Reliability and Validity of the Nintendo® Wii Fit™

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PURPOSE: The aim of this study was to investigate the reliability of the Nintendo Wii Fit™ and concurrent validity by comparing it to the Neurocom EquiTest®. It is hypothesized that the Wii Fit™ will not be as precise or accurate as the EquiTest®.

DESIGN: This was a reliability and concurrent validity study.

METHODS: 31 subjects (mean=22.6; range=18-25) were recruited using convenience sampling. All participants completed two trials of the Body Test on the Wii Fit™, then two trials each of the EquiTest® Sensory Organization Test (Trial One) as well as the Weight Bearing Squat (Trial One). Outcome measures analyzed included center of gravity and left right symmetry.

RESULTS: The center of gravity and left-right symmetry measurements given by the Wii Fit™ were determined to not be reliable (ICC=.253; .270). There was no correlation found between the Wii Fit™ center of gravity measurements with those of the EquiTest®. The left-right symmetry measurements given by the Wii Fit™ were not correlated with those from the EquiTest® when the subjects stood without their feet properly aligned (r=.218). When the subject's feet were lined up on the EquiTest®, the left-right symmetry measurements from the Wii Fit™ were shown to have a fair level of correlation (r=.532).

CONCLUSIONS: The Wii Fit™, though convenient and affordable, does not provide consistent, accurate results when compared to the EquiTest®. Caution should be used when interpreting the Body Test results of the Wii Fit™.

INTRODUCTION

A holistic approach to therapeutic intervention for a patient of any age should incorporate balance. This focus is integral in treatment, either to address fall risk in an older adult or to analyze the success of a training program in a young adult. A broad topic, balance has been difficult to measure and document effectively in the past, either to demonstrate improvement with therapy or to provide a means to precisely identify the source of impairment.[1] However, with current technology, analysis of balance has been quantified with the use of computerized dynamic posturography, an electronic system that employs a force plate equipped with sensors to detect abnormal postural sway during testing.[2]

Recently, with the development of virtual reality gaming systems, an interactive, three-dimensional experience to train and challenge a patient became available.[3] Particularly, the use of the Nintendo® Wii™ gaming system is becoming more popular and widespread in therapy for varying populations. There is a multitude of practical advantages associated with its use, including increased patient safety, decreased amount of time, space, and amount of equipment necessary, increased cost efficiency, and quantified results that allow ease of documentation.[4] In addition, patient experience in rehabilitation programs is improved. Two recent studies reported subjective results from participants that motivation and desire to complete therapy was increased when using the virtual gaming system.[5] It is a legitimate supplement to rehabilitation programs because it encourages patients to actively participate in simulated real-life games.[4] The activities tend to be more enjoyable to patients than traditional rehabilitation because they are both fun and motivating. Improvements in functional mobility, visual-perceptual processing, and postural control have all been observed following an 11-session training program with the Wii™.[4]

A cost-efficient and commercially available option for the Wii™ that is focused on balance activities is the Wii Fit™. Launched by Nintendo® in 2008 to work with the Wii™ gaming system, the Wii Fit™ utilizes a thin Balance Board™ with a Body Test and Training Games to assess, then improve and track, an individual's static and dynamic balance.[6] The Wii Fit™ provides results related to an individual's Body Mass Index, Center Of Gravity (COG), and left-right symmetry via the Body Test. Sensors imbedded within the board are used to directly influence an on-screen character through aerobics, yoga, strength training or balance games.[6] Research, however, is lacking on the Wii™, inhibiting a therapist from being able to use all its features with reasonable confidence since its reliability is unknown.

The most commonly used balance assessment tool by physical therapists is the NeuroCom EquiTest®, a research standard tested primarily on older adults to identify fall risk, and used to improve static and dynamic balance.[1] A visual surround frame with a strain-gauge-integrated force plate, the EquiTest® can be digitally controlled to either translate or rotate in the horizontal plane. These features, combined with the ability to control visual stimuli, are used to examine and challenge each component of balance, consisting of the proprioceptive, visual and somatosensory systems. Reported values provide a way to quantify and document deficiencies in a specific component of balance, as well as to identify if reliance exists on either hip or ankle strategies.[2]

Overall, research literature offers praise for the EquiTest®, namely reporting positive results regarding sensitivity, test-retest reliability and validity.[7] One study demonstrated the

