THE EFFECT OF EXERGAMING USE ON THE ENHANCEMENT OF THE PSYCHO-MOTOR COMPONENT OF PHYSICAL LITERACY

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Abstract

A proposed use of exergaming is the enhancement of a child's physical literacy. Physical literacy is defined as the fundamental physical, cognitive, and affective skills that are necessary for a person to confidently participate in physical activity. This study determined whether or not an exergaming intervention could improve physical literacy, specifically the psycho-motor component of agility, balance, and coordination among six to nine year old children.

Pre and post-tests of agility, balance and coordination were compared for a control group and an experimental group. The experimental group completed an exergaming intervention that consisted of 12, 30-minute exergaming sessions spread out over seven and a half weeks. The experimental group demonstrated an improvement in agility ($p = 0.02$) whereas the control group showed none. There was no improvement found in either group in balance or coordination. More research is required to further explore the relationship between exergaming and physical literacy.

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List of Abbreviations

AHKC – Active Healthy Kids Canada

ANOVA – Analysis of Variance

AVG – Active Video Games

CSEP – Canadian Society of Exercise Physiology

CS4L - Canadian Sport for Life

LTAD – Long-term Athlete Development

Chapter 1: Introduction

1.1 Background of Study

We currently live in a society where technology is constantly evolving, improving and exerting a greater influence in our lives. From television, computers to new cutting edge tablets and touch screens, technology is being used in almost every aspect of daily life. As use of new technologies becomes more and more popular, it is only natural that technologies are also developed for use during physical activity. With the combination of already existing video games and new motion detecting technology comes the development of exergaming: the combination of gaming and exercise. Exergaming uses motion detecting technology to make the player's own body the joystick to control and play video games (Vander Schee & Boyles, 2010). The emergence of this new technology begs the question: is it a viable way to increase physical activity in an age where screen activities dominate over traditional exercise?

Based on previous research, exergaming has been used in a variety of other environments such as rehabilitation centres, school physical education classes, recreation centres and senior's complexes (Fogel, Miltenberger, Graves & Koehler, 2010; O'Huiginn, Smyth, Coughlan, Fitzgerald & Caulfield, 2009; & Vander Schee & Boyles, 2010). It is suggested that exergaming can also be a tool to increase physical activity in children in two ways. One, exergaming can be used to encourage physical activity in children when they are not interested in traditional sports (Graves, Ridgers & Stratton, 2008). Since exergaming combines popular video games and exercise, it could target the population of children that may not participate in physical activity but could increase their physical activity via exergames (Mears & Hansen, 2009). Two, exergaming can be used a means to enhance a child's development of physical literacy (Sheehan & Katz, 2010).

Canadian Sport for Life (CS4L) defines physical literacy as: "*the development of fundamental movement skills and fundamental sport skills that permit a child to move confidently and with control, in a wide range of physical activity, rhythmic (dance) and sport situations"* (2008). The development of physical literacy is an important building block of any child's development, necessary for future participation in any physical activity (Whitehead, 2001).While past research has deemed the development of physical literacy as crucial to a child's development (Higgs, 2010 &Whitehead, 2001), there is currently little research on the link or influence of exergaming on physical literacy.

1.2 Purpose of Study

The purpose of this study is to determine whether or not the use of exergaming can enhance the development of the psycho-motor component of physical literacy. For the purpose of this thesis, the Nintendo Wii gaming system exergames were used and activities that measured agility, balance and coordination were used to represent fundamental skills of physical literacy. Released in 2006, the Nintendo Wii system is an interactive gaming system that uses physical movements from the player to translate into action in the Wii games. The Nintendo Wii has been used in a variety of settings such as a form of entertainment, as a physical rehabilitation tool, as a recreational activity for seniors and as a form of physical activity for school-aged children (De Bruin, Schoene, Pichierri, & Smith, 2010; Duncan & Staples, 2010; O'Huiginn et al.,2009;

Vander Schee & Boyles, 2010).

1.3 Significance of Study

It was estimated in 2010 that over 42 million children under the age of five were overweight throughout the world, and almost one in three Canadian children was either overweight or obese (Candeias, Armstrong & Xuereb, 2010 & He, Harris, Piché & Beynon, 2009). This problem in part is due to the fact that children today are participating less in physical activity (Active Healthy Kids Canada, 2012). The annual 2009 Active Healthy Kids Canada Report gave Canadian children a grade of "F" in physical activity since only 13% of Canadian youth are participating in the recommended sixty minutes of physical activity per day (Sheehan & Katz, 2010).

Physical literacy has been identified as vital to a child's development. If children are more comfortable and confident in physical situations they are more likely to participate in physical activity (Sheehan & Katz, 2010). If the development of physical literacy can help children develop the necessary movement and sport skills to grow up in an environment where they lead active and healthy lives, then perhaps Canadians can better combat the growing problems of increased sedentary behaviours and obesity (Higgs, 2010).

