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Effects of a Structured Exergaming Curriculum on Postural Balance in Older Adults

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Effects of a Structured Exergaming Curriculum on Postural Balance in Older Adults

by

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Abstract

Postural balance is a key component of mobility and functional independence, and it progressively declines in older adults. This randomised control trial (n=42) assigned participants aged 65 and over, in a six-week exergaming balance training (EBT) program using the Nintendo® Wii Fit U™ platform, a traditional balance training (CBT) program, and a control group in order to examine the effectiveness of these training programs in improving balance. The outcomes were measured at pre, post and three weeks follow up. The results suggested that dynamic balance improved in the EBT group as measured by Fullerton Advanced Balance Scale (Pre: 31.797 ± 1.556 SE, Post: 34.130 ± 1.315 SE, $p<0.05$) and Gait Speed (Pre: 0.865 m/s ± 0.040 SE, Post: 1.013 m/s ± 0.040, $p<0.05$). No significant changes were observed in self-reported measures of balance (Activities-specific Balance Confidence Scale and Tinetti Falls Efficacy Scale) and static balance as measured by center of pressure excursion in the intervention groups. These findings should guide future researchers and health professionals about Exergames selection, utility and application in balance rehabilitation programs.

Acknowledgements

The completion of this study is result of support and cooperation of several organizations and individuals. I would take this opportunity to recognize them for the role they played to turn this whole project into reality.

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Dedication

I dedicate this study to all the seniors, who give years of their youth to our society and nation and definitely deserve the best facilities and treatment in their golden years.

Table of Contents

List of Tables

List of Figures

List of Symbols and Abbreviations

ABC	Activities-specific Balance Confidence Scale
ADL	Activities of daily living
AP	Anterior-posterior
ANOVA	Analysis of Variance
APA	Anticipatory postural adjustments
AVG	Active video games
BMI	Body Mass Index
BOS	Base of support
CBT	Conventional balance training group
CHREB	Conjoint Health Research Ethics Board
COG	Center of gravity
COP	Center of pressure
CPA	Compensatory postural adjustments
CST	Chair Stand Test
EBT	Exergames balance training group
FAB	Fullerton Advanced Balance Scale
FES	Tinetti Falls Efficacy Scale
FFA	Fit for All
GEE	Generalized estimating equation
LOS	Limits of stability
ML	Medial-lateral
NT	No training group
PAR-Q+	The Physical Activity Readiness Questionnaire for Everyone
POMA	Tinetti Performance Oriented Mobility Assessment
SD	Standard deviation
SE	Standard error
SPSS	IBM® Statistical Package for the Social Sciences
STRL	Sports Technology Research Laboratory
TCPS	Tri-Council Policy Statement
TUG	Timed Up and Go Test
VE	Virtual Environment
VR	Virtual Reality
VRehab	Virtual Rehabilitation
Wii	Nintendo® Wii Fit U™ or Nintendo® Wii Fit Plus™

CHAPTER 1: INTRODUCTION

The senior population is the fastest growing age group in Canada. According to Statistics Canada by 2036, one out of four Canadians will be 65 years or older. This increase in number will undoubtedly add more pressure on our health care system in order to cater to their needs in terms of diseases and disabilities (Statistics Canada, 2014).

The factors that can influence postural balance include deficits in vision, joint proprioception, vestibular sensations, muscle strength, and postural reflexes (O'Sullivan, Schmitz, & Fulk, 2014). These disorders affect the functional independence and activities of daily living (ADL) in seniors. Falls are a highly reported incidence, and one-third of this age group reports one or more falls each year with the majority of the subjects reporting loss of balance to be the cause of their fall (Morris et al., 2004). Falls are the result of multiple factors that combine and decrease a person's ability to maintain or regain balance. Chronic conditions, acute illness, muscle weakness, cognitive impairment, vision disorder, previous history of falls and gait deviations are considered to be leading risk factors for the increased incidence of falls in the elderly (Kisner & Colby, 2007; Stinchcombe, Kuran, & Powell, 2014). Falls not only cause physical injury but also result in fear of falling which results in further avoidance of physical activity and increased risk of falls. These falls are avoidable by both addressing the risk factors and providing a well-designed exercise program (Guccione, Wong, and Avers, 2012).

Balance disorders are a serious concern for public health experts due to the high financial burden attached to the medical care of these individuals. The Public Health Agency of Canada (2nd report) stated that the direct cost associated with falls among the older adults is estimated around $2 billion annually (Stinchcombe et al., 2014). Balance disorders impact an individual's ability to perform ADLs and participation in leisure activities. (Weening-Dijksterhuis, de Greef, Scherder, Slaets, & van der Schans, 2011). The literature shows that older adults who regularly involve in physical activity have less chance of falling and sustaining fracture as compared to inactive individuals (Gregg, Pereira, & Caspersen, 2000). Exercise is always encouraged as a component of older adults' routine to maintain physical health, postural balance, and general wellbeing. The Canadian Society of Exercise Physiology has established guidelines for this age group, which calls for at least 150 minutes of moderate to vigorous intensity aerobic activity per week. Apart from formal involvement in sports or gym classes, activities like mall walking, taking the dog for a walk or just a walk around the block can be beneficial for general health and physical activity promotion (Canadian Physical Activity Guidelines, 1999). Research on physical activity suggests that most Canadians, including the elderly, are sedentary (Colley et al., 2011). A sedentary lifestyle, with decreased physical competence and increased load of disease, severely challenges postural balance in older adults (Todd & Skelton, 2004).

Therapeutic exercises like aerobics, strength training, flexibility exercises, and balance training were found to be the most effective interventions in older adults with balance issues. These exercises encourage overall mobility and target muscle strength, endurance and in some cases vestibular rehabilitation (Cadore, Rodríguez-Mañas, Sinclair, & Izquierdo, 2013). The affected individuals are treated by exercises, either by supervised training in clinics or home exercise programs. The traditional methods of exercise therapy seem useful but pose challenges, especially in terms of motivation, engagement, accessibility and adherence to an exercise program (Bethancourt, Rosenberg, Beatty, & Arterburn, 2014).

In the last decade, virtual reality has been identified as a possible tool for enhancing rehabilitation and researchers (Beaulieu, 2015; Clark & Kraemer, 2009; Soares, Amorim, Leite, Brizola, & Yonamine, 2018; Lund & Jessen, 2014) have found promising results. Yang defined exergames as "videogames that require physical exertion or movements that are more than sedentary activities and also include strength, balance, and flexibility activities" (Yang, 2010). Active video games (AVG) or exergames are video games that demand physical interaction with the player, targeting the movement of a specific body segment or the whole body. AVGs require active involvement and the performance of fundamental movement skills by the participants. They allow the participants to control the environment, provide a challenge and can be engaging. Exergames have been shown to improve performance and attitude of the older adults as part of rehabilitation programs for recovery from illness, strokes, social isolation, and to decrease fall risk (Chen, Jeng, Fung, Doong, & Chuang, 2009; Clark & Kraemer, 2009; Gamberini et al., 2008). Exergames are known to be intrinsically motivating and have the potential to improve physical literacy due to their blend of technology and physical activity (Sheehan & Katz, 2010).

This specific research project is part of a more extensive study which was aimed to explore the use of exergames in the elderly and how they affect their functional abilities, confidence, and motivation. The physical literacy model was adopted for the application of interventions to promote meaningful and enjoyable forms of physical activity. The study also explored the subjective experience of the participants using conventional vs. exergames based balance training.

Objective

The objective of this study was to determine if a structured curriculum of exergames in older adults would improve postural balance, confidence in balance and reduce the fear of falling when compared to conventional balance training programs and controls.

Research Question

This study was divided into three groups: 1. Balance training using structured Exergames (EBT), 2. Conventional balance training (CBT), and 3. Control group) and compared the change in postural balance in older adults. The effectiveness of the program (s) was investigated across the groups (EBT, CBT, and Controls).

The study investigated four research questions:

- What is the impact of a six-week structured exercise program on seniors' postural balance?
- Can Exergames be as effective as conventional physiotherapy exercises in improving functional balance and ambulation?
- Does regular participation in group exercise affect perceived confidence in balance as measured by The Activities-specific Balance Confidence (ABC) Scale?
- Do group exercise programs reduce the fear of falling in seniors as measured by Tinetti Falls Efficacy Scale (FES)?

CHAPTER 2: LITERATURE REVIEW

This chapter includes a review of literature in the field of Exergames or active video games (AVGs) for physical and cognitive rehabilitation. First, the core concepts around postural balance are discussed, followed by the impact of aging on balance. The next section includes the literature supporting different traditional interventions used with the elderly to improve postural balance. The conceptual framework around the application of virtual reality in healthcare under the term, Virtual Rehabilitation (VRehab) is presented in the next section. The current evidence for the use of virtual reality-based interventions is discussed in detail in this chapter.

(a) Postural Balance; Background

This section explains the basic concept and definition of terminologies related to postural balance. Balance is a state of an object where it maintains its position in response to different forces acting on it. Mechanically, the concept of balance is associated with the center of gravity (COG) and the base of support (BOS). BOS is the area of contact between the body and support surface, i.e., the area between two feet in a standing position (Saeedkondori, 2016). An object attains this balance if the line of gravity falls within BOS (Figure 1). If the line of gravity displaces outside of BOS, it will lose the state of balance and will be displaced or even fall. COG is the point where the weight of an object is concentrated. The line of gravity is a vertical line that passes through COG and directs toward the center of the earth. When the human body assumes the anatomical position, the COG is estimated to be located anterior to the body of the second sacral vertebrae, and the body is stable as long as the line of gravity is passing through the BOS (Trew & Everett, 2005). The human body is a dynamic unit; hence the COG can vary its position based on different postures or the position of limbs during different activities. Center of Pressure (COP) is the ground reaction force in response to a body's weight, and it usually falls within BOS in the standing position. Limits of stability (LOS) is the area which requires intrinsic adjustments to maintain COG within BOS avoiding the loss of balance (Saeedkondori, Christopher, Shahian, & Ary, 2016).

Figure 1. BOS and stability limits in the standing position

If the line of gravity displaces out of BOS, the body tends to lose balance and uses a mechanism or strategy to maintain or restore the balance (Guccione, Wong and Avers, 2012). In clinical settings, different terms are used for balance including stability, postural control, postural balance, and equilibrium. Figure 2 gives a visual representation of the line of gravity with reference to different body segments in standing position.

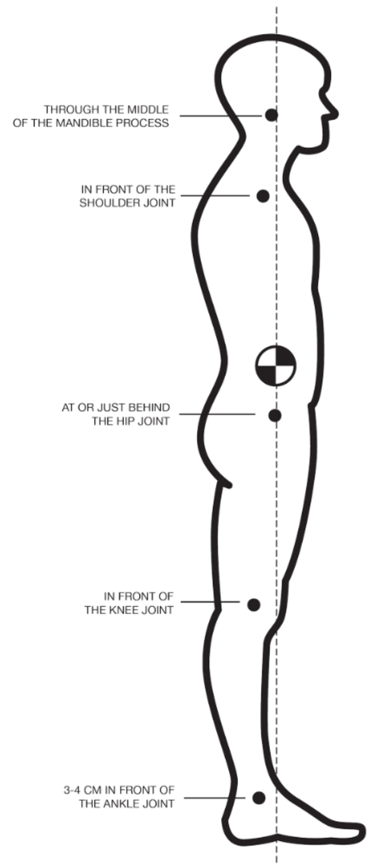

Figure 2**.** Line of Gravity projected through COG in the standing position

Balance is the ability of the human body to use its sensory and motor systems in different postures and mobility to effectively respond to environmental demands. Human balance is defined as "A multidimensional concept, referring to the ability of a person not to fall" (Pollock, Durward, & Rowe, 1999, p. 405). It is a complex interplay of multiple body systems including nervous, musculoskeletal, visual, somatosensory, and vestibular. These systems are influenced by contextual effects including environment, support surface, lighting, gravity and task characteristics (Kisner & Colby, 2007).

The maintenance of balance is the result of anticipatory and compensatory postural adjustments. Anticipatory postural adjustments (APAs) are the response of the body toward predicted perturbations while compensatory postural adjustments (CPAs) are the reactions of the body to adjust toward unpredicted perturbations. Humans start developing these adjustments from birth and use them for assuming different positions, posture and locomotion. These adjustments are programmed synergies used by the body to control balance and posture. The task-dependent postural adjustments keep developing with age and refine as a child grows (Girolami, Shiratori, & Aruin, 2010).

(b) Impact of Aging on Postural Balance

This section evaluates, how the aging affects multiple body systems that control postural balance and control. From a physiological point of view, input from visual, vestibular and somatosensory systems and coordination among them influence the human postural balance (Jacobson & Shepard, 2016). Balance disorders are prevalent in older adults and impact their ability to perform activities of daily living (ADL) and participation in leisure activities (Weening-Dijksterhuis, de Greef, Scherder, Slaets, & van der Schans, 2011).

When discussing the importance of different systems synchronizing the body's balance, vvestibular system plays the vital role. It is a central system that helps the body adjustment based on changes in position in space and works closely with the visual and somatosensory system. The role of vestibular and visual systems in balance has been explored over several decades of research and based on this, elderly individuals use these sensory systems more than younger people. Manchester, Woollacott, Zederbauer-Hylton, & Marin (1989) completed a study to understand the balance control between young and older adults, when experiencing a dynamic platform and to keep the visual and somatosensory input minimized. Their results showed that the elderly rely on these systems and there was a significant decrease in stability when only foveal vision was available (peripheral vision blocked by goggles), and with ankle proprioception blocked. The study also found that elderly individuals who were physically active showed muscle activation patterns similar to younger adults . Sundermeir (1996) and colleagues compared the postural response in elderly with impaired balance, and elderly who were asymptomatic and healthy young adults. The researchers calculated the COP displacement and horizontal shear forces over a force plate in the presence of moving visual surround. The results showed that elderly with balance issues rely more on visual inputs and use hip strategy more than the younger participants to maintain their balance (Sundermier, Woollacott, Jensen, & Moore, 1996). Thus it would appear that variations in the body's postural control system initiate altered responses to environmental demands.

These age-related changes in balance and cognition modify the functional activities such as gait speed and pattern. The longitudinal study conducted by Atkinson and colleagues (2007) involved 2349 community living seniors in which the gait speed, global cognitive function, and executive control function were tracked for three years. The study found an incremental decline in gait speed and cognition function. The participants also reported an increased incidence of falls and hospitalization with increasing age. Another longitudinal study completed in Australia attributed the changes in gait variables (speed, cadence, step length, and width) with age due to brain tissue atrophy (Callisaya et al., 2013). The study also suggested that any lifestyle modifications including exercises can limit the brain atrophy and in turn maintain the mobility in terms of ambulation. Hausdorff suggested that other than the gait speed, stride to stride variability can help to identify the elderly at risk of falls (Hausdorff, 2007).

The previous research indicates that one of the primary indications of a decline in balance with aging is increased sway in the stance phase. Laughton et al., 2003, explored the relationship between sway and muscle activity in the elderly (fallers, non-fallers) and young adults. The study measured the balance scale on Tinetti Performance Oriented Balance and Mobility Assessment (POMA), COP calculation on the force plate and electromyography studies of four major muscle groups in lower limbs. The results showed significant anteroposterior sway in elderly fallers compared to young participants. The elderly subjects who scored lower in POMA also showed increased mediolateral sway compared to the elderly who scored better in the same test. The study concluded that an increase in postural sway and altered muscle activation patterns are evident with increasing age (Laughton et al., 2003).

Age-related changes affecting these physiological systems can progressively decrease the efficiency of the postural control system making them vulnerable to falls and impaired mobility (O'Sullivan et al., 2014). Mostly, aging affects the physical systems, but external or environmental factors also influence postural balance. There is strong evidence suggesting the importance of regular physical activity in primary and secondary prevention of chronic diseases and reduced risk and incidence of falls in seniors (Warburton, Nicol, & Bredin, 2006).

(c) Traditional Balance Rehabilitation

The traditional training for balance rehabilitation advocates a multisystem and multifactorial approach to design the rehabilitation programs. It combines different forms of exercises to enhance muscle strength, flexibility, endurance, balance in functional activities and fall recovery exercises (Chang et al., 2004). Some of the other recommended forms of exercise for balance improvement include Tai Chi, yoga, walking program, circuit training and obstacle course (Sherrington et al., 2008; Kisner & Colby, 2007). To identify the effects of different exercises on balance in elderly individuals a systematic review was completed and found that the strengthening exercises, 3D exercises (Tai Chi, qi gong, dance, yoga) and multiple exercise programs have a significant impact on postural balance. This study also indicated that different exercises address different components of balance, therefore a balance rehabilitation program should include different types to maximize the efficiency of the balance training (Te et al., 2012). Means and colleagues (2005) conducted a randomized case-control study to analyze the effects of a multiple exercise program to see its effect on balance on community-dwelling older adults. The participants attended a six weeks supervised group exercise program which included walking, stretching, strengthening and balance exercises. There were three sessions each week, each session lasting for 90 minutes including warm up and cool down. The results showed significant improvement in functional abilities and decreased in the incidence of falls in the following six months when compared to controls (Means, Rodell, & O'Sullivan, 2005).