EquiTest®'s ability to distinguish elderly patients experiencing decline in health as displayed by lower results in five out of six conditions on the Sensory Organization Test (SOT).[7] Another study showed similar results, with the elderly patients experiencing a decline in health showing an increase in response time and sway in all six conditions on the SOT as compared to controls.[8] Regarding test-retest reliability, one study reported an overall interclass-correlation coefficient of 0.66 for the SOT, a score equivalent to fair-good reliability.[9] On its own, condition 1 of the SOT has moderate reliability (ICC=.57).[9] The EquiTest® has also demonstrated predictive validity for loss of balance, with one study reporting moderate-high reliability for all six conditions, as long as they were experienced at least twice on the same day.[10] However, despite the wealth of evidence crediting EquiTest's® accuracy and precision, it remains elusive to many average therapy clinics, given its high expense and large space requirement.

The Wii Fit™ is considerably more affordable than the EquiTest®, or other force plates. Nintendo's® suggested retail price for the Wii Fit™ software and Balance Board™ is US$89.99.[6] The Wii™ console and controller must also be purchased in order to use the software. The system's MSRP is listed as $249.99 in the U.S.[11] Force plates themselves cost thousands of dollars, and the EquiTest® can be purchased for approximately $100,000 in the U.S.[12]

This study aims to investigate the possibility of placing a feasible, more affordable and portable tool for balance into the hands of the average rehabilitation clinic. Using an industry standard, we examined the reliability of the Wii Fit™ and concurrent validity with the NeuroCom EquiTest® to assess for its efficiency and efficacy. The study was approved by the Institutional

Review Board at The Sage Colleges in Troy, New York.

METHODS

Subjects were recruited using convenience sampling by sending an “e-mail blast” to the Sage Colleges’ Troy campus, as well as using posters and word-of-mouth. For homogeneity purposes, participants were included in the study if they were between the ages of 18 and 25 years old and did not weigh over 300 pounds, so as not to exceed the weight capacity of the Wii Fit Balance Board™. Before participating, all subjects completed a university-approved informed consent form and had height and weight measurements taken without wearing footwear.

Both values were entered into the machines to help compute their body mass index and balance measurements. In addition to providing their name and date of birth, subjects were screened using a health questionnaire to rule out the possibility of any physical or neurological impairments that may have prevented them from completing both exams successfully. Measurements for height and weight were obtained using a standard tape measure and bathroom scale.

The Nintendo® Wii Fit Balance Board™ with the Nintendo® Wii Fit™ gaming system was utilized for the first half of balance assessments in this study.[6] The Wii Fit™ gaming system includes the Balance Board™, shown in Figure 1, with sensors built in to report distribution of weight between both lower extremities. The latter portion of balance assessments were completed using the NeuroCom EquiTest®, a dynamic force plate using strain-gauge technology and imbedded sensors to sense distribution and shifting of weight.

The participants were positioned in front of a screen, as shown in Figure 2, to prevent any horizontal or vertical visual cues from influencing their balance or posture.[13] The screen also prevented the subjects from viewing the TV or the investigators so that they were not prompted on how to stand. In addition, the TV volume was turned off, not allowing for any auditory feedback to either provide knowledge of results or to give a point of reference for the subject. Each subject was then asked to stand on the Wii Fit Balance Board™ and complete the “Body Test” on the Wii Fit™ game, which consisted of entering their height and birth date and standing on the Wii Fit Balance Board™ for 20 seconds to complete a “Center of Balance” exam. This test asks the user to stand on the balance Wii Fit Balance Board™ in a normal posture, placing their feet within the two boxes where comfortable. The user is then required to stand as still as possible for 10 seconds while the board measures COG and left-right symmetry. The measures are reported on the screen for COG and the percentages for each foot’s amount of weight-bearing. Two trials were completed and recorded on a Data Recording Sheet which mimicked the four square cell that was viewed on the TV screen (see Appendix).

Afterwards, each subject completed two tests on the NeuroCom EquiTest®. For the first set of measurements, the primary investigator lined up the feet of the subjects on the force plate according to the protocol outlined by NeuroCom®, and were asked not to move their feet. First, each completed the first trial of the Weight Bearing Squat test, which required them to stand on the Equi-Test® force plate with their feet positioned by the researcher and keep their legs extended for one second (see Figure 3). This test is used to measure left-right symmetry, reported as a percentage for each leg, and was meant to mimic the portion of the Center of Balance test on the Wii Fit™ measuring left-right symmetry. Afterwards, they completed Condition 1 of the

SOT, which required the participant to stand on the force plate for 30 seconds while center of balance was measured. This test intended to mimic the Center of Balance test on the Wii Fit™ measuring COG. Both sets of trials were completed twice and documented on the Data Recording Sheet (see Appendix1).

