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LOMA LINDA UNIVERSITY
School of Allied Health Professions
in conjunction with the
Faculty of Graduate Studies

Virtual Reality Gaming as a Tool for Rehabilitation in Physical Therapy

by

Abel A. Rendon

A Dissertation submitted in partial satisfaction of
the requirements for the degree of
Doctor of Science in Physical Therapy

September 2011

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Each person whose signature appears below certifies that this dissertation in his/her opinion is adequate, in scope and quality, as a dissertation for the degree Doctor of Science.

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ABBREVIATIONS

VR	Virtual Reality
LOS	Limits of Stability
WBB	Nintendo Wii Balance Board
COP	Center of Pressure
NSBM	NeuroCom Smart Balance Master
SOT	Sensory Organization Test
UST	Unilateral Stance Test
COB	Center of Balance
8ft UG	8 Foot Up and Go Test
ABC	Activities specific Balance Confidence
GDS	Geriatric Depression Scale
CG	Control Group
VRG	Virtual Reality Group

ABSTRACT OF THE DISSERTATION

Virtual Reality Gaming as a Tool for Rehabilitation in Physical Therapy

by

Abel A. Rendon

Doctor of Science Graduate Program in Physical Therapy
Loma Linda University, September 2011
Dr. Everett Lohman III, Chairperson

Balance control decreases in the elderly and currently 33 to 50 percent of people over 65 years of age experience a fall each year resulting in ten thousand deaths annually. Many balance-training programs use expensive equipment and a clinical setting for the training. The need for reliable and low cost tools is essential for fall prevention and rehabilitation of the aging population. Virtual reality gaming is emerging as a solution for this problem. The purpose of the six week study was to determine the effects of virtual reality gaming, specifically the Nintendo Wii Fit Balance Board (WBB), on dynamic balance in older adults that was accomplished using a randomized repeated measures research study which included a control group design utilizing the 8 foot Up and Go (8ft UG), Activities-specific Balance Confidence Scale (ABC), and Geriatric Depression Scale (GDS) before and after 6 weeks of balance training. Forty subjects (female=26; male=14) between the ages of 60 and 95 were voluntarily recruited for the study and were randomly divided into a control group (CG) and a virtual reality group (VRG). The CG received pre-post testing only while the VRG was assigned to use the WBB under the supervision of a physical therapist; pre-post testing was completed by two additional physical

therapist that were blinded to the randomized groupings. The WBB exercises included lunges, single leg extensions and twist with a warm up and cool down before and after each session. Results of the study revealed a significant increase in confidence with activity and functional movement for the VRG relative to CG ($p < .05$). GDS were normal for both groups with no significant difference. The results of this study indicate the Wii Fit virtual reality gaming system improves balance and postural stability in older adults. Improved confidence with functional activities was reported. The sample pool from which the participants were selected is a limiting factor in terms of generalizing the outcomes measures. A second limitation relates to the lack of comparison to any other form of traditional physical therapy balance training program. Further study would address these identified factors.

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW FOR VIRTUAL REALITY GAMING IN REHABILITAION

Introduction

Balance control is the manifestation of concerted interaction between the neuromusculoskeletal, proprioceptive, vestibular and visual systems.[1] As age increases, the influence of these systems deteriorates resulting in an increased susceptibility for falling.[2]

Every year approximately 33 to 50 percent of people 65 years and older experience a fall.[3-6] According to the United States Census Bureau there were 308 million Americans counted on April 1, 2010 and of this number approximately 12% of the population is comprised of individuals over the age of 65.[7-8] Today roughly 37 million Americans over the age of 65 are residing in the United States and statistics suggest 12.2 – 18.5 million of these Americans will experience a fall.[3-8]

The need of reliable and low cost tools for maintenance, fall prevention and rehabilitation for people at risk for falls are essential for the care of this population. Nearly 20 percent of Americans between the ages of 65 and 75 suffer from balance disorders; by age 75 that figure rises to 25 percent.[9] For many years strength training and aerobic activities have been cited for their valuable benefits for overall health, improved posture and balance.[10] Current standards of fall prevention and

rehabilitation vary greatly depending on the patient's needs and functional outcomes.

Literature Review

Virtual reality (VR) is a term that applies to computer-simulated environment that can simulate physical presence in places in the real world. Rehabilitation using VR has been shown to improve lower extremity power and force for individuals with chronic hemiparesis.[11] Videogames have been used to educate and improve problem solving for many years. Videogames require the participant's to use logic, problem solving, and memory to complete the objectives of the games; these components are the most important elements of a game for the participants.[12] Specifically gaming consoles such as the Nintendo Wii, Sony PlayStation 2 and Microsoft Xbox have task specific games which require participant's to use volitional upright stance movement to achieve the objective of the game. In a case report by Flynn et al, the feasibility of using the Sony PlayStation 2 for a motor and sensory recovery to a stroke patient was documented and recorded.[13]

These new gaming consoles which use VR gaming requires participants to use logical thought and problem solving in order to correctly produce body movements to achieve results in the game. For example, if the game played were golf, the participants would be required to use logic to understand how to move the remote in order to send the virtual golf ball down the fairway towards the green displayed on the screen. Also, the subject would have to know how hard to swing

the remote and maintain their standing balance. This sequence uses various cognitive skills as well as volitional movements to achieve the goal.

These new gaming consoles all have activities and games that require the user to practice activities and play games. However, the Nintendo Wii offers a specific software package entitled Wii Fit. This specific software package requires participants to use dynamic and static controlled movements in double limb support in order to achieve results and scores which gauge and assess the subjects balance performance. For example, if the game is Twists, the participants are required to maintain their limits of stability (LOS) while rotating their trunk to the right and to the left. This sequence uses proprioceptors, mechanoreceptors and the inner ear semicircular canals to maintain upright balance and complete the game. It stands to reason that participants would be able to transfer these repetitive tasks to every day movements such as turning around or reaching for an object on the floor because the movements necessary to play Wii Fit games are equivalent to the same movements required in many daily activities; and hence, could be used in therapy emphasizing strength and stability.

Video games and virtual reality gaming provide sensory input in order to elicit a motor output. Specifically, the Wii provides tactile, auditory, and visual input. During game play vibration of the Wii hand held remote provides tactile input to the participant in regard to contact with the desired object/character. Auditory input is provided by music and sound effects where relate to the game's environment and the movement of the characters. Visual input in video games and virtual reality provides the spatial concept of position and movement via the video screen. This

key sensory input allows the participant to "see" the environment of the games as well as anticipate or direct movement with in the game. Thus, the motor output needed to play the Wii is dictated by the game being played and is stimulated by tactile, auditory, and visual input provided by game.

