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WiiFit™ Plus balance test scores for the assessment of balance and mobility in older adults

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Abstract

The Nintendo Wii™ is becoming an increasingly popular technology for the training and assessment of balance in older adults. Recent studies have shown promising results for its use in fall prevention. However, it is not clear how scores on the WiiFit™ balance games relate to current standardized tests of balance and mobility. The purpose of this study was to evaluate the relationship between WiiFit™ Plus balance tests, and standardized tests of older adult fitness, balance, mobility, self-reported balance confidence, and visual attention and processing. Results from 34 older adult participants indicate that WiiFit™ balance tests do not correlate well with standardized functional balance, mobility and fitness tests. However, the Wii balance score, as measured by the Basic Balance Test of the WiiFit™, does correlate with visual processing speed as measured by the Useful Field of View (UFOV) test. These results indicate that WiiFit™ balance tests may provide advantageous information supplementary to information obtained through standard functional mobility and balance tests; however, caution should be used when using the WiiFit™ balance tests in isolation. Further research is necessary as these technologies become widely used in clinical and home settings for balance training and assessment.

Keywords

Wii balance board; older adults; fall prevention; UFOV; mobility

1.0 Introduction

Falls and fall related injuries continue to be a serious health concern for older adults. They are the leading cause of injury related death for people over the age of 65 [1]. Each year one in three older adults will experience a fall and by 2020, the cost for fall-related injuries is projected to reach \$32.4 billion [2,3]. Falling among older adults affects not just the individuals themselves but significantly affects their families and society overall, as it

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decreases life expectancy, reduces independence, and dilutes quality of life [2]. As such, national healthcare programs have identified that fall prevention is becoming increasingly important [4].

A growing body of evidence supports the use of virtual reality and video gaming programs for improving balance in older adults [5,6,7]. Virtual reality balance training typically requires participants to produce discrete, controlled movements to and beyond their base of support in response to visual targets. A force plate measures the performance of the participant and can provide online feedback of postural control. The real-time visual feedback provided by these systems may be effective in training precision body control and be useful for fall prevention.

An increasingly popular system for virtual reality balance training is the Nintendo Wii™ [6,7,8]. Williams et al. [6] performed a pilot study on healthy, independent community living adults over 70 years of age and found significant improvement in Berg Balance Scale performance following 4 weeks of Wii training, though this was not maintained at 12 weeks. Young et al. [7] conducted a study using the Wii Balance Board (WBB) with custom video games on six healthy older adults. After completing 10 sessions of 20 minutes each over a four-week training period, decreases in medial-lateral and anterior-posterior postural sway with eyes open and eyes closed were observed, though only eyes closed was statistically significant. In both studies participants reported training on the Nintendo WiiFit™ was enjoyable and that they felt more confident in their abilities. These positive results, in addition to high attendance and low dropout rates, illustrate that older adults are open to exercising with virtual reality based games such as the WiiFit™ as part of a falls prevention program [6,7].

The advantage of the Nintendo Wii with WBB is that it not only offers an alternative balance exercise-training tool but it can also record balance measurements. The WBB is more portable than heavy and expensive laboratory equipment while still providing valid and reliable measurements. A recent study evaluated the validity of the WBB in measuring balance variables [8]. The authors found that the WBB possesses many of the same characteristics as a traditional force plate for measuring center of pressure (COP) during postural control, though there are limitations for use beyond balance tests. Nevertheless, the findings support the use of the WBB as an alternative for simplified balance testing, particularly in field test settings.

However, a major limitation of the above studies for their application to field settings is that they have evaluated the Nintendo Wii™ and WBB as a tool for balance training and testing using their own custom software [7,8]. There has not been a systematic comparison of WiiFit™ balance tests with standard measures of fitness, mobility and balance in older adults. One of the advantages of the Wii and the reason behind its growing popularity for balance training in older adults is its potential for use at home and other care centers with little expense. It is unlikely that these users will modify the system with custom software. As such, there is a need to evaluate the balance tests available with the WiiFit™ to extend the results of research to the field. The purpose of the current study was to evaluate the correlation of WiiFit™ balance test scores with standardized fitness, mobility and balance measures to determine its validity for use in assessment of balance in older adults.