A second set of measurements was taken, this time with the intention of accounting for any differences in testing protocol between the Wii Fit™, which does not require feet to be lined up, and the EquiTest®. For this set of testing, the EquiTest® force plate was taped to outline the dimensions of the Wii Fit Balance Board™ as shown in Figure 4, and each participant was asked to step onto the plate in a posture and foot position that was most similar to their typical stance (see Figure 5). Values were taken again for both tests, repeated twice, and recorded on the Data Recording Sheet. After the data was collected, each subject was offered a chance by the researchers to review their results of all trials. The results of each individual's trials on the Wii Fit™ and EquiTest® were reviewed with the subjects upon their completion. The purpose of sharing the results was to inform the participants of any balance abnormalities that were indicated in the findings. Along with this information, brief, qualitative advice was given for how to improve the balance deficits noted. This guidance could be beneficial if utilized, as the participants could potentially enhance their COG and left-right symmetry, leading to improvements in functional performance and prevention of injuries.

DATA ANALYSIS

All values were analyzed using SPSS 15.0. Analysis for reliability of the Wii Fit™ was calculated first using an intraclass correlation coefficient (3,1). Values for COG and symmetry (left-right and forward-behind) were then analyzed using Pearson's Correlation Coefficient and Spearman's Rho, to look at interval and nominal data, respectively. With regards to the EquiTest®, values were first run to analyze the data from when subjects' feet were lined up according to the NeuroCom® protocol, then when the subjects were allowed to stand comfortably.

Values used for data analysis were first computed from the Data Recording Sheet to account for the variability in the interval and nominal data. Data regarding each subject's left-right and forward-behind symmetry, being nominal data, were reported as either "1" or "2" to indicate which side of either the midsaggital or midtransveral line the subject's COG fell. Left-right symmetry was determined by indicating which side the COG was on using the midsagittal line for reference–a "1" indicated COG to the left, and a "2" for the right. Forward-behind symmetry was also measured and reported by indicating if the COG lay above or below the transverse line drawn in the middle of the box, recorded as a "1" or "2" respectively. The amount of correlation between the Wii Fit™ and EquiTest® for both left-right and forward-backward symmetry was analyzed using Spearman's Rho.

Values for COG were depicted with a dot drawn by the examiner on the four square cell on the Data Recording Sheet simulating the footplate of both the Wii Fit™ and EquiTest®. COG was measured by a standard ruler from the midpoint of the four squares to the COG dot drawn by the examiner. These values, being interval data, were averaged to provide a comprehensive picture. The amount of correlation between COG measurements from the Wii Fit™ and EquiTest® were analyzed using Pearson's Correlation Coefficient.

RESULTS

Thirty-one subjects between the ages of 18 and 25 years old participated in the study (mean = 22.6 ± 1.87). Twenty-three were female and eight were male. The Wii Fit's™ COG measurement was found not to be reliable (ICC = .253). The percentages given for left-right symmetry were also not reliable (ICC = .270). However, using the Wii Fit™ as a measure for body weight was determined to be correlated with the measurements given by a standard bathroom scale (r = 1.000). When the subjects' feet were appropriately lined up on the EquiTest®, the measurement given by the Wii Fit™ for COG as distance from the origin was not correlated (r = .080; p = .120). The Wii Fit's™ forward-behind data for COG was also not correlated with that of the Equi- Test® (r = .218; p = .334). However, a fair level of correlation was detected between the left-right symmetry reading provided by the Wii Fit™ and that from the EquiTest® (r = .532; p= .001). By not aligning the subjects' feet on the EquiTest®, so as to mimic the standing posture on the Wii Fit™, higher correlations were not produced for COG measurements as distance from the origin (r = .147; p = .300), and forward-behind data (r = .147; p = .171). The Wii Fit's™ left-right symmetry percentages were not correlated (r = .210; p = .226).