Chapter 2: Literature Review

2.1 Introduction

The prevalence of overweight and obese children is a worldwide health problem. It has been determined there is an increased prevalence of overweight and obese youth in today's society, and the occurrence of this issue has increased drastically in the last several decades (Bailey & McInnis, 2011). In Canada, shocking information about the sedentary lifestyles of Canadian youth has been revealed (AHKC, 2012). The annual 2009 Active Healthy Kids Canada Report gave Canadian children a grade of "F" in physical activity since only 13% of Canadian youth are participating in the recommended sixty minutes of physical activity per day (Sheehan & Katz, 2010). The alarming rate at which obesity is rising is affecting the short and long term health of children as this increase puts them at much higher risk for unfavourable health conditions such as cardiovascular disease, diabetes and chronic respiratory diseases (Candeias et al., 2010). According to Bailey and McInnis (2011), this trend is also troubling since in addition to adverse health implications, childhood and adolescent obesity continues into early adulthood; youth who are overweight as adolescents will have a harder time maintaining a healthy weight as adults.

There is an increased use of screen technologies such as computers, televisions and video games among youth (He et al., 2009). Youth today see technology as an integral part of their lives and, as such, screen technologies dominate how children spend their spare time as compared to time that could be spent participating in physical activity (Sheehan & Katz, 2010). It is reported that children spend an average of approximately

49 minutes a day playing video games and up to two hours a day participating in other screen activities such as television viewing or computer use (Daley, 2009 & Hansen & Sanders, 2010). It is well documented that there is a positive and prevailing relationship between obesity and screen activities, with higher weight status correlating with a greater time spent participating in video gaming (Bailey & McInnis, 2011 & Russell, 2009).

Exergaming combines traditional video games and exercise, where the player of the game interactively controls the game using body movements (Vander Schee & Boyles, 2010). It is proposed that exergaming can potentially enhance a player's physical literacy, thus increasing confidence in their physical abilities and increasing the likelihood of long-term participation in physical activity (Sheehan & Katz, 2010). The purpose of this literature review is to compile and evaluate the current research on the use of exergaming, the development of physical literacy and the interaction of these two concepts as a potential way to increase the participation in physical activity. The review will also identify new directions for future research.

2.2 Exergaming

Exergaming, also called "active gaming", "interactive fitness" or "active video games (AVG)" combines the screen technology of traditional video games and exercise, where the player uses their own body to interactively play the game and becomes, according to Vander Schee & Boyles (2010), "the ultimate human joystick". Instead of using traditional simple finger or hand movements, exergames use the player's full body movements to play virtual sports, group fitness exercises and other interactive physical activities as an active alternative to traditional sedentary video gaming (Mears & Hansen, 2009 & Sheehan & Katz, 2010).

One of the first games to be introduced as an exergame is credited to Konami Digital Entertainment's "Dance Dance Revolution", followed by Nintendo's Wii and Microsoft X-Box Kinect systems, further popularizing exergaming (Mears & Hansen, 2009). These games are described as entertaining and fun and are considered exergame systems as they require the participant to use their body to move and interact with the game as opposed to traditional video games where the user is relatively sedentary (Mears & Hansen, 2009 & Vander Schee & Boyles, 2010).

For the purpose of this study, the chosen exergaming system is the Nintendo Wii game console. The Nintendo Wii system was chosen for this study as it has been used in a number of other studies in a variety of conditions that include measurement of energy expenditure during use, level of enjoyment while playing Wii and use during physical therapy (Adamo, Rutherford & Goldfield, 2010; Graves et al., 2010 & O'Huiginn et al., 2009). Released in 2006, the Nintendo Wii system is an interactive gaming system that requires the player to hold a remote during play that transmits their physical movements to the Wii console. The movements are then translated into action in a Wii game (Nintendo, 2011).

Different uses of exergaming

Exergaming has been used in a variety of other environments such school physical education classes and in rehabilitation centres and therapy (Duncan & Staples, 2010;

Fogel et al., 2010, & O'Huiginn et al., 2009). Exergaming has been proposed as a means to increase physical activity in the school setting (Duncan & Staples, 2010, & Fogel et al., 2010). Fogel et al. (2010) incorporated exergaming in a physical education class among fifth grade students. Results demonstrated that exergaming provided more minutes and more opportunities of physical activity than did the traditional physical education class. According to the authors this was due to the fact that the time for providing instruction was reduced since little instruction was required for the exergames. The wait time for exergaming was also reduced since there were fewer students in the exergame groups and multiple exergame stations were available. The authors of the study also suggested that the implementation of an exergame laboratory in school settings would be beneficial to all students since it could be available to students before and after school, providing opportunity to be physical active in a safe location (Duncan & Staples, 2010; Fogel et al., 2010; & Hansen & Sanders, 2010).

In the field of rehabilitation, exergaming has been identified as a useful tool. Patients receiving therapy often experience delays returning to full physical function due to poor exercise adherence and technique (O'Huiginn et al., 2009). To combat this problem, "therapeutic exergaming" which involves the combination of exergaming and exercise therapy (O'Huiginn et al., 2009) has been introduced. The underlying principle behind therapeutic exergaming is that patients can perform the necessary exercises while playing an exergame that corresponds to the specific area that is being rehabilitated (Lange, Flynn & Rizzo, 2009). Essentially the use of exergaming during therapy should help increase patient adherence to exercise programs and improve their performance and technique, thus accelerating the time to recovery (O'Huiginn et al., 2009). Studies by Fitzgerald, Trakarnratanakul, Smyth and Caulfield (2010), Lange, Flynn and Rizzo (2009) & O'Huiginn et al., 2009) examined the performance of rehabilitation exercises when performed with an exergame compared to being performed alone and found that exercise adherence was greater when exercises were performed as part of an exergame.

