results of the normative group to the entire group of concussed collegiate athletes at PC1 (N=78).

Figure 3.1 reflects this comparison demonstrating no statistical significant difference on the Wii Basic Balance Test performance between these two groups. However, a cursory observation of the performance of the concussed athletes suggests that the more severely impaired concussed athletes showed poorer performance on the Wii. Therefore, those concussed athletes who performed at or below two standard deviations on the ImPACT at PC1 were pooled to create a severely impaired sample from the larger concussed sample. 20 participants, 20.6% of the entire concussed group, were considered severely impaired based on their ImPACT results. This severely impaired group was then compared to the normal/nonconcussed sample on (1) number of trials completed, (2) duration to complete trial one and trial three, and (3) differences

found when compared to those who completed less than four rounds and those who completed four rounds or more.

Significance was later found when the concussed group was sub-categorized into those whose ImPACT composite scores fell at or below two standard deviations and those who did not. Therefore, final comparisons on the Wii Basic Balance Test were made strictly between the nonconcussed/normative and PC1 collegiate athletes with low ImPACT scores. By subcategorizing the concussed group into those whose ImPACT scores fell at or below two standard deviations, allowed for those with a severe concussion to be distinguished from those with a mild concussion.

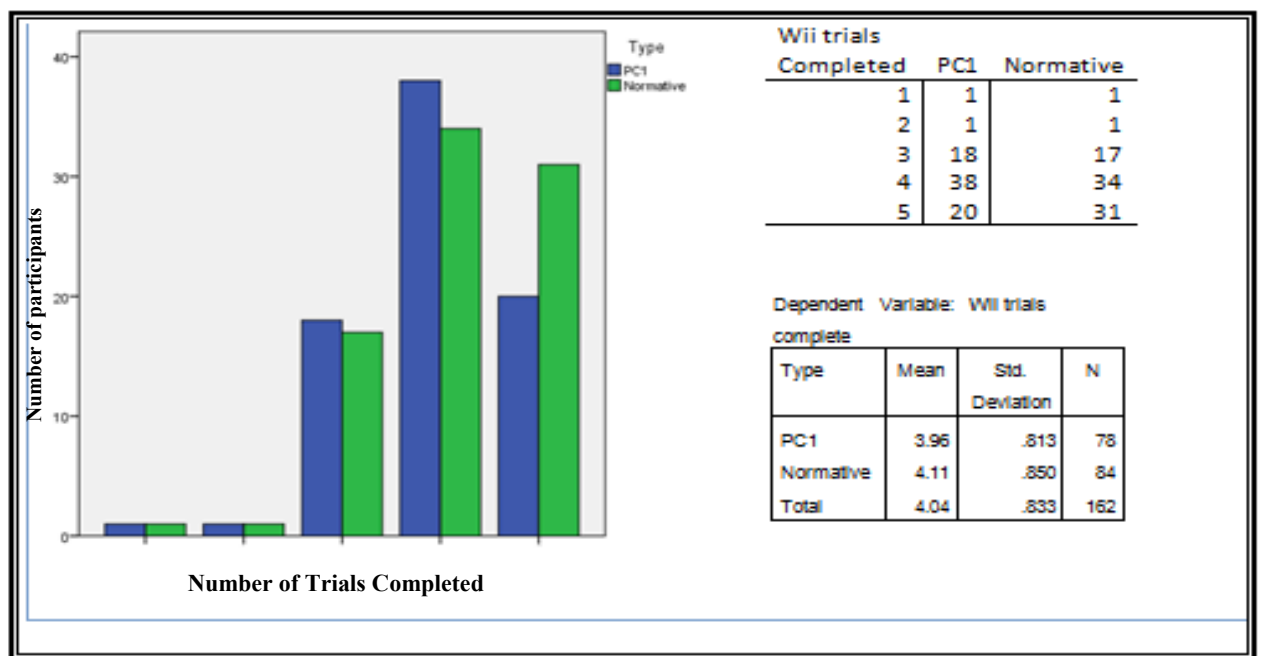


Figure 3.1 Wii Basic Balance Test number of trials completed between the concussed participants at post-concussion one ( $n=78$ ) and the normative sample ( $n=84$ ).