Video games and virtual reality gaming provide sensory input in order to elicit a motor output. Specifically, the Wii provides tactile, visual, and auditory input. During game play, the Wii remote vibrates thereby providing tactile input, while the game provides auditory input depending on the location of virtual surroundings and environment. By far the most important sensory input is provided visually from the onscreen display, depending on the location of the individual's virtual character and the game being played. The motor output that is needed to play the Wii varies depending on each game, but the motor output has to be controlled by the visual input so that the player moves the controller in the correct direction at the correct time.

The Wii approaches virtual reality in a manor different than most other video games. Other video games provide sensory input to elicit the motor output of pressing a button or a combination of buttons. The Wii approaches virtual reality in a way that approximates actual reality; that is to say the motor output that is needed to play the Wii is much like the motor output one would perform when playing a specific sport or doing a specific activity in reality. For example, when playing Wii Tennis the player holds the remote in his hands and swings it when the ball is hit to him as if the remote were a real tennis racket. No buttons need to be pressed because in reality people who play tennis they do not press a button or a

combination of buttons to swing the racket, they simply hold the racket in their hand and swing. Therefore, when playing the Wii the sensory input that is received has to elicit motor output from the entire body, not just the fingers and thumb to be successful.

The Wii Fit software and hardware package contains a balance board. The board acts as a control and uses of four pressure sensors at the four corners of the board. These sensors detect weight shifting and control of movement, which is transmitted via Bluetooth technology to the video game console resulting in a visual display on screen. The coordination and movement necessary for individuals to participate and succeed in a game requires the use of muscle groups and motor practice that replicates real life movements such as turning around, grasping for something outside ones reach, going up a curb or step, bending over for a newspaper or stepping into a bathtub.

Not all research involving the Wii has centered on the aging population. Deutsch et al (2008) reported a study involving therapy with a cerebral palsy child within a school setting. Using the Wii in therapy, the study sought to ascertain changes in impairment and functional levels of the subject. Results of this study revealed positive functional gains in subject attention span and stance time, as well as upper and lower extremity limb involvement. The positive increase in the attention span of the subject in this study supports similar findings in studies involving the increased attention span of older subjects using the Wii in a therapy setting. [15-17]

Since the initial release to the public in 2006, the use of the Wii Fit Balance Board (WBB) has produced significant pilot and case studies. One such Wii Fit pilot study by Nitz JC et al. was performed on ten women 30-58 years old. Their report revealed success in improving unilateral stance with eyes open as well as an increase in lower extremity muscle strength with 30 minute session twice weekly.[15] In a case study of an elderly 89 year old individual with a history of multiple falls, Clark and Kraemer found overall improvement on the Berg Balance Score, Dynamic Gait Index, Time Up & Go test, and ABC scores with decrease in risk of fall after the use of the Nintendo Wii for balance training.[18] In a study involving two patients with multiple disabilities, Shih CH et al reported an increase in target response (body swing) during the intervention phase of the controlled environment stimulation which utilized the WBB.[19]

Most studies have reported the clinical and/or functional use of the Nintendo Wii for rehabilitation, however, in 2009, Clark et al studied the validity and reliability of the Nintendo WBB for assessment of standing balance in comparison with gold standard laboratory grade force platform on 30 young injury free individuals. Both devices showed excellent center of pressure (COP) path length test retest reliability.[20]

The most recent publication, March 2011, by the Journal of Strength and Conditioning research stated: "Intermediate level Wii Fit games produced similar energy expenditure as compared to walking at 3.5 mph. These findings suggest that the Wii Fit can be used as an effective activity for promoting physical health". [21]

The use of commercially available game consoles for recreational pastime has been around. However, the health benefits of participating in a video game which require increased physical activity demand also produce some produce adverse events with the use of this new novel gaming system.[22, 24,25] Bonis coined the term Wiitis one morning when he woke up and realized his Wii gaming had created symptoms of a sports injuries.[22] A more serious case was published in 2008 concerning major trauma to a 16 year old boy's knee while playing the Nintendo Wii which resulted in surgical fixation and ligamentous repair. This case highlighted the force that could be generated while using this new gaming technology.[24] Other potential adverse events while using the Wii involve damage to property due to loss of grip of a controller and/or striking another participant in close proximity while mimicking the natural motions of swinging a tennis racket, golf club or baseball bat.[25]

It is evident that many uses are being practiced and reported in conjunction with the Nintendo Wii Fit. It has made a significant impact in regard to stability and mobility in hospitals, nursing homes, fitness gyms, schools, rehabilitation clinics, and private settings.[12-19] VRG has brought new terminology such as Wiihab, Wiitis and Exergaming to our common lexicon. Despite the positive outcomes of the VR gaming technology there are potential risks as previously mentioned. Nevertheless, after careful review of potential outcomes and in agreement with Lange et al[23] who reported functional gains that virtual reality gaming technology that benefits the participant is a valid and useful tool in which to engage, improve and motivate fall risk individuals who need a multi-facet approach to improve their impairments. A

variety of gaming devices that offers positive evidence based results but also low cost, ease of use and reliability appears to be a good fit for the rehabilitation needs of fall risk individual of the aging US population.[26]

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CHAPTER TWO

THE CONCURRENT VALIDITY OF NINTENDO WII BALANCE BOARD VERSUS THE NEUROCOM SMART BALANCE MASTER

By

Abel Rendon

Abstract

Valid tools of balance assessment are found in the academic setting, but their hefty price tag precludes them from most rehabilitation centers. Economically priced balance assessment tools need to be discovered and utilized in the local Physical Therapy setting for the benefit of patient balance and mobility. The study seeks to determine if the Nintendo Wii Balance Board (WBB) measure of balance is valid when compared to the NeuroCom Smart Balance Master (NSBM). The participating 31 subjects were divided into two study groups: Group A (ages 20-29 years, n = 20) and Group B (ages 50-75 years, n = 11); these two groups were assessed for unilateral stance stability and bilateral stance measures of center of balance. Study results indicated no significant correlation for mean center of balance measures on the NSBM and mean center of gravity measure on the WBB (r = .49) for double limb stance in both age groups. However, in Group B a significant correlation difference was found between mean sway measures on the NSBM and mean stability measure on the WBB (r = .79). Group B demonstrated a higher correlation on single leg assessment than Group A. Additionally, study results found tests for balance assessment were not equally sensitive on the WBB for bilateral stance and unilateral stance. Further testing for balance assessment is warranted.