Other interventions including whole body vibration exercises have found to be beneficial in improving balance and mobility. A study in China involving frail elderly patients exposed to whole body vibration exercises for eight weeks (3-5 times/week) showed significant improvement in both objective and subjective outcomes, knee extensors strength and balance in confidence when compared to controlled intervention group which received regular care and physiotherapy (Zhang et al., 2014).

A systematic review of exercise programs for fall prevention showed that exercise programs are an essential component of such programs in the elderly population. The review studies included suggested that the programs involving multiple interventions (patient education, reducing hazards in living place, dietary changes and exercises like Tai Chi and dance along with traditional exercises) were more effective in reducing falls as compared to programs using exercises exclusively (Gardner, Robertson, & Campbell, 2000). The addition of cognitive and motor tasks during walking is also found to be effective with balance exercises. Older adults with osteoporosis and fear of falling attending a 12 weeks program, involving balance training and walking superimposed with dual/multi-tasking have shown improved walking speed and fall-related self-efficacy in comparison to a control group (Halvarsson, Franzén, & Ståhle, 2015). Several research studies demonstrate that carefully designed exercise programs can improve balance in older adults and subsequently a reduction in the number of falls. (Cadore, Rodríguez-Mañas, Sinclair, & Izquierdo, 2013; Kalron et al., 2017; Sturnieks, St George, & Lord, 2008; Osugi, Iwamoto, Yamazaki, & Takakuwa, 2014). The World Health Organization's report on fall prevention recommended some additional interventions for community living older adults; including gait training and appropriate use of assistive devices, review, and modification of medications, appropriate treatment of medical conditions and modification of environmental hazards. An effective approach to address balance issues in the elderly would be a combination of exercises, education, addressing risk factors and environmental modifications (Todd & Skelton, 2004).

The challenges with the traditional exercise programs are compliance, engagement, delivery model and monitoring (Bethancourt et al., 2014). Compliance is variable as most of these programs are organized in community settings and lack of travel arrangements and harsh weather conditions can limit the participation. For home based exercise programs, monitoring the participants' compliance is not possible other than self-reporting. Community based programs also need the resources like space and instructors to conduct these programs. These programs also lack of variability and unsuitable intensity of exercise techniques and after a while become monotonous and boring and participants do not find them challenging enough. Other factors that should be considered when designing these exercise programs for the older adults are the associated cost, appropriate program for age and ability, challenge and engagement, trained instructors and flexible schedule (Arterburn, 2014; Gardner et al., 2000).

(d) Exergames and Virtual Reality; a Rehabilitation Tool

Exergames or AVG are popular terms used when video games are used in the healthcare domain. Most of these games provide real-time feedback and create a virtual environment in which to interact. Virtual reality has the advantage of being more immersive and engaging when compared with traditional activities (Proffitt, Lange, Chen, & Winstein, 2015). There are several commercially available hardware units used for exergames; the most common being Nintendo® Wii®, and Microsoft® X box and Play Station® Eye Toy. No adverse effects have been reported in these studies, indicating they are relatively safe, however more evidence is required to further establish their overall safety for different age groups (Morris et al., 2004; Skjæret et al., 2015).

In the last fifteen years, Exergames or Active video games have been extensively researched in the elderly population. Multiple studies reported improved functional balance, decrease fall risk, gait speed and improved muscle strength after undergoing exergames based balance training programs (Agmon, Perry, Phelan, Demiris, & Nguyen, 2011; R. Clark & Kraemer, 2009; Kim, Son, Ko, & Yoon, 2013).

Apart from healthy populations, virtual reality and AVGs have been tested in different health conditions such as stroke, shoulder pain, traumatic brain injury, Parkinson disease, heart failure, and Multiple sclerosis (Barry, Galna, & Rochester, 2014; Klompstra, Jaarsma, & Stromberg, 2014; Laver, George, Thomas, Deutsch, & Crotty, 2012; Staiano, Abraham, & Calvert, 2013; Sveistrup et al., 2003).

(e) Exergames; Physiological Effects

A practical application of Exergames is its use as a tool to enhance physical activity. A meta-analysis was completed by Peng, Lin, and Course (2011) to explore the physiological effects of exergames play in different age groups. The findings suggested that Exergames increase heart rate, oxygen consumption, and energy expenditure. The overall effects are similar to light to moderate intensity physical activity and can be used for improving aerobic fitness. Majority of the studies included in the meta-analysis investigated effects of exergaming in children, therefore caution should be taken when generalizing results to adult populations.

Similar results were found in other studies that categorized Exergames as light to moderate intensity physical activity and recommended it to induce physical activity in adult sedentary population (Graves et al., 2010; Griffin, Shawis, Impson, Shanks, & Taylor, 2013). Although the energy expenditure is low as compared to traditional sporting activities, the effects can be used in selected adult populations which are sedentary. These findings support the idea of classifying Exergames as a form of physical activity of light to moderate intensity.

(f) Balance Rehabilitation with Exergames

This section explains the use of exergaming specific for balance rehabilitation in seniors. Beaulieu (2015) evaluated the effects of commercially available Exergames for balance training. This pilot study was a multiple case series and included three participants who went under a ten-week supervised balance training using Microsoft® X box Kinect. The outcomes were improved balance, lower limb strength, and patient satisfaction pre and post-intervention. The researchers concluded that Exergames were an effective balance rehabilitation tool. Since the study was conducted in a supervised hospital setting, concerns were expressed for safety protocol when using Exergames in unsupervised situations. The findings cannot be generalized due to the small sample size and other confounding variables like sex (all female participants).

Exergames were also found to produce significant improvement in balance in community-living older adults who participated in supervised balance training programs. These quasi-experimental studies had several limitations including non-randomisation of subjects, absence of control group and lack of defined inclusion and exclusion criteria and selection bias (Afridi, Malik, Ali, & Amjad, 2016; Lund & Jessen, 2014; Roopchand-Martin, McLean, Gordon, & Nelson, 2015). These findings are supported by a recent systematic review completed by evaluating Exergames in older adults. Exergames are found to be effective in improving physical function like balance and gait. The 47 included studies in adults over 65 years measured physical function pre and post-intervention Skjæret et al., 2015 stated that there was a limited evidence regarding the use of exergaming- based programs specific to older adults with complex medical conditions as most of the studies involved healthy populations and were based in community-dwelling individuals.

Other studies have also investigated the physical and cognitive impact of digital video games in seniors. Zhang & Kaufman, (2015) reported significant improvement in postural balance, balance confidence and functional mobility in both independent living and nursing home residents with the use of active video games. This research suggests that most of the games are learned effectively by almost all older adults

Generally, these studies use commercial Exergames as an intervention. The commercial Exergames and consoles have an advantage in terms of easy access and affordability but also have limitations of game design and languages available. Some researchers developed and tested customized games for the elderly. The results showed significant improvement in balance and gait outcomes and found these games to be an immersive and effective form of balance training. These studies also call for specially designed Exergames for older adults that addresses their concerns and respects their limitations (Whyatt, Merriman, Young, Newell, & Craig, 2015; Wüest et al., 2014; Yen et al., 2019).

The researchers in Greece developed a balance training platform, specific to the elderly population and evaluated adherence and quality of life (Konstantinidis et al., 2016). The platform used commercial hardware Wii® with customized exergames which provided feedback to players and adjusted exercise intensity and difficulty level. This case-control study with n=232 involved the two months training program with a frequency of three days a week, and each session was 60 minutes long. The controls were given cognitive training for the same duration. The study reported a high level of usability, adherence level and significant improvement in most components of physical function like balance, strength, and endurance. The study had some promising results, but since it is a commercial product, third-party testing in different populations should be done to further investigate the validity.

Nawaz et al., conducted a qualitative study that focused on the challenges of an elderly population when developing and testing user-centered games (2015).The researcher suggested: the use of a simple interface to lessen distraction, be more flexibility in difficulty levels for progression and use of appropriate music. Another study on balance training in older adults with Nintendo Wii® mentioned challenges with the application of Exergames like difficulty in navigation and nature of the game for the elderly population (Agmon et al., 2011).

Although most of the literature recognizes the encouraging results of Exergames, some studies did not find a significant association between balance improvement and this intervention. An observer blinded RCT done in Denmark tested the Nintendo Wii® Exergames training in older adults of 65 years with poor to average self-reported balance. The participants completed ten weeks training with two sessions per week, each session lasting for approximately 35 minutes and controls were asked to wear ethylene-vinyl acetate insoles. Muscle strength and balance were tested pre and post-intervention. The muscle strength of lower extremities and functional performance significantly improved when compared with the controls, but there was no significant improvement in postural balance (Jorgensen, Laessoe, Hendriksen, Nielsen, & Aagaard, 2013). Nitz, Kuys, Isles, & Fu, also performed a pilot study with eight women aged thirty to sixty years to investigate the effect of strength and balance (2010). Following this a ten-week training using Wii® Fit Exergames (two thirty minute's session each week), muscle strength and unilateral stance improved but not functional balance.

Program parameters and the criteria for the selection of games is limited in the literature. The current study will employ a structured curriculum approach with both self-reported and clinical outcome measures.

(g) Exergames and General Well-being

Exergame research includes studies on motivation, adherence and general wellbeing. Participating in Exergames resulted in improved self-esteem and physical activity during a six-week program and significantly lowered loneliness when compared to a control group that played board games (Jung, Li, Gladys, & Lee, 2009). The results suggested that playing Exergames in group settings would reduce feelings of isolation or loneliness.

Other studies reported positive mood, reduced isolation, greater enjoyment, increased confidence, improved executive function and divided attention in seniors (Carrasco, Ortiz-maqués, & Martínez-rodríguez, 2019; Kahlbaugh, Sperandio, Carlson, & Hauselt, 2011; Sveistrup, 2004). Multiplayer and group sessions using video games provide interaction of seniors with peers and expand their social network. An added benefit is that seniors and older adults can enjoy this experience with their family members as video games are highly popular among the younger generation. Therefore participating in Exergames resulted in a high level of adherence and shows the usability and user-friendly nature of this intervention (Konstantinidis et al., 2016; Nitz et al., 2010).

The limited literature in Exergames and general well-being points toward the need for further research and perhaps the implementation of a more systematic approach toward designing interventions with a comparison to a standardized balance rehabilitation program.

(h) Virtual Rehabilitation – Conceptual framework and applications in healthcare

"Rehabilitation" is a commonly used term in healthcare that denotes the restoration of abilities lost due to a disease, injury or a congenital condition. This process helps the individual to restore and maintain maximum functional independence and quality of life and prevent future impairments. It is a client-focused process that addresses the physical and psychological consequences of disability and involves multiple health care and social service providers (Barnes & Ward, 2005). Virtual Rehabilitation (VRehab) is the use of virtual environments (VE) as a medium to perform specific tasks and enable an individual to improve his/her physical and cognitive functions.

VRehab is a relatively new addition to existing methods of rehabilitation, and the applied model includes four main components: VE, users, applications in healthcare and the limiting factors (Hashim, Campelo, Weisberg, & Katz, 2017).

1. A virtual environment is a critical component for successful implementation. Three key aspects of VE must be considered during application: a safety protocol, an interface that

connects the user with the environment, and matching the activities to the specific function being restored.

2. The primary user is the patient, and secondary users are researchers and healthcare providers who implement these VRehab programs.

3. Three key areas where Virtual Reality (VR) are used in healthcare include assessment & diagnosis, therapeutic intervention and in healthcare education and training.

4. Some of the limiting factors for clinicians and researchers when using VR based systems include associated costs, maintenance, quality and accessibility of equipment, cultural sensitivity, and safety of the user.[2]

New advancements in technology have increased the potential use of VR based applications for healthcare interventions. The commercial availability of relatively inexpensive VR interfaces have enabled researchers and practitioners' to experiment with these tools to validate their effectiveness. Moreover, well-designed VE's are more motivating and engaging than traditional programs resulting in improved outcomes (Lányi, 2006).

Ideally, healthcare professionals should develop new activities specifically designed for rehabilitation, but they can also adapt existing commercial VR tools and games for it. The principles of rehabilitation can be used for the application of VRehab for the senior population. One of the primary challenges in the usability of VR technology is the lack of specific design adaptation and customization for the elderly, and limited training and expertise of healthcare professionals (Campelo, Hashim, Weisberg, & Katz, 2017).

[2] The model described in this section has been presented as a poster at the International Rehabilitation Sciences Congress, 2017.

CHAPTER 3: MATERIALS AND METHODS

This chapter outlines the screening and recruitment process, the inclusion and exclusion criteria and explains the research and assessment protocols with the outcome measures. A detailed description of the interventions (Exergames Balance Training and Conventional Balance Training), the control group and curriculum development are also outlined. At the end of the Chapter, both statistical analysis and ethical considerations are briefly discussed.

Participants

Convenience sampling was used to recruit participants (N=62, aged 65 and over) for a pre-screening sessions. These sessions were conducted either at a local senior residence or at the Sports Technology Research Laboratory (STRL), at the University of Calgary. Individuals who scored less than three on the Mini Cog test (Appendix A) were considered ineligible to continue. A registered physiotherapist reviewed the self- administered Physical Activity Readiness Questionnaire (PAR-Q+) and excluded participants with serious acute/chronic medical conditions (available on line http://eparmedx.com/wp-content/uploads/2013/03/FINAL-FILLABLE-ParQ-Plus-Jan-2019,pdf). Individuals using an assistive device (i.e., walker, cane or crutches) or having visual or auditory conditions that could limit their active participation were excluded from the pre-testing session. The screening interview also checked for any balance disorders, neurological conditions or incidents of falling in the last year; more than one fall was part of the exclusion criteria.

Fifty-three individuals fulfilled the study criteria and were deemed to be sufficiently physically and cognitively capable to safely participate in the study. They were invited by emails and telephone to attend the pretest session. Eleven individuals decided not to attend the pretest session for a variety of reasons. The calculated sample size of each group was 11, assuming a power of 80% and a 95% confidence interval. (Appendix B). The researchers originally targeted to recruit 25 participants per group but on the final day for registration, only 42 (13 males and 29 females) between the ages of 65 and 94 years qualified to participate. To avoid extension of the study over the winter break, the group sizes were set unequal to have more participants in the experimental conditions. Another reason was that participants in the experimental groups were more likely to dropout than the control group and the aim was to train as many of them as possible to see differences in the experimental groups. The participants were randomly assigned to one of three groups by a computer-generated random sequences (Cicciarella, 1997). The number of participants in the control group (n=11) was less than the two intervention groups (EBT n=16; CBT n=15), based on the ratio of 5:5:3 used in random assignment. Forty participants completed the study through the post-testing. Two people dropped out during the intervention at the one-week mark. One participant had to travel outside Canada due to job requirements while the other participant was having difficulty commuting to the venue.

The volunteers fulfilling the inclusion criteria were randomly allocated to one of three study groups: (Group1: Exergames Balance Training (EBT), Group 2: Conventional Balance (CBT) Training with Physiotherapy Exercises, Group 3: Control - No Training (NT)).

Inclusion Criteria

- Participants aged (65 years and over)
- Ability to ambulate independently without an assistive device
- Adequate vision and hearing to interact with the game
- Able to read and speak English (to follow the instructions)
- Individuals with chronic conditions, but already cleared by their Family physician to participate in regular exercise were included

Exclusion Criteria

- Subjects failed to clear the screening session
- Evidence of Cognitive impairment (Mini-Cog Test score, score<3) (Appendix B)
- Individuals with active acute/chronic disease process (PARQ-Plus assessment form, not cleared by their physician)
- Individuals diagnosed for balance disorders or who have a history of falls due to balance issues (more than one) in the last year
- Individuals with neurological disorders that seriously affect motor function (e.g., stroke, traumatic brain injury, spinal cord injury, nerve injury, Multiple sclerosis or Parkinsonism)

Screening and Recruitment

Potential participants were recruited from Calgary using posters displayed in community centers, senior clubs, and senior residences. Interested individuals were requested to contact the lead researcher and project coordinators for enrollment. The project coordinators responded to phone calls and emails of interested individuals and scheduled them for the screening sessions. Candidates who appeared in screening sessions were provided with the description and nature of the study and were asked to complete an informed consent form to participate in the screening session. The candidates who cleared the screening process were booked for pre-assessment. The primary screening session included;

1. Par-Q +, a self-filled questionnaire (Appendix C)
2. Screening questionnaire (Appendix D)
3. Mini Cog test for cognition conducted by the research assistant
4. Weight, Height and Blood pressure measurements and BMI calculation

Five participants failed to clear the pre-screening included: three for serious medical/surgical conditions that could potentially put them at risk participating in the study and two for failure to clear the cognition test. Figure 3 provides a flow chart describing the different stages of the study.