The results of a One-way ANOVA revealed a significant difference ( $F(1,102)=6.475$ ,  $p=.012$ ,  $\eta^2=.060$ ) between the number of trials completed in the normative group (Mean=4.11,

SD=.850) and the PC1 concussed group (Mean=3.55, SD=.999). The normative group completed a significantly larger number of trials on the Wii Basic Balance Test when compared to the PC1 concussed group. Figure 3.2 represents a visual of the Normative vs. PCI groups providing information on how these two groups are normally distributed along with their descriptive statistics.

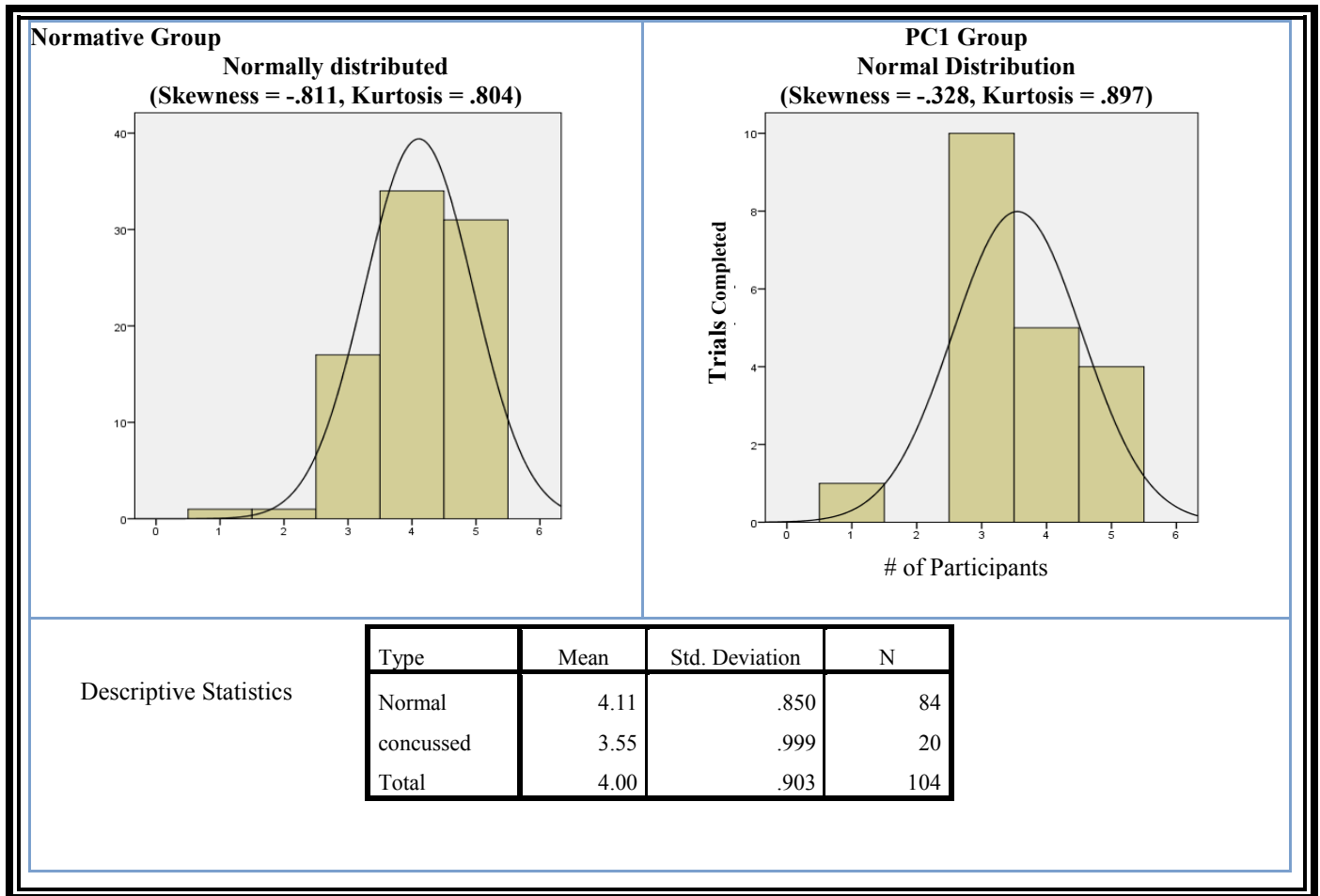


Figure 3.2 Compares severely concussed participants (n=20) to the nonconcussed/normative participants (n=84) in terms of trials completed. Average rounds completed along with the standard deviation were derived from the normal distribution data pertaining to these two groups.

Table 3.3 represents the PCI group and their composite scores (verbal memory composite, visual memory composite, reaction time composite, impulse control composite) that fell at or below two standard deviations from the mean. These composite score(s) demonstrate the severity of the concussion for the PC1 group.

*Table 3.3 demonstrates the ImPACT composite scores that the severely concussed group (n=20) scored at or below two standard deviations from the mean*