Introduction

It is no secret that people are living longer than in the past[1], but this increased longevity does have its downside. This fact is evidenced by approximately ten thousand deaths each year[2,3] as a result of injuries sustained by 33-50 percent of 65 years and older who experience a fall. [4-7] Aging has been associated with the decline of physiological systems that control balance [8] and subsequently, a number of studies have appeared within the last 15 years which attempt to document the amount of decline in balance parameters in the geriatric population.[9-14] Research has indicated that balance impairment is a primary risk factor in the occurrence of falls, leading clinicians to develop gross standardized balance assessment tests to distinguish elderly non-fallers from fallers.[15] There is a wide variety of balance tools available today for assessment of balance such as, NeuroCom Pro Balance Master, NeuroCom Smart Equitest and NeuroCom Smart Balance Master. Of these tools, the NeuroCom Smart Balance Master (NSBM) has been the gold standard for balance assessment in previous studies.[16] Despite this fact the NSBM is rarely found outside the academic/research setting due to its price tag (70,000 USD); that is to say, the majority of rehabilitation offices and centers do not have the funds necessary to purchase the NSBM. An alternative to the NSBM is virtual reality systems that have been specifically developed for balance rehabilitation; unfortunately, these systems are equally as expensive as the NSBM. Due to the substantial lack of economical balance assessment tools outside the academic setting, which provide immediate visual feedback, current technologies such as readily available low cost gaming,

systems are being tested for rehabilitation application; Nintendo Wii FIT is one such gaming system.

This study seeks to determine if the Nintendo Wii and the Wii Balance Board (WBB) is able to measure balance in the same manner as the NSBM, a highly reliable and a valid tool for balance measurement. The Nintendo Wii WBB is based on the same principle as NSBM (forced plate system to measure the center of gravity changes of the body); however; the Wii WBB it is drastically more affordable and has wider availability. The hypothesis of this study is Nintendo Wii can be used to measure balance with the same validity as the NSBM for the body control test.

Methods

Subjects

Thirty-one subjects were recruited via flyers, posters and word of mouth at Loma Linda University School of Allied Health Professions. Study subjects read and signed the informed consent regarding their voluntary participation in the validation study. Subjects completed a visual clearing test for binocularity[17], and a lower extremity clearing test[18] prior to random assignment to the NSBM or the Nintendo Wii Fit Balance Board for balance assessments. Table 1 demonstrates the characteristics of the study subjects.

Table 1. Characteristics of Study Participants (N= 31) and Group Characteristics A & B.

Characteristics	Mean	SD	Range
Sex	19 females / 12 males		
Age (y)	37.6	16.59	23-75
Group A Sex	12 females / 8 males		
Age (y)	26	1.52	20-29
Group B Sex	7 females / 4 males		
Age (y)	58.8	7.52	51-75

Procedures

Prior to balance assessment testing, each subject was asked to remove his or her shoes and be fitted with a small, medium or large vest/harness, which was strapped to an overhead bar to minimize any fall risk while testing balance. Each subject was randomly assigned to initiate balance testing on either the NSBM or WBB. The sequence of procedures for a subject who was randomly assigned to begin the study using the NSBM is as follows:

1. (NSBM) Three trials to assess the center for gravity using Condition 1 (Eyes open, fixed support surface) of the Sensory Organization Test (SOT): This condition addresses the subject's ability to maintain balance in double limb support with no visual, somatosenory or vestibular interferences. This trial was performed three consecutive times per subject.

2. (NSBM) Three trials to assess the degree per second sway velocity for Unilateral Stance Test (UST)

The UST is a performance test quantifying the subject's ability to maintain postural stability while standing on one leg with the eyes open. The UST enhances the observational testing of single leg stance performance by providing an objective measure of patient sway velocity.

3. (WBB) Three trials to assess the center of balance (COB) on the WBB

   The COB assessment on the Nintendo WBB requires the subject stand still on the balance board while the console assesses the subjects COB. Once the COB analysis is calculated, the visual score is displayed on the monitor. All data produced by the Wii was hand documented (Appendix 1).

4. (WBB) Three trials to assess unilateral stance stability

   Upon the visual and auditory cueing the subject lifts his/her non-dominate leg and maintains his/hers stability as long as possible or signals the end of the test at which time the percentage of stability is determined.

Study Design: ANOVA, Concurrent Validation

An average score of three trails of balance assessment was calculated for each subject. Each subject was assessed using both the NSBM and the WBB; however, the order in which each subject started their assessment was randomized.

Results

Demographics of Subjects

Data was gathered in two different age groups: Group A (ages 20-29 years, n = 20) and Group B (ages 50-75 years, n = 11). The mean age was 26 years for Group A with 12 females and 8 males, while in Group B the mean age was 59 years with 7 females and 4 males. A total of 31 subjects participated in this study that included 19 females and 12 males with a mean age of 37.6 years. All subjects were healthy ambulatory individuals with no know orthopeadic or neurological impairments. No subject required the use of an assistive device for mobility or dynamic balance.

Comparison on the Performance Measures

There was no significance correlation [r = .49] for mean center of balance (NSBM) and mean center of gravity (Wii) with both age groups. A significant correlation [r = .79] difference was found in Group B between mean sway (NSBM) and mean stability (Wii). Group B demonstrated a higher correlation on single leg assessment than Group A.

Discussion

Data analysis between Group A and Group B on the NSBM and the Wii revealed no correlation for the assessment of center of balance or center of gravity respectively. However, this is in contrast to the results found by Clark et. al.[19] A potential lack of correlation in the balance scores between Group A and Group B may be attributed to the high homogenous sample of Group A.

An additional limiting factor of the study could result from the cohort sample selection of subjects; Group A was composed predominately of Physical Therapy students who tend to be active and athletic while Group B was composed of administrative and faculty of the School of Allied Health Professions who tend to be more sedentary.

Furthermore, two other limiting factors of this study could be related to the small sample size and the fact that all data was collected on one day. Thereby reducing the variance of balance performance over time.

Conclusion

This study clearly indicates the WBB as a valid tool of single leg balance assessment. The WBB is not an appropriate tool to assess center of gravity in double limb stance due to its poor correlation to the NSBM (r=. 49). However, the high correlation (r=. 79) for single leg stance between the WBB and the NSBM reveals the two tests are not equally sensitive and thus, the WBB can be used in the clinical setting to assess body control and performance in aging subjects, particularly for assessment of single leg balance.