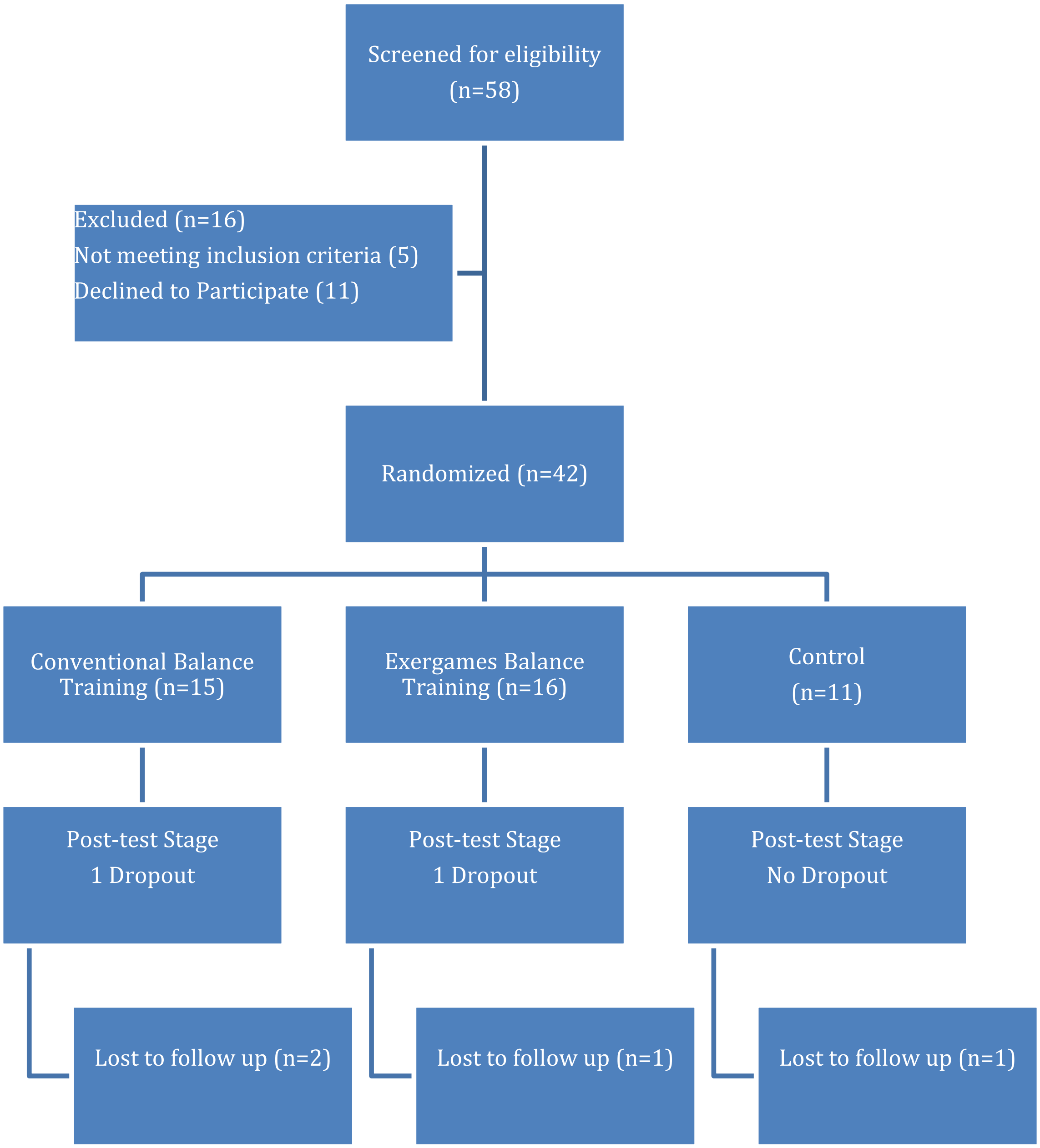

Figure 3. Study Flow chart

Research Protocol

The study was a randomized control trial with a pre-test, post-test design and follow up. The EBT group attended a six-week curriculum-based exergaming balance training program using selected active video games on Nintendo® Wii Fit U™ (see appendix E). The curriculum was designed to address components of physical abilities including aerobics, strength, flexibility, balance, and coordination. Major components of the Exergames training program were six to seven games per session for approximately five minutes each or to completion of defined levels within the game's structure.

The CBT group went through a six-week conventional balance training program that included the specific physiotherapy exercises commonly used for balance rehabilitation. The conventional balance rehabilitation program was adapted from guidelines provided by Kisner & Colby (2007) but addressed the same physical ability components as the EBT group. The control group did not receive training and continued their regular daily activities including any unstructured physical activity program. Table 1 presents the timeline of the research study.

Table 1: *Timeline of Research Study*

Group	Pre-Test Assessment	Six Weeks Training	Post-Test Assessment	Three Weeks Follow-up
EBT	X	X (Exergames)	X	X
CBT	X	X (Conventional)	X	X
Control	X	No Training	X	X

Participants in each group attended their respective training programs in two similar meeting rooms located in an assisted living senior residence under the supervision of instructors. Classes were offered three times per week (Monday, Wednesday and Friday) and the duration of each session lasted from 35-40 minutes. The dependent variables were postural balance, confidence in balance, and fear of falling, which were measured pre-test and post-test intervention and three weeks follow up. Postural balance was measured dynamically by utilizing the Fullerton Advanced Balance Scale (FAB) and statically by using the Center of Pressure (COP) excursion on Wii Balance board. In addition, gait speed was measured using the 3 meter walk test protocol, and the Activities-specific Balance Confidence Scale (ABC) and Tinetti Falls Efficacy Scale (FES) were used to measure self-reported confidence in balance.

Assessment Protocol (Pre and Post Testing)

Based on participant availability, some pre and post assessments were completed at the community senior residence, while others were conducted at the STRL, University of Calgary. After signing the consent form, the participants completed a set of self-reported questionnaires that included the ABC and FES. Once completed, balance was tested using the FAB scale (Appendix F), gait speed, and COP excursion on the Wii Balance board. The pre-test interaction lasted for 30 to 45 minutes. After pre-assessment, the subjects were provided with their program schedule for the next six weeks. The information included details and time for their exercise session. The participants in the control group were advised to maintain their usual exercise activity (i.e., daily walking or any leisure activity) and were also given a date for their post-test. The post-test was scheduled immediately following the last exercise session and based on the availability of the participants. Post-testing included the same questionnaires and physical tests as in the pre-test. Height and weight were not measured in either the post-test or follow-up test. Post-test and follow-up testing sessions lasted for approximately 40 minutes per participant.

Self-rated Questionnaires

Participants were provided with the purpose and instructions to complete the self-reported questionnaires. They were instructed to ask for clarification if any questions were not clear. A research assistant/volunteer was present to facilitate the completion of the questionnaires. Once completed, the researcher checked to ensure that all questions were answered entirely.

Activities-Specific Balance Confidence Scale (ABC)

This scale required responses from participants to rate their confidence in performing different activities of daily living and functional mobility. The responses are given on a scale of 0% (no confidence) to 100% (completely confident) for sixteen items. The participants self-reported and entered the appropriate numbers corresponding to their confidence in performing different activities of daily living. The researcher eventually calculated the percentage of self-confidence in balance by adding all the item scores and dividing by the total number of items.

Falls Efficacy Scale (FES)

This self-reported questionnaire was used to measure the fear of falling while performing different functional tasks. The ten items ordinal scale asked participants to give numbers from 1 (very confident that they would not fall) to 10 (no confidence – extremely likely to fall). The total of all responses was calculated as an FES score. Scores higher than 70 points indicated a fear of falling.

Balance Testing

The balance testing was performed immediately after the completion of the questionnaires. During testing, the administrator made sure that participants stayed hydrated, took breaks if needed and, reported any physical symptoms such as dizziness, headaches or fatigue.

Fullerton Advanced Balance Scale (FAB)

This test measures the postural balance ability and can also be used as a tool to assess the risk of falls in community-living older adults. The test was administered by a trained physiotherapist who followed the standardized scoring sheet for ten tasks to test different static and dynamic components of postural balance. Standardized instructions were given to the participants at each step to explain each task. All tasks were rated on an ordinal scale (0-4), a higher score meant that tasks are performed in a timely manner and without assistance; lower scores corresponded to the inability to perform the tasks or requiring assistance. The final score was based on a cumulative score of all items in the scale. The cut-off score for the scale is 25/40 (i.e., score less than 25 indicates a high risk of falls).

COP Excursion Using the Wii® Balance Board

COP excursion or postural sway was measured on the Wii® Balance board using a balance-assessment, web-based application developed by Neurorehabilitation & Brain Research Group from Spain. Participants removed their shoes and stood on the Wii® Balance board and the program calculated the speed and maximum excursion of COP in anteroposterior and mediolateral direction with eyes open and in standing posture. During testing, the participants were asked to put hands on their hip, focus on the wall opposite to them while trying to maintain balance. They were asked to stand quiet and still during each measurement which lasted for 20 seconds. Three consecutive measurements were taken, and the balance score of each participant was generated based on their height, weight, and age (measured during the screening assessment). A higher score of sway measurement corresponded to poor balance while lower score indicated good postural control. The generated score sheets were stored for later analysis in an encrypted folder.

Gait Speed Using Three Meters Walk Test

The gait speed test (Appendix G) is a clinical test used to assess functional mobility and dynamic balance and requires the participant to walk over the distance of three meters. This test is a modification of the standard four-meter gait speed test, due to space limitation in the testing facility. The participants were asked to walk between the starting and end points, marked with cones, at a comfortable pace. One meter acceleration and deceleration distance were also added to the straight pathway. The examiners used a stopwatch to calculate the time (seconds) and then converted it into speed by dividing distance (three meters) and time. The participants were categorized based on their gait speed;

- Household ambulatory: less than 0.4 m/sec
- Limited community ambulatory: 0.4 to 0.8 m/sec
- Community ambulatory: 0.8 to 1.2 m/sec
- Able to safely cross streets: 1.2 m/sec and above

Training Programs

Exergames Program: Nintendo® Wii Fit U ™

The Exergames program curriculum was designed by the researchers at STRL and then tested in the lab using a volunteer (age 66) to ensure the safety of the games selected. The session helped to estimate the time required to complete each training session and to test the equipment. The lead trainer became comfortable with the designed curriculum and equipment before the program began. The curriculum contained the information about the game selected, including the specific instructions for the participants, equipment needed and difficulty level. It also included instructions about the exercise progression to the next level and pictorial screenshots of selected games. Each session was conducted by the trainer and one volunteer (undergraduate or graduate students). Sixteen participants attended the sessions three times a week and each session comprised of 35-40 minutes for six weeks (18 sessions). Table 2 illustrates the number of participants in each subgroup and when groups were scheduled.

Table 2: *Distribution of Participants in EBT group*

Sub-Groups in EBT Group	Number of Participants	Time
1	5	9:00 am
2	5	10:00 am
3	6	1:00 pm

The first session of the program took longer than anticipated (approximately one hour) as each participant was briefed about the equipment, purpose of the game and direction regarding how to use the equipment. A Mii character (profile) was set up for each participant in the first session, which included entering details of the participant including height, weight, balance score, and avatar selection. The participants were also given tracking sheets for recording scores of each game every session (Appendix H). All sessions were scheduled at a senior community residence which provided the required space. Although there were 5 participants in each training session, it was made clear to the participants that there is no competition among the participants and their performance in the games will not be evaluated. The participants were also advised to seek help if they find any difficulty using the equipment. They were also advised to wear comfortable clothing and shoes for the training and keep a water bottle with them if they want. Five stations were set in the training room, and one station was assigned to each participant to play and complete their program. The participants could take breaks if they felt tired.

Participants completed the beginner level, they were allowed to challenge the next difficulty level without risking their safety. The participants were also allowed to interact with each other during the sessions to have peer support and encouragement. During all sessions, the lead trainer and researchers ensured that participants were using proper technique and body position when playing and provided feedback where required.

The first session included six games with each game addressing one specific physical ability (i.e., aerobics (warm-up), strength, balance, flexibility, and coordination). The number of exercises in each session was increased progressively. The average number of games in the first two weeks was seven. In week three and four one-half of the sessions included seven games while the other half had eight games. During the last two weeks, the average number of games was 8, and the last session included nine games. Each session had different combinations of exercises, and those modifications were made to follow a progression to more difficult tasks and also to keep participants involved with learning new skills. Appendix H describes the exergames played in each session.

After the 9th session, weights were used for the progression of difficulty in the games of Torso Twist and Bird's Eye Bull's Eye. The difficulty level of Ski Slalom was increased, and the longer course was selected in the game's parameters for progression. The client who returned after the cardiac surgery did not use weights and followed the precautions given by the surgeon only doing the exercises which were painless and did not cause fatigue.

There were no injuries or unusual events reported during the program. One participant took a break for two weeks due to an ear infection that caused dizziness and remained under treatment for the episode. Another participant had cardiac surgery for a pacemaker, had to stay away for two weeks, and rejoined the program only after the surgeon's clearance. One participant had active knee pain and had to get a cortisone injection.

Conventional Exercise Program

This program was designed for group classes under the supervision and followed the standard guidelines for balance training programs. It sequenced warm-up activities, strengthening exercises, flexibility exercises, and balance and coordination exercises. The curriculum was designed at STRL by a registered physiotherapist in consultation with an exercise physiologist and physical trainer. The selected exercises were tested in the laboratory with a volunteer to validate the time and difficulty levels and to make any required modifications. The curriculum included whole body exercises but focused more on lower limbs, core strengthening and balance activities (Appendix J). The curriculum also contained the general instructions for the clients, pictorial demonstration and instruction for each exercise along with exercise dosage (frequency, repetitions, and sets). It also included the warm-up protocol and series of exercises on a weekly basis. The program replicated the EBT in terms of number and timing of sessions, subgroups, and duration of exercises. Thus the program ran side by side with EBT in a separate hall in the same location. Each session lasted for 35-45 minutes, and initial sessions were longer due to participants learning and pace. The EBT group was also subdivided into three groups each comprising of 5 participants and sessions were run at 9:00 am, 10:00 am and 1:00 pm.

All the clients were advised about precautions at the start of each session which included;

- Not holding their breath when performing exercises
- Taking a snack half an hour before the activity, if diabetic
- Stopping in the event of any unusual pain, chest tightness, breathlessness, fatigue and immediately reporting difficulties to the instructor
- Following instructor guidelines and asking questions, if there is any

The exercises were progressed in terms of repetitions, and with the addition of exercises and the use of ankle weights on a bi-weekly basis. The total number of participants in this group at the start was 15, and they were subdivided into three groups (5 participants each). No unusual events or injuries were reported during the program.

Independent Variables and Dependent Variables

The independent variables were balance training programs (EBT, CBT, and control) and trials (pre, post and follow up). Dependent variables included the postural balance on Fullerton Advanced Balance (FAB), Center of Pressure (COP) excursion on Wii Balance board, gait speed, confidence in balance on Activities-specific Balance Confidence Scale (ABC) and fear of falling on Tinetti Falls Efficacy Scale (FES).

Measures

The primary outcome of this study was postural balance which was measured by FAB. The FAB is a tool to measure balance with an associated risk of falls in functionally independent older adults. The FAB has a high inter-rater (ICC=.94-.97), intra-rater (ICC=.97-1.00) and test-retest reliability (*p*=.96) (Rose et al., 2006) in the elderly population. The FAB is a time and space efficient measure and requires minimum equipment to conduct the test. The balance in the standing position was evaluated using a Wii balance board and measure the COP excursion. Wii balance board was used instead of a force plate due to its portability and availability to most clinicians. When compared to force plates (the gold standard in balance measurement), the Wii balance board showed superior test-retest reliability within the device (ICC=0.66-0.94) and between the device (ICC=0.77-0.89) (Clark et al., 2010). Wii balance boards are found to be less accurate when compared to laboratory grade force plates, but COP uncertainty values were similar in both devices (Bartlett, Ting, & Bingham, 2014). The application used for posturography was also tested and compared with standardized clinical tests, showed moderate to high correlation in AP ($r= 0.873$; $p < 0.01$) and ML ($r = 0.708$; $p < 0.01$) planes (Llorens, Latorre, Noé, & Keshner, 2016). Gait speed tests have different versions and modifications based on distance used to test gait speed. The test is included in the British Columbia guidelines for frailty assessment in older adults. The gait speed for both 4 meters and 10 meters tests has excellent test-retest reliability (ICC=0.96-0.98). Although the 10-meter test is more valid when compared to the 4-meter walk test (Peters, Fritz, & Krotish, 2013). Another study found high inter-rater reliability (greater than 0.9) for gait speed test (Studenski et al., 2003).