DISCUSSION

The purpose of this study was to determine the feasibility of using the Wii Fit™ as a means of quantifying patients' balance affordably in the clinic and at home. Though the Wii Fit™ is a more convenient and cost-effective tool for measuring COG and left-right symmetry than the EquiTest®, it is not as accurate or consistent. The only measurement that was comparable to that of the EquiTest® was left-right symmetry. Even so, the correlation was only fair, and the measurements were not found to be reliable from trial to trial. The COG measurements given by the Wii Fit™ were not correlated with those from the EquiTest®. There was also no consistency in the COG measurements given by the Wii Fit™. The body weight measurement that the Wii Fit™ provided was correlated with the digital reading given by a bathroom scale. What may account for the difference in the Wii Fit™ compared to the EquiTest® is that they are designed differently for detecting balance. These mechanical variations may contribute to their differing capacities for measuring COG and left-right symmetry. The Wii Fit Balance Board™ is comprised of four sensors that are attached as legs. These sensors are strain gauges, which measure vertical forces applied to them. The positioning of the sensors at the four corners of the Wii Fit Balance Board™ allows for both precise body weight measurement and the recognition of balance shifts in every direction.[14] In the EquiTest®, a dual force plate is located in the base platform, where the subjects stand with one foot on each force plate. The force plates quantify the vertical and horizontal forces exerted on them by each foot via strain gauges, which measure the anterior posterior center of vertical force position.[15,16]

When using the EquiTest®, users are prompted to line up their feet with specific markings on the force plate so that their foot placement is symmetrical, with the medial malleoli in line with the force plate's center of rotation to allow the platform and the screen enclosure to rotate around the joint axis of the ankles.[15] Since this may not be a person's natural stance, this positioning may be awkward and it may not reflect the balance measurements that they might have if they were standing as they normally would. The Wii Fit™ does not require users to position their feet in a particular manner on the Wii Fit Balance Board™. Rather, those using the balance board to obtain balance measurements are able to stand comfortably in their natural stance. In this study, upon obtaining data that was not correlated between the EquiTest® and the

Wii Fit™ when participants had their feet properly aligned on the EquiTest®, participants were asked to perform additional trials without their feet adjusted to the specifications in order to see if the data would show greater correlation for left-right symmetry and COG measurements. However, regardless of foot positioning on the force plate, correlation of the balance measurements did not improve.

The only measurement that was found to be correlated between the Wii Fit™ and the EquiTest® was left-right symmetry. This correlation only occurred with the trials in which the participants' feet were aligned on the force plate of the EquiTest® as directed. Though the researchers believed that having participants stand without their feet aligned on the EquiTest®, as they would with the Wii Fit™, would improve the correlation of the left-right symmetry and COG measurements, the correlation levels actually dropped. The lack of reliability in the balance measurements given by the Wii Fit™ may be attributed to participants shifting their stance and foot positioning between trials.

A strength of this study is that the balance-measuring capabilities of the Wii Fit™ were compared to the industry's gold standard, the EquiTest®. The narrow inclusion criteria for the age of the subjects adds to the study's internal validity, but at the same time the data from the 18 to 25 year-old age group cannot be generalized to other populations. Another limitation to the study is that the two systems were not designed to examine the exact same balance measures. Rather, the EquiTest® was manipulated to simulate the tests that the Wii Fit™ was performing. The EquiTest® is known for its adequacy in dynamic balance measures, however, only static measures which would be comparable to those accessible with the Wii Fit™ were used.

CONCLUSION

This study found that the Nintendo® Wii Fit™ may not be used with the same level of confidence to accurately analyze balance as the NeuroCom EquiTest® in the clinic. As more clinics acquire the Wii Fit™ for use in rehabilitating their patients, physical therapists may feel inclined to use the Balance Test as a quick and easy way for tracking gains in balance throughout the course of treatment. Though an improvement in the COG and left-right symmetry scores can be motivating to patients, these scores do not meet a standard of accuracy for use in documentation.

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FIGURES

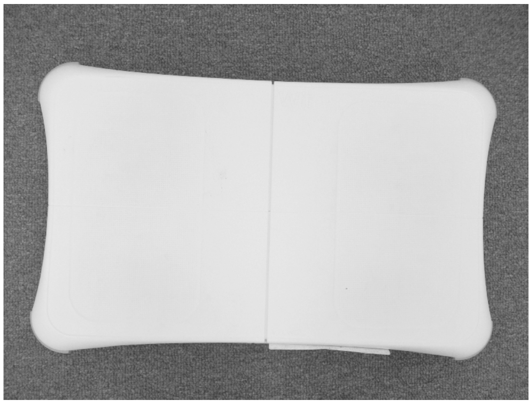

Figure 1. The Wii Fit Balance Board™ weighs 10 pounds, with the dimensions of 20.5 x 3.2 x 13.4 inches.