If the WBB demonstrates improved correlation with the NSBM upon further study involving increased sample size and data collection over multiple days, then it can be used as a tool for double limb stance assessment; this result would also further broaden its scope of balance assessment.

With an economical price tag and wide accessibility, the WBB could become the “Poor Man’s Balance Master.”

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CHAPTER THREE

THE EFFECT OF VIRTUAL REALITY GAMING ON DYNAMIC BALANCE IN OLDER ADULTS

By

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(A paper prepared for submission for publication)

Abstract

BACKGROUND: Physical therapy interventions that increase functional strength and balance have been shown to reduce falls in older adults. AIM: This study compared a virtual reality group (VRG) and a control group (CG). DESIGN. Randomized controlled 6-week intervention with pre and post-test evaluations. SETTING: Outpatient geriatric orthopedic and balance physical therapy clinic. POPULATION: Forty participants were randomized into two groups. METHOD: The VRG received 3 different Nintendo® Wii FIT balance interventions 3 times per week for 6 weeks and the CG received no intervention. RESULTS: Compared to the CG, post intervention measurements showed significant improvements for the VRG in the 8 foot Up & Go test (median decrease of 1.0 versus -0.2 second, (P = .038) and the Activities-specific Balance Confidence Scale {(6.9 % versus 1.3%) (P= .038)}. CONCLUSION: Virtual reality gaming provides clinicians with a useful tool for improving dynamic balance and balance confidence in older adults.

Introduction

In the United States, falls are the leading cause of injury death in adults 65 years of age and older accounting for approximately ten thousand deaths annually [1,2]. Every year approximately 33 to 50 percent of people 65 years and older experience a fall [3-6]. According to the United States Census Bureau, there are 308 million Americans of which approximately 12% are comprised of individuals over the age of 65 [7,8]. Functional mobility and balance confidence are critical components of the multi-faceted treatment approach for an aging population with increased fall risk. Nevertheless, decreased strength, balance, and stamina contributing to decreased independence in older adults have become a normative cultural acceptance. Research has shown that this acceptance is "out dated" and not true [9,10].

The Centers for Disease Control and Prevention (CDC) reports that older adults have the opportunity and the ability to decrease their fall risk through regular exercise [11]. Many balance-training programs use expensive clinical equipment, professional staff and a clinical environment for balance training [12-14]. Bellew et al [15] reported the growing need for simplistic, concise, short-term balance training programs that address dynamic balance and can be performed independently without expensive clinical equipment.

Virtual reality gaming is an emerging technology that is being used for that purpose. A variety of health care practitioners are using virtual reality technology to enhance patient treatments as well as provide multiple innovative interventions requiring attention and active patient participation [16,17]. Researchers and

physical activity directors are using virtual reality to increase compliance and improve function for their participants [18,19]. In 2005, Shigeru Miyamoto designed the Nintendo® Wii with its innovative remote and Wii Balance Board (WBB) control [20]. The WBB was introduced to the public in 2007 as the first advanced controller of its kind [20]. Most recently the WBB has been integrated into the rehabilitation programs of patients who suffer from balance deficits [17]. The WBB is portable, widely available, and inexpensive balance assessment tool suitable for clinical setting [18,22]. The WBB has shown positive response in improving balance and reducing risk of falls in patients with balance deficits [21-23]. The purpose of this investigation was to determine the feasibility and outcome using the WBB for improvement of dynamic balance in older adults classified as fall risk individuals.

Methods

The research design for this investigation was a randomized repeated measures. Participants were included in the study if they were, independent community-dwelling adults between 60 and 95 years of age, able to participate in physical activity for 45-60 minutes, and verbally reported having normal vision. Participants with known orthopedic, neurological or circulatory disorders that would prevent them from participating in the study were excluded. A pre-test/post-test control group design was used to assess 3 independent measures of gait/dynamic balance, balance confidence, and depression. Specifically, we used the 8 foot Up and Go (8ft UG), Activities-specific Balance Confidence scale (ABC), and

Geriatric Depression Scale (GDS), respectively, before and after 6 weeks of balance training.

Participants

Forty participants were recruited via flyers, posters and word of mouth at the Air Force Village West retirement community located in Riverside, California. Participants read and signed an informed consent regarding their voluntary participation in the investigation. Participants then completed the GDS and ABC followed by a physical therapist conducting an 8ft UG and an assessment of body control using the WBB. The timed results of the 8ft UG were kept blinded from the physical therapist who conducted the 6-week intervention study. The participants were randomly divided using a random number table for two groups. The control group (CG) received pre-post measurements only. The virtual reality group (VRG) was assigned to use virtual reality gaming using the WBB with the Nintendo® Wii Fit Software package. The VRG was under supervision of a physical therapist and was pre-post tested by two additional physical therapists that were blinded to the randomized groupings.

Procedures

Pre-tests and Post-tests assessments

Geriatric Depression Scale- Depression in community dwelling older adults is often related to decreased activity and perception of poor self worth [24]. The GDS is a valid and reliable self-assessment tool for measuring depression [24].

The Activities-specific Balance Confidence scale- Fear of falling and avoidance of activities due to fear of falling are highly prevalent in older adults [25]. The ABC scale is a valid and reliable questionnaire that allows individuals to self report their balance confidence during specific activities [13,26].

The 8 foot Up & Go test- This test assesses the ability to transfer from sit to stand, maintain dynamic balance, change direction during ambulation, and transfer from stand to sit, which are necessary for functional movement and independent living. The 8ft UG is a valid and reliable standard clinical assessment of balance and gait [27]. Participants sat in a firm chair with armrests. Each participant was timed in seconds with a stopwatch and asked to ambulate quickly and safely towards an object on the floor placed 8 feet away, turn around and sit down. The 8ft UG was performed twice and the best of two scores was recorded.

Wii Balance Board- The WBB has been shown to be a valid tool for assessing standing balance [23]. The WBB transmits its data to the Wii console through Bluetooth technology. The data is generated from four pressure sensors which give different pressure value readings on alteration of position [28]. Participants performed 2 tests of body control to collect an average score of stability using the WBB. Those tests included assessment of limits of stability in double limb stance and single leg stance.

Intervention: The 3 Wii FIT Exercise Games

An eight-minute cardiovascular warm up on a stationary bicycle and an eight-minute cool down was performed in the VRG intervention. Participants unable

to sit on an upright stationary bicycle had the option of using a recumbent stepper for warm-up and cool down.