The secondary outcomes of this study were confidence and self-efficacy in balance evaluated by the Activities-specific Balance Confidence Scale (ABC) and Tinetti Falls Efficacy Scale (FES). ABC (Appendix K) is a self-reporting scale of perceived confidence during activities of daily living. ABC is an important tool for determining an individual's confidence to complete different daily tasks and functions and has a moderate test-retest reliability (ICC=0.70) (Holbein-Jenny, Billek-Sawhney, Beckman, & Smith, 2005). FES (Appendix L) is used to determine the fear of falling associated with different tasks. It measures the individual's perceived confidence associated with falling when performing non-dangerous ADL's. The test-retest reliability of FES was found to be good (r=0.71) (Tinetti, Richman, & Powell, 1990). The FES and ABC were found to be valid and reliable measures of mobility confidence and balance (Powell & Myers, 1995). The outcome measures were selected to indicate changes in postural balance following the balance training programs. The study included both objective and subjective measures of balance to differentiate between quantifiable changes and perceived balance abilities of the participants.

Statistical Analysis

Statistical analysis of the data was completed using IBM® Statistical Package for the Social Sciences (SPSS) version 22.00. Descriptive statistics, estimated marginal means, and standard errors from the generalized estimating equation (GEE) were reported for outcome variables. One way analysis of variance (ANOVA) was conducted to investigate the difference in age, height, weight, and BMI between groups (EBT, CBT, and Control). The significant variables found by ANOVA (p-value < 0.05) were used as controlled variables in the final multivariable model, i.e., BMI. Before adding the covariate in the GEE model, interaction with group effect was checked, and if found insignificant, it was included in the GEE model, so that it satisfies the assumption of including covariate(s) in the model.

For multivariable analysis, GEE was employed (GENLIN procedure under SPSS version 22.0) to determine the effects of interventions. Due to correlated observations among study participants and an unequal number of observations (i.e., unbalanced) we employed the GEE model, and this model has been used in a previous study of a similar design (Horton, Stergiou, Fung, & Katz, 2017; Wang, 2014). An alpha level of 0.05 was chosen and any computed p values less than 0.05 were considered statistically significant. The study investigated the group by time interaction effect, group effect and time effect. If a statistically significant group by time interaction effect detected, which means that the group effect varied with time, or time effect varied with the group, testing of simple effect was performed, i.e., test the group effect broken down by time, test the time effect broken down by group.

Ethics and Data Confidentiality

The researchers involved in this study completed the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2) tutorial. The study was approved by the Conjoint Health Research Ethics Board (CHREB) REB16-1633, University of Calgary. All participants signed an informed consent form before undergoing screening, assessment and intervention. The trained and qualified staff ensured the safety of participants by continuous supervision during the intervention.

Collected data was filed and secured in locked cabinets in principal investigator's office. The data was kept confidential and de-identified to protect the identification of participants. The digital data was kept on an encrypted hard drive on the testing computer and on an encrypted backup drive. Only the researcher and supervisor have the encryption key and access to cabinets.

Chapter 4: RESULTS

This chapter includes the demographic information of participants of the study and the statistical analysis performed on the collected data. Results are organized based on the outcome measures.

Demographics

The characteristics of study participants are listed in Table 3.

Table 3: *Mean, SD, range, minimum, maximum values of age, height, weight & BMI*

	Females (n=27)		Males (n=13)	
	Mean (SD)	**Min/Max**	**Mean (SD)**	**Min/Max**
Age (years)	72.89 (6.76)	66/94	72.00 (6.13)	65/83
Height (cm)	161.85 (5.26)	72/151	172.69 (4.80)	165/181
Weight (kg)	70.41 (10.36)	57/102.1	92.66 (18.47)	62.6/131
BMI	29.96 (4.37)	21.49/37.50	31.00 (5.75)	22.99/44.28

The mean and standard deviation of participant attendance in the Exergames Balance Training (EBT) were M =14.5 and SD = 2.92 and in Conventional Balance Training (CBT) were M = 15 and SD = 2.40. Among the demographics, Body Mass Index (BMI) was statistically significant ($p < .05$) in the three groups. No statistically significant differences were found in the other variables. Therefore, BMI was used as a covariate in the generalized estimating equation (GEE) model.

Fullerton Advanced Balance (FAB)

For each participant, the FAB score was calculated three times during the study (Pre, Post, and Follow-up). EBT and CBT groups both improved their average score from pre to post-test. The control group showed a progressive decline in the average score from pre-testing to post-testing. Table 4 and Figure 4 provide the estimated marginal means of FAB scores for all the groups at baseline, after the intervention, and at follow-up after fixing covariate BMI at value 28.297. The results showed a statistically significant group by phase interaction effect (χ^2 (4)

=37.343, p<.001) which means that the phase effect varies with the group and group effect varies with the phase. Testing of simple effects (i.e., examine phase effect broken down by group, and group effect broken down by phase) was performed.

Table 4: *Estimated marginal means of FAB scores for EBT, CBT & Control group at baseline after the intervention and at follow-up stage*

Group	Pre (n=42)		Post (n=40)		Follow-up (n=36)	
	M	SE	M	SE	M	SE
EBT	31.79	1.55	34.13	1.31	32.76	1.63
CBT	34.67	.98	36.08	.98	35.68	1.30
Control	34.21	1.22	32.76	1.07	33.25	.99

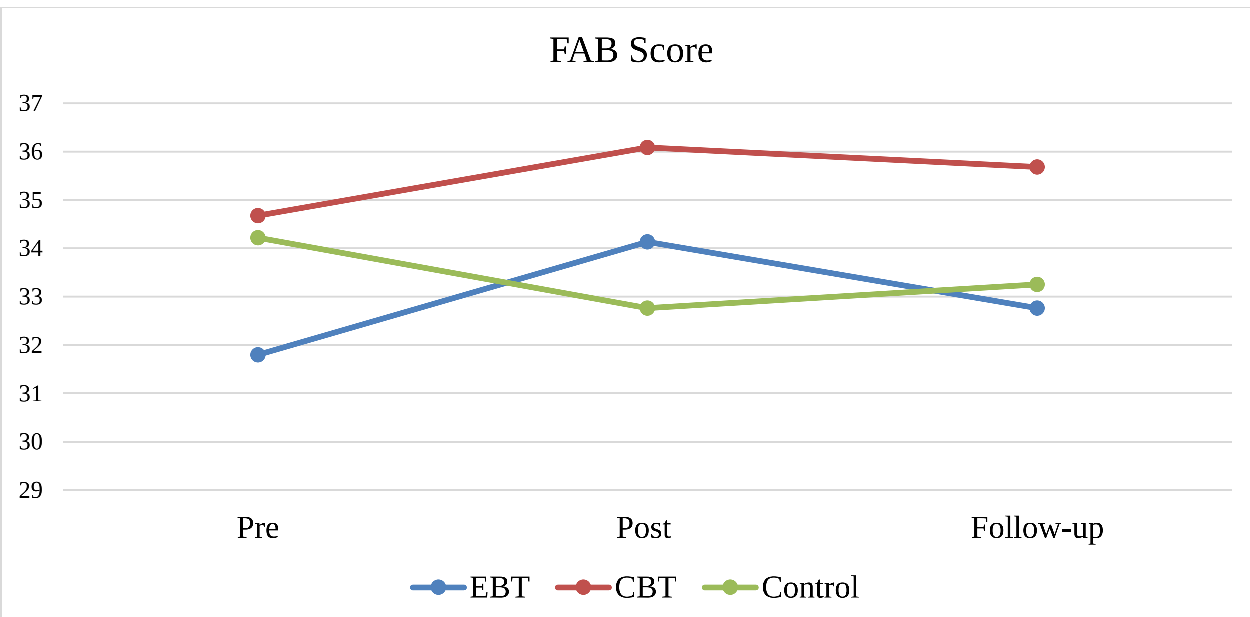

Figure 4. *Estimated marginal means of FAB scores for EBT, CBT and Control group*

The analysis indicated significant improvement of FAB score in EBT group and significant decrease in control group. There was no significant change observed in the CBT group.

Table 5 describes the phase effect of FAB in each group while Table 6 represents pairwise comparisons of phases in the groups. The group and phase interaction show significant ($p<0.05$) improvement in FAB score in EBT group from pre to post phase but no significant change from pre to follow up stage. There is significant reduction in FAB score pre to post phase in control group.

Table 5: *GEE; Testing of Phase effect of FAB broken down by EBT, CBT & Control group*

Group	Wald chi-square	df	p-value
EBT	21.66	2	.000*
CBT	4.19	2	.123
Control	13.05	2	.001*

*significant at .05 level

Table 6: *Pairwise comparisons of phases of FAB scores by EBT, CBT & Control group*

Group			Mean Difference	SE	df	Bonferroni Significance
EBT	Pre	Post	-2.333[a]	.586	1	.000*
		Follow-up	-.967	.830	1	.734
	Post	Pre	2.333[a]	.586	1	.000*
		Follow-up	1.367	.580	1	.055
	Follow-up	Pre	.967	.830	1	.734
		Post	-1.367	.580	1	.055
CBT	Pre	Post	-1.413	.721	1	.151
		Follow-up	-1.010	1.004	1	.944
	Post	Pre	1.413	.721	1	.151
		Follow-up	.403	.691	1	1.000
	Follow-up	Pre	1.010	1.004	1	.944
		Post	-.403	.691	1	1.000
Control	Pre	Post	1.455[a]	.433	1	.002*
		Follow-up	.962	.945	1	.926
	Post	Pre	-1.455[a]	.433	1	.002*
		Follow-up	-.492	.758	1	1.000
	Follow-up	Pre	-.962	.945	1	.926
		Post	.492	.758	1	1.000

*significant at .05 level

Postural Sway around Center of Pressure (COP)

The two variables used are sway in anterior-posterior (AP) and medial-lateral (ML) directions measured in centimeters (cm) in quiet stance. The decreased sway suggests improvement in postural control. A significant difference was found in control group by phase effect, in both directions. Table 7 represents the estimated marginal means and standard error for COP measured in both directions. Estimated means of ML directions are calculated with fixing covariate BMI at value 28.344.

Table 7: *Estimated marginal means of COP AP and ML scores for EBT, CBT and Control group at baseline, after intervention and at follow-up stage*

Direction/Group	**Pre (n=42)**		**Post (n=40)**		**Follow-up (n=36)**	
AP Direction	**M**	**SE**	**M**	**SE**	**M**	**SE**
EBT	1.98	.28	1.32	.17	1.14	.21
CBT	1.76	.21	1.46	.19	1.47	.24
Control	1.90	.14	1.49	.23	1.48	.23
ML Direction						
EBT	1.31	.30	.73	.13	.57	.11
CBT	1.25	.24	.86	.09	.84	.11
Control	1.23	.11	.97	.10	1.02	.10

Figure 5 and 6 graphically represents the estimated marginal means and their trend during the study.

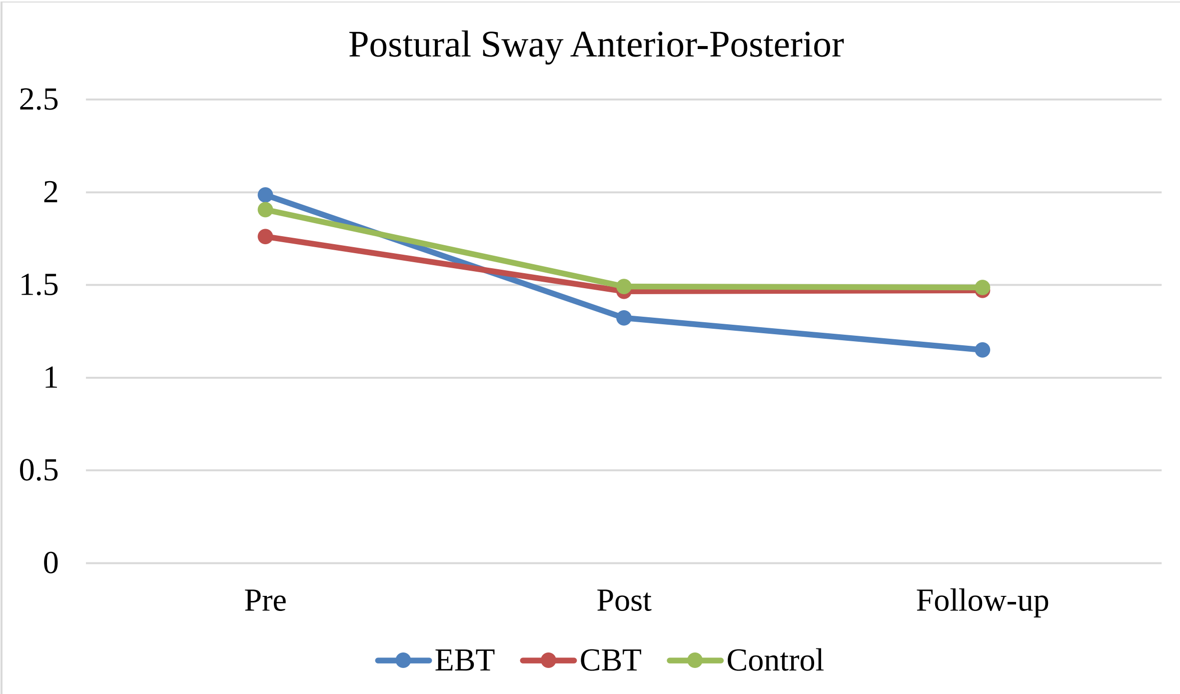

Figure 5. *Estimated marginal means of Postural Sway Anterior-Posterior direction*

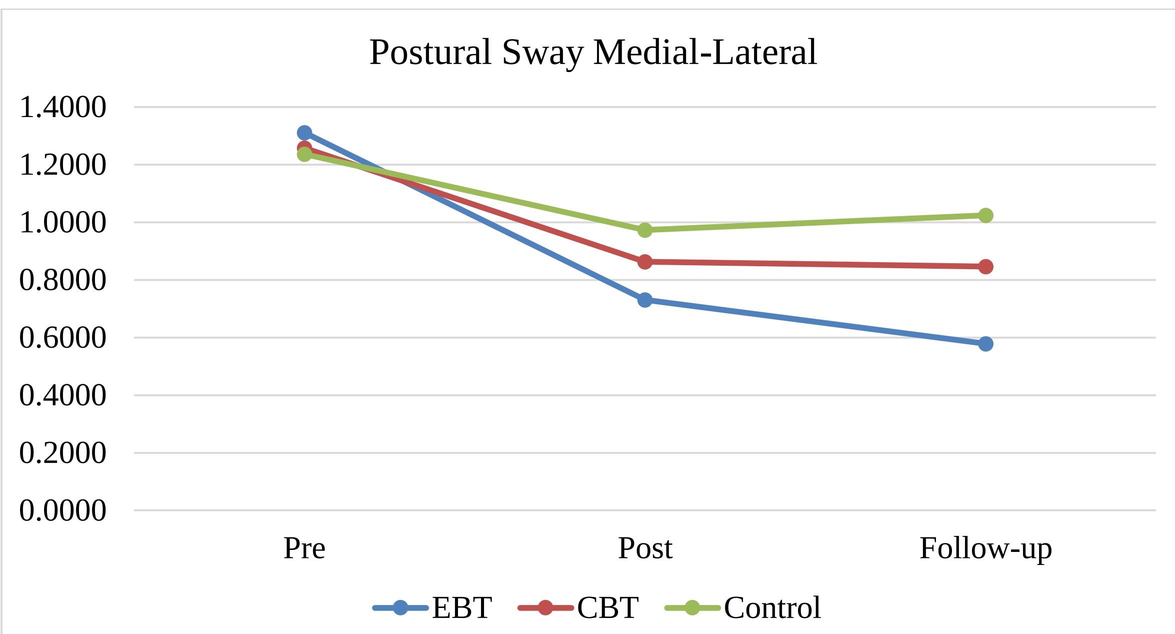

Figure 6. *Estimated marginal means of Postural Sway Medial-Lateral direction*

Table 8 and Table 9 provide the phase effect of COP in AP and ML directions respectively in intervention and control groups.