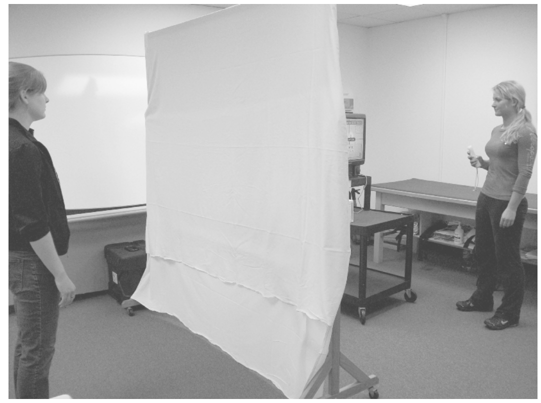

Figure 2. Subject performing a trial of the Wii Fit™ Body Test.

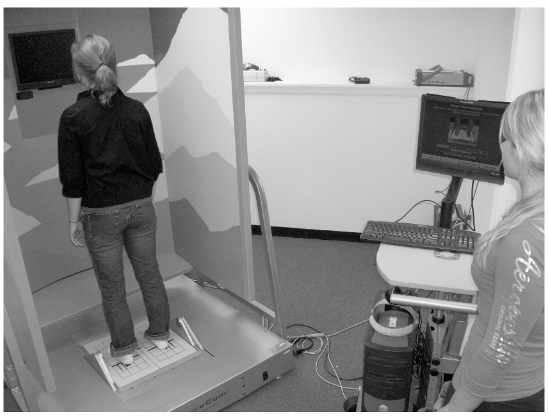

Figure 3. Subject performing a trial of the Weight Bearing Squat on the EquiTest® with her feet aligned according to the NeuroCom® protocol.

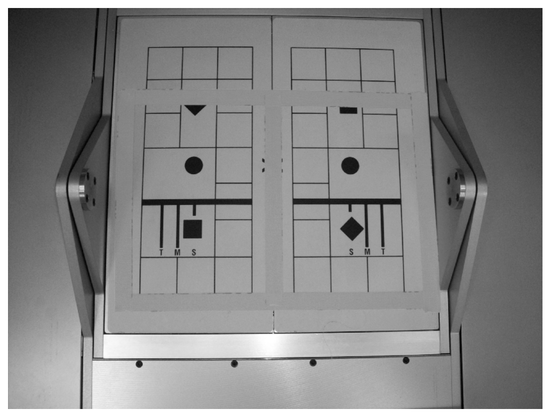

Figure 4. EquiTest® force plate with the dimensions of the Wii Fit Balance Board™ indicated by a tape outline.

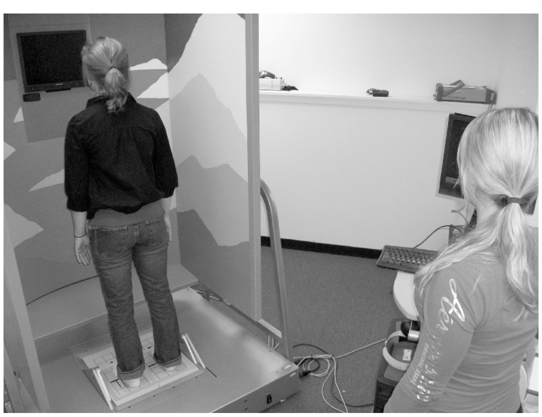

Figure 5. Subject performing a trial of the Weight Bearing Squat on the EquiTest® without her feet aligned. She is standing in a natural stance to simulate the stance that is used on the Wii Fit Balance Board™.

APPENDIX

Data Recording Sheet

Name:______________________________

Birthdate:____/_____/____
Height: ___'____"
Weight: _______ lbs

<u>Wii Fit</u>
Trial One
COG:

Left-Right Symmetry:
L:_____
R:_____
Weight: _______ lbs
BMI:_______

Trial Two:
COG:

Left-Right Symmetry:
L:_____
R:_____
Weight: _______ lbs
BMI:_______

<u>Equitest (without foot alignment)</u>
SOT Trial One:

Weight Bearing Squat Trial One:
L:_______
R:_______

<u>Equitest (with foot alignment)</u>
SOT Trial One:

Weight Bearing Squat Trial One:
L:_______
R:_______

SOT Trial Two:

Weight Bearing Squat Trial Two:
L:_______
R:_______

SOT Trial Two:

Weight Bearing Squat Trial Two:
L:_______
R:_______