In the VR group, each participant used three different balance games from the Wii Fit software package. Participants were instructed to follow the onscreen visual displays while maintaining their limit of stability during dynamic stance activities. All participants wore a gait belt to aide the physical therapist in the event of a loss of balance. Additionally, each participant had the use of, as needed, a quad cane, a front-wheeled walker, or hand held assistance during all the games for added safety. A chair was available for rest periods if participants required a break. During the VR balance training a physical therapist was present to assist the participant in the operation of the game or in stepping on or off of the WBB.

Lunges

The participants had the option of placing one or both hands on the front-wheeled walker, on their hips or behind head. To complete the lunge exercise, the participant stood with both feet on the WBB. They then stepped off of the WBB with the left leg while keeping the right foot on the WBB and followed the display instructions to shift their weight from the left foot to the right foot. This was repeated with the right foot on the WBB and the left foot off. Ten shifts on and off the WBB were attempted with each leg. An onscreen cue gave visual response to the amount of weight shifting and timing of weight shifting. This exercise was repeated three times per session. See Figure 1.



Figure 1. Participant practices the lunge by weight shifting his weight onto his right foot without assistance.

Single Leg Extensions

One or both hands were placed on a front-wheeled walker or a quad cane. The exercise directed participants to start by lifting left hip, knee and contralateral shoulder to 90 degrees of flexion, followed by simultaneously extending their left lower extremity while reaching forward with the contralateral upper extremity six consecutive times. This sequence was then repeated to the other limbs. The whole sequence of exercise was repeated three times per session.

Twists

Participants placed both hands on hips or held arms abducted to 90 degrees. They were instructed to follow the on screen display for upper trunk rotations while maintaining their center of balance within their limits of stability. Three twists to each side were performed followed by a rest and then three more twists with diagonal angles were performed with the same emphasis of maintaining their center

of balance within their limits of stability. This exercise was repeated three times per session.

In order to avoid acclamation to the exercises, the order of the exercises was reversed each week. During the first week of intervention the order of exercise was: Warm up, single leg extensions, twists, lunges and cool down. During the second week of intervention the order of exercises was: Warm up, lunges, twists, single leg extensions and cool down. Participants continued to alternate the exercise game sequence week-to-week during the 18-session intervention (3x/week x 6 weeks). Each session lasted approximately 35-45 minutes.

Modifications to the exercises were needed for some participants. The main modification was the use of a front wheel walker for the exercise and balance tasks. Another modification for those participants who could not perform a lunge, due to self reported osteoarthritic discomfort in the knees, was a change of weight or "weight shift" while keeping up with the same tempo and rhythm as the game continued. Twists modification was made for participants who were unable to hold their hands and arms up in the air to perform trunk rotations. The modification was to allow them to place their hands on their hips while completing the twists.

The pre and post-test for the CG and the VRG were administered in the same manner. During the interim the CG was instructed not to alter their normal daily activities, whereas the VRG commenced exercise game intervention with the WBB. Figure 2 represents the intervention participation of VRG and CG. Twenty participants were randomly assigned to the intervention group of which 14 met the 15-minimum treatment requirement. Of those, two participants lost interest and

chose not to continue, two participants stopped because of pain and discomfort to arthritic knees, and two discontinued because of unexpected travel commitments. Also, two of the 20 control participants did not show up to the post-test and were not available to reschedule.

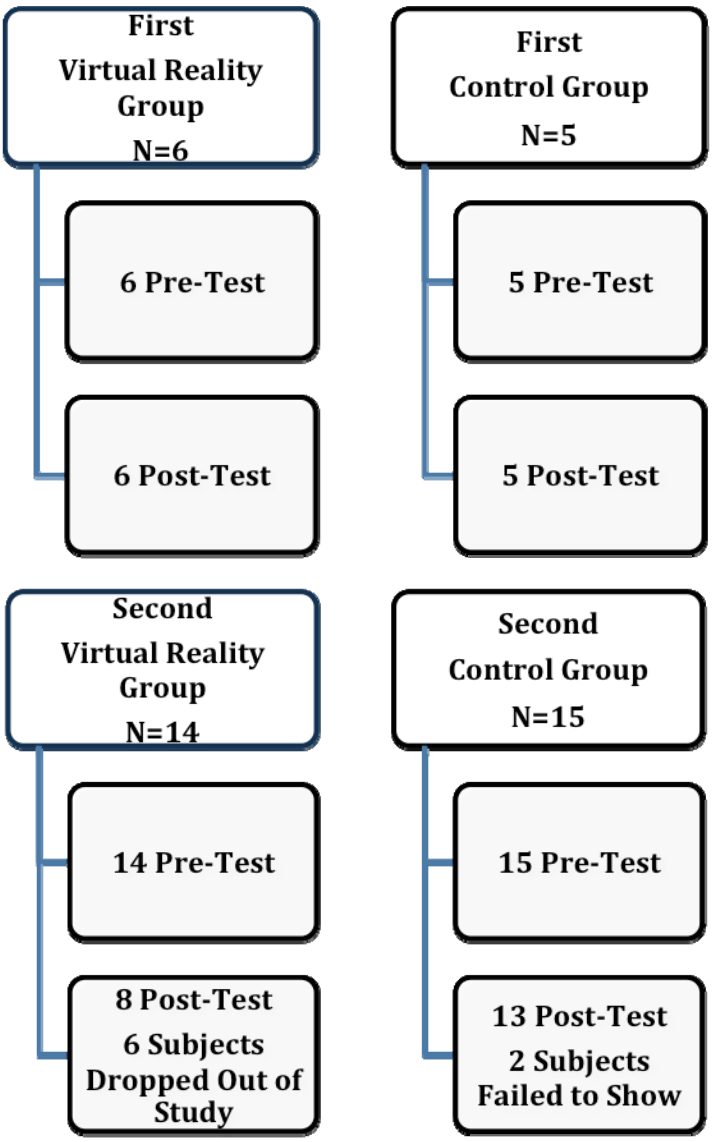


Figure 2: Flowchart of Virtual Reality Group and Control Group Data Collection.

Data Analysis

Non-parametric statistics was chosen for all inferential analyses because two outcome measures were non-normally distributed and heterogeneity of variances existed between groups (8-foot Up and Go & GDS). Thus median, minimum and maximum values were used for descriptive statistics for outcome measures. The Mann-Whitney test was used to determine significant differences ($P<.05$) between groups at baseline and change in outcome measures over time. The data was analyzed using PASW Statistics 17.0 for Windows (SPSS, Inc. Chicago, IL)

Results

The mean ages (SD) of the VRG and CG were 85.7(4.3) and 83.3 (6.2) years, respectively. The majority of participants were female (65%) and six out of 40 participants (15%) used an assistive device with regularity (a single point cane or a 4-wheeled walker).

