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THE EFFECT OF BALANCE TRAINING WITH AN INNOVATIVE APPROACH COMPARED TO TRADITIONAL BALANCE EXERCISES

By

Brian Curtis Waite

Bachelor of Science
University of Nevada, Las Vegas
2010

A thesis submitted as partial fulfillment
of the requirements for the

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Department of Kinesiology and Nutrition Sciences
School of Allied Health Science
Division of Health Sciences
Graduate College

University of Nevada, Las Vegas
August 2013

THE GRADUATE COLLEGE

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Brian Waite

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Abstract

The Effect of Balance Training with an Innovative Approach Compared to Traditional Balance Exercises.

By

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Objective: The purpose of this study was to evaluate the use of an X Box 360 Kinect™ game as a modality for improving balance. Specifically, this study explores the use of the Target Kick mini game on Kinect Sports™ as a tool for VR rehabilitation. Subjects (N=18, age 23.3 ±2.87 yrs, mass 71.83 ±15.25 kg, height 168.4 ±7.79 cm) with no lower extremity injury were randomly placed into three groups (X Box n = 6, Traditional n = 6, and Control n = 6). The X Box (XBOX) group performed ten minutes of balance training by playing an X Box game for 18 sessions over six weeks. The Traditional (TRAD) group preformed 2 balance exercises for the same duration as the X Box group. Subjects were tested on the Bertec Balance platform (Model BP5050) while performing a single leg stance for 15 sec (100 Hz) before and after the 6 weeks of intervention. Total excursion (TE) of center of pressure (COP) in the medial-lateral (M-L) and anterior-posterior (A-P) planes and root mean square velocity (RMS vel) of COP in the M-L and A-P planes were extrapolated from COP data. A 3 (treatment group) x 2 (time) mixed model analysis of variance with post hoc Tukey follow-up test and paired t-test as appropriate ($\alpha = 0.05$) was used to determine significant changes. Also game scores in the XBOX group were recorded to compare balance performance with game

performance. Pearson's *r* was used to determine a correlation between game score and balance. It was determined that there were differences for TE in the M-L plane ($F_{(2,15)}$ = 5.554 p = .016), TE in the A-P plane ($F_{(2,15)}$ = 5.565 p = .016) for time and a difference in RMS vel. A-P ($F_{(2,15)}$ = 3.740 p = .048) for groups. Specifically, TE M-L saw a decrease from pretest to post test for the TRAD group ($t_{(5)}$ = 5.263 p = .003); TE A-P saw a decrease from pretest to posttest for the TRAD ($t_{(5)}$ = 3.044 p = .029) and CON ($t_{(5)}$ = 3.335 p = .021) groups; and RMS vel. A-P was significantly lower at posttest between XBOX and TRAD groups ($F_{(2,15)}$ = 5.340 p = .018). Although the TRAD group did decrease from pretest to posttest in TE M-L and TE A-P, the results from this study are not strong enough to determine that the treatment was effective. No correlation was found between game scores and COP (pretest TE M-L r = .358 p = .486, TE A-P r = .785 p = .064, posttest TE M-L r = .305 p = .557, TE A-P r = .684 p = .134).

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CHAPTER 1

INTRODUCTION

Virtual reality (VR) rehabilitation has been around for many years. It is being used to help many patients with a variety of health issues ranging from motor learning for musculoskeletal dysfunction to rehabilitation for cognitive dysfunction (Burdea, 2003). There is a wide array of VR devices used for rehabilitation. Traditionally, systems have been custom engineered from computers with special equipment such as gloves and robotic arms. These engineered systems are expensive and not readily available (Burdea, 2003). However, with shifts in the video game industry clinicians now have access to less expensive and commercially available VR devices (Sung, 2011). The Nintendo™ Wii™, Playstation Move™, and X Box Kinect™, all have potential as a rehabilitation tool. The X Box is especially intriguing due to the ability to track full body movement without the assistance of markers or other equipment.

Research to support the use of VR rehabilitation is positive but limited. VR devices have been shown to reduce perception of pain, increase motivation, and improve balance (Brummels et al., 2008; Hoffman et al., 2011; Wiederhold & Wiederhold, 2007). Primack, Carrol, & Nayak (2012) found that there is potential for video games to improve health-related outcomes especially in the areas of physical therapy and psychological therapy. Some of the disadvantages and challenges to VR devices have been cost and accessibility (Burdea, 2003). Also the variety of devices used and the inconsistency in research with sample populations create an environment with vast variety yet shallow

depth. As more research is conducted in specific areas, a better understanding of the clinical benefits of different VR applications will emerge (Parson et al., 2009).

Balance exercises have become an intricate part of lower extremity rehabilitation. There is moderate data to support its use to prevent lower extremity injury (McKeon and Hertel, 2008; Hubscher et al., 2010). McKeon and Hertel (2008) and Hubscher et al. (2010) observed that long term programs may have greater preventive effects. VR devices have shown positive results to improve balance with cerebral palsy patients and the elderly (Brien and Sveistrup, 2011; Sztrurm et al., 2011). Brummels et al., (2008) found that two video game training groups improved balance over traditional exercises. Due to the fun nature of VR, especially video games, it may be a more effective tool for maintaining compliance during long term programs (Burdea, 2003).

IMPLICATIONS

Recent shifts in video game technology have created an opportunity for less expensive and easily accessible VR devices to be used for rehabilitation (Sung, 2011). This study pioneers the way for the Kinect™ to be used in musculoskeletal rehabilitation.

PURPOSE OF THE STUDY

The purpose of this study was to evaluate the use of an X Box 360 Kinect™ game as a modality for improving balance. Specifically, this study explores the use of the Target Kick mini game on Kinect Sports™ as a tool for VR rehabilitation.

RESEARCH HYPOTHESIS

It is hypothesized that a Kinect Sport™ Target Kick mini game on X Box 360™ will improve balance more than traditional (Trad) balance training and no training over 6 weeks.

$H_{0\ Xbox}$: $U_{pre} = U_{post}$

$H_{0\ Trad}$: $U_{pre} = U_{post}$

$H_{0\ control}$: $U_{pre} = U_{post}$

H_0 for interaction: The effect of treatment group is independent of the effect of time.

H_1 for interaction: The effect of treatment group is not independent of the effect of time.

DEFINITION OF TERMS

Balance (postural stability) – The ability to maintain upright posture while keeping the center of gravity within the base of support.

Center of Pressure – The point where the resultant of the vertical force components intersects the support surface (Zatsiosky, pg.46)

Postural sway – The deviation from the mean center of pressure of the foot (Verhagen et al., 2005).

Video Game – An electronic or computerized game designed for recreation played by manipulating images on a video display or television screen (Primack et al., 2012).

Virtual Reality – An artificial environment which is experienced through sensory stimuli (as sight and sound) provided by a computer and in which one's actions partially determine what happens in the environment (Merriam-Webster Dictionary)

Functional (Chronic) Ankle Instability – a condition in which one suffers from recurrent ankle sprains and/or a feeling of the ankle instability (Loudon et al. 2008).

LIMITATIONS AND DELIMITATIONS

This study was limited to a sample population of healthy individuals with no known balance deficit. Also the training period was limited to 6 weeks. Balance performance was also limited to measurement during a condition with eyes open and on non-compliant surface.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Virtual reality (VR) rehabilitation sounds like a term from a sci-fi movie. However, it is being used to help many patients with a variety of health issues. It is being applied for pain control in burn patients, motor learning for musculoskeletal dysfunction and even for patients with cognitive dysfunctions (Burdea, 2003; Hoffman, Patterson, & Carrougher, 2000). There is a wide array of VR devices used for rehabilitation. They range from engineered systems with modified computers with equipment such as gloves and robotic arms, to commercially available gaming systems such as the Wii™. The engineered systems used for many years are expensive and hard to come by (Burdea, 2003). Furthermore, the graphics, sound, and design are often simple and non-engaging when compared to video games (Halton, vol.9.6). These and other challenges have encouraged the use of commercially available video games as a medium for VR rehabilitation.

The usage of common household video gaming systems has been augmented by a shift in the development of these systems. For many years developers have focused on making their systems faster, and with superior graphics (Sung, 2011). However, with the release of the Nintendo Wii™, the focus shifted to increasing interaction with the user (Sung, 2011). The Nintendo Wii™ incorporates a hand held controller, Wiimote™, which uses an infrared camera and accelerometers to track position and movement (Sung, 2011). The Wiimote™ also interacts with the console via blue tooth technology (Sung, 2011). Soon after, Sony™ released the Playstation Move™, which is similar to the

Wiimote™ (Sung, 2011). The Move™ is compatible with the Playstation 3™ (PS3). In November of 2010 Microsoft™ released the Kinect™, which is used with the X Box 360™. It differs from the Wii™ and Playstation™ in that it does not require the user to hold a remote. It is equipped with two depth-sensing range cameras, a system of infrared structured light sources, a microphone, and a 30Hz RGB camera (Sung, 2011). This allows the Kinect™ to capture full-body movement (Sung, 2011). All three systems have potential as a rehabilitation tool, yet need further evidential support.

Video Games for VR Rehabilitation

There is growing interest in investigating the use of video games as a platform for VR rehabilitation. Anderson and colleagues (2010) modified a Wii™ console in order to record clinical measurements, be customizable, and to provide appropriate feedback. These modifications helped to ramify some of the disadvantages imposed by a commercially available gaming system. Their system, which they named Virtual Wiihab, used a Window-based computer with Nintendo™ Wii™ system and Virtools 4.1 software. Using this combination they were able to create activities with specific rehabilitative goals, such as balance and lower extremity control. They were also able to eliminate loading screens and time wasting animations. Another useful feature was being able to customize each activity to patient needs. Some variables they modified were: range of movement needed to complete task, frequency of stimuli, speed, size, and location of goal objects. Also, appropriate feedback could be adjusted by amount and timing (concurrent, terminal, and delayed). The Virtual Wiihab system offered varying levels of auditory, visual, and heptic feedback. The four Wiihab activities that Anderson

and colleagues designed were Snowball Fight, Mouse House, Startle Fish, and Alien Abduction. Snowball Fight consisted of the player swaying from side to side to dodge snowballs that were thrown by a virtual penguin. It could be played with two players where the second threw the snowballs. The researchers proposed that this activity will emphasize dynamic postural control and movement accuracy. The Mouse House activity consisted of a mouse controlled by the patient's shift in balance on the Wii™ Balance board. The object was to navigate through the house to find pieces of cheese. The multiplayer version consisted of two players competing to collect the cheese. This activity was suspected to work balance and movement precision. The Startle Fish activity required patients to stand as still as possible on the Wii™ Balance Board to avoid being eaten by a virtual shark. As more sway was created more attention was drawn, and if the set threshold was exceeded the shark would eat the virtual character. This activity could be played multiplayer with the challenge to outlast the opponent or compete to spear the most fish while maintaining balance. In Alien Abduction the patient controlled an alien spaceship and attempted to abduct farm animals. The patient navigated the ship over the object by shifting weight on the Wii™ Balance Board and then maintained the position while the object was "beamed" on board. If the patient was unable to remain steady the object would fall to the ground (Anderson et al., 2010).

The Virtual Wiihab system created by Anderson and colleagues may have great therapeutic advantages, however, to this author's knowledge; there is no data to support it at this time. Anderson et al. (2010) stated that the effectiveness and usefulness are currently being studied. When data are presented, and if the results are favorable, this

system may become commercially available and more common. Until such time it is more similar to the expensive, custom designed VR devices that are not easily obtained.