2.0 Methods

2.1 Participants

Thirty-four older adults (25 female and 9 male) mean $\pm$ SD age 67.1 ± 5.2 years, mean $\pm$ SD BMI 28.21 ± 5.37 participated in the study. Participants were independent community

dwelling residents who were involved in the same 24-week exercise program practicing cardiovascular, strength, agility and balance exercises. Prior to inclusion in the study, older adults completed a health and fall history questionnaire and were required to provide written approval from their health care provider indicating that their health was conducive to regular physical activity. Participants were excluded if their health care provider did not provide an approval letter. Approval was obtained from the university's Institutional Review Board prior to the start of the study.

2.2 Fitness, balance and mobility assessment

Assessment of the older adult participants included a combination of fitness tests to assess muscular strength and cardiovascular endurance, an obstacle course to assess functional mobility, Nintendo WiiFit balance tests to assess balance, the Useful Field of View (UFOV) test for visual processing speed and visual attention, and the Activities-specific Balance Confidence scale for self-reported falls risk.

Functional fitness of the older adults included the Senior Fitness Test proposed by Rikli and Jones [9]. The functional assessment included grip dynamometry (isometric upper-body muscular strength); 30-second chair stand and 30-second arm curl tests (lower- and upper-body muscular endurance); 6-minute walk test (cardiovascular fitness); and 8-ft Timed Up-and-Go (TUG) test (motor agility and dynamic balance). Performance on the 30-second chair stand and 30-second arm curl tests was defined as the maximum number of repetitions achieved in 30 seconds. Cardiovascular fitness performance was defined as the maximum distance (in yards) walked in 6 minutes. Finally, the least amount of time (in seconds) required completing the 8-ft Timed Up-and-Go test defined motor agility. Additional physical performance tests were included to further assess muscular power. The ramp-walk power test [10] assessed lower limb power. Two different ramp sizes were used to assess both short and endurance bursts. The short ramp had a 5.53 m walking distance at 4.1 degrees angle, and the long ramp had a 19.05 m walking distance at 7.9 degree angle. Assessment of upper body muscular power included the Gallon-Jug Shelf-Transfer Test (GJSTT) [11] and medicine ball chest-press throw test.

The obstacle course included rising from a chair, stepping over, ducking under, going around, picking a weight off the ground, going up and down steps, walking along a foam beam, turning 360° around an obstacle and sitting back in a chair at the start position [12]. This technique allowed for the analysis of functional mobility capabilities relevant to daily living activities. Three variables defined obstacle course performance: Completion time (CT), the number of collisions made with obstacles (HITS) and a combined CT + HITS variable. Participants performed two obstacle trials on each testing day. A stopwatch recorded course completion time and started from the command "Go" to the end position. The number of obstacle collisions was recorded during performance on a topographical figure of the course.

Two balance tests were performed on the Nintendo WiiFit Plus™ with Balance Board. Both tests are included in the WiiFit basic body test. The Basic Balance Test involved shifting weight mediolaterally to direct center of pressure to target areas on the display. The Wii instructions were "Spread your feet apart; lean left and right to keep the red bar in the blue area for 3 seconds". The test had five possible levels with a time limit of 30 seconds to complete all levels. Outcome score included the number of levels that were successfully completed (Wii Level) and the time taken to complete each level (Wii Level Time). Each participant performed the test twice on each test day. The Prediction Test involves shifting COP to avoid obstacles, a blue area appears after the first 20 seconds that blocks the view of the next immediate obstacle and therefore the player must predict where the obstacle is to appropriately direct COP.

Instructions for the Prediction Test were “Shift your center of balance to the right or left to avoid hitting the walls or obstacles”. Outcome score for this test was the time from “start” until the first obstacle was contacted (Wii Obs Time). Participants performed this test three times and the best time was taken for analysis.