The VRG median change score for the 8ft UG revealed a 1.0 second decrease as compared to a 0.2 second increase for CG ($P=.038$). See Table 1 and Figure 3. The VRG also showed a 6.9% median increase for the ABC as compared to a 1.3% increase for CG ($P=.038$). These changes reflect a significant increase in confidence with activity and functional movement for the VRG relative to controls which showed no appreciable changes in the outcome scores. Both groups scored in the "normal" classification of depression scoring by the GDS (0-9 = normal). Median improvement for the VRG was 1.0 and for the CG was 0.0 ($P = .112$).

Table 1. Comparison Between Groups of Outcome Measures over 6 Week Study Period.

Measures	VRG (n = 14)		CG (n = 18)		
	Pre-Test	Post-Test	Pre-Test	Post-Test	
	Median (Min-Max)	Median (Min-Max)	Median (Min-Max)	Median (Min-Max)	*P* *
8-foot Up and Go	9.02 (5.56-18.3)	8.52 (5.1-16.5)	8.55 (5.1-17.3)	8.32 (5.2-19.5)	
Median Change	1.0 (-1.9-3.7)		-0.2 (-2.63-4.47)		.038
ABC	71.7 (47.5-96.9)	81.9 (55.0-96.9)	78.4 (29.1-100.0)	76.9 (45-100.0)	
Median Change	6.9 (-1.9-20.0)		1.3 (-31.2-40.9)		.038
GDS	6.5 (1-16)	4.0 (0-13)	3.5 (0-14)	4.0 (1-14)	
Median Change	1 (-2-7)		0 (-11/4)		.112

*Mann Whitney test

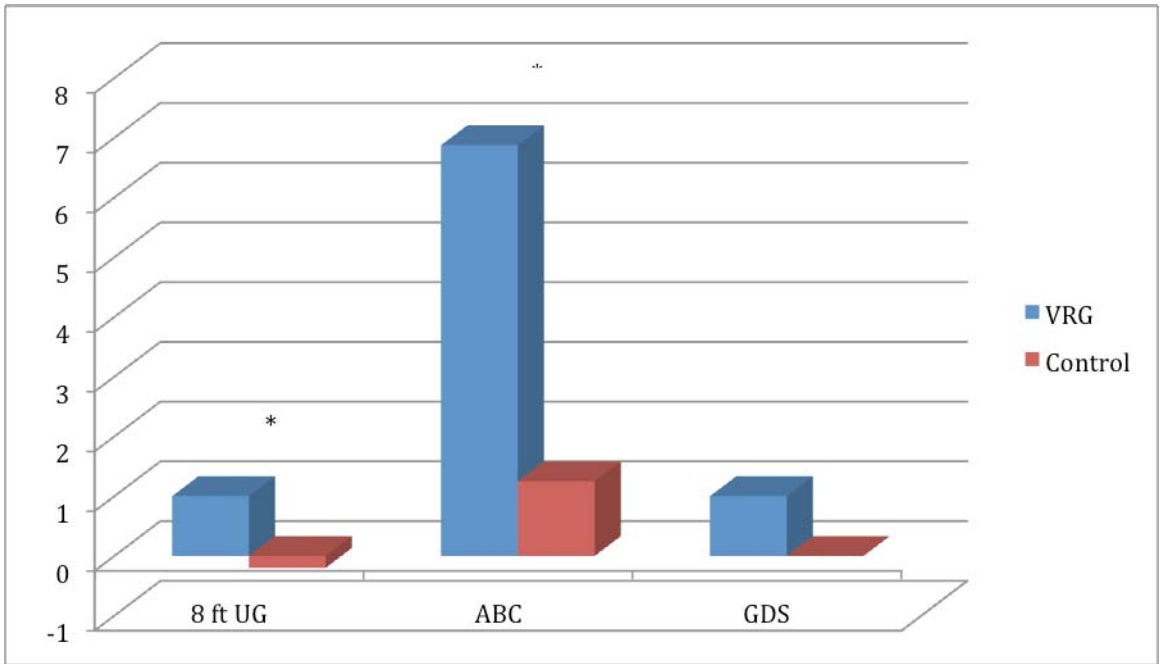


Figure 3. Outcome measure changes over six-week study period.
* = Mann Whitney U P< .038

A post hoc analysis of effect size and power was conducted at the conclusion of the study. Using the number of subjects that completed the study (34), the f effect size was .35. An f effect size of .4 is considered large. [29] The power to detect this effect was 50%. For 80% power, a sample size of at least 30 per group would have been required.

Discussion

The purpose of this investigation was to compare the outcome measures of balance on older adults using a VR gaming system and a CG. Participants in the VRG showed positive changes towards clinical assessment outcomes versus the CG that showed minimal to no change. Participants in the VRG showed positive gains in the 8 ft UG, ABC and GDS.

Similarly, as reported in a study by Williams et al [30], this investigation demonstrated the willingness and compliancy of older adults in balance training using the Wii Fit. During the 6 week intervention, a minimum requirement of 15 training session was set in order to allow for schedule changes and unexpected emergencies. Participants were allowed to reschedule sessions missed in the same week. At the end of the study, 70% of the participants were able to complete the minimum number of training sessions required to post-test. This high compliancy and positive responses to qualitative questions during post-testing interviews further credits the usefulness of this gaming/rehabilitation option. Individuals who regularly exercise will gain in strength, functional capacity and confidence versus a group of individuals who do not exercise [31]. One of the main goals of this study

was to determine the feasibility of increasing dynamic balance and static stability in older adults when using virtual reality gaming as an exercise intervention. Since significant improvement in dynamic balance and confidence were made on healthy community-dwelling older adults, than an argument could be made for similar benefits this new gaming system could provide by using it as a fall risk prevention intervention to at-risk groups.

There were several limitations in this investigation. The need for verbal and tactile cueing by the physical therapist for compliance and motivation was not considered prior to the study initiation. Several participants reported the need for cueing in order to understand the main emphasis of the exercises and strategies to improve their scores. Feedback was graded as high, medium and low through the six-week intervention to encourage participation and balance training. High feedback was considered to be verbal or tactile cueing with 80-100% of the exercises. Moderate feedback was considered to be verbal or tactile cueing with 50-80 % of the exercises. Low feedback was considered to be < 49 % of verbal or tactile cueing for the exercises. These parameters were set on the basis of the older population that was studied and the need of repeated instructions for an exercise intervention, which was new to the participants.