Wii Fit has been shown to be valuable in the rehabilitation process, especially for exercises that aid stability training. Researchers in India have developed the Balance Virtual Rehabilitation System, a rehabilitation system based on the Wii Fit and its balance board (Wii device used as part of the Wii Fit balance games). The system incorporates the use of the balance board for exercises specifically developed for the rehabilitation of balance disorders. This user-friendly system can also be used as an at-home rehabilitation aid as the cost is relatively affordable (Kamal, 2011). In a similar study, researchers investigated the performance of exercises concerning dynamic postural stability involving exergaming or being performed alone. Results indicated improvements in dynamic postural stability were similar to that of a regular training program. Not surprising, results showed a greater level of interest and enjoyment among patients compared the traditional training program (Fitzgerald et al., 2010).

Use of exergaming among special populations

Exergames have been modified and developed for a range of other populations including visually impaired individuals, elderly adults, children with autism, and people who have suffered from stroke or other neurological diseases (Burke, McNeill, Charles, Morrow, Crosbie, & McDonough, 2009; deJong, 2010; Huber, Rabin, Docan, Burdea, Nwosu, Abdelbaky, & Golomb, 2008). Exergaming has the potential to benefit children of all ages, including those that are deemed overweight or obese. Adamo et al. (2010) found positive results with interactive game cycling and overweight and obese adolescents. They concluded that interactive game cycling elicited improvement in submaximal indicators of aerobic fitness, and at the end of the training period, a reduction in body fat percentage and total cholesterol among their participants. Overall, the interactive cycling game improved fitness, body composition, attendance to exercise sessions, intensity of the activity and the distance pedaled (Adamo et al., 2010).

Researchers at the University of Nevada have developed a haptic/audio based exergame to benefit visually impaired individuals (Morelli, 2010). The Wii Tennis game has been enhanced with audio feedback and additional haptic cues from the Wii hand remote to allow visually impaired students to play. From the initial trials with the modified games, visually impaired students elicited higher energy expenditure than compared to regular video game play (Morelli, 2010).

Exergaming is also commonly used by elderly adults since the benefits of exergaming can be applied to this population since one of the most important benefits of exergaming for the elderly population is falls prevention (De Bruin, Schoene, Pichierri, & Smith, 2010). One of the most popular exergames Wii Fit offers balance training games that improve balance and flexibility (deJong, 2010). A European study incorporated a six-week exergame balance intervention with elderly people with postural control and balance being measured before and after the intervention. Balance improved after the exergame training compared to the start of the intervention and not only were there balance improvements, participants of the study were also very motivated to do the balance exercises since they found the games challenging and fun. The enjoyment of therapeutic exergaming could support increased long term adherence to balance training (Lamoth, Caljouw & Postema, 2011). Aside from fall prevention, exergaming has the potential to help the elderly population maintain good health, promote functional independence and reduce premature disability (deJong, 2010).

Another exergame called "Astrojumper" has been designed for users with autism. It is well known that children with autism benefit from vigorous physical activity but it is usually difficult to engage these individuals outside of their usually sedentary lifestyle (Finkelstein, Nickel, Barnes & Suma, 2010). The development of the Astrojumper has combined exercise and virtual reality to fit the needs of the autistic child with positive results from the initial testing of the exergame. The participants of the preliminary testing were given a survey to evaluate the enjoyment of the activity and the ratings on the 7-point Likert scale questions were very promising and suggested all participants enjoyed playing the exergame (Finkelstein, Nickel, Barnes & Suma, 2010).

Exergaming has the potential to benefit those who have suffered from neurological conditions such as cerebral palsy, hemiplegia and stroke (Burke et al., 2009; Deutsch, Borbely, Filler, Huhn & Guarrera-Bowlby, 2008; Huber et al., 2008 & McNeil, Charles, Morrow, Crosbie & McDonough, 2009). For individuals that have suffered a stroke, it is important their rehabilitation is started in a timely fashion following the incident and that it is also intense and repetitive (Burke et al., 2009). This is usually a challenge since patients often lose interest A study by Burke et al. (2009) evaluated the usability of different exergames for individuals that suffered a stroke and concluded that exergames contribute to the promotion of the limb movements during participation due to their the engaging and addictive natures. The promotion of limb movements is very important to rehabilitation following stroke since this could lead to partial or full recovery of the upper limb and thus the benefits of exergaming for this population could be significant (Burke et al., 2009).

For individuals with cerebral palsy and hemiplegia, exergaming could also prove to be beneficial. A study by Deustch, Borbely, Filler, Huhn & Guarrera-Bowlby (2008) investigated the feasibility of the Nintendo Wii game system for rehabilitation use of an adolescent with cerebral palsy. The participant completed 11 Wii Sport training sessions lasting between 60 and 90 minutes. Results were promising. Postural control, visual-perceptual processing and functional mobility improved in the teenager. In another study children with hemiplegia played the PlayStation 3 system at home for 30 minutes a day over a 3-month period. Following the training period, the children showed significant improvements in Activities of Daily Living (ADL) and hand function (Huber, Rabin, Docan, Burdea, Nwosu, Abdelbaky & Golomb, 2008).