<b>PC1 Participant</b>	<b>Composite score at or below 2SD</b>	<b>PC1 Participant</b>	<b>Composite score at or below 2SD</b>	<b>PC1 Participant</b>	<b>Composite score at or below 2SD</b>
1	Visual Mem.	8	Visual Mem	15	Visual Motor Speed, Reaction Time
2	Visual Mem.	9	Reaction Time	16	Visual Motor Speed
3	Visual Mem.	10	Verbal Mem.	17	Verbal/Visual Mem., Reaction Time
4	Reaction Time	11	Visual Motor Speed, Reaction Time	18	Verbal Mem.
5	Visual Motor Speed, React. Time	12	All composite scores	19	Visual Motor Speed
6	Visual Motor Speed	13	Visual Mem.	20	Verbal/Visual Mem., Reaction Time
7	Verbal/Visual Mem, Visual Motor Speed, Reaction Time	14	Verbal Mem		

Figure 3.4 represents the results on Wii Balance Board Basic Balance Test for the normative and PC1 groups with respect to the number of trials completed. It is important to keep in mind that with each trial (5 trials in total), an increase in the level of demand is required from each participant. For example, trial one is a much simpler task than that of trial two. Trial two is less demanding than trial three and, so on. With this graph, it is much easier to visualize the number of participants which completed the Wii Basic Balance Test at different levels of complexity. On average, the normative group successfully completed four trials, whereas, the PC1 group on average completed 3 trials.