Table 8: *GEE; Testing of Phase effect of AP sway broken down by EBT, CBT and Control group*

Group	Wald chi-square	df	p-value
EBT	5.16	2	.076
CBT	3.43	2	.179
Control	7.41	2	.025*

*significant at .05 level

Table 9: *GEE; Testing of Phase effect of ML Sway broken down by EBT, CBT and Control group*

Group	Wald chi-square	df	p-value
EBT	4.03	2	.133
CBT	4.54	2	.103
Control	11.62	2	.003*

*significant at .05 level

The results show progressive decline in sway in all three experimental groups from pre to post-test stage in AP direction. This decline continued in both EBT and Control group and showed slight increase in CBT group. A Similar trend is observed in ML direction where sway decreased in all three groups from pre to post. This decline continued in EBT group but was not observed in CBT and control groups. For the EBT group, AP sway has a slightly statistical significant phase effect (i.e., significant at alpha=0.10 level but not at alpha=.05 level) with $\chi 2$ (2) =5.165, p=.076. The analysis shows no significant improvement in postural control in the experiment groups.

Gait Speed

Gait speed was used to see the effect of the EBT and CBT programs on dynamic balance and functional mobility. Increasing value shows improved gait speed (meters/second). Table 10 provides the estimated marginal means of Gait speed for all the groups at baseline, after the intervention and at the follow-up stage. Figure 7 shows the means and how they varied over the timeline.

Table 10: *Estimated marginal means of Gait Speed for EBT, CBT and Control group at baseline, after intervention and at follow-up stage*

Group	Pre (n=42)		Post (n=40)		Follow-up (n=36)	
	M	SE	M	SE	M	SE
EBT	0.86	0.04	1.01	0.04	1.04	0.05
CBT	0.93	0.03	1.09	0.06	1.13	0.05
Control	1.07	0.08	0.87	0.05	0.98	0.04

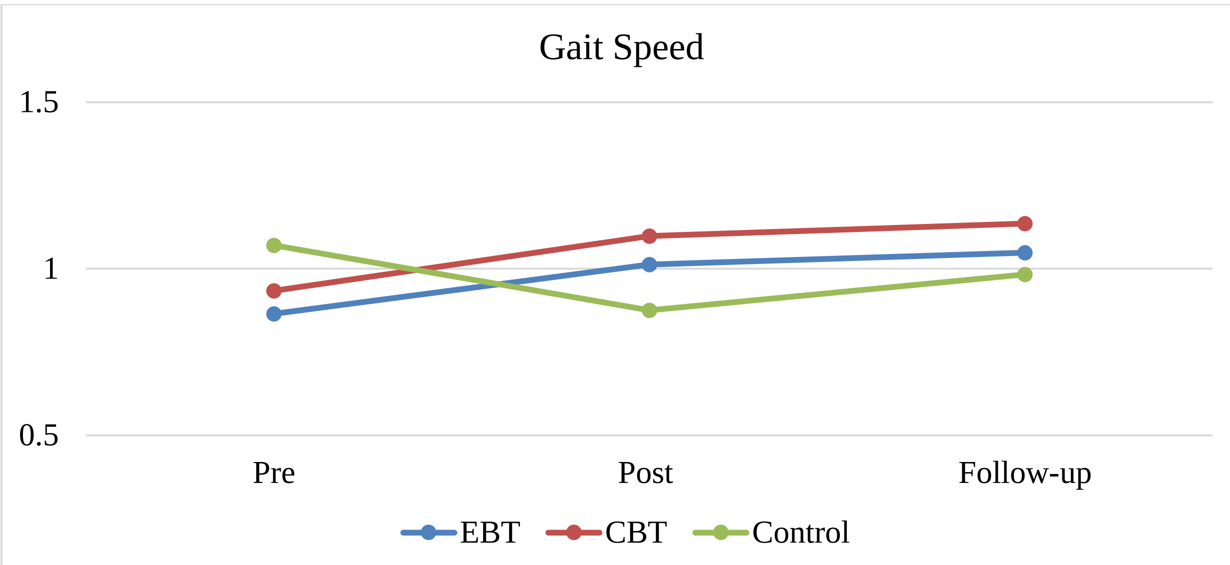

Figure 7. Estimated marginal means of Gait Speed

All three groups showed a significant change in gait speed with phase interaction. The gait speed improved significantly in both intervention groups EBT and CBT but decreased significantly in the control group. Table 11 shows the statistical analysis of the phase effect of gait speed broken down by the groups.

Table 11: *GEE; Testing of Phase effect of Gait Speed by EBT, CBT and Control group*

Group	Wald chi-square	d.f	p-value
EBT	19.53	2	0.000*
CBT	18.24	2	0.000*
Control	20.18	2	0.000*

*significant at .05 level

In EBT and CBT groups, significant improvement was noticed at post and follow-up assessments when compared to pre-intervention measurement.

Table 12 includes the pairwise comparison of phases and their significance in each group.

Table 12: *Pairwise comparisons of phases of Gait Speed by EBT, CBT and Control group*

Group			Mean Difference	SE	df	Bonferroni Significance
EBT	Pre	Post	-1.477[a]	0.443	1	0.003*
		Follow-up	-.183[a]	0.467	1	0.000*
	Post	Pre	.147[a]	0.443	1	0.003*
		Follow-up	-.035	0.514	1	1.00
	Follow-up	Pre	.183[a]	0.467	1	0.00*
		Post	.035	0.514	1	1.00
CBT	Pre	Post	-1.634[a]	0.050	1	0.003*
		Follow-up	-.201[a]	0.059	1	0.002*
	Post	Pre	.163[a]	0.501	1	0.003*
		Follow-up	-.038	0.697	1	1.000
	Follow-up	Pre	.201[a]	0.597	1	0.002*
		Post	.038	0.069	1	1.00
Control	Pre	Post	.195[a]	0.053	1	0.001*
		Follow-up	.086	0.066	1	0.570
	Post	Pre	-.195[a]	0.053	1	0.001*
		Follow-up	-.108[a]	0.039	1	0.020*
	Follow-up	Pre	-.086	0.066	1	0.570
		Post	.108[a]	0.039	1	0.020*

*significant at .05 level

Confidence in balance and Fear of fall

Self-reported measures of balance (Activities-specific Balance Confidence Scale (ABC) and Tinetti Falls Efficacy Scale (FES) are the secondary outcomes. A higher score on the FES scale indicates an increased fear of falling (decreased perception of balance) and vice versa. On the other higher score on the ABC scale depicts increased confidence in balance.

Table 13 illustrates the estimated marginal means and standard error for ABC and FES (BMI controlled at 28.315). A higher score for ABC and a lower score for FES shows favorable outcomes. The results showed that there was no significant change in these scores from pre to post or from post to follow up stage.

Table 13: *Estimated marginal means of ABC and FES scores for EBT, CBT and Control group at baseline, after intervention and at follow-up stage*

Group	Pre (n=42)		Post (n=40)		Follow-up (n=36)	
FES	**M**	**SE**	**M**	**SE**	**M**	**SE**
EBT	14.98	2.20	14.08	2.23	16.78	4.40
CBT	10.60	.86	10.29	.32	10.66	.65
Control	10.02	.78	13.38	2.99	10.91	1.16
ABC	**M**	**SE**	**M**	**SE**	**M**	**SE**
EBT	87.38	4.91	88.54	5.32	88.76	4.78
CBT	94.55	1.52	92.71	1.81	92.05	2.15
Control	94.22	2.97	92.53	3.21	94.43	2.72

Table 14 and 15 includes the details of statistical test applied to see group, phase and group into phase effect on FES and ABC respectively.

Table 14: *GEE; testing of group, phase and group into phase effect on dependent variable FES*

	Wald chi-square	df	p-value
Group	3.80	2	.149
Phase	1.61	2	.446
Group*phase	2.99	4	.559

*significant at .05 level

Table 15: *GEE; testing of group, phase and group into phase effect on dependent variable ABC*

	Wald chi-square	df	p-value
Group	.83	2	.659
Phase	1.48	2	.476
Group*phase	7.52	4	.111

*significant at .05 level

CHAPTER 5: DISCUSSION

This study examined the effectiveness of Exergames to improve postural balance in older adults compared to a traditional balance training model, and a control group. In this chapter, the results are interpreted, and explanations for the changes observed are proposed and compared to the previous literature. Study limitations are specified, and directions for future research are provided.

Postural Balance

The primary outcome of this study is the change of postural balance in seniors as measured by Fullerton Advanced Balance (FAB) scale. This scale was selected because it was specifically developed to measure the postural and functional balance in community-living older adults. The test is relatively new as compared to other commonly used objective balance assessment tests. For example, a survey conducted among physiotherapists in Saskatchewan to identify commonly used tools to assess balance (Oates et al., 2017) revealed that less than 3% of physiotherapists use the FAB scale in clinical settings, even though the FAB comprehensively and accurately tests multiple balance components. Although many clinical tests might not be suitable for the general geriatric population, FAB showed excellent reliability, even when utilized with Parkinson patients. Additionally, there are minimal ceiling effects when compared to standardized tests like the Mini-Balance Evaluation Systems Test and the Berg Balance Scale (Schlenstedt et al., 2015).

In this study, results showed a significant improvement in FAB scores in the Exergames Balance Training (EBT) group from pre-test to post-test stage (Pre: Mean 31.79 SE 1.55 Post: Mean 34.13 SE 1.31, $p<0.05$). While FAB scores also improved in the Conventional Balance Training (CBT) group, the changes were not significant (Pre: Mean 34.67 SE 0.98 Post: Mean

36.08 SE 0.98). The results indicate that exercise interventions that are designed specifically for balance rehabilitation and administered regularly have the potential to improve postural balance in older adults. The significant improvement in the exergames group seems promising showing that they can be as effective as traditional exercises. There was also a significant reduction in FAB scores in the control group from pre-test to post-test stage (i.e., Pre: Mean 34.21 SE 1.22 Post: Mean 32.76 SE 1.07, $p<0.05$). Slight decreases in FAB scores were observed in the follow-up measurements of both intervention groups which is common in most learning situations on follow-up.

Bieryla and Dold (2013) used the FAB as a primary outcome using similar populations and interventions, and reported slight, but not statistically significant, improvements (Pre: 27, Post: 28.5) in FAB scores after three weeks of intervention using Wii Fit games. The study was limited by the small sample size (n=12) and a short intervention period, i.e., three weeks. Meanwhile, physiotherapists in Texas completed a study to determine the effectiveness of Pilates compared to traditional balance exercises in community-living older adults (Josephs, Pratt, Calk Meadows, Thurmond, & Wagner, 2016). Balance was tested pre-intervention and post-intervention in both groups using the FAB scale. The participants in both the Pilates and traditional balance exercise groups showed significant improvement in the FAB score after regularly participating for 12 weeks. (Pilates: Pre *M*= 18.54 *SD*= 10.08, Post *M*= 24.85 *SD*= 12.54. Traditional balance exercises: Pre M= 19.82 SD= 8.86, Post *M*= 27.27 *SD*= 6.41) The increase in FAB scores was higher as compared to our results; possibly because the participants were also doing home exercises for 15-20 minutes on days, they were not attending supervised sessions.

These studies support the effectiveness of the FAB in measuring a change in the elderly and the idea that structured exercise programs improve balance in the elderly. However, the variability in program design, type of intervention, and duration of programs make it difficult to assess the comparative effectiveness. The improvement in balance may be attributed to physiological adaptation in participants. The physiological response of the human body to the exercises was not examined, but it is assumed that improved balance resulted from engaging in structured exercise programs (Centers for Disease Control and Prevention, 1999).

A second, unexpected outcome involved body sway around the center of pressure (COP). Decreased sway around COP indicates improved static balance and postural control. While the results showed improvement in postural control for all groups, only the control group improved significantly in both the anterior-posterior (AP) and medial-lateral (ML) directions. There does not appear to be any explanation for the resultant overall improved balance in the control group. Other studies using COP as an outcome had mixed findings. Bainbridge, Bevans, Keeley, & Oriel (2011) conducted a pilot study involving six community-living older adults. They measured COP excursion as an outcome for balance, before and after a six weeks exergames program. Their study found no significant change in COP excursion in participants. An RCT, by Jorgensen, Laessoe, Hendriksen, Neilsen & Aagard (2013), reported no significant change in COP velocity moment among participants after ten weeks of Wii ® exergames training. Another RCT, conducted in France, by Toulotte, Toursel, and Olivier (2012) investigated the effectiveness of Wii® Fit games in comparison to the adapted physical activities group. After 20 weeks, the researchers reported significant improvement in the position of the center of gravity in all intervention groups (i.e., Adapted Physical Activities, Wii Fit® training, Adapted Physical Activities + Wii Fit® training) with no observed change in the control group.

While COP excursion measurement using a laboratory grade force plate is considered the gold standard for static balance assessment, it is not clear how long interventions should be employed to produce significant results. The measurement by force plate might be more sensitive in detecting changes in static balance, but the correlation with functional abilities and activities of daily living needs further study.

Functional Mobility

There is a progressive reduction in gait speed with aging, and this reduction is more evident when discussing maximum gait speeds (Bohannon, 1997). Gait speed is an indicator of functional mobility and dynamic balance. The results showed significant improvements in gait speed from pre-test to follow up assessment in both EBT (Pre: Mean 0.86 m/s, SE 0.04 FU: Mean 1.04m/s, SE 0.05, $p<0.05$) and CBT (Pre: Mean 0.93 m/s, SE 0.03 FU: Mean 1.13m/s, SE 0.05, $p<0.05$) groups. The control group showed a significant reduction in gait speed from pre-test to follow-up stage (Pre: Mean 1.07m/s, SE 0.08; FU: Mean 0.98m/s, SE 0.049, $p<0.05$). These findings support the idea that involvement in structured physical activity improves not only functional balance but also impacts functional mobility as measured by gait speed. Perhaps improved speed might translate into improved activities of daily living.

A previous study found the mean gait speed to be 1.35 m/s (men) and 1.29 m/s (women) for the age group 60 to 69 and 1.33m/s (men) 1.27 m/s (women) for the age group 70 to 79 (Bohannon, 1997). A study, by Steffen, Hacker, and Mollinger (2002), using a 10-meter walk test with community living older adults found a similar trend in gait speed. The average comfortable gait speed, for the age range of 60 to 69 years, was reported to be 1.59 m/s (SD 0.24) for men and 1.44 m/s (SD 0.25) for women. Within the age group of 70 to 79 years, the reported gait speeds were 1.38 m/s (SD 0.23) for men and 1.33 m/s (SD 0.22) for women. Further reduction was observed for the age group 80 to 89 years. Here, it declined to 1.21 m/s (SD 0.18) for males and 1.15 m/s (SD 0.21) for females (Steffen, Hacker, & Mollinger, 2002). A cross-sectional study done in Brazil involving 1112 community-living older adults found gait speed to be 0.81 m/s to 0.78 m/s for women and 0.86 m/s for men. The same study found that this rate was lower when compared to developed countries (Busch et al., 2015). Additionally, a study done in Canada to explore the age-related changes in gait speed found the mean speed to be 0.89 m/s for women and 1.21 m/s for men aged 63 years and above (Himann, Cunningham, Rechnitzer, & Paterson, 1988). In our study, the mean gait speed in all three groups measured at the pre-test stage corresponds to the gait speed of older adults reported in the studies described above. In addition to age, gender, and physical capacity, these findings also indicate that gait speed may be influenced by multiple factors including geographical location and socioeconomic status.

The effect of playing exergames on gait speed was explored in a pilot study by (Agmon et al., 2011), which reported increased speed gait from 1.04 m/s (0.2) to 1.33 m/s (0.84) m/s in seniors 65 years of age or older using 50 sessions with the Nintendo Wii Fit exergames. Nicholson, McKean, Lowe, Fawcett, & Burkett (2015) found a significant pre to post improvement in gait speed with 19 participants using a Wii Fit balance training program. The control group showed a decline of 0.04 m/s. The intervention was administered three times per week for six weeks. The findings of their study support the results of our study as the decline in gait speed was observed among control group participants.

The literature also supports the idea that gait speed is responsive to exercise programs among community-dwelling older adults. A meta-analysis study to review the effects of physical exercise interventions in community-dwelling, frail older adults found that exercise improved gait speed (Mean difference of 0.07 m/s) when compared to a control group (Giné-Garriga, Roqué-Fíguls, Coll-Planas, Sitjà-Rabert, & Salvà, 2014).

It appears that Exergames may help improve physical functions including gait speed and could be used in conjunction with traditional exercise programs to enhance physical activity in the elderly. Further explorations into the characteristics of Exergames, and the design, frequency, nature of implementation, and social interactions can improve our understanding of the most effective ways of utilizing Exergames with the elderly.