Energy expenditure and other benefits of exergaming

One of the benefits of exergaming is an increase in energy expenditure during participation compared to that of traditional, sedentary video gaming (Graves et al., 2010). According to some research, exergaming can prove to be a way for youths to increase energy expenditure and levels of physical activity so that they can meet the reported guidelines of 60 minutes of moderate to vigorous intensity physical activity a day for least three days a week (CSEP, 2011). Compared to video games where the player is typically seated and using a controller, exergaming can be a healthier choice since it increases energy expenditure during use (Graves, Ridgers & Stratton, 2008). Children who play exergames regularly experience increased heart rates, total body movements and exertion (Graves et al., 2010). In fact, the intensity experienced while playing Wii Boxing and Dance Dance Revolution is similar with the current physical activity recommendations for children (Bailey & McInnis, 2011).

Graves et al. (2010) examined the energy expenditure associated with Nintendo Wii and found that the increased upper limb and total body movements during Wii participation is responsible for the increases in energy expenditure and heart rate. Previous studies have concluded that the amount of energy expended while playing exergaming is also significantly greater than that of traditional sedentary video games. Studies by Graves et al. (2010), Lanningham-Foster, Jensen, Foster, Redmond, Walker, Heinz and Levine (2006), Maddison, Mhurchu, Jull, Jiang, Prapavessis and Rodgers (2007), Mellecker & McManus (2008) and Penko and Barkley (2010) compared the amount of energy expended while playing both exergames and traditional sedentary ones and concluded that playing such games as Wii Fit, Wii Sports and Dance Dance Revolution demonstrated greater physiologic (i.e. minute ventilation, oxygen uptake and heart rate) and metabolic (i.e. energy expenditure, fat oxidation, carbohydrate oxidation and respiratory exchange ratio) responses.

The energy expenditure during exergaming to other aerobic activities such as treadmill walking. It was concluded that average values of physiologic and metabolic responses of Nintendo Wii Boxing were equal to brisk treadmill walking (Graf, Pratt, Hester & Short, 2009 & Willems & Bond, 2009). Another study by Warburton, Sarkany, Johnson, Rhods, Whitford, Esch, Scott, Wong and Bredin (2009) compared the metabolic requirements of interactive video game exercise in comparison to traditional stationary cycling at matched incremental workloads. It was determined that despite, the matched incremental workloads and feelings of similar perceptions of exertion, the interactive video game cycling resulted in greater metabolic requirements than traditional cycling. With these findings, it is conceivable that participants of interactive cycling are able to exercise at a higher intensity without a noticeable difference in exertion (Warburton et al., 2009).

Exergaming can elicit light to moderate intensity activity through the alteration of a typically sedentary activity (Graves et al., 2010). For example, it was estimated that if the most frequent users of sedentary video games in the United Kingdom replace sedentary gaming for exergaming with the Wii Fit, the average seven, two-hour weekly sessions would result in an increase in total energy expenditure of 4.5% a week. If this substantial increase was sustained, this could potentially contribute to weight management (Graves et al., 2010). For youths who normally spend a great deal of time participating in sedentary video games, new generation exergames can prove to be a new means of providing entertainment and increased energy expenditure (Graf et al., 2009).

Aside from increased energy expenditure, exergaming significantly increases heart rate, step counts and provides overall positive health benefits (Mears & Hansen, 2009). Another benefit of exergaming was noted after students who participated in exergaming as part of their physical education curriculum demonstrated a “persistence to game” which is defined as a reluctance to stop participation. The “persistence to game” and reluctance to cease activity are both important to a student’s intrinsic motivation which aids in increasing healthy behaviours such as exercise adherence (Mears & Hansen, 2009). A study by Hansen and Sanders (2010) investigated children’s experiences as they participated in exergaming during their physical education classes. The study determined that while children play exergames, they experience “flow” (Hansen & Sanders, 2010) which is defined as a condition where a person is completely involved in what she or he is doing during an optimal state of intrinsic motivation (Csikszentmihalyi, 1975). According to the study, while children participate in exergames, they experience flow and therefore are intrinsically motivated to keep playing the exergame. This state of flow or intrinsic motivation is essential for children to enjoy physical activity and thus increase its occurrence.

Exergaming does not only have physiological benefits, but also psychological benefits. Given that exercise in general increases cognitive and affective aspects such as concentration and short-term memory (Russell, 2009) there is the potential for exergaming to elicit these benefits. Russell (2009) examined whether a single bout of exergaming improved short-term psychological factors such as mood, concentration and short-term memory compared to traditional video game play. Although no differences in concentration were found, results indicated that exergaming could provide other psychological benefits besides just motivational and entertainment. There was an improvement in short-term memory for children who participated in the exergame activities compared to their peers who played traditional video games. For school aged children brain function can indirectly benefit from physical activity since there is an increase in cerebral flow, nutrient uptake and greater arousal. Exergaming could further increase these benefits since children are more likely to be motivated to participate in exergames and thus increase the length of physical activity (Russell, 2009). Although exergaming can increase physical activity and energy expenditure among other benefits it is a complement, not a replacement, for traditional physical activity (Daley, 2009). Participation in real life versions of exergames has substantially greater benefits and cannot be replaced by exergaming alone (Graves et al., 2010).

2.3 Physical Literacy

In the last ten years a new concept of physical activity has emerged: physical literacy. In 2001, Dr. Margaret Whitehead wrote the first introductory paper on physical literacy and since then physical literacy has attracted the attention of researchers in Canada, the United States and Europe alike. While the concept of physical literacy had been used in some research context, Dr. Whitehead's 2001 paper generated considerable interest and academic debate on the subject (Higgs, 2010). The paper describes a need to define physical literacy in terms of a universal concept and addresses the vast potential of physical literacy to enhance quality of life.