The Useful Field of View test (Visual Awareness Inc., Birmingham, AL) was used to measure visual processing speed, divided visual attention, and selective visual attention. The UFOV is the area from which one can extract useful visual information at a brief glance without movement of the head or eyes [13]. The UFOV test provides scores reported in milliseconds for each subtest and therefore a lower score represents greater performance.

Participants completed the Activities-specific Balance Confidence (ABC) scale [14]. The ABC scale is a 16 item questionnaire that allows participants to rate their confidence when performing certain daily activities such as walking in a crowded place and picking up an object off the floor. The scale is rated from 0% (no confidence) to 100% (absolute confidence).

2.3 Statistical Analysis

The test battery was conducted for all participants in the 13th and 24th week of the program. Mean score between the two test days was used for statistical analysis. To address the research purpose, separate two-tailed Pearson Product Correlations were conducted comparing Wii balance variables with variables of fitness, mobility and balance, and UFOV.

Three separate hierarchical linear regression models examined the interrelationships of the Wii variables in combination with one or more of the fitness variables, mobility/balance variables, and UFOV variables on their interactions with a complex functional test such as the TUG. Statistical procedures were based on those described by Pua et al. [15]. For Step 1, as predictors in the all the models we included, Gender, BMI, and Wii Level. Then for Model 1 (Fitness) we included the predictors Chair Stand, Six Min Walk, and Short Ramp; Model 2 (Mobility/Balance) we included the predictors ABC score, and CT+HITS; Model 3 (Visual) we included the predictor Divided Attention. For Step 2, we included the cross-product interaction terms for Wii Level and the fitness, mobility/balance or UFOV variables and checked for significance.

3.0 Results

Correlations among the Wii balance factors (Table 1) indicated a strong relationship between the variables of the Basic Balance Test (Wii Level and Wii Level Time), however; the Basic Balance Test scores did not significantly correlate with performance on the Prediction test (Wii Obs). No significant correlations were determined for Wii balance variables and variables of fitness (Table 2) or mobility and balance (Table 3). However, significant correlations were determined between the Basic Balance Test variables (Wii Level and Wii Level Time) and Processing Speed of the UFOV (Table 4). Divided and selective visual attention did not significantly correlate with the Wii balance scores.

Hierarchical regression models examining the association of Wii variables with standard tests of fitness, mobility/balance and vision (UFOV) for predicting TUG performance were non-significant (Table 5). In addition, all cross-product terms in Step 2 were non-significant.

4.0 Discussion

The purpose of the current study was to determine whether balance assessed by tests on the WiiFit™ Plus relate to tests of fitness, balance and mobility, and vision in an older adult

population. The Wii is becoming an increasingly popular tool for both the assessment and training of balance in clinical populations such as older adults. Yet, comparisons of WiiFit™ assessment with standard balance and mobility tests have not been made. The results of the current study suggest that balance tests on the Wii do not correlate with tests typically used to assess older adult fitness and mobility. No significant correlations (Table 2 and 3) were found between the Wii tests and tests of muscular power, muscular endurance, cardiovascular endurance, and mobility (as measured by the TUG and obstacle course). Further, hierarchical regression models examining the association of Wii variables with other test variables in their prediction of performance on a comprehensive test, the TUG, were non-significant (Table 5). Therefore, Wii Level does not seem to be a predictor for TUG performance.

The Wii balance test takes place in a stationary position (on the board) and therefore muscular power and endurance, and cardiovascular endurance may not play a considerable role (particularly in a functionally mobile older adult group). In addition, perhaps the dynamic nature of movement in the TUG and obstacle course requires different balance skills than stationary balance skills. Unfortunately, static balance tests were not performed in this study, but studying tests such as single leg stance eyes open and closed may reveal greater correlation with Wii tests. Another possibility is that the biofeedback nature of the Wii tests could contribute to differences in how balance is controlled between the Wii tests and clinical tests. In the clinical tests, feed-forward and anticipatory control may dominate postural control. Conversely, because the Wii has a visual target and gives online feedback during performance, these tests may require closed loop postural control mechanisms. Further study is clearly required to determine these differences.