Levac et al. (2010) explored the types of movement produced while playing the Wii™. They looked at the quantity and quality of movement of children playing four different Nintendo™ Wii™ games. The quantity of movement was taking from center of pressure displacement. The quality of movement was defined as smoothness of pelvic movement abstracted from a sensor pack and an optoelectronic motion-capture system. The four games used in this study were tennis, and boxing from the Wii Sports™ game and soccer, and skiing from the Wii Fit™ game. They found a significant difference for quantity of movement between all three of the games included in this test. The tennis game was excluded by the authors to allow subjects to play the game as designed by the manufacture. The boxing game had the greatest movement followed by soccer then Skiing (boxing-soccer mean difference = 4.77, $p = 0.004$; soccer-skiing mean difference = 10.32, $p < 0.001$; boxing-skiing mean difference = 15.09, $p < 0.001$). Therefore, it appears that the Wii Sports™ Boxing game may have greater use where increasing center of pressure movement is desirable. This could be applied to areas such as improving balance. For quality of movement, only soccer and tennis showed a significant difference (mean difference of 0.196, $p<0.001$) with soccer having the least smooth motion and tennis having the smoothest motion. It was observed however, that the quality of movement for all the games had great variability between subjects and would require further exploration to identify appropriate clinical applications.

In Anderson et al (2010) and Levac et al (2010), the purpose of the study was not to investigate the video game's direct application as a rehabilitation tool. However, in a

recent systematic review, Primack, Carroll, & Nayak (2012) investigated the use of video games to improve health-related outcomes. They included only studies that were randomized clinical trials (RTCs) and that used gaming systems designed specifically for recreation. Their search was narrowed to 38 studies that were included in their review. This review included studies from 7 different categories; physical therapy setting (*n*=8), psychological therapy (*n*=7), disease self-management (*n*=4), health education (*n*=7), distraction from discomfort (*n*=5), physical activity (*n*=4), and clinician skills (*n*=3). Primack et al. (2012) concluded that there is great potential for video games to improve health-related outcomes especially in the areas of psychological therapy and physical therapy. Of the 8 studies in the area of physical therapy, 5 (62.5%) had positive findings for the primary outcomes investigated. The effect of two different video games compared to traditional exercises on balance was examined by Brumels, Blausius, Cortight, Oumedian, & Solberg (2008). In this study, subjects (*N* = 25) were tested on the Star Excursion Balance Test (SEBT) and on a force plate before and after a 4 week exercise program. The traditional exercise group (*n* = 7) performed exercises similar to what would be found clinically. They performed SEBT in eight directions, Dynadisc® balance with eyes open and with eyes closed, Dynadisc® ball toss, and DynaDisc® ORBITS. Each exercise was performed for 3 minutes for a total of 15 minutes. The two video game groups played games on either Dance Dance Revolution™ (DDR) or the Nintendo™ Wii Fit™. Both groups had total exercise time of 12 to 15 minutes. The DDR group (*n* = 7) performed a single leg stance while tapping the opposite foot on the arrow coinciding with the arrow presented on the screen during three songs. The Wii™ group (*n* = 6) played three different games using the Wii Fit™ Balance Board. Subjects

were required to stand with both feet on the board and use postural sway to control the game. A fourth group (n = 7) was used as a control and only performed the pre and post testing procedures. The traditional group showed significant improvement in the SEBT anteromedial (p = 0.004) and medial (p = 0.027) directions. The authors suspect this improvement was only seen in the traditional group because SEBT was used as part of the training. They also found a significant improvement in all 3 treatment groups from pre to post test. The DDR group had improved average deviation of center of pressure (COP) from the y centroid of the base of support (BOS) (p = 0.031) and improved average displacement in the y-axis (assumed to be A-P, although not explicitly stated) on the force plate (p = 0.027) (Brumels et al., 2008). The Wii Fit™ group showed improvement in the average deviation from the COP from the y centroid of the BOS (p = 0.043). The y-axis is assumed to be associated with the anterior-posterior plane; however, the authors did not specify its orientation in this study. Brummels et al. (2008) also found that the DDR group showed significant improvement over the traditional group for average displacement from the center of the force platform (p = 0.029). Furthermore, the DDR and Wii Fit™ showed significant improvement over the traditional group for average deviation of the COP from the y centroid of the BOS (p = 0.014 and p = 0.028) respectively. This means both the DDR and Wii Fit™ groups showed improvement in the anterior-posterior plane. Therefore these data give some support in the use of video games as a modality for balance exercise.

Benefits of VR Rehabilitation

VR rehabilitation offers many benefits to clinicians and patients. Most of the limited research has been conducted on VR systems specifically designed for therapy. However, there is growing research to support the use of video games as a VR rehabilitation tool. The following section reviews benefits of VR rehabilitation in general. Research specific to commercial gaming systems are included but it is not exclusive due to the scarcity of such research. Therefore, these benefits should be viewed as such, with the understanding that further clinical research is needed to determine the specific effects and benefits of each commercially available gaming system.

Pain Distraction

A potential benefit to using VR rehabilitation is pain distraction. It is thought that by immersing the patient in the virtual environment it will decrease the awareness or perception of pain (Wiederhold & Wiederhold, 2007; Hoffman et al., 2011). Studies of this effect date back to 1984 where Seyrek et al. (1984) examined the use of a video game to distract patients from a dental procedure (as cited in Wiederhold & Wiederhold, 2007). This study found that those who viewed a video-comedy and those who played the video game perceived less pain than those who listened to a comedy-audio (as cited in Wiederhold & Wiederhold, 2007). A systematic review was compiled to investigate VR intervention for pain distraction (Wiederhold & Wiederhold, 2007). They concluded that there is a correlation between the level of interaction and amount of reduction in perceived pain. The more immersive virtual reality is; the more likely it will be successful in reducing pain. Their review included 20 articles. Ten of the articles (50%)

specifically measured for pain and all ten found reduction in pain with VR. In one of these studies, the use of VR during physical therapy of burn patients was investigated (Hoffman, Patterson & Carrougher, 2000). They had twelve subjects with an average of 21 percent total body surface area burned (Hoffman et al., 2000). Subjects participated in three minutes of physical therapy without VR and three minutes with VR. The VR intervention was administered with Silicon Graphics Octane MXE, a VR helmet and a Polhemus Fastrak motion sensing system. Subjects viewed Spiderwold which is an interactive room with countertops, cabinets, a window and a virtual spider. Subjects were able to physically touch the virtual spider by touching a toy spider connected to a position tracker. The level of pain was measured with a visual analog scale (VAS) for five areas; time thinking about pain, worst pain, average pain, bothersomeness, and unpleasantness. All five variables were significantly less with VR intervention. The mean value for worst pain without VR was 42.00mm and with VR was 19.92mm ($p = 0.002$, SE = 5.49). The mean values for average pain without VR and with VR were 36.33mm and 14.67mm respectively (p value = 0.002, SE = 5.31). In another study, Hoffman et al. (2004) investigated the effect of VR on brain activity associated with pain. They measured activity in the anterior cingulated cortex, primary somatosensory cortex, secondary somatosensory cortex, insula and thalamus via fMRI on subjects receiving a painful stimulus with and without VR (Hoffman et al., 2004). They found that brain activity in all five areas had reduced when using VR (all p's < 0.002). This study provided objective data to support that VR may be an effective tool to reduce pain through reduced brain activity in areas associated with pain (Hoffman et al., 2004).

Increased Motivation

The effectiveness of rehabilitation may be less when patients are not motivated (Szturm, Betker, Moussavi, Desai, & Goodman, 2011). Therefore it is important for clinicians to find ways to keep patients engaged. Szturm et al. (2011) suggest there is a need for rehabilitation programs that promote motivation. Similar to pain distraction, VR has the potential to increase motivation (Burdea, 2003). It is suggested that the fun nature of VR will increase the patient's motivation to perform (Burdea, 2003). This hypothesis is difficult to test directly but has been addressed. Colombo, Pisano, & Minuco, (2007) suggest that participation in rehabilitation is usually directly correlated with the level of motivation. Hence, if a patient is highly motivated they will be more compliant with the rehab protocol. Middlemas, Basillicato, Prybicien, Savola, & Biodoglio, (2009) mentioned a case of a 19-year-old basketball player who had 100% compliance (8 out of 8 days) when implementing the Wii™ into rehabilitation. Before the Wii™ integration compliance was at 37.5% (6 out of 16 days) (Middlemas et al., 2009). It is important to note that video games may have an advantage over other VR devices in this area; as they were designed for entertainment, which may make them more engaging.

In the aforementioned study conducted by Brumels et al. (2008), secondary variables of engagement and perceived difficulty were evaluated using a post study questionnaire on a scale from 1 (not very) to 5 (very). The subjects were asked three questions; 1) How difficult was your program? 2) How engaged were you during your program? 3) How enjoyable was your program?. The average difficulty for the traditional exercise group was 3.17, for DDR group was 2.17 and the Wii Fit™ group

was 1.60. There was a significant difference between traditional exercises group and Wii fit™ ($p = 0.014$) with the traditional group being perceived as more difficult. Significance was approached between the traditional and DDR groups ($p = 0.073$) for perceived difficulty. Similarly with perceived enjoyment, both DDR and WiiFit™ exercises were significantly more enjoyable than traditional exercises ($p = 0.007$, and $p = 0.006$) respectively. There was no significant difference between all 3 groups for engagement but the traditional exercises had the lowest average score; giving way that it was perceived as slightly less engaging. Therefore, subjects found the video game based programs to be less difficult, more fun, and somewhat more engaging.

Increased Balance

One area of rehabilitation that has seen some use of virtual reality use is balance training. Balance training has become an intricate part of lower extremity exercise for both post-injury rehabilitation and injury prevention (Hubscher et al. 2010; McKeon & Hertel, 2008; Loudon, Santos, Franks, & Liu, 2008). Brummels et al. (2008) found balance improved more with DDR and WiiFit™ over traditional type exercises. Both groups showed significant improvement over traditional exercises with improved COP deviations (Brumels et al., 2008). In this study traditional exercises did show better improvement on the SEBT; however, it must be taken into account that SEBT was part of the exercises implemented for that group.

In another study performed by Brien and Sveistrup (2011), favorable results with a short duration, high intensity VR intervention on patients with cerebral palsy was found. They took 4 subjects (mean age = 16yrs, SD = 2.25yrs) that were classified as

level 1 in the Gross Motor Function Classification System (GMFCS). Level 1 classification are those with Cerebral Palsy who are able to successfully function but have some limitation as to difficulties walking on uneven surfaces and in crowded or confined spaces, and decreased balance and coordination (Brien and Sveistrup, 2011). The intervention in this study consisted of two 45 minute sessions a day of VR-based balance training for 5 consecutive days. The VR system used was the GestureTek's Interactive Rehabilitation and Exercise System software (IREX). IREX consist of 5 task oriented games which were Soccer, Snowboard, Sharkbait, Zebra Crossing, and Gravball. In each 45 minute session subjects completed 4 sets of all 5 games, with each game lasting 2 minutes. As subjects improved, the difficulty was increased. The authors did not mention if the change in the level of difficulty was intrinsic to the system or adjusted by the physical therapist. During the IREX game play, patients performed weight shifting, single leg stance, reaching away from center of gravity (COG), squats and jumps, side-lungs, side-steps, and gallops. Four variables were measured over the course of 3 periods (Baseline, Intervention period (IP) and Follow-up). Community Balance and Mobility Scale (CB&M), Six-Minutes Walk Test (6MWT), Timed Up and Down Stairs (TUDS), and Gross Motor Function Measure (GMFM) Dimension E were the variables measured. In both the CB&M and 6MWT, all participants showed statistically significant change during intervention phase and the follow up. In the TUDS, only one subject showed significant change in IP and follow-up periods. There was also only one subject who showed significant improvement in the GMFM Dimension E. The lack of significant change in this variable may be contributed to the high score of all subjects during the baseline period. All subjects scored an average above 90% on this test;

therefore it is possible that a ceiling effect occurred. These authors suggest that their findings of improved CB&M and 6MWT translated into improved coordination, timing, and speed of balance and walking.