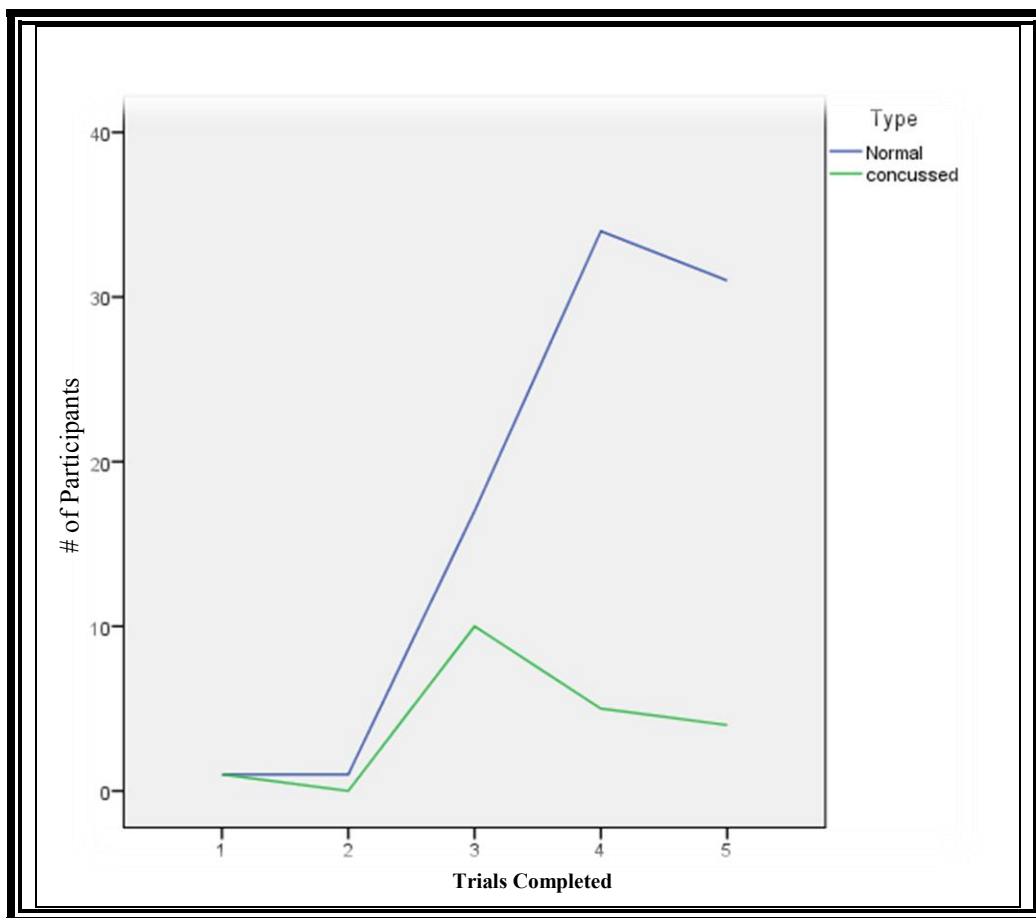


Table 3.4 compares the number of Wii Basic Balance Test trials completed between the severely concussed ( $n=20$ ) and the nonconcussed/normative ( $n=84$ ) groups.

Given the statistically significant difference between the two samples further evaluation of these results was conducted. The question that derived from comparing the number of trials completed between the normative and concussed groups led to the following questions: “At what point does the number of trials on the Wii Basic Balance Test differ between the normative and PC1 group?” That is, “Where is the cut-off to differentiate the number of trials completed by the two groups?” Furthermore, Is there a time difference that differentiates the number of trials completed? To answer these questions, a Krsuskal- Wallis Test non-parametric statistical analysis, was conducted to compare the performance in terms of time each group required to complete each trial.

Table 3.5 represents the descriptive statistics demonstrating, on average, the time participants in each group required to complete trial 1 and trial 3 of the Wii Fit Basic Balance Test reflecting a potential difference between groups. PC1 trial 1 on the Wii (WiiR1) is not normally distributed when compared to the normative sample whereas, WiiR3 is normal for both groups.

*Table 3.5 provides the descriptive statistics for the severely concussed (n=20) and nonconcussed/normative (n=84) groups in terms of trials completed (WiiR1, WiiR2, WiiR3, WiiR4 and WiiR5), and total time required to complete all 5 trials.*

Normative Sample Descriptive Statistics									
	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
WiiR1	84	3.00	11.55	4.5256	1.38527	1.757	.263	6.647	.520
WiiR2	84	3.00	12.53	5.4607	1.71954	1.827	.263	4.637	.520
WiiR3	83	3.00	14.26	6.4625	1.89675	1.114	.264	2.554	.523
WiiR4	65	3.89	13.47	7.7248	2.07929	.634	.297	.008	.586
WiiR5	31	3.51	9.62	5.8806	1.40680	.486	.421	.280	.821
TotalTime	84	21.51	30.00	28.8670	2.19833	-1.969	.263	2.733	.520
Trials Comp	84	1	5	4.11	.850	-.811	.263	.804	.520
Valid N (listwise)	31								