Participants were encouraged to use the assistive device for safety during interventions, but they were encouraged to increase the difficulty of the exercise by reducing the use of the assistive device. No participant was able to complete the entire series of exercises without the use of the assistive device at least one time. The highest safety scaled reached by participants was a safety score of 3. This fact is

cause for concern for potential injury in regard to independent practice devoid of supervision.

The sample pool from which the participants were selected from is a limiting factor in terms of generalizing the outcome measures. All participants were veterans or spouses of veterans from the United States military, which created a specific mindset of accountability of appointment keeping, and exercise rigor, which is possibly higher than the average population. Another potential limitation is that this intervention was not compared to any other form of traditional physical therapy balance training programs.

Conclusion

The results of this study suggest that the Wii Fit virtual reality gaming system improves balance and postural stability. Improved confidence with functional activities was also reported. Although no significant change was revealed from the depression scale in either group, both groups median scores were in the normal range of 0-9. With appropriate supervision, a gaming device such as that used in this investigation can improve the dynamic balance and postural stability of older adults and reduce fall risk.

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APPENDIX A

QUALITATIVE QUESTIONS AND ANSWERS

At the end of the six-week intervention, the participants that finished the study were asked exit interview questions regarding their experience with the research, and feedback of the personal perception of the experience by the primary investigator.

The following questions were asked in person to the nine participants who completed the six-week intervention as part of the Virtual Reality group.

12/21-22/2010

1) Could you tell me of your overall experience with the Balance Program?
2) Was it a Positive of negative experience?
3) Would you buy a Wii console gaming system of your personal home use?

The following is a verbatim record of the dialogue and question response.

Subject 01:

Interviewer: "Could you tell me of your overall experience with the Balance Program"?

S 01: "Oh I found it challenging and I enjoyed it?

Interviewer: "Was the balance program a positive of negative experience"?

S 01: " Oh Positive, very definitely"

Interviewer: " Would you buy a Wii gaming system (like used in the Physical Therapy clinic) of your personal home use?

S 01: "Well, it would kind of depend on how much it was, and how I could manage to use it."

Interviewer: Would you buy it if you had some personal training?

S 01: “I think I might.”

Interviewer: I just want your honest opinion, that’s all I need.

S 01: “You know, I’m limited financially so I have to be very careful.”

Interviewer: Sure I understand, I completely understand.

That concludes this interview, thank you for your participation.

Subject 02:

Interviewer: Could you tell me of your overall experience with the Balance Program?

S 02: “Well I like it very much, because you know I’ve been really sad all the time, but when I do it, I seem to forget it that time, so it was just a good experience for me.”

Interviewer: Was it (the balance training) a Positive of negative experience?

S 02: “Oh I think definitely positive, I don’t know whether I’m improving in anything, but I feel positive.”

Interviewer: Would you buy a Wii console gaming system of your personal home use?

S 02: “I don’t know, I don’t think I would know how to use it properly.”

Interviewer: Perfect, I just need your personal honest feedback, that helps me out tremendously.

S 02: “I wish I could stand on one leg, I use to pretty well. When Donna was making us do it a little bit at a time, but she’s gone and I haven’t done it.”

Interviewer: So do you have anything that has changed? In your balance or your leg strength? Do you feel anything has changed in your balance or in your leg strength?

S 02: "Leg strength has improved, only the first day, Oh my God, it hurt me so much, I couldn't sit, without hold it and I couldn't stand up with out holding on to something, but then by the next session it didn't hurt at all. I must have been stronger, because it didn't hurt any more. I thought you were great, you were wonderful."

Subject 03:

Interviewer: Could you tell me of your overall experience with the Balance Program?

S 03: "Well I found it interesting, not too mind boggling by any means, it was an incentive to try to do better believe it or not, is that what you need?"

Interviewer: Was the balance program a positive of negative experience?

S 03: "Was positive, definitely, I can't say I came out never losing my balance again, but it was definitely positive."

Interviewer: Would you consider buying a Wii console gaming system of your personal home use?

S 03: "You mean, the one with the man who directed you to do all the time?"

Interviewer: That's right.

S 03: "Uhh, it would be the same thing?"

Interviewer: Well that is what is commercially available, its pretty standardized.

S 03: "I didn't really give it a thought, uhhh, I really honestly don't think I would, unless I found out other people I knew had decided to buy one and they felt the continued help was helpful."

Subject 04:

Interviewer: Could you tell me of your overall experience with the Balance Program?

S 04: "It started out very bad, as you know, it was really bad because it was asking me to do something that I could just not do, and I put strain on me where I was hurting so bad the next 2-3 days I thought I was gonna drop, and after we got that resolved, it was interesting, not unpleasant to any extent, and it's been helpful. But if you wanna know, whether I feel like I've gained any more balance now because of that I can't really say that I have."

Interviewer: You haven't' felt significant change in your balance?

S 04: "No significant change, except that you've made me think about my feet and how they're balancing out better."

Interviewer: So there is more of a body awareness with you on your feet.

S 04: "That's right."

Interviewer: Was the balance program a positive of negative experience?

S 04: "Positive, even up to very positive. I like to see things like this being done."

Interviewer: Would you buy a Wii console gaming system of your personal home use?

S 04: "I wouldn't hesitate to buy something like this."

Subject 05:

Interviewer: Could you tell me of your overall experience with the Balance Program?

S 05: "I was grateful to be in it and I think it was a good idea. It shows you where your balance is off and where your weak and uh scores both legs, even though it doesn't matter, it helps to keep you motivated to improve those. I think it helped but I wasn't able to stand on one foot. But I was never able to do that before either."

Interviewer: Was the balance program a positive of negative experience?

S 05: "It was a positive experience."

Interviewer: Would you buy a Wii console gaming system of your personal home use?

S 05: "I don't think so, I think I'm gonna go down to the exercise room and use the machines that we have, you know I found that 6 weeks was enough of that, I doubt it would be any much more improvement on that and there are other things I need more. And I'm not good at doing things by myself, and I'll go down to the exercise room and use that equipment."

Subject 06:

Interviewer: Could you tell me of your overall experience with the Balance Program?

S 06: “It was excellent, I thought it was a good program, it was understandable to me and I got some results from it.”