Szturm et al. (2011) investigated the use of VR rehab for elder adults with balance deficits. The control group consisted of 13 subjects (mean age = 81yrs) who participated in a typical rehabilitative program (Szturm et al., 2011). This program consisted of strength exercises with Thera-band and leg weights, a cycle ergometer for endurance, and balance exercises such as hip flexion, side-leg raises, squats, and unassisted sit-to-stand from a chair. The experimental group consisted of 14 subjects (mean age = 80.5yrs) who participated in a dynamic balance exercise regimen delivered through computer games. The games were played by having the subject stand on a flexible pressure mat connected to a laptop. Both groups attended two 45 minute sessions a week for 8 weeks for a total of 16 sessions. The variables measured were Berg Balance Scale (BBS), Timed "Up & Go" Test (TUG), Spatial-temporal gait parameters assessed through using a GaitRite instrumented walkway, Activities-specific Balance Confidence Scale (ABC), and Loss of Balance (LOB) through the Clinical Test of Sensory Interaction and Balance (CTSIB). The VR group had greater improvements over the control group for BBS, LOB count, and ABC scores ($p<0.001$, $p<0.007$, and $p<0.02$) respectively. The results from the TUG test and GaitRite were not significantly different. These data showed that adding VR exercises improved balance over non-VR balance exercises but did not change gait performance.

Other Proposed Benefits

There are some potential benefits to VR rehabilitation that have no supporting empirical evidence at this time. Future research is needed to solidify these benefits. One such benefit is the ability to identify patients that purposefully do not try to progress (Burdea, 2003). This benefit is proposed by the ability of computer systems to collect large amounts of data (Burdea, 2003). In essence, as the patient is performing exercises the computer may be able to monitor the effort the patient is producing. This intrinsic ability would have to be programmed into the VR system and is not as likely to be found within commercial video gaming systems.

Disadvantages of VR Rehabilitation

Even though VR has shown great potential in the rehabilitation setting, there have been many obstacles. The biggest challenges have been cost and accessibility (Burdea, 2003). Equipment specifically designed for rehabilitation is very expensive. The cost to potential benefit did not encourage its use. Similarly, accessibility is limited due to the fact that some systems are custom designed, which requires advanced engineering skills. This has even been seen with the use of video game systems (Anderson et al., 2010). Although useful, it is not an available option for most clinicians.

Another challenge is the variety of options available to clinicians. This imposes a challenge as to choosing which system is best for their needs; as well as how to use such system once attained. One review was found which addressed this issue. In Galvin and Levac's (2011) review, they attempted to provide a descriptive analysis of VR systems with a framework of classification based on VR systems used in literature. This

classification and overview of different systems may benefit clinicians in choosing VR applications. Their review was limited to VR intervention on motor skills of children with neurological impairments (Galvin and Levac, 2011). From the 14 papers reviewed, they analyzed six different VR systems; DDR, Sony Eye Toy for Playstation 2™, Nintendo Wii™, GestureTek Interactive Rehabilitation Exercis™e system (IREX), Paediatric Intensive Therapy System™ (PITS) and a sensor glove system used with Playstation 3™. Two tables were constructed from their findings. The first was a descriptive analysis made up of specific features of each system. Some of these features were: Type of interaction, degrees of freedom (refers to ability to adjust difficulty, stimuli and duration), minimal motor requirements, and maximal motor challenge. The second table was a classification framework which organizes the systems by important features for clinicians. Each VR device was placed in a classification which matches its specific properties. The IREX/GX, PITS, PS3 glove all have the ability to manipulate therapeutic variables, whereas the DDR, Eyetoy, Wii/WiiFit do not. The same three games are also able to track therapeutic variables. Another category is the ability to target whole body, or isolate movement of upper extremities or lower extremities. The PITS and PS3 glove only isolate upper extremities, DDR only isolates lower extremities, and EyeToy, IREX/GX, and Wii/WiiFit can isolate all. The information from these tables gives clinicians a foundation for choosing one of these VR devices appropriate for their needs. However useful this may be, there are many other systems used in research and clinically not provided in this review. Other VR devices should be evaluated using the same system to create a broader spectrum of VR device classified by features.

Another obstacle for VR rehabilitation is clinician acceptance (Burdea, 2003). The limited research available that supports the use of VR rehabilitation covers many populations and a vast variety of devices. Research ranges from normal children to children with psychological disorders, geriatric patients, stroke patients, musculo-skeletal injuries and so forth. This creates an evidence environment with a vast variety yet shallow depth. None of the many areas of study have been evaluated extensively. Likewise, none of the many devices have been well validated (Parson, Rizzo, Rogers, & York, 2009). As more research is conducted in specific areas, clinicians will be able to make an informed decision regarding how and when VR is most effective in rehabilitation (Parson et al., 2009).

Effectiveness and Use of Balance Exercise

Balance training has become a widely used tool for injury rehabilitation. A systematic review was performed by McKeon and Hertel (2008) to investigate the effectiveness of balance training for ankle sprain injuries. They reviewed three areas: 1) Prophylactic balance training to prevent lateral ankle sprains, 2) Balance training to improve outcomes of acute lateral ankle sprains, and 3) Balance training to improve outcomes of chronic ankle instability (CAI). Preventative balance training was effective for decreasing risk of ankle injury especially in persons who had previous history of an ankle sprain. Similarly they found that those who had acutely sprained their ankle benefitted more from balance training by decreasing the risk of re-injury. However, it is mentioned that longer programs have greater preventive effects and there may be a cumulative effect for balance training.

In another systematic review it was found that balance, proprioceptive, and strengthening exercises were effective for decreasing symptoms of patients with functional ankle instability (FAI) (Loudon et al., 2008). There were 16 articles included in this study. Twelve of the studies measured balance and 10 (83%) of these studies had positive results for increased balance. Most interventions that were positive included different balance exercises.

A third systematic review explored the effectiveness of proprioception training/neuromuscular training in preventing sports related injuries (Hubscher et al. 2010). It was found that balance exercises and multi-intervention training both were effective at reducing risk of injury for sports with pivoting; i.e. basketball, volleyball, and soccer (Hubscher et al. 2010). From the reviewed studies, balance training was effective in reducing the risk of ankle sprains by 36%. Individual study results were similar to McKeon & Hertel (2008) in that balance exercises were more effective for those with past history of injury than those without (Hubscher et al. 2010). Multi-intervention training programs were found to be effective at reducing lower limb injuries by 39%, acute knee injuries by 54%, and ankle injuries by 50% (Hubscher et al. 2010). Although it was unclear as to which specific aspect of the multi-intervention contribute to the decrease in risk, balance training was part of the intervention. It was also suggested by Hubscher et al. (2010) that training should be warranted for at least 10 minutes once a week for at least 3 months. Although variability in study design prevents exact recommendations for treatment duration, this is similar to what was mentioned by McKeon & Hertel (2008). Balance treatment over long periods of time may have greater effect at preventing injury.

There have been several studies comparing the effect different exercises and techniques have on balance. Kidgell, Horvath, Jackson, & Seymour (2007) explored the effectiveness of two devices commonly used to implement balance training; dura disc and mini-trampoline. Patients identified with chronic ankle instability were trained for six weeks on either the dura disc or mini-trampoline. The mini-trampoline group improved total distance of medial-lateral COP by 32%, and the dura disc group improved by 25.6%. Both were statistically significant, where as the control group had no significant change. There was no significant difference between the two groups; therefore they were equally effective at improving balance. Han, Ricard, & Fellingham (2009) looked at using elastic tubing as a perturbation force to improve balance. They found a decrease in total travel distance of the COP with the use of the elastic band. Subjects who performed the elastic band exercises showed a decrease of 11.1cm where the control group only decreased by 0.5cm. Therefore, this data supports the use of elastic tubing as a perturbation force when performing balance exercises (Han et al., 2009). In another study, Michell, Ross, Blackburn, Hirth, & Guskiewicz (2006) compared the effect of using exercise sandals during balance training. Both groups with and without the sandals improved with no difference between the 2 groups. Michell et al. (2006) deduced that the improvement was seen due to the functional exercises that both groups performed.

Summary of Literature Review

VR is an exciting area of rehabilitation. With the new direction of video gaming systems, a less expensive, easily accessed source of VR is available to clinicians. VR has the potential to decrease perception of pain during rehabilitation as well as increase

compliance through engagement. Evidence to support its use is positive but limited. Balance improvement is one area that has become critical to rehabilitation. There is already some data to support the use of VR devices in balance rehabilitation.

CHAPTER 3

METHODOLOGY

The purpose of this study was to evaluate the use of an X Box 360 Kinect™ game as a modality for improving balance. Specifically, this study explored the use of the Target Kick (TK) mini game on Kinect Sports™ as a tool for VR rehabilitation

SUBJECT CHARACTERISTICS

A convenience sample of 18 subjects was taken from the UNLV undergraduate/graduate population. Subjects were excluded if they had a current lower extremity injury or a history of lower extremity surgery within the past 12 months. Also, subjects were required to be free from any circumstance that may disrupt normal balance such as ear infection, medications, neurological disorders, or visual disorder.

INSTRUMENTATION

Balance was assessed before and after a 6 week intervention period by measuring center of pressure (COP) on a Bertec balance platform (Model BP5050). The X Box 360™ with Kinect™ (Microsoft Co.) was used to play the TK mini game on Kinect Sports™ for one of the treatment groups.

COLLECTION OF DATA

Upon giving written consent, subjects were screened for exclusion criteria. Subjects were tested for balance on the non-dominate leg using the Bertec balance platform. Non-dominate leg was determined by asking; with which leg would you feel more comfortable kicking a soccer ball? Subjects were instructed to perform a single leg stance for 15 seconds on the Bertec balance platform (100Hz). Before data collection subjects were given three pre trials to familiarize themselves with testing procedure. Subjects were required to be barefoot during testing. They were also required to place hands on hips, and were asked to remain completely silent during data collection. Each testing session consisted of 5 acceptable trials. Trials were discarded if; hands were removed from hips, subject made a sound (such as talking, sneezing, or coughing), non-stance foot made contact with platform, or complete balance was lost. A 30 second rest period was given between each trial. The same procedure was followed after 6 weeks of intervention. In addition, game scores were recorded as a secondary outcome to investigate if there was a correlation between the game scores and balance.