PC1 Group Descriptive Statistics									
	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
WiiR1	20	3.00	30.00	7.4225	5.54154	3.892	.512	16.416	.992
WiiR2	19	3.83	8.95	5.9295	1.44977	.539	.524	-.132	1.014
WiiR3	19	4.57	12.62	7.8984	2.44341	.328	.524	-1.013	1.014
WiiR4	9	5.07	10.78	7.7589	2.01305	.110	.717	-1.554	1.400
WiiR5	4	3.73	5.57	4.6725	.82447	-.108	1.014	-2.691	2.619
TotalTime	20	23.42	30.00	29.4805	1.55320	-3.601	.512	13.501	.992
Trials Comp	20	1	5	3.55	.999	-.328	.512	.897	.992
Valid N (listwise)	4								

Overall, the results from these comparisons revealed that there is a significant difference in the median scores ( $p<.001$ ) of the amount of time participants took to complete Trial 1 of the WiiFit Basic Balance Test between the normative (mean rank=46.14) and the PC1 group (mean rank=79.20). Thus, it took the PC1 group significantly longer to complete Trial 1 of the WiiFit basic balance game when compared to the normative group.

A parametric, One-way ANOVA was also conducted to analyze the total duration of time that was needed to complete the third trial on the Wii Basic Balance test between both groups. Table 3.6 presents the descriptive statistics allowing us to visualize the average time it took both groups to complete the third trial on the Wii Basic Balance Test.

*Table 3.6 represent the average amount of time (in seconds) it took the severely concussed (n=20) and the nonconcussed/normative group (n=84) to complete the third trial (WiiR3) on the Wii Basic Balance Test.*

Descriptive Statistics			
Dependent Variable: WiiR3			
Type	Mean	Std. Deviation	N
Normal	6.4625	1.89675	83
Concussed	7.8984	2.44341	19
Total	6.7300	2.07376	102

The results of a One-way ANOVA revealed a significant difference ( $F(1,100)=7.920$ ,  $p<.006$ ,  $\eta^2=.073$ ) in the total duration of time required to complete trial 3 between the normative group (Mean=6.45, SD=1.89) and the PC1 group (Mean=7.89, SD=2.44). Thus, the PC1 impaired group took significantly longer time to complete trials 1 through 3 of the Wii Basic Balance Test when compared to the Normative group.

A non-parametric Chi-Square Tests was used to compare the two distributions between the normative sample group and the PC1 group to determine the difference between groups when categorizing each group as those who completed greater than or equal to four trials and those who did not. Table 3.7 displays the differences between normative and concussed groups when separated into these two categories.

*Table 3.7 demonstrates the percentage of the severely concussed group (n=20) and the nonconcussed/normative group (n=84) who completed greater or equal to four trials vs. less than four trials on the Wii Basic Balance Test.*

Greater than or equal to 4 trials completed * Type Crosstabulation					
			Type		Total
			Normal	concussed	
Greater than or equal to 4 trials completed	No	Count	19	11	30
		% within Greater than or equal to 4 trials completed	63.3%	36.7%	100.0%
	Yes	Count	65	9	74
		% within Greater than or equal to 4 trials completed	87.8%	12.2%	100.0%
Total	Count		84	20	104
	% within Greater than or equal to 4 trials completed		80.8%	19.2%	100.0%

These results demonstrate that there is a significant difference ( $p=.004$ ) between the proportion of participants who did not successfully completed four trials or more (Normative = 63.3%, PC1 = 36.7%) and the proportion of participants who did successfully complete four

trials or more (Normative = 87.8%, PC1 = 12.2%). Thus, PC1 impaired group is significantly different than the normative group in completing a total of 4 trials..