Secondary Outcomes

The secondary outcomes of this study included the confidence in balance scores (Activities-Specific Balance Confidence Scale (ABC)) and fear of falls (Falls Efficacy Scale (FES)). Both scales were self-report, and no significant changes were observed pre, post or follow-up. Most of the participants were community-based, and all were ambulatory with no history of diagnosed balance disorders. It is possible that participants could have over-estimated their abilities and balance before the intervention. While the ABC is a scale used in various clinical populations related to balance issues it does not appear to have been validated for use with community living older adults.

A study done on the suitability of the ABC scale for older people living in the community found that scores were significantly different between activity avoiders and non-avoiders. The study also suggested that further research was necessary to explore the use of scale in high functioning older adults (Van-Heuvelen et al., 2005). Another study, by Talley, Wyman, and Gross (2008) conducted on psychometric properties of this scale reported limited responsiveness to change in non-frail elderly women. The findings also mentioned that the ABC scale might not be able to detect change in fear of falling in this age group A systematic review (Jorstad, Hauer, Clemens, and Lamb, 2015) done on fall-related psychological outcome measures mentioned that both ABC and FES have good evidence in terms of reliability, validity, and responsiveness. However, they also noted that there was limited evidence of the responsiveness of these constructs within different populations. Previous studies (e.g., Esculier, Vaudrin, Bériault, Gagnon, and Tremblay, 2012; Mhatre et al., 2014) also found that even when participants showed improvement in objective measures of balance, they did not report improvement in balance confidence when exergames were used as an intervention.

A possible limitation could be the sample size of our study which was determined based on scores of the functional scale of balance not on the subjective scales. We recommend future studies with a sample size calculation based on subjective scales.

Another important factor that may have influenced the self-perceived scoring is the weather. The study initiated in September 2017 when the weather was mild but by the end of the study in December 2017 there was substantial snow, and the temperature had dropped considerably. Many of the elderly participants mentioned decreased confidence when walking outside on icy sidewalks.

Limitations

The study was a randomized controlled trial with a repeated measure design conducted over nine weeks. It included assessments at pre-test, post-test, and follow-up. Extending the follow-up to six weeks would have given a better understanding of changes in balance. The number of participants was limited by recruitment and time, therefore a larger sample size would have increased the power and validity of the study. As this study is exploratory, the sample size is justifiably adequate in this instance. The participants were predominantly elderly females, without balance disorders, living in community and senior residences. Most of the participants were physically active but not enrolled in any formal exercise program. Therefore, these results cannot be generalized to a heterogeneous population of seniors, who sometimes have medical conditions that impact their balance or limit their inclusion in community activities and exercise programs.

The experiment used the same facility to conduct both exercise programs and collect data. It was, therefore, not feasible to blind subjects as to their assigned groups. Additionally, some participants were living in the same facility, so it was not possible to blind subjects to the treatment groups. Initially it was planned that the same researcher would evaluate the balance and gait speed test; however, due to availability and scheduling, two examiners conducted these tests. Despite using a standardized protocol, there could be an impact on the reliability of results. Although the same trainer conducted the majority of EBT sessions, three sessions were conducted by a substitute trainer who was familiar with the curriculum and assisted the lead trainers. Most of the CBT sessions were conducted by the same trainer except for a few afternoon sessions when the lead trainer was unavailable.

The FAB scale was considered as the primary measure of the postural balance and previously tested for its validity and reliability with community living older adults. Another advantage of the scale is that it does not have a ceiling effect, which is inherent in many other balance scales (Hernandez & Rose, 2008). COP excursion was measured using the Wii ® balance board as compared to laboratory grade force plate (gold standard). The balance board has the advantage of being portable and a cost-effective means to measure postural stability. Although the COP uncertainty of the balance board was slightly more than the force plate, it is still valid when measuring quiet stance movements (Bartlett et al., 2014). For more accurate measurements it is advisable to use laboratory grade equipment and applications.

The study also used a 3-meter walk test for gait speed to measure the dynamic aspect of balance. This test is a commonly used indicator of physical competency along with a prediction of survival in older adults (Hardy, Perera, Roumani, Chandler, & Studenski, 2007). The literature describes multiple ways to test gait speed by either modifying pace (slow, comfortable, and fast) or changing distances (3 meters, 4 meters, 5 meters, and 10 meters) (Middleton, Fritz, & Lusardi, 2016). We selected the comfortable speed and 3 meters' distance due to time limitations and the use of other variables in the study. For future studies, it is recommended that researchers use the gait assessment protocol given by Canadian Consortium on Neurodegeneration in Aging (CCNA) (Cullen et al., 2018).

The study also used self-reported scales to measure confidence in balance and fear of falling. Both scales were self-report and could be influenced by events outside the experiment. Weather changes can contribute to participants' confidence in their balance as adverse weather can result in decreased confidence. Like all self-reported questionnaires, there is an inherent risk of response bias and misunderstanding of the context of the questions. Including focus group interviews, in conjunction with self-reported measures, could increase the validity of the responses.

The primary intervention used in this study was Exergames using the Nintendo® Wii Fit U. Although this console is designed for all age groups, it is primarily used by the younger generation. The non-customization of these games to this age group was challenging in terms of technology adoption and learning new skills. Participants scored their performance and recorded it during the training. However, this scoring does not represent their physical abilities. Trusting game responses could have impacted their responses in terms of confidence in balance. The other limitation with the commercial exergames is the lack of control the clients have in terms of progression or modifications. The console used in the study only uses English for communication, user directions, and visuals. Hence, it was not suitable for individuals who are not English language proficient. Finally, many of the games required that participants stand on the Wii balance board which is slightly elevated. In some cases, participants required assistance getting up on the boards. No adverse events were reported in this study, but it can be challenging to use similar devices with clinical populations who have an increased risk of falling. For clinical populations, it is recommended that the environment be re-designed with harnesses and one-on-one supervision. This study did not address the psychosocial aspects of engagement during the interventions or how the use of technology influences attitudes, interactions, and performance.

Future Directions

Newer technologies such as Virtual Reality (VR), Exergames, and active video games (AVGs) are beginning to be used in healthcare and physical activity. The potential for positive change in balance and other fundamental movement skills, and motivation to participate is enormous. There is ongoing research globally and publications discussing the usability, applications, design considerations, and application in various health care situations (Molina, Ricci, de Moraes, & Perracini, 2014; Zhang & Kaufman, 2015). The current literature calls for more in-depth research studies with improved research design and validity. Further investigation in the form of high quality, randomized controlled trials will increase the quality of scientific evidence for expanding the use of these technologies.

Future research should also test interventions customized to the needs of participants. Technology is most effective when it is designed for the specific needs of users. Since the elderly have characteristics that differ from other age groups, exploring their perspectives and then using their input in design would increase the validity of the findings. Researchers should explore Exergames and other virtual reality applications in clinical populations before their inclusion in healthcare interventions. The majority of research completed, to date, is quantitative in nature. More qualitative research could improve our understanding of the field since subjective experience (e.g., compliance, motivation, enjoyment, capability) are essential parameters to consider. Older adults are getting more familiar with the technology, and therefore are more willing to consider technology-oriented opportunities to engage in physical activity. Use of these interventions could also be extended to addressing the challenges of a sedentary lifestyle in this population which may have the potential to reduce the associated risk factors.

Conclusion

The unique aspects of this project include the development of detailed activity curriculums for both interventions that were matched for the nature of the activity, length of training, and the size of the training group. These findings suggest that Nintendo® Wii Fit UTM Exergames can be used to improve postural balance in community-living older adults. However, the sustainability of these benefits and how they can be used in conjunction with other balance rehabilitation interventions still requires further research. The Exergames and virtual-reality based applications might be a new concept for many seniors. Therefore, the adaption and usability, among this age group should ensure their specific needs are met. Seniors, healthcare professionals, and support staff who work with this age group should partner in bringing these new interventions, in order to help provide effective, meaningful, and enjoyable ways of engaging in physical activity.

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Appendix A – Mini-Cog Instructions for Administration & Scoring

Mini-Cog™

Instructions for Administration & Scoring

ID: ____________ Date: ____________________

Step 1: Three Word Registration

Look directly at person and say, "Please listen carefully. I am going to say three words that I want you to repeat back to me now and try to remember. The words are [select a list of words from the versions below]. Please say them for me now." If the person is unable to repeat the words after three attempts, move on to Step 2 (clock drawing).

The following and other word lists have been used in one or more clinical studies.[1-3] For repeated administrations, use of an alternative word list is recommended.

Version 1	Version 2	Version 3	Version 4	Version 5	Version 6
Banana	Leader	Village	River	Captain	Daughter
Sunrise	Season	Kitchen	Nation	Garden	Heaven
Chair	Table	Baby	Finger	Picture	Mountain

Step 2: Clock Drawing

Say: "Next, I want you to draw a clock for me. First, put in all of the numbers where they go." When that is completed, say: "Now, set the hands to 10 past 11."

Use preprinted circle (see next page) for this exercise. Repeat instructions as needed as this is not a memory test. Move to Step 3 if the clock is not complete within three minutes.

Step 3: Three Word Recall

Ask the person to recall the three words you stated in Step 1. Say: "What were the three words I asked you to remember?" Record the word list version number and the person's answers below.

Word List Version: _____ Person's Answers: _______________ _______________ _______________

Scoring

Word Recall: _____ (0-3 points)	1 point for each word spontaneously recalled without cueing.
Clock Draw: _____ (0 or 2 points)	Normal clock = 2 points. A normal clock has all numbers placed in the correct sequence and approximately correct position (e.g., 12, 3, 6 and 9 are in anchor positions) with no missing or duplicate numbers. Hands are pointing to the 11 and 2 (11:10). Hand length is not scored. Inability or refusal to draw a clock (abnormal) = 0 points.
Total Score: _____ (0-5 points)	Total score = Word Recall score + Clock Draw score. A cut point of <3 on the Mini-Cog™ has been validated for dementia screening, but many individuals with clinically meaningful cognitive impairment will score higher. When greater sensitivity is desired, a cut point of <4 is recommended as it may indicate a need for further evaluation of cognitive status.

Appendix B – Sample Size Calculation

Sample Size Calculation

$$N = \frac{2SD^2\ (\mathrm{Z\alpha}\ +\ \mathrm{Z\beta})^2}{\Delta^2}$$

SD = Standard Deviation

Δ = Difference in Mean

The difference in mean used is the clinically significant change expected with improvement in postural balance on the Berg balance scale and the standard deviation used for sample calculation has been taken from previous literature (Whyatt et al., 2015). The sample size is calculated assuming a power of 80%, a 95% confidence interval.

$$N = \frac{2(6.40)^2\ (1.96\ +\ 0.84)^2}{(8)^2}$$

$$N = \frac{(81.92)\ (7.84)}{64}$$

$$N = 10.03 \approx 11$$

Appendix C – Physical Activity Readiness Questionnaire for Everyone

CSEP approved Sept 12 2011 version

PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

Regular physical activity is fun and healthy, and more people should become more physically active every day of the week. Being more physically active is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

SECTION 1 - GENERAL HEALTH

	Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1.	Has your doctor ever said that you have a heart condition OR high blood pressure?	☐	☐
2.	Do you feel pain in your chest at rest, during your daily activities of living, OR when you do physical activity?	☐	☐
3.	Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4.	Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?	☐	☐
5.	Are you currently taking prescribed medications for a chronic medical condition?	☐	☐
6.	Do you have a bone or joint problem that could be made worse by becoming more physically active? Please answer NO if you had a joint problem in the past, but it does not limit your current ability to be physically active. For example, knee, ankle, shoulder or other.	☐	☐
7.	Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.

Go to Section 3 to sign the form. You do not need to complete Section 2.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow the Canadian Physical Activity Guidelines for your age (www.csep.ca/guidelines).
- You may take part in a health and fitness appraisal.
- If you have any further questions, contact a qualified exercise professional such as a CSEP Certified Exercise Physiologist® (CSEP-CEP) or CSEP Certified Personal Trainer® (CSEP-CPT).
- If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the questions above, please GO TO SECTION 2.

Delay becoming more active if:

- You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
- You are pregnant – talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
- Your health changes – please answer the questions on Section 2 of this document and/or talk to your doctor or qualified exercise professional (CSEP-CEP or CSEP-CPT) before continuing with any physical activity programme.

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SECTION 2 - CHRONIC MEDICAL CONDITIONS

		Please read the questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1.		Do you have Arthritis, Osteoporosis, or Back Problems?	☐ If yes, answer questions 1a-1c	☐ If no, go to question 2
	1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/ or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	☐	☐
	1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	☐	☐
2.		Do you have Cancer of any kind?	☐ If yes, answer questions 2a-2b	☐ If no, go to question 3
	2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?	☐	☐
	2b.	Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?	☐	☐
3.		Do you have Heart Disease or Cardiovascular Disease? This includes Coronary Artery Disease, High Blood Pressure, Heart Failure, Diagnosed Abnormality of Heart Rhythm	☐ If yes, answer questions 3a-3e	☐ If no, go to question 4
	3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	3b.	Do you have an irregular heart beat that requires medical management? (e.g. atrial brillation, premature ventricular contraction)	☐	☐
	3c.	Do you have chronic heart failure?	☐	☐
	3d.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer YES if you do not know your resting blood pressure)	☐	☐
	3e.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	☐	☐
4.		Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes	☐ If yes, answer questions 4a-4c	☐ If no, go to question 5
	4a.	Is your blood sugar often above 13.0 mmol/L? (Answer YES if you are not sure)	☐	☐
	4b.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, and the sensation in your toes and feet?	☐	☐
	4c.	Do you have other metabolic conditions (such as thyroid disorders, pregnancy-related diabetes, chronic kidney disease, liver problems)?	☐	☐
5.		Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome)	☐ If yes, answer questions 5a-5b	☐ If no, go to question 6
	5a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	5b.	Do you also have back problems affecting nerves or muscles?	☐	☐

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	Please read the questions below carefully and answer each one honestly: check YES or NO.		YES	NO
6.	Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure		☐ If yes, answer questions 6a-6d	☐ If no, go to question 7
	6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	6b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	☐	☐
	6c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	☐	☐
	6d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	☐	☐
7.	Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia		☐ If yes, answer questions 7a-7c	☐ If no, go to question 8
	7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	7b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	☐	☐
	7c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	☐	☐
8.	Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event		☐ If yes, answer questions 8a-c	☐ If no, go to question 9
	8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	8b.	Do you have any impairment in walking or mobility?	☐	☐
	8c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	☐	☐
9.	Do you have any other medical condition not listed above or do you live with two chronic conditions?		☐ If yes, answer questions 9a-c	☐ If no, read the advice on page 4
	9a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months OR have you had a diagnosed concussion within the last 12 months?	☐	☐
	9b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	☐	☐
	9c.	Do you currently live with two chronic conditions?	☐	☐

Please proceed to Page 4 for recommendations for your current medical condition and sign this document.

PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active:

- It is advised that you consult a qualified exercise professional (e.g., a CSEP-CEP or CSEP-CPT) to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually – 20-60 min. of low- to moderate-intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate-intensity physical activity per week.
- If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the follow-up questions about your medical condition:

- You should seek further information from a licensed health care professional before becoming more physically active or engaging in a fitness appraisal and/or visit a or qualified exercise professional (CSEP-CEP) for further information.

Delay becoming more active if:

- You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise profesional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
- Your health changes - please talk to your doctor or qualified exercise professional (CSEP-CEP) before continuing with any physical activity programme.

SECTION 3 - DECLARATION

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The Canadian Society for Exercise Physiology, the PAR-Q+ Collaboration, and their agents assume no liability for persons who undertake physical activity. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.
- Please read and sign the declaration below:

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that they maintain the privacy of the information and do not misuse or wrongfully disclose such information.

NAME ____ DATE ____________________________________

SIGNATURE _______________________________WITNESS ____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ____

For more information, please contact:
Canadian Society for Exercise Physiology
www.csep.ca

KEY REFERENCES

1. Jamnik VJ, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the eectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or BC Ministry of Health Services.

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Appendix D – Effects of Structured Exergaming in Older Adults Screening Questionnaire

UNIVERSITY OF
CALGARY

FACULTY OF KINESIOLOGY

Sport Technology Research Lab
2500 University Drive NW
Calgary, AB, Canada T2N 1N4
ucalgary.ca

Effects of Structured Exergaming in Older Adults
Screening Questionnaire

Date:______________________

Thank you for working with the Sports Technology Research Laboratory regarding our study on the effects of exercise programs in older adults. The participants will follow a six-week exercise program. During the six-week period, there are three sessions each week. Each session will last 30-45 minutes. If you are interested to participate in this study I would like to ask you few questions to make sure that you fit the criteria. All the data collected will be kept confidential.