The concept of physical literacy is described by Dr. Whitehead as a lifelong process in which individual's minds and bodies adapt to the ever changing environment around them (Whitehead, 2001 as cited in Higgs, 2010). A more recent definition of physical literacy according to her work is: "the motivation, confidence, physical competence, understanding and knowledge to maintain physical activity at an individually appropriate level, throughout life" (Whitehead, 2007, pg. 287). The four key concepts of physical literacy are: 1) the embodied capacities that are needed to interact effectively with the environment; 2) the range of environmental situations with which an individual should be able to interact; 3) the range of personal and inter-personal situations in which the individual should be able to deploy their embodied dimension effectively; and 4) the holistic capacities essential to achieving physical literacy (Whitehead, 2001). Of these four key components, all of them are currently integrated into the most recent definition of physical literacy. CS4L defines physical literacy in its physical literacy resource paper as:

> *...the development of fundamental movement skills and fundamental sport skills that permit a child to move confidently and with control, in a wide range of physical activity, rhythmic (dance) and sport situations. Physical literacy also includes the ability to "read" what is going on around them in an activity and react appropriately to those events"*(Higgs et al., 2008).

C4SL has developed an applied approach to physical literacy where physical literacy is a crucial piece of a child's development since it provides the necessary tools to participate in physical activity, sport and a lifetime of physical activity. CS4L developed the Long Term Athlete Development (LTAD) program and is currently adapted by Sport Canada and the Canadian Sport System. According to the LTAD program, physical literacy is emphasized in its first three stages. Essentially, from birth to the start of adolescence, all children develop the necessary movement skills, attitudes and knowledge to be successful in any physical activity. The LTAD also emphasizes continued participation in physical activity through all stages of life (Higgs, 2010).

The ideal environment in which to promote physical literacy is through the already established physical education curriculum of all school systems (Killingbeck, Bowler, Golding & Gamon, 2007). Physical education curriculums are a great environment in which to teach the fundamentals of physical literacy since all important aspects of physical literacy are addressed in the goals of physical education (Mandigo, Francis, Lodewyk, & Lopez, 2009). Physical education encourages all children to take part in a life filled with physical activity and supports every student on their quest to develop physical literacy (Taplin, 2011).

While all aspects of physical literacy are important, the most obvious link between physical education and physical literacy is the development of movement and sport skills. According to Killingbeck et al. (2007), the four areas of activity - athletics, dance, games and outdoor activities - each contribute to the development of physical literacy through its four key concepts: 1) physical competencies; 2) ability to read and respond efficiently and effectively to the environment and to others in interaction; 3) ability to use the body as an instrument of expression/communication; and 4) ability to articulate/demonstrate knowledge, skills and understanding of health. For example, athletic activities develop the physical competencies of walking, running, jumping and throwing (Killingbeck et al., 2007); all of which are crucial skills in a variety of other sports such as basketball, baseball, tennis and soccer. Participation in athletics also introduces children to the ABC's of athleticism: agility, balance and coordination (Killingbeck et al., 2007). The research on physical literacy and physical education stresses the importance of using physical education to promote and develop physical literacy so that all children have equal opportunities to grow into physically competent and healthy individuals.

Measurement of physical literacy

According to Higgs et al. (2008), the definition of physical literacy encompasses a broad description that includes a person's physical, mental, and affective skills. Physically literate individuals: 1) have a variety of fundamental movement and sport skills and demonstrate the ability to use these skills in different environments; 2) are intrinsically motivated to learn and apply different forms of movement; and 3) understand the importance of participating in physical activity how it contributes to their mental and physical health (CS4L, 2012). For the purpose of this study, the acquisition and performance of fundamental movement and sports skills will be explored, specifically the development of the basic fundamental skills of agility, balance and coordination. These skills according to CS4L are the four skills that form the base of a child's physical literacy development (CS4L, 2012).

The CS4L LTAD model outlines the different stages in which people develop their physical skills and participate in activity (Higgs et al., 2008). When choosing the participants of this study, the second stage of the LTAD model, called the FUNdamentals stage, was considered since according to the model children between the ages of six and nine should develop agility, balance and coordination - the foundation of physical literacy, at this stage.

To date, there is no research on how to quantifiable measure physical literacy. Physical literacy is a relatively new concept and with it comes the need to develop a proper evaluation and measurement tool (Tremblay & Lloyd, 2010). Without any physical literacy measurement literature to guide this study, physical education literature was examined to better understand how to measure agility, balance and coordination among children between the ages of six and nine. Physical education literature was chosen since it is commonplace for fitness testing to be included in physical education curriculums (Lloyd, Colley, & Tremblay, 2010) which could include the evaluation of a child's agility, balance and coordination.

According to Lacy and Hastad (2006), the Illinois Agility Run (Cureton, 1951as cited in Lacy & Hastad, 2006) is a reliable measure of agility among children aged six to nine. It is a relatively simple test that requires little equipment and set-up. The Illinois Agility Run is considered a standard test of agility (Sheppard & Young, 2006) as it is a valid and reliable means of assessing agility (Lacy & Hastad, 2006). According to Lacy and Hastad (2006), reliability coefficients range from 0.77 to 0.92 which demonstrates consistency. Given this data along with administration ease, the Illinois Agility Run was selected for the current study.