INTERVENTION

Subjects were randomly placed into one of 3 groups by drawing from a hat. One group was a control group (CON) that only participated in balance testing on the Bertec. The control group was instructed to perform normal activity between testing periods. A second group was trained with the X Box 360 Kinect™ Target kick (TK) mini game 3 times a week for 6 weeks. A third group performed exercises that are used clinically for balance rehabilitation for the same duration.

X Box Group (XBOX)

During the first session subjects had 2 minutes to familiarize themselves with the X Box gesture controls. Then subjects were given a 3 minute warm-up on a stationary bike. In the Kinect Sports™ game, the mini game TK was selected. The object of this game was to score as many points as possible by kicking balls at targets while a simulated goal keeper tried to block them. Subjects were instructed to play the game as designed while balancing on their non-dominate leg. Subjects were required to play the game for a total of 10 minutes. The length of each TK game was determined by performance. As targets are hit, the game automatically added time. There was a 30 second rest period between each game. Since better performance increased the time of each game, a stopwatch was used to record total game time up to 10 minutes. When 10 minutes was reached subjects were instructed to stop playing, even if in the middle of a game, and the score at that point was recorded. During each session subjects were monitored for loss of balance. Loss of balance consisted of: 1) Touchdown of non-stance leg 2) Contact between stance leg and non-stance leg 3) Foot displacement of stance leg 4) Uncontrolled arm movement. When subjects were able to complete 2 games without any loss of balance they progressed to the next level of difficulty. The progression of difficulty was as follows: 1) Arms free to move, 2) Arms at 90˚ shoulder abduction, 3) Hands placed on hips, and 4) Foam Balance pad.

Traditional Exercise Group (TRAD)

Subjects started with the same 3 minute warm-up on a stationary bike. After this, subjects performed 2 exercises; Single leg ball toss and 4-way toe taps. Each exercise

consisted of five 1-minute repetitions with a 30 second rest between each repetition. This made the total exercise time 10 minutes. The Single leg ball toss was performed by having the subject stand on their non-dominate foot and tossing a soccer ball to the examiner 6-8ft (1.8-2.5 cm) away. The soccer ball used for this study was an official size 4 ball (Franklin Sports Inc.). The 4-way toe taps were performed by having the subject balance on the non-dominant leg while reaching with the opposite foot out in four positions. The subject was required to reach and tap the floor directly in front of them, to the lateral side, behind them, and to the opposite lateral side by crossing stance leg from behind. Subjects continued tapping in each position until the repetition time was complete. Subjects were monitored for loss of balance using the same criteria as the X Box group. When subjects were able to complete 1 repetition of each exercise without any loss of balance they progressed in difficulty. The progression of difficulty was as follows: 1) Arms free to move, 2) Arms at 90˚ shoulder abduction, 3) Increase intervals to 90 seconds, 4) Hands placed on hips, and 5) Foam Balance pad. The increased time was to mimic the longer intervals that were seen in the X Box group as they improved with the TK game. The repetitions changed to three 90 second repetitions and one 30 second repetition for both exercises. This gave the longer repetitions and preserved the total exercise time of 10 minutes.

DATA REDUCTION

The independent variables were treatment group (CON, XBOX, TRAD) and time (pretest, posttest). The dependent variables included total center of pressure excursion (TE) in the medial-lateral (M-L) plane and anterior-posterior (A-P) plane, and root mean

square of center of pressure velocity (RMS vel.) in the M-L and A-P planes. The COP data were extracted from the Bertec and exported to Microsoft Excel 2007. TE was calculated by finding the sum of the difference of each center of pressure point for the 15 seconds using the equations:

$\sum_{t=0}^{T}\left|COP_{x,t+1} - COP_{x,t}\right|$ for M-L excursion, and

$\sum_{t=0}^{T}\left|COP_{y,t+1} - COP_{y,t}\right|$ A-P excursion.

RMS Vel. was calculated using the following equation:

$\frac{\sum_{t=0}^{T}\left|COP_{x,t} - COP_{x,mean}\right|}{Time}$ for M-L excursion, and

$\frac{\sum_{t=0}^{T}\left|COP_{y,t} - COP_{y,mean}\right|}{Time}$ for A-P excursion.

The average values for each subject were used in subsequent statistical analyses to give an overall representation of balance across conditions.

STATISTICAL PROCEDURE

Statistical analysis was performed using SPSS v21 (IBM Corp). A 3 (treatment group) x 2 (time) mixed model analysis of variance (ANOVA) with post hoc Tukey follow-up tests and paired t-test as appropriate ($\alpha = 0.05$) was used to examine effects of treatment condition across time (balance group vs pre-post). Also, game score per minute for week 1 was compared to the pretest M-L and A-P TE to investigate if there was a correlation between the game scores and balance. Pearson's *r* was used to examine this relationship. The same process was used to compare week 6 scores to the posttest data.

CHAPTER 4

RESULTS

The purpose of this study was to evaluate the use of an X Box 360 Kinect™ game as a modality for improving balance. Specifically, this study explored the use of the Target Kick (TK) mini game on Kinect Sports™ as a tool for VR rehabilitation. This was achieved by measuring Total COP Excursion (TE) in the M-L and A-P directions as well as COP Root Mean Square velocity (RMS vel.) in the M-L and A-P planes before and after 18 balance training sessions.

Participants

A total of 18 participants completed this study. The demographics of the participants are given in Table 1. Three one-way ANOVAs by group were conducted for each demographic measure (age, height, mass). There were no significant differences between any groups (age $F_{(2,15)} = .304$ $p = .742$, height $F_{(2,15)} = 1.532$ $p = .248$, mass $F_{(2,15)} = 1.279$ $p = .307$) across parameters. Mean and standard deviation values for age, mass and height are presented in *Table 1*. Both the XBOX (n = 6) and TRAD (n = 6) groups consisted of 2 males and 4 females. The CON (n = 6) group had 3 males and 3 females.

Table 1. Participant demographic information (mean, standard deviation) for each group.

Group	Age (yrs)	Std. Deviation	Mass (Kg)	Std. Deviation	Height (cm)	Std. Deviation
Xbox	22.5	±2.88	70.17	±13.571	166.83	±6.306
Trad	23.7	±3.56	65.33	±13.852	166.00	±8.556
Con	23.7	±2.42	80.00	±16.745	172.50	±7.944

Total Excursion in M-L plane

Descriptive data for TE in the M-L are given in Table 2. There was a significant interaction for time x group ($F_{(2,15)} = 5.554$ $p = .016$). Paired t-tests identified a difference between TE in the M-L plane from pretest and posttest for the TRAD group ($t_{(5)} = 5.263$ $p = .003$) only. Therefore, the TRAD group improved from pretest to posttest and there were no time differences for the other two groups (*Figure 1*).

Table 2. Mean and Standard Deviation values (m) for Total Excursion in the M-L plane at pretest and posttest.

	Group	**Mean (m)**	**Std. Deviation**		**Group**	**Mean (m)**	**Std. Deviation**
TE M-L Pretest	XBOX	.41530	±.088190	**TE M-L Posttest**	XBOX	.42917	±.065588
	TRAD	.51853	±.097878		TRAD	.43183	±.098943
	CON	.47483	±.108036		CON	.43867	±.096218

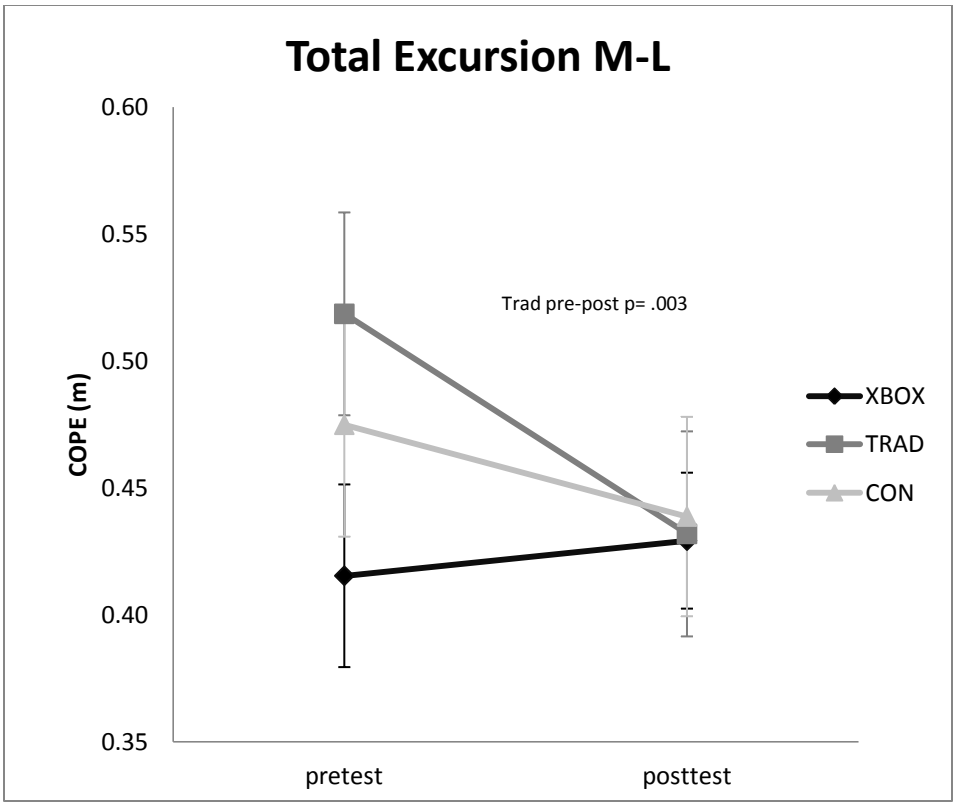

Figure 1. Total Excursion in the M-L plane (m) for XBOX, TRAD and CON group from pretest to posttest.

Total Excursion in A-P plane

Descriptive data for TE in the A-P plane are presented in Table 3. There was a significant time x group interaction ($F_{(2,15)}$ =5.565 p = .016). Paired t-tests for simple main effects showed a significant change from pretest to posttest for the TRAD ($t_{(5)}$ = 3.044 p= .029) and CON ($t_{(5)}$= 3.335 p = .021) groups but not the XBOX group (*Figure 2)*. This shows that both the TRAD and CON group improved from pretest to posttest.

Table 3. Mean and Standard Deviation values (m) for Total Excursion in the A-P plane at pretest and posttest.