1. Name:______________________________Age:________

2. How did you hear about this study?
   a. Recruitment Poster b. U of C website c. Family/Friend d. Other

3. Living Setting:
   a) Independent/Community
   b) Senior Residents
   c) Assisted Living/Nursing Home

4. Do you own or have access to a gaming console(e.g. Microsoft X Box/ Play Station/ Wii Fit)?
   Yes No

5. Do you regularly perform any kind of Physical activity?

   Yes No

UNIVERSITY OF CALGARY

FACULTY OF KINESIOLOGY

Sport Technology Research Lab
2500 University Drive NW
Calgary, AB, Canada T2N 1N4
ucalgary.ca

6. If "Yes"?

Explain the type of activity (ies):

____

____

____

____

Total Weekly Duration: ___________

7. Did you participate in any regular physical activity program in last 3 months?

   Yes No

8. Do you have problems with Balance?

   Yes No

9. If "Yes", Have you ever been diagnosed with a Balance disorder such as Positional Vertigo, Labyrinthitis, Motion Sickness, Multiple Sclerosis, Parkinsonism or Cancer?

   Yes No

10. Did you experience any falls in the last year?

    Yes No

11. If Yes, How many incidences of falls in the last year?___________

12. How do you rate your balance abilities?

    a) Excellent b) Good c) Fair d) Poor

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13. Smoking Status:
    a) Never smoked b) Quit Smoking c) Currently Smoke

14. Do you regularly consume alcohol?
    a. Yes b. No

15. If "Yes"?

    Type ____

    Quantity and Frequency ____

16. Occupation: __________________________

17. Employment Status
    a. Employed b. Not employed

18. When did you begin living in an urban setting?
    a. Childhood b. Young Adulthood c. Presently

19. Can you please provide us with your contact details?

    Postal Address____

    Email Address____

    Phone____

20. What is your preferred method of communication?
    a. Email b. Phone call c. Text Message d. Other_______________

We appreciate your time and interest,

Sport Technology Research Lab

Appendix E – Active Videogame Training

Keep difficulty at "BEGINNER" level OR progress to "PROFESSIONAL" if desire to increase the intensity

WII FIT U WORKOUT (~30-40 minutes, includes instruction time)

ROUTINE:

• WARM UP (3 minutes)

- Use **<u>Free Step</u>** as a warm-up.
    - Participants free step (on and off) using a balance board. Allows a sense of control on activity intensity.
    - Requires: Wii Balance Board
    - Difficulty Level: Easy

- After 3 weeks, group can progress to **<u>Basic Step</u>**:
    - Step to the front, back, left, and right on the balance board to improve your sense of rhythm.
    - Requires: Wii Balance Board
    - Difficulty Level: Moderate

• FLEXIBILITY GAME (5 minutes)

- Use **<u>Sun Salutation</u>** as a Flexibility exercise.

- Participants perform a yoga sun salutation which stretches back and tones arms and thighs.
- Requires: Balance Board
- Difficulty Level: Moderate



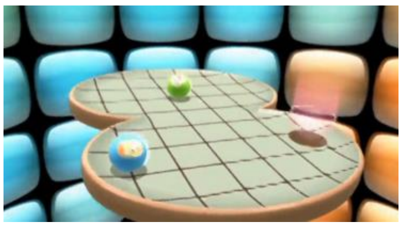
• STATIC BALANCE (5 minutes)

- Use **Hula Hoop** as a Static Balance exercise.
  - Stand strong on the balance board. Sway your hips to spin the Hula Hoop. Helps pelvis alignment.
  - Difficulty Level: Easy


- After 3 weeks, group can progress into **Super Hula Hoop:**
  - Advanced Hula Hoop with more calories burning.
  - Difficulty Level: Moderate

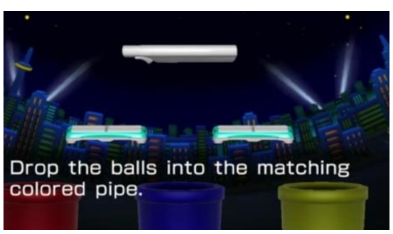

• STATIC BALANCE (OPTIONAL - 5 minutes)

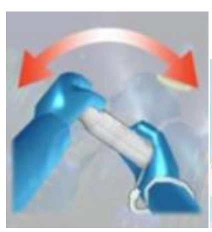
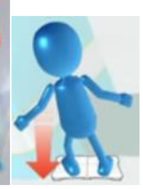
- Use **<u>Table Tilt</u>** as a Static Balance exercise.
    - Lean your body left, right, and forward, and backward to drop different colored ball in their respective colored holes.
    - Difficulty level: Difficult




• STATIC BALANCE (OPTIONAL - 5 minutes)

- Use **<u>Tilt City</u>** as a Static Balance / Coordination exercise.
    - Lean your body left, right, and forward, and backward to drop different colored ball in their respective colored holes.
    - Difficulty level: Difficult




• DYNAMIC BALANCE (5 minutes)

- Use **<u>Ski Slalom</u>** as a Dynamic Balance exercise.
    - Participants lean left and right on the balance board to go through the gates. Also helps with coordination and strength as well.
    - Requires: Wii Balance Board
    - Difficulty level: Moderate


DYNAMIC BALANCE (5 minutes)

- Use **<u>Trampoline Target</u>** as a Dynamic Balance exercise.
    - Participants squat up and down and step on the balance board. Also helps with coordination and strength as well.
    - Requires: Wii Balance Board
    - Difficulty level: Moderate


DYNAMIC BALANCE (5 minutes)

- Use **<u>Bird's Eye Bull's Eye</u>** as a Dynamic Balance exercise.
    - Participants will flap their arms on the balance board. Also helps with coordination as well.
    - Requires: Wii Balance Board
    - Difficulty level: Moderate

• STRENGTH (6 minutes)

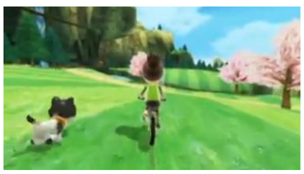
- Use **Rowing Squat** as a Strength exercise.
  - Builds your thigh and back muscles to help promote good posture.
  - Requires Wii Balance Board
  - Difficulty Level: moderate to difficult (intensity)

- Use **Side Lunge (OPTIONAL)** as a Strength exercise.
  - Helps strengthen inner thighs
  - Requires Wii Balance Board
  - Difficulty Level: moderate to difficult (intensity)

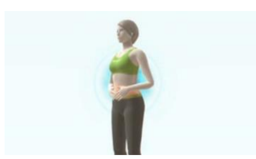
• COORDINATION (5 minutes)

- Use **Island Cycling** as a Coordination exercise.
    - Cycle through an island by maintaining constant pedaling through rhythmic left and right steps on the balance board. At the same time, use the Wii remote to steer through the island. Helps strengthen lower body.
    - Requires: Wii Balance Board, Wii remote
    - Difficulty level: Moderate to difficult



COOL DOWN (2 minutes)

- Use **Deep Breathing** as a Cool Down exercise.
    - Use a popular yoga deep breathing method to help improve metabolism.
    - Requires: Wii Balance Board
    - Difficulty level: Easy



Appendix F – Scoring Form for Fullerton Advanced Balance (FAB) Scale

California State University, Fullerton
Center for Successful Aging

Scoring Form for Fullerton Advanced Balance (FAB) Scale

Name: ______________________________ Date of Test: ____________

1. Stand with feet together and eyes closed

( ) 0 Unable to obtain the correct standing position independently

( ) 1 Able to obtain the correct standing position independently but unable to maintain the position or keep the eyes closed for more than 10 seconds

( ) 2 Able to maintain the correct standing position with eyes closed for more than 10 seconds but less than 30 seconds

( ) 3 Able to maintain the correct standing position with eyes closed for 30 seconds but requires close supervision

( ) 4 Able to maintain the correct standing position safely with eyes closed for 30 seconds

2. Reach forward to retrieve an object (pencil) held at shoulder height with outstretched arm

( ) 0 Unable to reach the pencil without taking more than two steps

( ) 1 Able to reach the pencil but needs to take two steps

( ) 2 Able to reach the pencil but needs to take one step

( ) 3 Can reach the pencil without moving the feet but requires supervision

( ) 4 Can reach the pencil safely and independently without moving the feet

3. Turn 360 degrees in right and left directions

( ) 0 Needs manual assistance while turning

( ) 1 Needs close supervision or verbal cueing while turning

( ) 2 Able to turn 360 degrees but takes more than four steps in both directions

( ) 3 Able to turn 360 degrees but unable to complete in four steps or fewer in one direction

( ) 4 Able to turn 360 degrees safely taking four steps or fewer in both directions

***4. Step up onto and over a 6-inch bench**

( ) 0 Unable to step up onto the bench without loss of balance or manual assistance

( ) 1 Able to step up onto the bench with leading leg, but trailing leg contacts the bench or leg swings around the bench during the swing-through phase in both directions

( ) 2 Able to step up onto the bench with leading leg, but trailing leg contacts the bench or swings around the bench during the swing-through phase in one direction

( ) 3 Able to correctly complete the step up and over in both directions but requires close supervision in one or both directions

( ) 4 Able to correctly complete the step up and over in both directions safely and independently

Revised Sept 2008 (DR)

***5. Tandem walk**

( ) 0 Unable to complete 10 steps independently
( ) 1 Able to complete the 10 steps with more than five interruptions
( ) 2 Able to complete the 10 steps with three to five interruptions
( ) 3 Able to complete the 10 steps with one to two interruptions
( ) 4 Able to complete the 10 steps independently and with no interruptions

***6. Stand on one leg**

( ) 0 Unable to try or needs assistance to prevent falling
( ) 1 Able to lift leg independently but unable to maintain position for more than 5 seconds
( ) 2 Able to lift leg independently and maintain position for more than 5 but less than 12 seconds
( ) 3 Able to lift leg independently and maintain position for 12 or more seconds but less than 20 seconds
( ) 4 Able to lift leg independently and maintain position for the full 20 seconds

***7. Stand on foam with eyes closed**

( ) 0 Unable to step onto foam or maintain standing position independently with eyes open
( ) 1 Able to step onto foam independently and maintain standing position but unable or unwilling to close eyes
( ) 2 Able to step onto foam independently and maintain standing position with eyes closed for 10 seconds or less
( ) 3 Able to step onto foam independently and maintain standing position with eyes closed for more than 10 seconds but less than 20 seconds
( ) 4 Able to step onto foam independently and maintain standing position with eyes closed for 20 seconds

Do not introduce test item #8 if test item #4 was not performed safely and/or it is contraindicated to perform this test item (review test administration instructions for contraindications). Score a zero and move to next test item.

8. Two-footed jump

( ) 0 Unwilling or unable to attempt or attempts to initiate two-footed jump, but one or both feet do not leave the floor
( ) 1 Able to initiate two-footed jump, but one foot either leaves the floor or lands before the other
( ) 2 Able to perform two-footed jump, but unable to jump farther than the length of their own feet
( ) 3 Able to perform two-footed jump and achieve a distance greater than the length of their own feet
( ) 4 Able to perform two-footed jump and achieve a distance greater than twice the length of their own feet

9. Walk with head turns

( ) 0 Unable to walk 10 steps independently while maintaining 30° head turns at an established pace

( ) 1 Able to walk 10 steps independently but unable to complete required number of 30° head turns at an established pace

( ) 2 Able to walk 10 steps but veers from a straight line while performing 30° head turns at an established pace

( ) 3 Able to walk 10 steps in a straight line while performing 30° head turns at an established pace but head turns less than 30° in one or both directions

( ) 4 Able to walk 10 steps in a straight line while performing required number of 30° head turns at established pace

10. Reactive postural control

( ) 0 Unable to maintain upright balance; no observable attempt to step; requires manual assistance to restore balance

( ) 1 Unable to maintain upright balance; takes two or more steps and requires manual assistance to restore balance

( ) 2 Unable to maintain upright balance; takes more than two steps but is able to restore balance independently

( ) 3 Unable to maintain upright balance; takes two steps but is able to restore balance independently

( ) 4 Unable to maintain upright balance but able to restore balance independently with only one step

TOTAL: 40 POINTS

<u>Evaluating Risk for Falls</u>:

Long Form Fullerton Advanced Balance (FAB) scale Cut-Off Score: ≤ 25/40 Points

Short-Form Fullerton Advanced Balance (FAB) scale Cut-Off Score: ≤ 9/16 Points

Appendix G – Gait Speed (self-selected)

Test Protocol: Measure and mark a standard distance, e.g. 3 meters. Then measure and mark one meter before the start, and one meter after the end. Put cones at the starting line and the finish line.

Gait Speed = distance / time   e.g. 3 meters / __ sec.

Instructions: “Walk at a comfortable pace”.

Participant’s performance: _________ seconds

Calculated gait speed: _________ m/sec

e.g. the person takes 8.5 seconds to walk 5 meters - 5/8.5 = 0.6 m/sec = Limited community ambulator

Interpretation:

Less than 0.4 m/sec: Household ambulatory

0.4 to 0.8 m/sec: Limited community ambulator

0.8 to 1.2 m/sec: Community ambulator

1.2 m/sec and above: Able to safely cross streets

Appendix H - Effects of Structured Exercise Programs in Older Adults Score Sheet

Effects of Structured Exercise Programs in Older Adults

Score Sheet

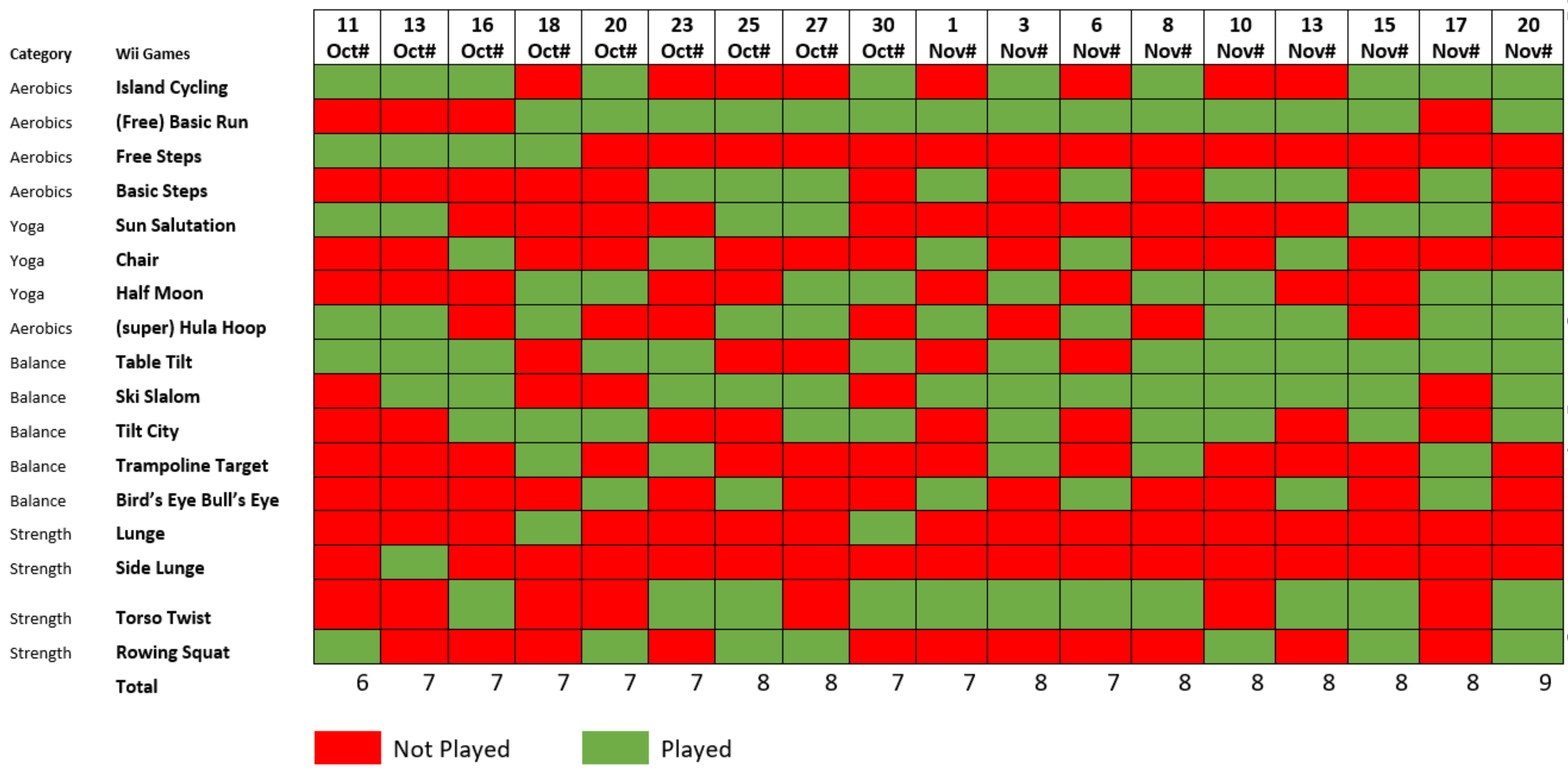
Name: ______________________________ **Date: _____________________**

SESSION 18:

Category	Game	Score 1	Score 2	Score 3
Aerobics	**Free Run** **(3 Minutes)**		X	X
Aerobics	**Super Hula Hoop**			
Strength	**Torso Twist** **(Add weights)**			
Balance	**Ski Slalom**			
Balance	**Table Tilt** **(Increased difficulty level)**			
Balance	**Tilt City**			
Strength	**Rowing Squat**			
Yoga	**Half Moon**			
Aerobics	**Island Cycling** **(Long Course - 5 Minutes)**		X	X

Appendix I – List of Exergames played in training sessions

Exercises Played and Not Played during 11 October – 20 November 2018



Appendix J – Structured Curriculum for Exercise Programs

STRUCTURED CURRICULUM FOR EXERCISE PROGRAMS

Objective: The curriculum is aimed to improve the physical fitness components of older adults by applying the exercise prescription guidelines and mixing different types of exercises.