To evaluate participants' balance, both static and dynamic balance need to be considered. To measure static balance (ability to maintain equilibrium while in a stationary position (Lacy & Hastad, 2006)), the Stork Stand balance test is a reliable test to use since according to Ribadi, Rider and Toole (1987), the Stork Stand has been demonstrated to be valid and reliable measure of static balance. Test-retest reliability coefficients range from 0.85 to 0.87 indicating strong reliability (Lacy & Hastad, 2006). The Stork Stand test involves the participant standing on their dominant leg, lifting their heel off the floor and attempting to balance as long as possible on the ball of their foot. Dynamic balance (ability to move through space in a steady and stable manner (Lacy & Hastad, 2006)) is commonly evaluated by using the balance beam test in physical education settings with children (Lacy & Hastad, 2006). According to Lacy and Hastad (2006) face validity of this test is accepted. This test involves walking the length of a low balance beam, turning around while still on the balance beam and walking back to the start.

The Lateral Movement Test is a supported measure of coordination in physical education (Schilling & Kiphard, 1976). The Lateral Movement Test is one part of a test battery that determines coordination among children. This test requires the participant to pick up a carpet piece from their left and place it on the floor to their right and step on it. This is done as fast as possible without any part of the participant touching the floor, only the carpet. The test's validity was reported with coefficients that ranged from 0.50 and 0.60 and reliability range between 0.65 and 0.87 (Lacy & Hastad, 2006) making it a good choice to evaluate coordination in this study.

2.4 Physical Literacy and Exergaming

Both concepts of exergaming and physical literacy support the need for increasing physical activity and the combination of the two could have significant implications for the fight against childhood inactivity. There is however a significant gap in the research concerning the use of exergaming and the development of physical literacy; therefore the need to conduct empirical research in this area is warranted. Sheehan and Katz (2010) have identified the potential for exergaming to develop physical literacy and the combination of the two to combat the increase in childhood physical inactivity.

According to Sheehan and Katz (2010), there are five components necessary for motivating children to participate in physical activity: control, challenge, constant feedback, creativity, and curiosity. Exergames include these five components since children can easily control the game, it is challenging, they receive constant feedback, it requires their creativity and games satisfy children’s curiosity to play the game. Without these essential pieces children are not as likely to participate in physical activity and will continue to “slip through the cracks” toward a lifetime of unhealthy behaviours and physical inactivity (Sheehan & Katz, 2010). The use of exergames could be a way to engage children to be physically active, especially those children who have started to lose interest in traditional forms of physical activity. The nature of exergames engages children since they are able to progress at their own individual pace and they can easily adjust the difficulty of the game to fit their needs (Sheehan & Katz, 2010).

One of the reasons exergaming can be used to increase physical activity is the increasing popularity of technology. Exergaming takes advantage of the increased use of technology and combines exercise and video games to promote physical activity among children (Mears & Hansen, 2009 & Sheehan & Katz, 2010). Essentially, exergaming creates an opportunity for children to be active during a time they would normally be sedentary. When children were given the opportunity to choose between participating in active or inactive video games, children were more likely to select the active option due to its interactive nature (Graves et al., 2010). The time allocated to a specific pursuit is largely determined by its degree of enjoyment. In particular, children are more likely to participate in exergaming for a longer period of time if they deem it enjoyable, thus increasing their physical activity levels (Graves et al., 2010).

Aside from increasing physical activity, exergaming is also regarded as an important tool to combat sedentary behaviours since, according to Hansen and Sanders (2010), while children are participating in exergaming they think they are only playing video games but do not realize they are exercising as well. For children who have started to lose interest in traditional physical activity, exergaming and interactive fitness activities could provide the stimulus necessary to keep them engaged in physical activity. The nature of exergaming allows children to progress at a rate that is comfortable to them and individualized to their physiological and psychological readiness. The various levels of games can serve as a motivational tool that creates excitement when advancement to a more difficult stage is achieved (Sheehan & Katz, 2010).

Physical literacy is defined as the development of fundamental movement skills and fundamental sport skills that permit a child to move confidently and with control, in a wide range of physical activity, rhythmic (dance) and sport situations. Physical literacy also includes the ability to 'read' what is going on around them in an activity setting and react appropriately to those events (Mandigo, Francis, Lodewyk, & Lopez, 2009). Exergaming can support the development of all of these characteristics since participation in exergames fosters the development of each (Sheehan & Katz, 2010).

Exergame Training

While no other study has investigated the relationship between the movement skills component of physical literacy and exergaming, other studies that used Wii as a therapeutic tool were examined during the design of this study. In a study by O'Huiginn et al. (2009), participants completed an exergaming programme as a form of physical therapy for 12 sessions over four weeks which yielded positive results. Another study by Fitzgerald et al. (2010) used an exergaming group that completed wobble-board exergames for 12 sessions over four weeks that resulted in balance improvements. Based on this previous work, the current study therefore included 12, 30-minute exergame training sessions spread out over four weeks. According to Sheehan and Katz (2010), exergames can enhance agility, balance and coordination since participation in these games supports the development and enhancement of these skills. Games cited by Sheehan and Katz that could specifically contribute to physical literacy include Wii Sports, Wii Fit and Just Dance; all of which will be used during the exergaming training of this study.