## **Chapter 4: Discussion**

The research question asked was the following: is there a statistically significant difference on the Wii Balance Board Basic Balance Test between a large sample of nonconcussed/normative individuals and concussed athletes? Parametric statistical analysis demonstrated no statistically significant differences between these two groups. Further analysis was conducted after observing the individual performance and the idea that severity of the concussion may play a role on the overall Wii Basic Balance Test performance. Through parametric and nonparametric statistical analysis, the findings in this study show a statistically significant difference between the normative sample and the PC1 group whose ImPACT composite score(s) fell at or below two standard deviations below the mean. The PC1 database consisted of 78 collegiate athletes. 20 of these 78 PC1 collegiate athletes scored 2 standard deviations at or below the mean on any of the ImPACT neurocognitive testing composite scores. In other words, based on the ImPACT results, 25.6% of the concussed collegiate athlete in the database demonstrated a more severe concussion. This 25.6% of concussed collegiate participants with more severe cognitive deficits also demonstrated deficits on their overall balance performance on the Wii Basic Balance Test when compared to the performance of the Wii nonconcussed/normative sample.

Statistical significance was found between the number of trials on the Wii Basic Balance Test completed between the normative sample (trials=4) and the PC1 group with low ImPACT composite scores (trials =3). Clinically, in terms of concussion management, this is a significant finding. These results will allow a clinician to determine the severity of a concussion based on the ImPACT results in conjunction with the Wii Balance Test results. If a concussed patient, at PC1, has low ImPACT composite scores along with 3 or fewer completed trials on the Wii

Balance test, the clinician can determine the participant's concussions is reflecting in cognitive deficits along with balance impairments. This finding was also seen in further analysis which consisted of dividing the normative and PC1 group into those who completed greater or equal to four trials on the Wii Basic Balance Test and those who did not. On average, the normative sample completed greater equal to 4 trials on Wii Balance test whereas the PC1 group did not. Clinically, this cut-off point may serve as a diagnostic marker when interpreting the results of concussed collegiate athlete at PC1 on the Wii Balance Test.

Furthermore, the results showed that it takes the PC1 group significantly longer to complete trial 1 (7.4225 seconds) of the Wii Basic Balance Test when compared to the normative group (4.5256 seconds). Thus, this finding may also be used in order to further analyze the performance of a concussed collegiate athlete on the Wii Basic Balance test at PC1. At PC1, 25.6% of concussed collegiate athletes will not only demonstrate difficulty getting past the third round on the Wii Basic Balance Test, but also, difficulty in completing the first round (4.5 sec. vs. 7.4 sec.) in order to be able to proceed to the remainder of the Wii Balance Test.

Moreover, the difference, in time, required to complete the first trial on the Wii Basic Balance Test between the nonconcussed/normative group and the severely impaired concussed group at PC1 (4.5256 vs. 7.4225) dismisses the possibility of the severely impaired group struggling to complete this trial due to a possible learning effect. If difficulties in completing the first trial were related to the participant becoming familiarized with the requirements of the test, the results would have reflected the nonconcussed/normative group encountering this same difficulty in completing the first trial on the Wii. Consequently, the severely impaired concussed group's difficulties in completing this first trial on the Wii Basic Balance Test are related to the effects of the concussion rather than to becoming familiarized with the assessment tool.

The findings in this study are of great clinical significance. This system has gone from entertainment purposes to becoming an inexpensive, interactive and attractive assessment tool (Sparrer et al., 2013; Holmes et al., 2013; Harvey & Ada, 2012). The Wii Fit Balance Board's Basic Balance Test may serve as a tool for clinicians when working with concussed patients specifically, when testing the effect that the concussion had with the patient's balance. As a result, this system may aid in making return-to-play decisions on concussed athletes.