Duration: The participants actively participated in 6 weeks training program. There were 3 sessions each week for a total of 18 sessions in six weeks. Each session lasts for 40 minutes approximately.

Types: Both programs followed the standard guidelines for fitness training programs and included warm up, strengthening, flexibility, and balance and coordination exercises.
Progression: The exercises should progress in terms of repetitions and addition of exercises in each sub component on bi weekly basis or participants pace.

Equipment: Gym mats, Weights (1lb., 2lbs., 3lbs), elastic bands, foam sticks and chair without arm rests.

Activities Summary:

Activity	Duration	Objective
Warm up exercises	5 Minutes	Warm Up
Strengthening Exercises	10 Minutes	Muscle Strength
Break	1 Minute	Rest
Balance Exercises	10 Minutes	Balance and Coordination
Stretching	10 Minutes	Flexibility
Breathing Exercises	5 Minutes	Cool Down
Total: 40 Minutes Approx.		

General Precautions:

Advise these precautions in the start of each session;

- Never holding breath when performing exercises.
- Taking a snack half an hour before the activity, if diabetic.
- Stopping in case of any unusual pain, chest tightness, breathlessness fatigued and reporting to the instructor immediately.
- Following instructor guidelines, ask if there is any question.

WEEK 1 (Day 1, Day 2, Day 3) and WEEK 2 (Day 4, Day 5, Day 6)

(a) Warm Up

1. Static Stepping (20 steps), 1 Set

2. Trunk Rotations (Right and Left) 12 repetitions, 2 Sets

3. Arm Circles Forward/Backward, 12 repetitions, 1 Set

4. Wrist Circles Forward/Backward, 12 repetitions, 1 Set

5. Arm Scissors, 12 repetitions, 1 Set

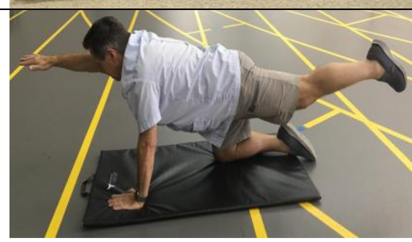
6. High Knees Marching, 20 repetitions, 2 Sets

(b) Strengthening Exercises

	Muscle Group	Type	Repetitions / Sets
1	Gluteus Medius		12 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body.
2	Quadriceps		12 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body.
4	Gluteus Maximus		12 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body.
5	Hamstrings		12 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body.

(c) Balance and Coordination Exercises 

Take 15 seconds break when moving from one exercise to other.

1	Bridging		10 reps (2 Sets). Maintain position for 10 seconds on the 10th rep.
3	Bird-dog		
2	Sit to Stand to Sit		12 reps (2 Stes)
4	Stepping in all directions (forward, side and backward)		3 Times. Step in all directions without losing balance.
5	Biceps Curls		10 Reps. 3 Sets. 3 Lbs dumbells

(d) Flexibility Exercises

Stretch following muscles using 15 second hold. Assume the shown position and feel the gentle stretch. 2 Repetitions each side of body. Keep breathing during the stretching.

1	Hamstrings	
2	Gluteus Maximus	
3	Gastrocnemius and Soleus	
4	Lumbar Paraspinals	
5	Shoulders	

(e) Cool Down

1. Static Stepping (10 steps) 2 Sets

2. Controlled Breathing: 1 minute. Breathe in slowly and deeply through the nose. Keep the shoulders relaxed and upper chest quiet, allowing the abdomen to rise slightly. Relax and exhale slowly through the mouth.

WEEK 3 (Day 7, Day 8, Day 9) and WEEK 4 (Day 10, Day 11, Day 12)

(a) Warm Up

1. Static Stepping (20 steps), 1 Set

2. Trunk Rotations (Right and Left) 12 repetitions, 2 Sets

3. Arm Circles Forward/Backward, 12 repetitions, 1 Set

4. Wrist Circles Forward/Backward, 12 repetitions, 1 Set

5. Arm Scissors, 12 repetitions, 1 Set

6. High Knees Marching, 20 repetitions, 2 Set

(b) Strengthening Exercises

	Muscle Group	Type	Repetitions / Sets
1	Gluteus Medius		10 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body. With 1 lb. - 3lb. weight.
2	Quadriceps		10 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body. Hold for 5 seconds. With 1 lb. - 3lb. weight.
3	Core Strengthening TA activation (drawing in maneuver with posterior pelvic tilt)		5 reps (3 Sets). Hold 5 Seconds.
4	Gluteus Maximus		10 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body. With 1 lb. - 3lb. weight.
5	Hamstrings		10 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body. With 1 lb. - 3lb. weight.
6	Biceps Curl		10 Reps. 3 Sets. 5 Lbs Dumbells

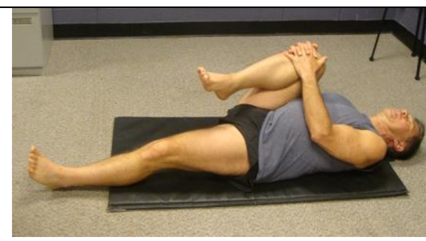
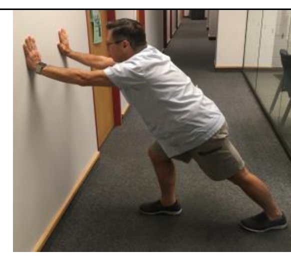
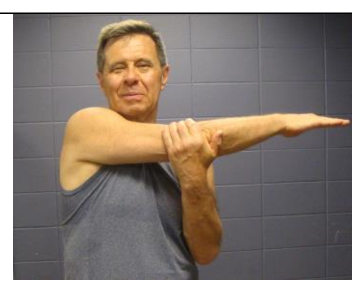
(c) Balance and Coordination Exercises

Take 30 seconds break when moving from one exercise to other.

1	Bridging		5 Times. Maintain position for 5 seconds.
2	Sit to Stand to Sit	 	5 Times. If unable to perform, use chair with arm rests for support.
3	Stepping in all directions (forward , side and backward)	 	5 Times. Step in all directions without losing balance.
4	Walking on a track		Five rounds on marked track with comfortable pace. Take break if required in between.
5	Tandem Walking		Take five steps and then come back to start positions. Two rounds
6	Lunges		5 Repetitions. 10 Seconds hold.

(d) Flexibility Exercises 

Stretch following muscles using 20 second hold. Assume the shown position and feel the gentle stretch. 5 Repetitions each side of body. Keep breathing during the stretching. Count loud to 20.

1	Hamstrings	
2	Gluteus Maximus	
3	Gastrocnemius and Soleus	
4	Lumbar Paraspinals	
5	Shoulders	

(e) Cool Down

Static Stepping (10 steps) 2 Sets

Controlled Breathing: 1 minute. Breathe in slowly and deeply through the nose. Keep the shoulders relaxed and upper chest quiet, allowing the abdomen to rise slightly. Relax and exhale slowly through the mouth.

WEEK 5 (Day 13, Day 14, Day 15) and WEEK 6 (Day 16, Day 17, Day 18)

(a) Warm Up 

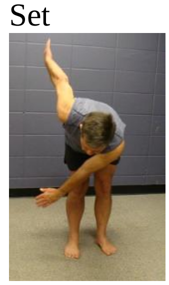
2. Static Stepping (20 steps), 1 Set

7. Trunk Rotations (Right and Left) 12 repetitions, 2 Sets

8. Arm Circles Forward/Backward, 12 repetitions, 1 Set

9. Wrist Circles Forward/Backward, 12 repetitions, 1 Set

10. Arm Scissors, 12 repetitions, 1 Set



11. High Knees Marching, 20 repetitions, 2 Set

(b) Strengthening Exercises 

	Muscle Group	Type	Repetitions / Sets
1	Gluteus Medius		10 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body. With 3 lb. – 5 lb. weight.
2	Quadriceps		10 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body. Hold for 5 seconds. With 3 lb. – 5 lb. weight.
3	Core Strengthening TA activation (drawing in maneuver with posterior pelvic tilt)		5 reps (3 Sets). Hold 5 Seconds.
4	Gluteus Maximus		10 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body. With 3 lb. – 5 lb. weight.
5	Hamstrings		10 reps (2 Sets) Take 15 seconds break between sets. Perform on both sides of body. With 3 lb. – 5 lb. weight.
6	Biceps Curls		10 Reps. 3 Sets. 3 Lbs dumbells

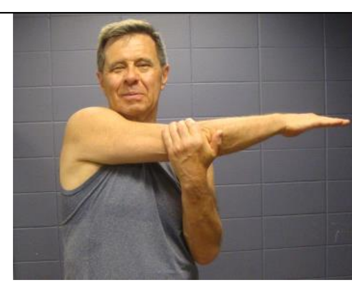
(c) Balance and Coordination Exercises

Take 30 seconds break when moving from one exercise to other.

1	Bridging		15 Times. 3 Sets of 5 Reps. Maintain position for 5 seconds.
2	Sit to Stand to Sit		10 Times. If unable to perform, use chair with arm rests for support.
3	Stepping in all directions (forward , side and backward)		10 Times. Step in all directions without losing balance.
4	Walking on a track		Five rounds on marked track with comfortable pace. Take break if required in between.
5	Tandem Walking		Take ten steps and then come back to start positions. Two rounds
6	Lunges		5 Repetitions. 10 Seconds hold. Holding 1 lb. – 3lbs. dumbbells in hands.

(d) Flexibility Exercises 

Stretch following muscles using 20 second hold. Assume the shown position and feel the gentle stretch. 5 Repetitions each side of body. Keep breathing during the stretching. Count loud to 20.

1	Hamstrings	
2	Gluteus Maximus	
3	Gastrocnemius and Soleus	
4	Lumbar Paraspinals	
5	Shoulders	

(e) Cool Down

Static Stepping (10 steps) 2 Sets

Controlled Breathing: 1 minute. Breathe in slowly and deeply through the nose. Keep the shoulders relaxed and upper chest quiet, allowing the abdomen to rise slightly. Relax and exhale slowly through the mouth.

Appendix K – Activities-specific Balance Confidence (ABC) Scale

Patient Name: ________________________________ **Date:** ________________

The Activities-specific Balance Confidence (ABC) Scale*

<u>Instructions to Participants:</u> For each of the following activities, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady from choosing one of the percentage points on the scale from 0% to 100% If you do not currently do the activity in question, try and imagine how confident you would be if you had to do the activity. If you normally use a walking aid to do the activity or hold onto someone, rate your confidence as if you were using these supports.

0%	10	20	30	40	50	60	70	80	90	100%
No Confidence										Completely Confident

How confident are you that you will <u>not</u> lose your balance or become unsteady when you…

1. …walk around the house? _____%
2. …walk up or down stairs? _____%
3. …bend over and pick up a slipper from the front of a closet floor? _____%
4. …reach for a small can off a shelf at eye level? _____%
5. …stand on your tip toes and reach for something above your head? _____%
6. …stand on a chair and reach for something? _____%
7. …sweep the floor? _____%
8. …walk outside the house to a car parked in the driveway? _____%
9. …get into or out of a car? _____%
10. …walk across a parking lot to the mall? _____%
11. …walk up or down a ramp? _____%
12. …walk in a crowded mall where people rapidly walk past you? _____%
13. …are bumped into by people as you walk through the mall? _____%
14. …step onto or off of an escalator while you are holding onto a railing? _____%
15. …step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing? _____%
16. …walk outside on icy sidewalks? _____%

*Powell LE & Myers AM. The Activities-specific Balance Confidence (ABC) Scale. Journal of Gerontology Med Sci 1995; 50(1):M28-34.

Total ABC Score: __________

Scoring: ____________ **/ 16 =** | __________% of self confidence |
Total ABC Score

MEDICARE PATIENTS ONLY
100% - _____% Function = _____% Impairment

Patient Signature: ________________________________ **Date:** ________________

Therapist Signature: ______________________________ **Date:** ________________

Appendix L – Falls Efficacy Scale

Falls Efficacy Scale

Name:__________________________________ Date:_________________

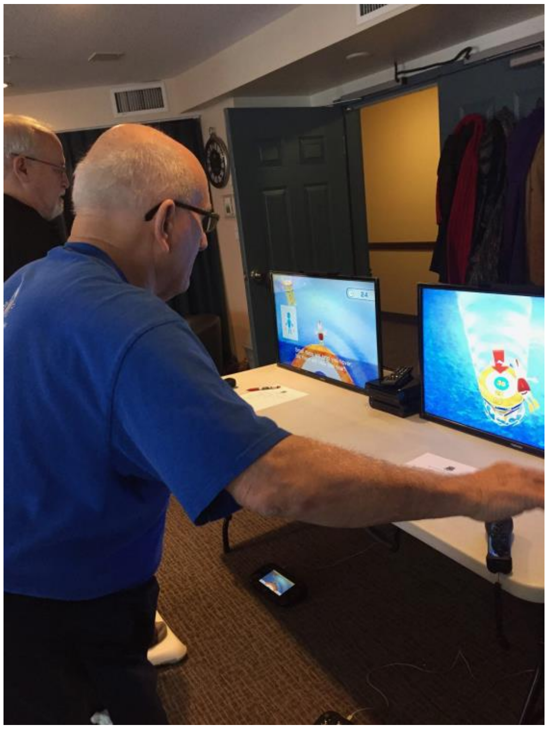
On a scale from 1 to 10, with 1 being very confident and 10 being not confident at all, how confident are you that you do the following activities without falling?

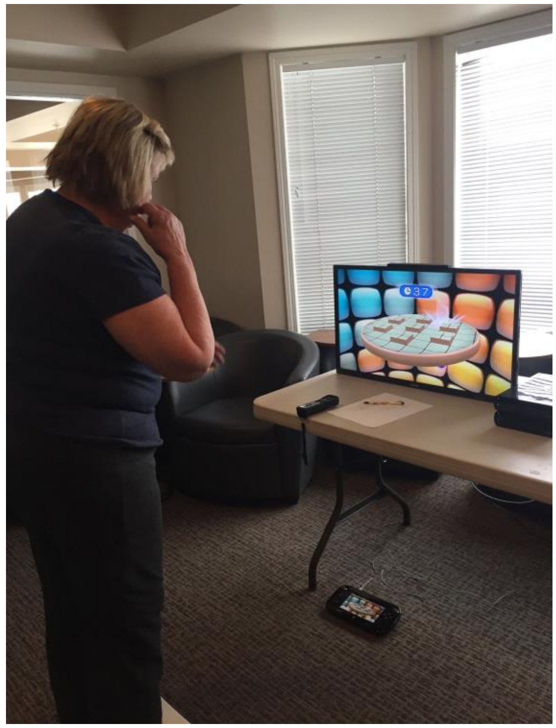
Activity:	**Score:** 1 = very confident 10 = not confident at all
Take a bath or shower	
Reach into cabinets or closets	
Walk around the house	
Prepare meals not requiring carrying heavy or hot objects	
Get in and out of bed	
Answer the door or telephone	
Get in and out of a chair	
Getting dressed and undressed	
Personal grooming (i.e. washing your face)	
Getting on and off of the toilet	
Total Score	

A total score of greater than 70 indicates that the person has a fear of falling

Adapted from Tinetti et al (1990)

Appendix M – Participants Playing Exergames & Doing Strengthening Exercises





Participants playing Exergames on Nintendo® Wii Fit U ™ station

Participants doing strengthening exercises with weights

Set up for supervised session in CBT group

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Study Title: Effects of Structured Exergaming Curriculum on Postural Balance in Older Adult Study

Objectives: The objective of this study is to determine if a structured curriculum of Exergames in older adults would improve postural balance, confidence in balance and fear of falling when compared to conventional balance training program and controls.

Source of Funding: Sports Technology Research Laboratory, University of Calgary

Name of PI: Dr. Larry Katz