2.5 Conclusion

This literature review compiled existing knowledge on exergaming, physical literacy and the relationship between these two concepts. The literature demonstrates the possibility of using exergaming to combat sedentary behaviours and physical inactivity through the development of physical literacy however there is limited empirical research on the interaction between the use of exergaming and the enhancement of physical literacy. Explorative research should be conducted to better understand the effect exergaming can have on the enhancement of physical literacy and quantifiably determine whether the use of exergaming is a viable way to increase physical activity in general.

Chapter 3: Methodology

3.1 Ethics

Application for ethical approval was sought from the Interdisciplinary Committee on Ethics in Human Research (ICEHR) at Memorial University. Full ethical clearance was granted on January 13, 2012.

3.2 Research Design

This study was an explorative study designed to contribute empirical research to the already existing literature on physical literacy and exergaming. This study used a 2-group (experimental and control) independent pre-post-test experimental design with a repeated measure on time. A purposeful sampling technique was used to recruit participants and each group was matched for age and gender. Each group completed a pre and post-test that measured three dependent variables: agility, balance and coordination. Each participant completed a pre-test followed by a post-test five to seven weeks later. The experimental group was subject to an exergaming intervention that involved twelve sessions of 30-minute exergaming play. The control group did nothing between pre and post-tests.

3.3 Participants

The participants of this study included 14 children between the ages of six and nine (seven males, seven females: age 7.50 ± 1.35 years, mass 36.96 ± 15.79 kg and 131.11 ± 13.02 cm). The six to nine age group was chosen in accordance with the LTAD FUNdamentals learning stage which emphasizes the development of agility, balance and coordination within this age group (Higgs et al., 2008). Children had to be physically able to participate in exergames and agility, balance and coordination activities. This was ensured when parents signed the consent form.

A purposeful sampling technique was used. The majority of volunteers were recruited from the St. John's Boys and Girls Club at the Buckmaster Circle location. At the request of the Boys and Girls Club, consent forms were distributed by their employees to the children attendees. This strategy was deemed appropriate as the staff at the Boys and Girls Club was already familiar with the attendees of the club. Of the approximately 230 number of children who are registered with the Boys and Girls Club, a third were eligible to participate in the study based on our age criteria. In total, sixty consent forms were distributed to the attendees of the club and club employees were instructed to recruit as many eligible participants as possible. Of the sixty forms distributed, 20 were returned and data collection began in March 2012. Of the 20 consent forms that were returned, only 10 participants finished the study; others dropped out due to lack of interest or sporadic club attendance. After the ten consented participants finished their part in the study, it was very difficult to recruit more participants. Although this study intended to include 40 participants (20 in each group) the combination of lack of interest, initial recruitment done by the club employees and the low numbers of program attendance made recruitment very difficult. After the initial requirement at the Boys and Girls Club additional participants were recruited from faculty family and friends at the School of Human Kinetics and Recreation at Memorial University.

Consent was determined when participants agreed to participate in the study and their parents signed the consent form. Once consent was given, participants were assigned into two groups, an exergaming group and a control group. Both groups were matched for age and gender.

3.4 Apparatus

Agility:

Four tests were used to measure agility, balance and coordination among participants. Agility was measured by the Illinois Agility Run (Cureton, 1951). Here participants ran around an obstacle course set up by pylons measuring 30 feet in length and 12 feet in width. The procedure was demonstrated and practiced by the participant by walking the course with the investigator. This decreased the likelihood of the participants going in the wrong direction. To start the course, participants assumed a prone position with hands at the sides of their chest at the starting line. When the investigator said "Go", the timing began and participants stood up and ran as fast they could straight ahead for 30 feet to the first pylon. Upon reaching that pylon, they turned around it and ran diagonally to the center of the course and began zig-zagging around pylons for 30 feet. When they reached the last pylon, they turned around it and began zig-zagging back around the pylons to the center of the course. After the zig-zagging was complete, they ran diagonally toward the far right pylon, turned around it and ran 30 feet to the finish line. Timing stopped as participants crossed the finish line. A stop-watch was used to record the time it took for participants to complete the run and eight pylons were used to mark the course. Participant's scores were based on time to complete run for one trial. If participants went in the wrong direction, they restarted the course.

Balance

To measure balance, two tests were used; one to measure static balance and the other to measure dynamic balance. Static balance was measured by the Stork Stand that involved balancing on the ball of the foot while in an upright position. To complete the Stork Stand, participants were instructed to stand in an upright position on their dominant foot. Their dominant foot or preferred kicking limb (Fitzgerald, Trakarnratanakul, Smyth & Caulfield, 2010) was determined by rolling a soccer ball to each participating and asking them to kick it back. This was repeated three times and whatever leg the participant used the most frequently to kick the ball was considered dominant. Standing on the dominant foot, participants were instructed to place their hands on their hips, and to place the opposite foot on the medial side of the supporting knee. When told to begin, participants lifted their supporting heel off the floor and attempted to maintain that position for as long as possible. Timing began when the participant's heel lifted off the ground and timing stopped when the participant was no longer able to maintain this position (i.e. they placed non supporting foot on ground or bounced supporting leg to maintain balance). This was repeated three times. Investigator used a stop-watch to time how long the participant could hold the position and a soccer ball to determine their dominant leg. Participants were scored on the best of three trials timed to the nearest second.