Interviewer: Was the balance program a positive of negative experience?

S 06: “Positive.”

Interviewer: Would you buy a Wii console gaming system of your personal home use?

S 06: “Well its according to how much they cost?”

Interviewer: So price would be the determining factor for you?

S 06: “Yes.”

Subject 07:

Interviewer: Could you tell me of your overall experience with the Balance Program?

S 07: “Well I enjoyed the Balance program very much, I tried my best to stay with what I thought they wanted me to do, keep level, keep balance, keep from moving to much, and it seem to me to give me the idea that I was doing better. For a while I thought I was doing real good, then later on I felt well maybe I was getting use to it and not concentrating. But I enjoyed it very much, and I thought it told you if you were gaining in balance or not.”

Interviewer: Was the balance program a positive of negative experience?

S 07: “It was a positive experience for me, I enjoyed it and I thought it was something that was making me think about my health and my balance.”

Interviewer: Would you buy a Wii console gaming system of your personal home use?

S 07: “Well I would have to give that a little bit of thought, whether I would or not. I’d think about the cost and think about whether or not stand to do it at all. I think I would consider it, but I’m not sure if I really want it or not.”

Subject 08:

Interviewer: Could you tell me of your overall experience with the Balance Program?

S 08: “I found it very helpful to me, from the beginning it was a bit tough, but as I progressed I could see the value of it and it definitely helped me physically, and I enjoyed it very much.”

Interviewer: Was the balance program a positive of negative experience?

S 08: “A very positive experience.”

Interviewer: Would you buy a Wii console gaming system of your personal home use?

S 08: “I feel it would be a bit inconvenient for my home use, but I would like one available. That would be my preference.”

Interviewer: So one that you would be able to use readily maybe not at home but with access:

S 08: “With-in ready access.”

Subject 09:

Interviewer: Could you tell me of your overall experience with the Balance Program?

S 09: “Well, it certainly did for me what I wanted it to do, because a few months ago I was in a wheel chair and I was still progressing from that. So I wanted to get all the strength I possibly could. And I think the balance program did everything I needed at this particular time.”

Interviewer: Was the balance program a positive of negative experience?

S 09: “Definitely positive.”

Interviewer: Would you buy a Wii console gaming system of your personal home use?

S 09: “Yes I would, I’m hoping that they continue to use it in the wellness center but if not I would certainly consider it for my home.”

Generalized Results

The Qualitative results gathered were from 9 out of 20 subjects. The reason behind this limited response was because during the first intervention period (n =6) the qualitative questions were not part of the plan of data collection and once the committee decided it was a prudent decision to gather more data from more subjects, 2 months since the last intervention date had past. In the second intervention period, n =14 participants were part of the Virtual Reality group. 6 of those 14 did not meet the minimum number of visit of 15 to be considered part of the group. So in the end, 9 out of 20 subjects were asked these questions within 2 days of finishing their posttest day.

After careful review of the responses to the qualitative questions of the 9 a concurrent theme was distinguished in three categories to the participation in the balance training intervention:

1) Physically Demanding, 2) Appreciated, 3) Valuable,

"In general, the patients felt that they appreciated the value of a physically demanding balance program."

Table 1 shows the main theme with the synonyms and adjectives the participants used to classify or categorize the main theme.

Table 1. Main theme of participants who participated in VRG.

Physically Demanding	Appreciated	Valuable
Challenging Difficult Control Emphasis Progressive	Enjoyed Excellent I Liked it Simple Interesting	Good Experience Helpful Beneficial

The majority of study participants found the initial training session to be challenging, with subsequent sessions being considered easier. When reflecting on the overall training experience, the participants consistently expressed appreciation for: 1) Clear and concise training directions which aided successful participation, 2) Individual game scoring which promoted increased motivation for improved performance, and 3) Audio and visual feedback which offered assistance in exercise tempo for maximum outcome.

Qualitative Results

Qualitative Questionnaire main theme response to the question: "Could you tell me your overall experience with the Balance Program?"

On the day following the post testing for the research project, 9 of the 14 subjects were available to give a personal account of their participation and experience during the 6 weeks of intervention. Three primary questions were asked and any additional comments regarding the program, positive or negative were encouraged.

Some of study participants, 22%, found the initial training session to be challenging, with subsequent sessions being considered easier. However 77% reported enjoying the intervention and when reflecting on the overall training experience, the participants consistently expressed appreciation for: 1) Clear and concise training directions which aided successful participation, 2) Individual game scoring which promoted increased motivation for improved performance, and 3) Audio and visual feedback which offered assistance in exercise tempo for maximum outcome.

One of the subjects reported (personal communication, Dec 21, 2010): "Well I enjoyed the balance program very much, I tried my best to stay with what I thought they wanted me to do, keep level, keep balance, keep from moving too much, and it seem to me to give me the idea that I was doing better. But I enjoyed it very much, and I thought it told you if you were gaining in balance or not."

Another subject stated (personal communication, Dec 22, 2010):

"I found it very helpful to me, from the beginning it was a bit tough, but as I progressed I could see the value of it and it definitely helped me physically, and I enjoyed it very much."

Conclusion

None of the Virtual Reality Group participants had any prior experience with the Nintendo Wii, nor had they done any sort of balance training intervention. Another keynote not reported in the study was that during the 6-week intervention, no participant reported the occurrence of loss of balance or injury due to a fall. In addition to the positive response of the participants who finished and completed the intervention, an objective indirect result could be noted that those who were in balance training sustained no falls during their intervention period.

APPENDIX B

NINTENDO WII FIT ASSESSMENT-BODY CONTROL FORM-

Date: _____

Name_____

ID _____

Height: _____Feet _____Inches

DOB: _____ (Month) _____ (Day) _____ (Year) / AGE:_____

Center of Balance assessment:

Left % _____ / _____ / _____ Right % _____ /_____ /_____

Body Mass Index scale:

BMI = _____

Underweight = <18.5
Normal weight =18.5-24.9
Overweight = 25-29.9
Obesity = BMI of 30 or >

30 second-Balance on One-leg stance test:

Trial 1:

Left %: _____ Right %: _____

Stability %: _____

Wii FIT Age: _____ + / - _____ Chronological Age.

Trial 2:

Left % _____ Right %: _____

Stability %: _____

Wii FIT Age: _____ + / - _____ Chronological Age.

Trial 3:

Left %: _____ Right %: _____

Stability %: _____

Wii FIT Age: _____ + / - _____ Chronological Age.