	Group	Mean (m)	Std. Deviation		Group	Mean (m)	Std. Deviation
TE A-P Pretest	XBOX	.36610	±.057187	**TE A-P Posttest**	XBOX	.37533	±.041015
	TRAD	.44283	±.091068		TRAD	.37267	±.085245
	CON	.43783	±.090183		CON	.37400	±.082496

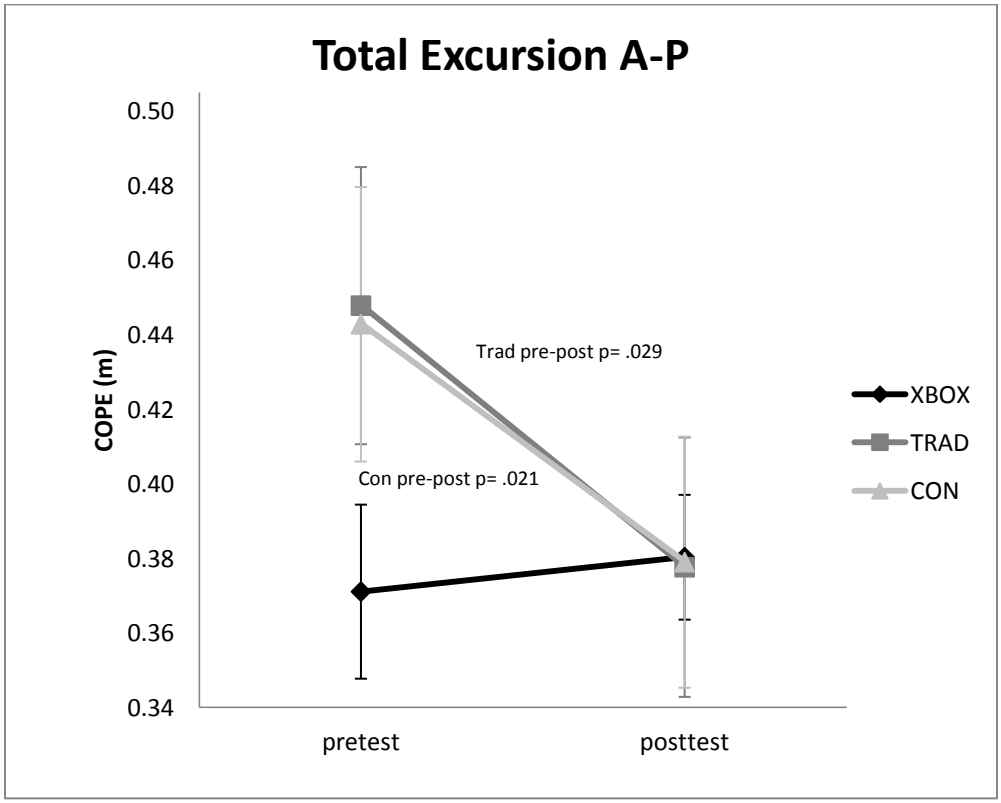

Figure 2. Total Excursion in the A-P plane (m) for XBOX, TRAD and CON group from pretest to posttest.

Root Mean Square Velocity M-L plane

Descriptive data for RMS vel. M-L are presented in Table 4. There was no significant interaction or main effects observed for RMS vel. M-L. Therefore no change was seen for this variable.

Table 4. Mean and Standard Deviation values (m/s) for Root Mean Square Velocity M-L at pretest and posttest.

	Group	Mean (m/s)	Std. Deviation		Group	Mean (m/s)	Std. Deviation
Vel. M-L Pretest	XBOX	.435	±.0335	**Vel. M-L Posttest**	XBOX	.430	±.0312
	TRAD	.496	±.1372		TRAD	.394	±.0575
	CON	.452	±.0916		CON	.448	±.0620

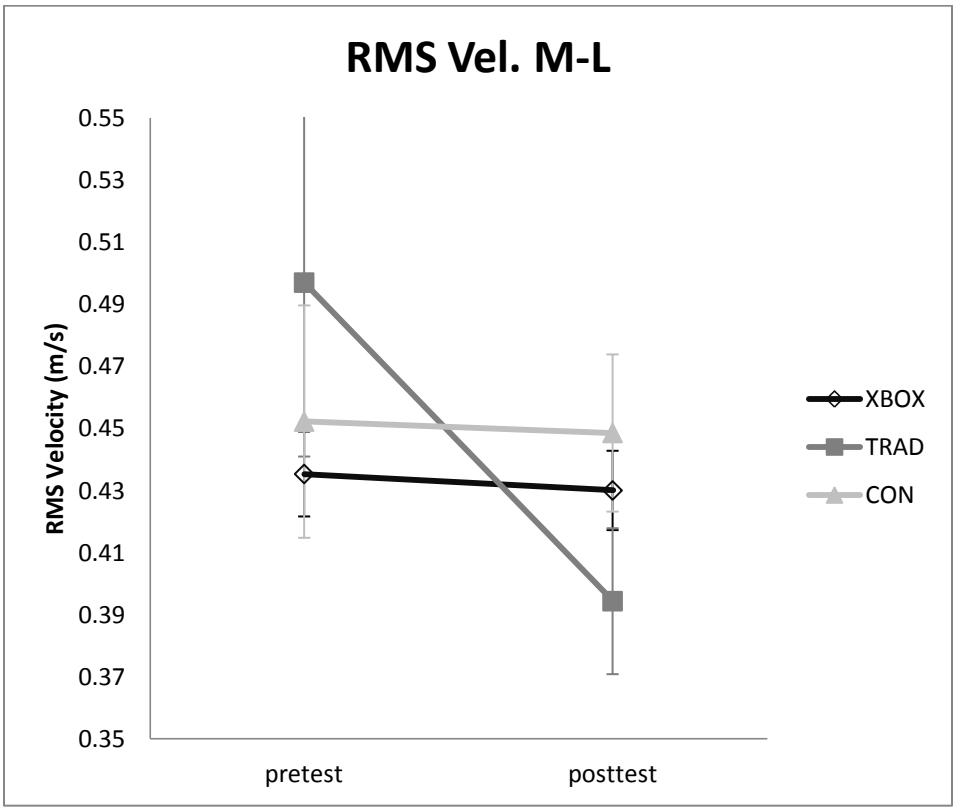

Figure 3. Root Mean Square Velocity in the M-L plane (m/s) for XBOX, TRAD and CON group from pretest to posttest.

Root Mean Square Velocity A-P plane

Descriptive data for RMS vel. in the A-P plane are given in Table 5. There was no significant time x group interaction or main effect of time. There was a significant group main effect ($F_{(2,15)} = 3.740$ $p = .048$). One way ANOVA with Tukey's *post hoc* tests for

simple main effect at posttest ($F_{(2,15)} = 5.340$ $p = .018$ *Figure 4*; Table 5) showed a significant difference between the XBOX and TRAD group ($p = .014$) with the TRAD group having better control. However, none of the groups exhibited a statistical difference from pretest to posttest.

Table 5. Mean and Standard Deviation values (m/s) for Root Mean Square Velocity in the A-P plane

	Group	**Mean (m/s)**	**Std. Deviation**
Vel. A-P	XBOX	.522	±.0435
	TRAD	.463	±.0963
	CON	.513	±.0719

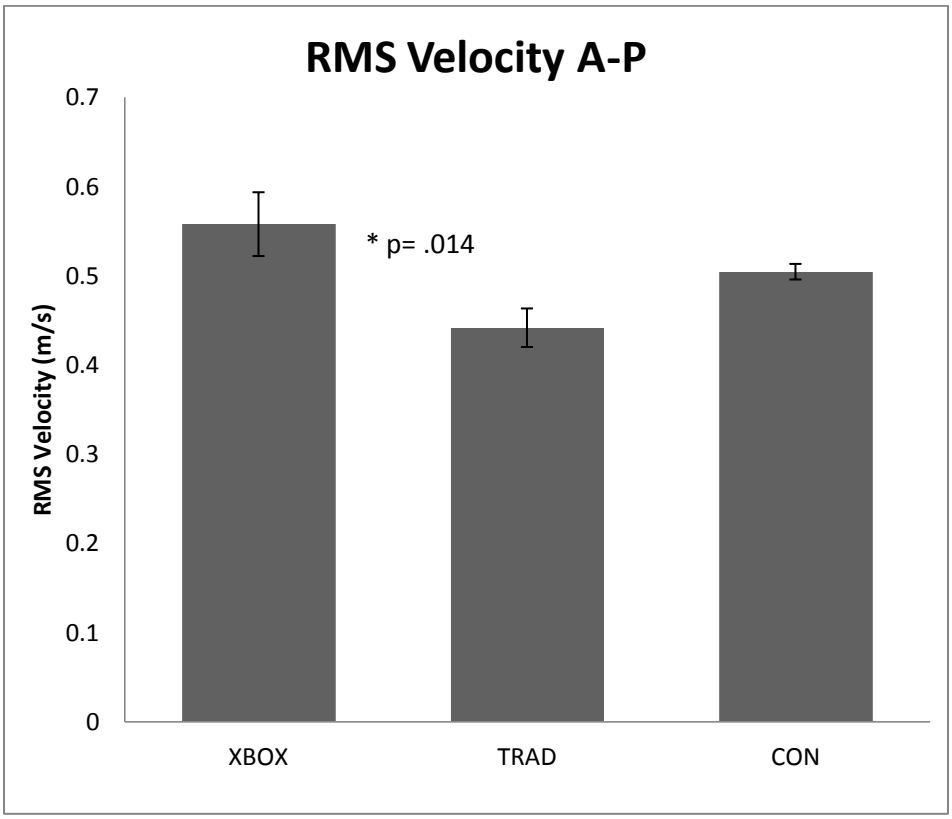

Figure 4. Root Mean Square Velocity in the A-P plane (m/s) for XBOX, TRAD and CON group

Correlations between Game Scores and TE

Game scores for each of the subjects in the XBOX group (n=6) were recorded each session as score/min (Table 6). The average of the first 3 sessions was compared to the pretest TE M-L and A-P. The average of the last 3 sessions was compared to the posttest TE M-L and A-P. Pearson product-moment coefficients were computed to determine any significant correlations. There were no significant correlations found between any of the variables (pretest TE M-L $r = .358$ $p = .486$, TE A-P $r = .785$ $p = .064$, posttest TE M-L $r = .305$ $p = .557$, TE A-P $r = .684$ $p = .134$; Table 6). This suggests that there is no correlation between game scores and balance.

Table 6. Average scores for First 3 sessions and Last 3 sessions with pretest and posttest Total COP Excursion in the M-L and A-P planes.

Sub #	First 3 Sessions (Targets/min)	Pretest TE M-L (m)	Pretest TE A-P (m)	Last 3 Sessions (Targets/min)	Posttest TE M-L (m)	Posttest TE A-P (m)
1	24.8	0.4328	0.513	37.2	0.484	0.484
4	29.8	0.456	0.521	41.7	0.441	0.441
5	24.5	0.378	0.441	34.6	0.402	0.402
7	24.1	0.418	0.559	35.2	0.434	0.434
9	23.3	0.462	0.548	33.8	0.42	0.42
13	26.5	0.465	0.55	31.0	0.399	0.399

CHAPTER 5

DISCUSSION

The purpose of this study was to evaluate the use of an X Box 360 Kinect™ game as a modality for improving balance by comparing it to traditional exercises used clinically. This study explored the use of the Target Kick (TK) mini game on Kinect Sports™ as a tool for VR rehabilitation. The results showed that the TRAD group had improved COP from pretest to posttest for both the TE M-L (p = .003) and TE A-P (p = .029). However, the interpretation of this improvement is diminished due to the fact that neither M-L nor A-P were significantly different from the XBOX or CON groups at posttest. Furthermore, these findings are diminished due to the CON group improving from pretest to posttest for TE A-P ($t_{(5)}$= 3.335 p = .021). Thus the change in COP TE A-P cannot be contributed to the treatment given. It is speculation that the changes seen were caused by variability from pretest to posttest and a possible learning effect. For both TE M-L and TE A-P there were greater differences in means between the 3 groups at pretest (*Figure 1* and *Figure 2*). For TE M-L the difference between TRAD and XBOX was .103 m, TRAD and CON was .044 m and, and between CON and XBOX was .060 m. For TE A-P the difference between TRAD and XBOX was .077 m, TRAD and CON was .005 and between CON and XBOX was .072 m. The differences between groups at posttest were much less for both variables (posttest TE M-L TRAD-XBOX = .003m, CON-TRAD = .007m, and CON-XBOX = .010 m; posttest TE A-P TRAD-XBOX = .003 m, CON-TRAD = .001 m and CON-XBOX = .001 m (*Figure 1* and *Figure*

2). It is possible that the subjects were better at the testing procedure at posttest, ie., they learned how to complete the test. For RMS vel. A-P there was a significant difference found between XBOX and TRAD at posttest (p= .014) but none of the groups had a statistically significant change from pretest to posttest. The velocity in the A-P plane of the TRAD group and CON group decreased, whereas the velocity for the XBOX group slightly increased from .522 m/s to .594 m/s from pretest to posttest. This explains how the means between the XBOX and TRAD groups at posttest showed a significant difference without either group having a significant change from pretest to posttest. Consequently, even though this study shows a trend toward the traditional exercises being effective; the results are inconclusive.