The most interesting finding of the current study was the significant relationship between the Wii tests and the UFOV test. Correlation analysis revealed that the level successfully completed (Wii Level) on the Basic Balance Test (BBT) was negatively correlated with visual processing speed of the UFOV test. Therefore, the lower the UFOV score (greater ability), the higher the balance level achieved (greater ability). In addition, the average time to complete each level (Wii Level Time) on the BBT was positively correlated with visual processing speed. Therefore, with faster visual processing speed, the time taken to complete each balance level was faster. Divided and selective visual attentions did not have significant correlation with the Wii tests; however, further study with a greater number of subjects may lead to significant correlations.

Impairment of visual attention and visual processing speed in older adults is independently associated with mobility problems [16]. The concept of visual attention is based on the idea that people can only process small amounts of visual information in a given moment and that there is a limited capacity for information processing. As a result, we must use skills such as selecting regions of interest within the visual field, dividing attention to more than one visual field location, and shifting information processing resources from one visual field to another to extract useful information from our environment [16]. If we are unable to do this effectively we risk missing key pieces of information regarding our environment. Mobility represents a person's ability to move purposefully and effectively through an environment, from one place to another to accomplish a task or goal. Effective mobility requires efficient processing of information about our environment such as obstacles or terrain. Therefore, impairments in visual processing and attention, due to the aging process or pathologies, have a negative impact on mobility [16]. Owsley and McGwin [16] have shown that there is a significant relationship between UFOV scores and mobility. These authors concluded that programs aimed at improving or slowing the deterioration of balance and mobility should consider visual attention/visual processing training in older adults [16].

The Wii may provide this needed addition to current fall prevention and mobility training programs for older adults.

Therefore, despite the lack of correlation of the Wii tests with other measures of fitness, balance and mobility in older adults, the correlation with the UFOV scores is promising. The results of the current study suggest that assessment of balance using the WiiFit™ may be a good addition to tests used to assess balance and mobility and that the use of the WiiFit™ tests may provide insight into deficits other standard tests are not sensitive to. Use of the WiiFit™ tests may provide insight into deficits related to visual information processing. The results of this study also suggest caution when considering using the Wii balance tests alone to evaluate balance and mobility in older adults as outcome scores may not accurately represent functional balance and mobility deficits.

5.0 Conclusion

Balance as assessed by the WiiFit™ Plus with Balance Board may be advantageous to use in conjunction with standard tests of balance, mobility and fitness. The Wii tests may give insight into other deficits of postural control dysfunction; however, further research on Wii test results and their comparison with other standardized tests are required. There needs to be a foundation of scientific evidence regarding the Wii and its use for assessment and training as this technology becomes more widely used in the clinic and at home.

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Table 1

Pearson Product Correlation Coefficients among Wii Balance Variables

N = 34		Wii Obs Time	Wii Level	Wii Level Time
Wii Obs Time	Coefficient	1.000	0.327	-0.140
	Sig. (2-tailed)		0.059	0.430
Wii Level	Coefficient	0.327	1.000	-0.371
	Sig. (2-tailed)	0.059		0.031*
Wii Level Time	Coefficient	-0.140	-0.371	1.000
	Sig. (2-tailed)	0.430	0.031*	

* Significance at the 0.05 alpha level

Table 2

Pearson Product Correlation Coefficients of Wii Balance with Fitness Variables

N = 34		Wii Obs Time	Wii Level	Wii Level Time
Handgrip	Coefficient	0.105	-0.086	0.155
	Sig. (2-tailed)	0.555	0.627	0.382
Gallon Jug	Coefficient	-0.163	-0.184	-0.056
	Sig. (2-tailed)	0.356	0.297	0.751
Chair Stand	Coefficient	0.111	0.118	-0.029
	Sig. (2-tailed)	0.532	0.507	0.868
Arm Curl	Coefficient	0.318	0.002	0.137
	Sig. (2-tailed)	0.066	0.991	0.438
Long Ramp	Coefficient	-0.104	0.078	-0.152
	Sig. (2-tailed)	0.558	0.661	0.392
Short Ramp	Coefficient	-0.099	0.065	-0.216
	Sig. (2-tailed)	0.578	0.716	0.220
Med Ball	Coefficient	0.259	0.025	-0.297
	Sig. (2-tailed)	0.138	0.886	0.088
Six Min Walk	Coefficient	0.225	0.092	0.114
	Sig. (2-tailed)	0.208	0.609	0.526