The results from this study demonstrate that the Wii Balance Board's Basic Balance Test may be a useful concussion management assessment tool. The gathering of normative data for this balance testing will aid in managing a concussion on athletes who do not have baseline testing. This normative data will aid in making clinical judgments for return-to-play decisions. Without baseline testing, it is a more challenging task for the clinician to know how a concussed patient normally functions on the Wii Basic Balance Test when his/her brain is not injured. The normative data for the Wii Balance Board will allow the clinician to reflect and compare the results of the concussed patients (who lack baseline data) to this normative data, in order to make clinical decisions. Even though having baseline data on all athletes involved in contact sports is ideal, unfortunately, it is not always the case. In cases like this, normative data becomes a useful tool to reflect patient's results for clinical decision making.

#### ***4.1 Conclusions***

The current study investigated the effects a concussion has on balance and how this can be assessed using the Wii Balance Board Basic Balance Test. The results of this study allow that 15.6% in this sample of concussed athletes show evidence of a balance dysfunction based upon their performance on the Wii Basic Balance Test. The Wii Balance Board Basic Balance Test is a valid assessment tool in concussion management in order to determine the effects of a

concussion on balance. The findings in this study may be beneficial when interpreting the results of concussed collegiate athletes at PC1 on the Wii Basic Balance Test. Normative data collected in this study will further aid clinicians in making return-to-play decisions for collegiate athletes who experience a concussion and lack baseline data to compare their pre and post-concussion performance on the Wii Basic Balance Test.

#### ***4.2 Study Limitations***

Some limitations are seen in this study. The study's normative sample of 84 college students, 53 females and 31 males, was small; therefore the results should be interpreted with caution. Significant differences between concussed and nonconcussed patients may have been found with a larger normative sample size. The normative sample should be expanded to a different age range. In particular, high school athletes may benefit from the availability of normative data on the Wii Balance Test that encompasses their age group. Due to time constraints and the availability of collegiate participants, age ranges that coincide with the high school population were not analyzed. Given that this study consisted of 20 severely impaired concussed athletes, a larger group of severely impaired participants may also benefit future studies. This study only looked at the sudden effects that a concussion has on balance, future studies should consider testing a concussed participant multiple times on different post-concussion dates to analyze recovery patterns. A longitudinal study, focused on testing concussed participants using the Wii Basic Balance Test during different times in the recovery of their concussion, may also detect the residual balance impairments that may linger afterward.

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## Appendix

### A

Participant Identification Number \_\_\_\_\_

#### Questionnaire

Name of participant:	
Age of Participant:	
Weight of participant:	
Have you ever participated in any sport?	
 If so, when and what sport?	
Are you a UTEP athlete?	
 If so, what sport?	

*Have you experienced any of the following?*

	Yes	No
mTBI/concussions		
Meningitis		
Hydrocephalus		
Hydranencephaly		
Balance disorders		
Seizures		
Attention deficit disorders		

## **Curriculum Vita**

Vanessa E. Fernandez-Vivar was born in Mexico City, Mexico where she spent her childhood. She attended El Paso High School, located in El Paso, TX and graduated in the top ten percent. Vanessa was employed at the University Medical Center of El Paso at the age of seventeen. She took a night shift data entry position at this hospital and quickly moved up to a position as Social Service Coordinator. She resigned her position at UMC eight years later after receiving notification of her acceptance into the Speech-Language Pathology Master's program at the University of Texas at El Paso. Vanessa discovered her interest in concussion management and fostered this interest as a volunteer in the Concussion Management Clinic at UTEP under the supervision of Dr. Salvatore, her mentor and clinic director. Vanessa met her husband in El Paso, TX in 2004 and gave birth to her two beautiful and inspiring twin boys in the year of 2006. Currently, Vanessa continues to take part in the CMC research clinic and continues to work toward obtaining her Master's degree in Speech-Language Pathology.

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