The design of this study was similar to that of Brumels and colleagues (2008). They compared four different groups. The groups were traditional training (n = 5), training with DDR (n = 7), training with Wii Fit (n = 6) and a control group (n = 7). They found that the traditional exercise group improved in the star excursion balance test (SEBT) and the DDR and Wii Fit group improved in COP parameters on the force plate. The SEBT was used as part of the training for the traditional group and therefore the authors suspect that the improvement that was seen may be due to this. Brumels et al. (2008) interpret their data to support the use of these games to improve balance. The results from the current study differ in that we only saw a decrease in COP for the TRAD group. This may suggest that the Wii Fit and DDR are better VR tools to improve balance. However, further investigation is warranted.

The lack of improvement in the XBOX group may be contributed to the lack of focus on balance. Subjective observations by the primary investigator (BW) note that

subjects in the XBOX group were more focused on hitting targets than holding the single leg stance (SLS). Before each session subjects were instructed to remain in a SLS throughout game play and no other instruction was given. This was consistent with the TRAD group. This caused more touchdowns by the non-stance leg and more erratic movements in the XBOX group per subjective observation. This observation suggests a need for patients to be monitored and given feedback by a clinician for proper technique or ensuring the source of VR has appropriate feedback incorporated into the system; such as the output on the Wii Fit balance board. Future studies investigating the X Box 360 Kinect should implement methods to give participants feedback on correct technique if appropriate feedback is not provided by the game used.

Another limitation was the design of the balance training. The subjects were permitted to play the TK game until the game time ran out. Game time varied upon targets hit. As players improved and were able to hit more targets, game length increased. The average time of the first session was 1.38 min and the average for the 18th session was 2.33 min (Table 16). Even though total play time was controlled at 10 minutes the length of each repetition may have affected the results. The repetitions of the TRAD group were controlled at 1 min and then increased to 1.5 minutes as part of the progression. This was done to mimic the change in TK game play; despite this effort the times for the XBOX group were much longer. Furthermore, this length of time is not similar to the testing procedure. COP data were collected for 15 sec. trials on the force plate. This study was designed to allow the participants to play normal lengths of time and these characteristics of game play on the X Box 360 Kinect have not been documented until now. However, future studies should explore a more controlled

method; possibly using a stopwatch and allowing participates to play for 30 sec. This would allow consistency across groups and reflect typical balance training repetitions.

There are several other confounding factors. The sample used in this study included healthy individuals without any known balance deficit. Therefore, these results cannot be assumed upon specific groups such as patients with chronic ankle instability (CAI). Similarly, it is not known if balance can be improved in healthy individuals (McKeon et al., 2008).

Another confounding factor is the use of COP variables for balance. TE is widely used in literature; however, it is unclear if there is a direct correlation between COP and balance (Palmieri, Ingersoll, Stone, & Kruase, 2002). Palmieri et al (2002) have suggested that even though it is accepted in literature that a large TE represents lesser balance control, it is possible to have a large TE with stable balance. A large TE could represent the postural control system's natural excursion to maintain balance (Palmeiri et al., 2002). Therefore, it is possible that improvement was not observed because the tested variables were unable to detect an improvement. Future studies should implement other testing procedures to detect improvements in balance.

This study only explored the use of the X Box Kinect as a tool for balance training. The Kinect's full body motion capturing system makes it an intriguing device. It is possible that the Kinect may have more benefit for other rehabilitative goals such as range of motion or fine motor skills. These areas have yet to be explored and research is needed.

CONCLUSION

The purpose of this study was to compare the mini game TK on the X Box 360 Kinect to traditional exercises. Although the results of this study do not support the use of the X Box Kinect to improve balance, this study provided information as to game play on this device. Playing the TK mini game on Kinect Sports should not be prescribed by only instructing the patient to perform a SLS. Further research with more stringent parameters on game play is needed to determine if the TK mini game can be used for balance training. Furthermore, studies exploring other possible uses of the Kinect's motion capturing system are needed to validate the Kinect as a rehabilitative modality.

APPENDIX 1

Individual Subject Data

Table 7. Individual Trials for each subject for Pretest Total Excursion (m) of COP in M-L plane.

Subject #	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Mean (SD)**
1	0.377	0.313	0.374	0.307	0.308	.336 (.036)
2	0.773	0.728	0.524	0.559	0.499	.617 (.125)
3	0.415	0.544	0.453	0.437	0.334	.437 (.075)
4	0.54	0.435	0.49	0.55	0.441	.491 (.054)
5	0.453	0.411	0.425	0.392	0.341	.404 (.042)
6	0.543	0.68	0.503	0.845	0.642	.643 (.134)
7	0.258	0.288	0.324	0.27	0.326	.293 (.031)
8	0.606	0.568	0.579	0.537	0.576	.573 (.025)
9	0.607	0.551	0.496	0.477	0.459	.518 (.061)
10	0.414	0.428	0.43	0.359	0.382	.403 (.031)
11	0.634	0.559	0.505	0.533	0.59	.564 (.050)
12	0.547	0.589	0.616	0.624	0.422	.560 (.083)
13	0.43	0.382	0.469	0.519	0.452	.450 (.050)
14	0.644	0.559	0.448	0.464	0.492	.521 (.081)
15	0.361	0.449	0.292	0.379	0.323	.361 (.060)
16	0.531	0.448	0.543	0.45	0.427	.480 (.053)
17	0.297	0.354	0.339	0.277	0.353	.324 (.035)
18	0.573	0.511	0.434	0.419	0.455	.478 (.063)

Table 8. Individual Trials for each subject for Pretest Total Excursion (m) of COP in A-P plane.

Subject #	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Mean (SD)**
1	0.443	0.355	0.333	0.307	0.325	.353 (.053)
2	0.73	0.623	0.508	0.517	0.438	.563 (.114)
3	0.483	0.518	0.454	0.407	0.372	.447 (.058)
4	0.497	0.43	0.424	0.526	0.39	.453 (.056)
5	0.385	0.372	0.292	0.345	0.272	.333 (.049)
6	0.462	0.517	0.417	0.629	0.495	.504 (.079)
7	0.249	0.262	0.331	0.246	0.338	.285 (.045)
8	0.57	0.472	0.511	0.449	0.495	.499 (.046)
9	0.483	0.401	0.367	0.317	0.327	.379 (.067)
10	0.366	0.39	0.39	0.321	0.338	.361 (.031)
11	0.595	0.411	0.423	0.418	0.427	.455 (.079)
12	0.472	0.407	0.395	0.353	0.356	.397 (.048)
13	0.396	0.392	0.449	0.413	0.321	.394 (.047)
14	0.685	0.55	0.349	0.42	0.54	.509 (.130)
15	0.352	0.314	0.284	0.279	0.251	.296 (.038)
16	0.556	0.458	0.446	0.475	0.449	.477 (.046)
17	0.315	0.33	0.27	0.242	0.3	.291 (.035)
18	0.486	0.498	0.456	0.509	0.474	.485 (.021)

Table 9. Individual Trials for each subject for Pretest Root Mean Square Velocity (m/s) of COP in M-L plane.

Subject #	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Mean (SD)**
1	0.519	0.555	0.424	0.263	0.403	.433 (.114)
2	0.502	1.743	0.551	0.414	0.528	.748 (.559)
3	0.575	0.482	0.473	0.415	0.74	.537 (.127)
4	0.42	0.4	0.572	0.528	0.36	.456 (.090)
5	0.406	0.392	0.434	0.291	0.365	.378 (.054)
6	0.339	0.467	0.442	0.519	0.384	.430 (.070)
7	0.436	0.443	0.426	0.379	0.408	.418 (.026)
8	0.401	0.449	0.415	0.319	0.319	.381 (.059)
9	0.52	0.473	0.336	0.592	0.389	.462 (.102)
10	0.431	0.402	0.322	0.275	0.33	.352 (.063)
11	0.552	0.48	0.514	0.57	0.394	.502 (.070)
12	0.407	0.472	0.426	0.383	0.374	.412 (.039)
13	0.447	0.385	0.506	0.486	0.502	.465 (.050)
14	0.622	0.532	0.45	0.695	0.497	.559 (.099)
15	0.383	0.46	0.306	0.42	0.44	.402 (.061)
16	0.539	0.447	0.524	0.323	0.456	.458 (.086)
17	0.248	0.55	0.34	0.262	0.387	.357 (.122)
18	0.512	0.629	0.573	0.553	0.52	.557 (.047)

Table 10. Individual Trials for each subject for Pretest Root Mean Square Velocity (m/s) of COP in A-P plane

Subject #	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Mean (SD)**
1	0.492	0.468	0.577	0.441	0.587	.513 (.066)
2	0.445	0.353	0.389	0.403	0.38	.394 (.034)
3	0.669	1.013	0.41	0.545	0.6	.647 (.225)
4	0.421	0.725	0.485	0.482	0.495	.522 (.117)
5	0.393	0.458	0.315	0.562	0.479	.441 (.093)
6	0.464	0.455	0.467	0.552	0.436	.475 (.045)
7	0.663	0.533	0.464	0.429	0.706	.559 (.121)
8	0.406	0.332	0.435	0.383	0.483	.408 (.056)
9	0.543	0.405	0.956	0.325	0.513	.548 (.244)
10	0.328	0.475	0.524	0.638	0.336	.460 (.131)
11	0.465	0.489	0.359	0.432	0.562	.461 (.075)
12	0.307	0.323	0.466	0.434	0.448	.396 (.075)
13	0.43	0.503	0.706	0.427	0.68	.549 (.135)
14	0.605	0.699	0.351	0.718	0.621	.599 (.147)
15	0.364	0.318	0.419	0.651	0.611	.473 (.150)
16	0.405	0.681	0.615	0.534	0.552	.557 (.103)
17	0.395	0.265	0.258	0.358	0.815	.418 (.230)
18	0.464	0.403	0.648	0.707	0.626	.570 (.130)

Table 11. Individual Trials for each subject for Posttest Total Excursion (m) of COP in M-L plane.