* Significance at the 0.05 alpha level

Table 3

Pearson Product Correlation Coefficients of Wii Balance with Mobility/Balance Variables

N = 34		Wii Obs Time	Wii Level	Wii Level Time
TUG	Coefficient	-0.146	-0.103	-0.038
	Sig. (2-tailed)	0.410	0.563	0.829
HITS	Coefficient	-0.086	0.120	-0.112
	Sig. (2-tailed)	0.627	0.498	0.527
CT	Coefficient	-0.172	-0.072	-0.034
	Sig. (2-tailed)	0.330	0.687	0.848
CT + HITS	Coefficient	-0.162	-0.010	-0.067
	Sig. (2-tailed)	0.360	0.957	0.705
ABC Score	Coefficient	0.049	0.025	0.260
	Sig. (2-tailed)	0.782	0.888	0.136

*
Significance at the 0.05 alpha level

Table 4

Pearson Product Correlation Coefficients of Wii Balance with Visual Variables

N = 34		Wii Obs Time	Wii Level	Wii Level Time
Processing Speed	Coefficient	0.016	-0.351	0.408
	Sig. (2-tailed)	0.929	0.042 *	0.017 *
Divided Attention	Coefficient	0.020	-0.243	0.245
	Sig. (2-tailed)	0.911	0.166	0.162
Selective Attention	Coefficient	-0.114	-0.272	0.245
	Sig. (2-tailed)	0.519	0.120	0.162

* Significance at the 0.05 alpha level

Table 5

Multivariable model of the associations of Wii Level, Fitness, Mobility/Balance and Visual variables with the TUG (dependent variable)

	$\beta \pm SE$	P
Model 1 Fitness		
Step 1 (adjusted R² = 0.78, p < 0.001)		
BMI	0.01 $\pm$ 0.02	0.55
Gender (0 = Female, 1 = Male)	0.38 $\pm$ 0.15	0.02
Wii Level	-0.10 $\pm$ 0.10	0.32
Chair Stand	-0.02 $\pm$ 0.02	0.17
Six Min Walk	-0.001 $\pm$ 0.001	0.44
Short Ramp	1.30 $\pm$ 0.31	0.0003
Step 2		
Wii Level $\times$ Chair Stand	-0.02 $\pm$ 0.03	0.56
Wii Level $\times$ Chair Stand	0.003 $\pm$ 0.002	0.10
Wii Level $\times$ Short Ramp	0.64 $\pm$ 0.42	0.14
Model 2 Balance/Mobility		
Step 1 (adjusted R² = 0.69, p < 0.001)		
BMI	-0.02 $\pm$ 0.02	0.26
Gender (0 = Female, 1 = Male)	0.09 $\pm$ 0.17	0.59
Wii Level	-0.06 $\pm$ 0.10	0.54
ABC score	-0.04 $\pm$ 0.10	0.004
CT+HITS	0.090 $\pm$ 0.01	0.001
Step 2		
Wii Level $\times$ ABC score	-0.004 $\pm$ 0.03	0.88
Wii Level $\times$ CT+HITS	0.02 $\pm$ 0.02	0.47
Model 3 Visual		
Step 1 (adjusted R² = 0.03, p = 0.33)		
BMI	0.05 $\pm$ 0.02	0.05
Gender (0 = Female, 1 = Male)	0.20 $\pm$ 0.33	0.55
Wii Level	-0.19 $\pm$ 0.19	0.33
Divided Attention	-0.15 $\pm$ 0.17	0.38
Step 2		
Wii Level $\times$ Divided Attention	0.12 $\pm$ 0.44	0.78