Subject #	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Mean (SD)**
1	0.378	0.337	0.376	0.536	0.513	.428 (.09)
2	0.538	0.562	0.501	0.471	0.562	.527 (.040)
3	0.309	0.333	0.312	0.317	0.373	.328 (.026)
4	0.475	0.484	0.438	0.46	0.433	.458 (.022)
5	0.457	0.484	0.497	0.448	0.506	.478 (.025)
6	0.442	0.517	0.543	0.524	0.73	.551 (.107)
7	0.346	0.33	0.282	0.392	0.397	.349 (.047)
8	0.498	0.567	0.512	0.507	0.513	.519 (.027)
9	0.491	0.464	0.601	0.475	0.508	.508 (.055)
10	0.364	0.441	0.433	0.424	0.416	.416 (.030)
11	0.386	0.423	0.461	0.379	0.393	.408 (.034)
12	0.413	0.514	0.553	0.508	0.528	.503 (.053)
13	0.437	0.35	0.277	0.31	0.398	.354 (.065)
14	0.497	0.52	0.538	0.585	0.52	.532 (.033)
15	0.315	0.319	0.331	0.246	0.314	.305 (.034)
16	0.513	0.465	0.437	0.465	0.434	.463 (.032)
17	0.308	0.318	0.284	0.332	0.275	.303 (.024)
18	0.506	0.406	0.383	0.416	0.382	.419 (.051)

Table 12. Individual Trials for each subject for Posttest Total Excursion (m) of COP in A-P plane.

Subject #	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Mean (SD)**
1	0.316	0.277	0.359	0.428	0.377	.351 (.058)
2	0.48	0.489	0.454	0.375	0.451	.450 (.045)
3	0.359	0.345	0.303	0.359	0.358	.345 (.024)
4	0.511	0.423	0.445	0.414	0.471	.453 (.039)
5	0.404	0.365	0.345	0.343	0.41	.373 (.032)
6	0.348	0.307	0.328	0.333	0.408	.345 (.038)
7	0.327	0.34	0.329	0.345	0.334	.335 (.007)
8	0.56	0.447	0.389	0.401	0.387	.437 (.073)
9	0.385	0.361	0.443	0.332	0.362	.377 (.042)
10	0.325	0.393	0.403	0.41	0.38	.382 (.034)
11	0.421	0.29	0.362	0.336	0.305	.343 (.052)
12	0.429	0.507	0.436	0.405	0.388	.433 (.046)
13	0.447	0.351	0.315	0.33	0.374	.363 (.052)
14	0.492	0.456	0.444	0.492	0.433	.463 (.027)
15	0.283	0.195	0.22	0.205	0.237	.228 (.035)
16	0.521	0.365	0.412	0.405	0.446	.430 (.059)
17	0.281	0.256	0.221	0.235	0.242	.247 (.023)
18	0.562	0.423	0.399	0.416	0.371	.434 (.074)

Table 13. Individual Trials for each subject for Posttest Root Mean Square Velocity (m/s) of COP in M-L plane

Subject #	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Mean (SD)**
1	0.387	0.385	0.674	0.508	0.465	.484 (.119)
2	0.507	0.491	0.52	0.414	0.539	.494 (.048)
3	0.251	0.402	0.319	0.287	0.343	.320 (.057)
4	0.434	0.409	0.495	0.38	0.485	.441 (.049)
5	0.448	0.367	0.393	0.386	0.415	.402 (.031)
6	0.499	0.46	0.4	0.487	0.464	.462 (.038)
7	0.381	0.418	0.374	0.584	0.412	.434 (.086)
8	0.443	0.387	0.351	0.371	0.317	.374 (.047)
9	0.445	0.379	0.461	0.388	0.429	.420 (.036)
10	0.391	0.563	0.402	0.489	0.404	.450 (.074)
11	0.314	0.325	0.411	0.427	0.424	.380 (.056)
12	0.293	0.518	0.397	0.369	0.345	.384 (.084)
13	0.488	0.34	0.399	0.303	0.464	.400 (.079)
14	0.441	0.525	0.572	0.658	0.353	.510 (.118)
15	0.384	0.309	0.407	0.315	0.654	.414 (.141)
16	0.454	0.333	0.484	0.44	0.666	.475 (.121)
17	0.328	0.37	0.314	0.36	0.271	.329 (.039)
18	0.515	0.478	0.405	0.548	0.379	.465 (.072)

Table 14. Individual Trials for each subject for Posttest Root Mean Square Velocity (m/s) of COP in A-P plane

Subject #	**Trial 1**	**Trail 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Mean (SD)**
1	0.473	0.413	0.408	0.52	0.886	.540 (.199)
2	0.495	0.6	0.37	0.477	0.379	.464 (.094)
3	0.412	0.791	0.354	0.378	0.485	.484 (.179)
4	1.01	0.519	0.545	0.469	0.747	.658 (.223)
5	0.492	0.518	0.485	0.573	0.414	.496 (.058)
6	0.406	0.37	0.37	0.464	0.402	.402 (.038)
7	0.444	0.552	1.244	0.972	0.868	.807 (.319)
8	0.414	0.369	0.36	0.297	0.257	.339 (.062)
9	0.447	0.338	0.543	0.61	0.698	.527 (.140)
10	0.373	0.436	0.446	0.422	0.564	.448 (.071)
11	0.532	0.341	0.464	0.348	0.387	.414 (.082)
12	0.435	0.442	0.37	0.375	0.337	.392 (.045)
13	0.372	0.403	0.488	0.543	0.86	.533 (.195)
14	0.472	0.436	0.643	0.736	0.498	.557 (.127)
15	0.392	0.317	0.728	0.311	0.382	.426 (.173)
16	0.469	0.775	1.044	0.496	1.236	.616 (.421)
17	0.271	0.269	0.337	0.469	0.614	.392 (.066)
18	0.589	0.713	0.553	0.503	0.435	.559 (.104)

Table 15. Average game scores (score/min) for each of the subjects in the X Box group for all 18 training sessions.

Sub #	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8	Session 9	Session 10	Session 11	Session 12	Session 13	Session 14	Session 15	Session 16	Session 17	Session 18
1	22.9	24.1	27.4	34.9	36.2	36.3	37.5	38.7	40.9	37.7	37	37.3	31.6	38.1	32.2	38.3	36.2	37.1
4	27.6	29.6	32.2	30.4	34.4	38.2	37.9	39.9	35	36.8	39.8	45.7	35.2	35.9	36.3	41.3	40.2	43.7
5	19.7	28	25.7	27.7	27.9	33.3	33.3	35.3	40.5	36.4	34.7	34	37.6	34.8	31	35.4	34.1	34.3
7	18.3	28.3	25.6	29.5	29.4	31	29.6	31.1	30.6	32.7	32.5	33.3	31.4	30.1	31.5	35.5	38.8	31.3
9	22	24.1	23.8	22.9	23.9	25.4	24	26.2	28.9	32.9	27.8	30.2	28.6	29.6	31.7	31.7	33.9	35.8
13	20.2	30.9	28.4	29.1	28.5	32	30.2	35.9	34.9	33.7	31.2	30.2	31.3	33.9	30.2	29.9	28.6	34.4

Table 16. Average game length (min) for each of the subjects in the X Box group for all 18 training sessions

Sub #	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8	Session 9	Session 10	Session 11	Session 12	Session 13	Session 14	Session 15	Session 16	Session 17	Session 18
1	1.43	1.43	1.67	2.5	2.5	2	2.5	2.5	2.5	2.5	2.5	2.5	2	2.5	2.5	2.5	2.5	2.5
4	1.67	2	2	2	2	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
5	1.25	1.67	1.67	1.67	1.67	2	2	2.5	2.5	2.5	2	2	2.5	2.5	2	2.5	2	2.5
7	1.25	1.67	1.67	2	2	2	2	2	2	2	2	2	2	2	2	2.5	2	2
9	1.25	1.43	1.43	1.43	1.43	1.67	1.43	1.67	2	2	1.67	2	1.67	2	2	2	2	2.5
13	1.43	1.67	1.67	2	1.67	2	2	2.5	2.5	2.5	2	2	2	2	2	1.67	1.67	2

APPENDIX 2

STATISTICAL SUMMARY

Total Excursion of COP in M-L plane

Descriptive Statistics

	group (IV)	Mean	Std. Deviation	N
Txpre	xbox	.41530	.088190	6
	trad	.51853	.097878	6
	con	.47483	.108036	6
	Total	.46956	.102144	18
Txpost	xbox	.42917	.065588	6
	trad	.43183	.098943	6
	con	.43867	.096218	6
	Total	.43322	.082972	18

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Powera
Time	Sphericity Assumed	.012	1	.012	8.699	.010	.367	8.699	.787
	Greenhouse-Geisser	.012	1.000	.012	8.699	.010	.367	8.699	.787
	Huynh-Feldt	.012	1.000	.012	8.699	.010	.367	8.699	.787
	Lower-bound	.012	1.000	.012	8.699	.010	.367	8.699	.787
time * group	Sphericity Assumed	.015	2	.008	5.554	.016	.425	11.107	.773
	Greenhouse-Geisser	.015	2.000	.008	5.554	.016	.425	11.107	.773
	Huynh-Feldt	.015	2.000	.008	5.554	.016	.425	11.107	.773
	Lower-bound	.015	2.000	.008	5.554	.016	.425	11.107	.773
Error(time)	Sphericity Assumed	.020	15	.001					
	Greenhouse-Geisser	.020	15.000	.001					
	Huynh-Feldt	.020	15.000	.001					
	Lower-bound	.020	15.000	.001					

Tests of Between-Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	7.335	1	7.335	455.772	.000
Group	.017	2	.009	.539	.594
Error	.241	15	.016		

Total Excursion of COP in A-P plane

Descriptive Statistics

	group (IV)	Mean	Std. Deviation	N
Typre	xbox	.36610	.057187	6
	trad	.44283	.091068	6
	con	.43783	.090183	6
Typost	xbox	.37533	.041015	6
	trad	.37267	.085245	6
	con	.37400	.082496	6
	Total	.37400	.068080	18

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Powera
Time	Sphericity Assumed	.016	1	.016	14.829	.002	.497	14.829	.949
	Greenhouse-Geisser	.016	1.000	.016	14.829	.002	.497	14.829	.949
	Huynh-Feldt	.016	1.000	.016	14.829	.002	.497	14.829	.949
	Lower-bound	.016	1.000	.016	14.829	.002	.497	14.829	.949
time * group	Sphericity Assumed	.012	2	.006	5.565	.016	.426	11.130	.773
	Greenhouse-Geisser	.012	2.000	.006	5.565	.016	.426	11.130	.773
	Huynh-Feldt	.012	2.000	.006	5.565	.016	.426	11.130	.773
	Lower-bound	.012	2.000	.006	5.565	.016	.426	11.130	.773
Error(time)	Sphericity Assumed	.016	15	.001					
	Greenhouse-Geisser	.016	15.000	.001					
	Huynh-Feldt	.016	15.000	.001					
	Lower-bound	.016	15.000	.001					

Tests of Between-Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Powera
Intercept	5.611	1	5.611	521.118	.000	.972	521.118	1.000
group	.010	2	.005	.486	.625	.061	.971	.115
Error	.162	15	.011					

Paired T-tests for Total Excursion of COP in both M-L and A-P planes

Paired Samples Statistics

group (IV)			Mean	N	Std. Deviation	Std. Error Mean
xbox	Pair 1	Txpre	.41530	6	.088190	.036003
		Txpost	.42917	6	.065588	.026776
	Pair 2	Typre	.36610	6	.057187	.023346
		Typost	.37533	6	.041015	.016744
trad	Pair 1	Txpre	.51853	6	.097878	.039958
		Txpost	.43183	6	.098943	.040393
	Pair 2	Typre	.44283	6	.091068	.037179
		Typost	.37267	6	.085245	.034801
con	Pair 1	Txpre	.47483	6	.108036	.044105
		Txpost	.43867	6	.096218	.039281
	Pair 2	Typre	.43783	6	.090183	.036817
		Typost	.37400	6	.082496	.033679

Paired Samples Test

			Paired Differences					t	df	Sig. (2-tailed)
						95% Confidence Interval of the Difference				
group (IV)			Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
xbox	Pair 1	Txpre - Txpost	-.013867	.072614	.029645	-.090071	.062337	-.468	5	.660
	Pair 2	Typre - Typost	-.009233	.030186	.012323	-.040912	.022445	-.749	5	.487
trad	Pair 1	Txpre - Txpost	.086700	.040352	.016474	.044353	.129047	5.263	5	.003
	Pair 2	Typre - Typost	.070167	.056472	.023055	.010903	.129430	3.044	5	.029
con	Pair 1	Txpre - Txpost	.036167	.035969	.014684	-.001580	.073914	2.463	5	.057
	Pair 2	Typre - Typost	.063833	.046885	.019141	.014631	.113036	3.335	5	.021

Root Mean Square of COP in M-L plane

Descriptive Statistics

	group (IV)	Mean	Std. Deviation	N
Vxpre	xbox	.43530	.033503	6
	trad	.49693	.137209	6
	con	.45217	.091672	6
	Total	.46147	.095158	18
Vxpost	xbox	.43000	.031299	6
	trad	.39433	.057570	6
	con	.44850	.062002	6
	Total	.42428	.054117	18

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Powera
Vx	Sphericity Assumed	.012	1	.012	3.881	.068	.206	3.881	.454
	Greenhouse-Geisser	.012	1.000	.012	3.881	.068	.206	3.881	.454
	Huynh-Feldt	.012	1.000	.012	3.881	.068	.206	3.881	.454
	Lower-bound	.012	1.000	.012	3.881	.068	.206	3.881	.454
Vx * group	Sphericity Assumed	.019	2	.010	3.002	.080	.286	6.004	.496
	Greenhouse-Geisser	.019	2.000	.010	3.002	.080	.286	6.004	.496
	Huynh-Feldt	.019	2.000	.010	3.002	.080	.286	6.004	.496
	Lower-bound	.019	2.000	.010	3.002	.080	.286	6.004	.496
Error(Vx)	Sphericity Assumed	.048	15	.003					
	Greenhouse-Geisser	.048	15.000	.003					
	Huynh-Feldt	.048	15.000	.003					
	Lower-bound	.048	15.000	.003					

Tests of Between-Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Powera
Intercept	7.061	1	7.061	788.371	.000	.981	788.371	1.000
group	.002	2	.001	.112	.894	.015	.225	.064
Error	.134	15	.009					

Root Mean Square of COP in A-P plane

Descriptive Statistics

	group (IV)	Mean	Std. Deviation	N
Vypre	xbox	.52200	.043525	6
	trad	.46323	.096314	6
	con	.51317	.071915	6
	Total	.49947	.074266	18
Vypost	xbox	.59350	.118485	6
	trad	.42000	.051552	6
	con	.49567	.093857	6
	Total	.50306	.113325	18

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Powera
Time	Sphericity Assumed	.000	1	.000	.037	.849	.002	.037	.054
	Greenhouse-Geisser	.000	1.000	.000	.037	.849	.002	.037	.054
	Huynh-Feldt	.000	1.000	.000	.037	.849	.002	.037	.054
	Lower-bound	.000	1.000	.000	.037	.849	.002	.037	.054
time * group	Sphericity Assumed	.022	2	.011	3.500	.057	.318	7.000	.562
	Greenhouse-Geisser	.022	2.000	.011	3.500	.057	.318	7.000	.562
	Huynh-Feldt	.022	2.000	.011	3.500	.057	.318	7.000	.562
	Lower-bound	.022	2.000	.011	3.500	.057	.318	7.000	.562
Error(time)	Sphericity Assumed	.047	15	.003					
	Greenhouse-Geisser	.047	15.000	.003					
	Huynh-Feldt	.047	15.000	.003					
	Lower-bound	.047	15.000	.003					

Tests of Between-Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Observed Powera
Intercept	9.045	1	9.045	#####	.000	1.000
Group	.081	2	.041	3.740	.048	.592
Error	.163	15	.011			

ANOVA

Vypre

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.012	2	.006	1.106	.356
Within Groups	.082	15	.005		
Total	.094	17			

Multiple Comparisons

Vypre
Tukey HSD

(I) group (IV)	(J) group (IV)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Xbox	trad	.058767	.042613	.376	-.05192	.16945
	con	.008833	.042613	.977	-.10185	.11952
Trad	xbox	-.058767	.042613	.376	-.16945	.05192
	con	-.049933	.042613	.487	-.16062	.06075
Con	xbox	-.008833	.042613	.977	-.11952	.10185
	trad	.049933	.042613	.487	-.06075	.16062

ANOVA

Vypost

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.091	2	.045	5.340	.018
Within Groups	.128	15	.009		
Total	.218	17			

Multiple Comparisons

Vypost
Tukey HSD

(I) group (IV)	(J) group (IV)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Xbox	trad	.173500	.053235	.014	.03522	.31178
	con	.097833	.053235	.191	-.04044	.23611
Trad	xbox	-.173500	.053235	.014	-.31178	-.03522
	con	-.075667	.053235	.355	-.21394	.06261
Con	xbox	-.097833	.053235	.191	-.23611	.04044
	trad	.075667	.053235	.355	-.06261	.21394

Correlation between pretest TE of COP in M-L plane to first 3 game scores and posttest TE of COP in M-L to last 3 game scores.

Correlations

		Txpre	(IV) 1st 3 game scores
Txpre	Pearson Correlation	1	.358
	Sig. (2-tailed)		.486
	N	6	6
(IV) 1st 3 game scores	Pearson Correlation	.358	1
	Sig. (2-tailed)	.486	
	N	6	6

Correlations

		Txpost	(IV) Last 3 game scores
Txpost	Pearson Correlation	1	.305
	Sig. (2-tailed)		.557
	N	6	6
(IV) Last 3 game scores	Pearson Correlation	.305	1
	Sig. (2-tailed)	.557	
	N	6	6

Correlation between pretest TE of COP in M-L plane to first 3 game scores and posttest TE of COP in M-L to last 3 game scores.

Correlations

		(IV) 1st 3 game scores	Typre
(IV) 1st 3 game scores	Pearson Correlation	1	.785
	Sig. (2-tailed)		.064
	N	6	6
Typre	Pearson Correlation	.785	1
	Sig. (2-tailed)	.064	
	N	6	6

Correlations

		Typost	(IV) Last 3 game scores
Typost	Pearson Correlation	1	.684
	Sig. (2-tailed)		.134
	N	6	6
(IV) Last 3 game scores	Pearson Correlation	.684	1
	Sig. (2-tailed)	.134	
	N	6	6

APPENDIX 2

IRB Approval

INFORMED CONSENT

Department of Kinesiology and Nutrition Sciences

TITLE OF STUDY: The Effect of Balance Training with an Innovative Approach Compared to Traditional Balance Exercises

INVESTIGATORS: B.C. Waite, B.S., J.S. Dufek, Ph.D.

CONTACT PHONE NUMBER: B.C. Waite, B.S., 702.862.0292; J.S. Dufek, Ph.D., 702.895.0702

Purpose of the Study

You are invited to participate in a research study. The purpose of this study is to evaluate the use of an innovative tool for improving balance by comparing it to traditional exercises used clinically.

Participants

You are being asked to participate in the study because you are an apparently healthy individual between the ages of 18-30 years. In addition, you do not have any current lower extremity injury and no history of lower extremity surgery within a year. Also you are free from any circumstance that may disrupt balance such as an ear infection, medications, neurological disorders, visual disorder etc. Finally, you are not a pregnant female.

Procedures

If you volunteer to participate in this study, you will be asked to arrive at the Sports Injury Research Center (SIRC 102) at which time we will measure and record your height, weight and age. Your balance will be assessed by having you perform a single leg stance on a balance platform with your non-dominant leg for 15 seconds several times. Following this baseline testing, you will begin the first balance training session. You will be asked to pedal on a stationary bike at a speed selected by you, for no less than three minutes to warm-up. Next, you will participate in 10 minutes of balance training. The training will consist of playing a soccer game on the X Box 360 which will require you to maintain balance while simulating kicking a soccer ball. You will be asked to return to the lab to participate in this same training 3 times per week for 6 weeks (Total sessions = 18). After the last training session you will be asked to report back to the SIRC 102 on a different day to repeat the balance assessment.

Benefits of Participation

There may be no direct benefits to you as a participant in this study. However, research has shown that balance training may increase balance and prevent injury. Also, the

information obtained from this study may provide insight to a new technique for improving balance.

Risks of Participation

There are risks involved in all research studies. This study includes only minimal risks. It is possible that you might experience delayed muscle soreness or discomfort as a result of your physical performance. This is a reversible outcome after rest. Every effort will be made to avoid soreness by asking you to warm up before the experiment and by providing adequate rest between conditions.

Cost /Compensation

There will be no financial cost to you to participate in this study. The study will take 12 - 15 minutes of your time for 19 days over a 6 week period. You will not be compensated for your time.

Contact Information

If you have any questions or concerns about the study, you may contact Brian Waite at 702.862.0292. For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted you may contact **the UNLV Office of Research Integrity – Human Subjects at 702-895-2794 or toll free at 877-895-2794 or via email at IRB@unlv.edu.**

Voluntary Participation

Your participation in this study is voluntary. You may refuse to participate in this study or in any part of this study. You may withdraw at any time without prejudice to your relations with the university. You are encouraged to ask questions about this study at the beginning or any time during the study.

Confidentiality

All information gathered in this study will be kept completely confidential. No reference will be made in written or oral materials that could link you to this study. All records will be stored in a locked facility at UNLV for 3 years after completion of the study. After the storage time the information gathered will be destroyed.

Participant Consent:

I have read the above information and agree to participate in this study. I am at least 18 years of age. A copy of this form has been given to me.

_____ _____

Signature of Participant Date

_____

Participant Name (Please Print)

Participant Note: Please do not sign this document if the Approval Stamp is missing or is expired.

INFORMED CONSENT

Department of Kinesiology and Nutrition Sciences

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Procedures

If you volunteer to participate in this study, you will be asked to arrive at the Sports Injury Research Center (SIRC 102) at which time we will measure and record your height, weight and age. Your balance will be assessed by having you perform a single leg stance on a balance platform with your non-dominant leg for 15 seconds several times. You will be asked to return to the SIRC 102 after 6 weeks for a follow-up test. At the follow- up test you will be asked to perform the same balance assessment. You will also be asked to continue normal activities between tests and avoid participation in any type of balance training.

Benefits of Participation

There may be no direct benefits to you as a participant in this study. However, research has shown that balance training may increase balance and prevent injury. Also, the information obtained from this study may provide insight to a new technique for improving balance.

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VITA

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Thesis Title: The Effect of Balance Training with an Innovative Approach Compared to Traditional Balance Exercises.

Thesis Examination Committee:
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Committee Member, Mr. Antonio Santo, Ph.D.
Committee Member, Dr. Richard Tandy, Ph.D.
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