To measure dynamic balance, participants performed a balance beam walk (Jensen & Hirst, 1980). This test involved balancing and walking on a balance beam placed on the floor. To perform the balance beam walk, participants were instructed to stand at one end of a four-inch wide balance beam. When instructed to start, the participant walked to the other end of the balance, turned around and paused for five seconds. When told to start again, participants walked back to the start of the balance beam. This was repeated for three trials. Participants were scored on a pass/fail basis. The only equipment required for this test was a four-inch wide low balance beam that could be placed on the ground.

Coordination

Coordination among participants was measured by a Lateral Movement Test (Schilling & Kiphard, 1976). To perform the Lateral Movement Test, participants were instructed to use two carpet pieces measuring 25cm x 25 cm to move laterally as fast as possible. Participants were instructed to retrieve the carpet piece to their left, place it approximately 12.5cm to their right and step on it. This process was repeated continuously for 20 seconds for two trials.

Participants earned a point if they successfully placed a carpet piece to their right and when they successfully stepped onto the carpet piece without touching the floor. Their total score was the sum of two trials. The investigator used two 25cm x 25cm carpet pieces and a stop-watch for this test.

3.5 Procedure

Prior to data collection, pilot testing was performed to determine how much instruction should be given and how to demonstrate each test to participants. This involved two sessions where children the same age of the study participants took part in the agility, balance and coordination tests. The investigator determined at this time the best way to demonstrate and instruct the participants on the tests.

Participant consent was obtained and general information was collected such as age, gender, weight and height. Pre-tests for agility, balance and coordination were then performed as each participant completed the Illinois Agility Run, Stork Stand, balance beam walk and Lateral Movement Test in that order. Each participant was given the same instructions before each test, including general instructions and a demonstration. Participants were then asked if they understood, and if so, proceeded with each test. After the pre-tests were completed, each participant was assigned to either the exergaming group or the control group. Each group had the same average age of seven years and had the same number of males and females of four and three respectively.

Exergaming Group

After completing the pre-tests, participants in the exergaming group started their exergame training. This training involved playing exergames on the Nintendo Wii gaming system. Wii training involved participating in 12, 30-minute sessions. Originally, it was aimed to complete the 12 sessions over a four week period however the

12 sessions were completed over an average of seven and a half weeks. This was due to the inconsistent participant attendance at the Boys and Girls Club.

Since the all exergaming participants' pre-tests were performed in one day, there was large discrepancy in the time between pre-test completion and the start of the Wii training. Five participants started their Wii training within three days of the pre-test while two participants started their training 60 days following their pre-tests. The last two participants had to wait 60 days to start their Wii training because they had to wait for other participants to be done their training first. This was due to time and resource constraints since only three participants could be trained per day since there was only one TV, one Wii system and only two hours between when participants arrived at the club and were picked up to go home.

During each session, participants could select a variety of Wii games to play (Wii Sport, Wii Fit and Just Dance). Within Wii Sports and Wii Fit, there was a variety of activities in which the participants could complete. These games were chosen because according to Sheehan and Katz (2010) these games could specifically contribute to the enhancement of agility, balance and coordination.   Children were allowed to select the games they wanted to play as freedom of choice is an important component to intrinsic motivation (Deci & Ryan, 1980a, 1980b). During the training sessions, participants played an average of six games or three games in combination with the Just Dance game and took short breaks between games (approximately 1-2 minutes).

After 12 Wii training sessions were completed, participants' agility, balance and coordination post-tests were measured in which they performed an Illinois Agility Run, Stork Stand, balance beam walk and Lateral Movement Test. Post-training height and weight were also measured to account for maturation effects on the internal reliability of the study. Participants in the exergaming group completed their post-tests within two weeks of finishing their Wii training.

Control Group

During the pre-tests, height and weight data was collected from participants in the control group. They also performed the same agility, balance and coordination tests and each completed an Illinois Agility Run, Stork Stand, balance beam walk and Lateral Movement Test. After completing the pre-tests, participants in the control group waited five weeks to complete the post-tests to mirror the experimental group. During the post-tests, agility, balance and coordination were measured again as well as height and weight. While participants were scheduled to complete the post-test after four weeks of the pre-test, they were actually completed after five weeks. This time discrepancy was due to scheduling conflicts between the researcher, participants and facilities used.

3.6 Statistical Analyses

All statistical analysis were conducted using Sigmaplot (version 12.5; Systat Software Inc.) and Microsoft Office Excel Spreadsheets (2013). A mixed (independent and factor) repeated measures analysis of variance (ANOVA) was used to determine any main effect of time (pre-test vs. post-test), group (experimental vs. control) and any interaction between time and group on performance of the Illinois Agility Run, Stork Stand and Lateral Movement Test. An independent t-test was performed to analyze difference scores between the agility post-tests of both groups. A power analysis was used to determine effect sizes. Differences were considered significant using an alpha level of .95. The data collected from the balance beam test was not analyzed because all participants passed the pre-test. Since the test was based on a pass/fail score (i.e., statistical regression), no change could be observed when all participants passed the initial trials.

Chapter 4: Results

Participants were asked to complete pre-tests and post-tests of agility (Illinois Agility Run), balance (Stork Stand and balance beam) and coordination (Lateral Movement Test). All analysis passed tests of equal variance and normality (Shapiro-Wilk). Table 1 lists the means and standard deviations for the pre and post-tests of the Illinois Agility Run, Stork Stand and Lateral Movement Test.

Table 1. Mean and standard deviation of Illinois Agility Run, Stork Stand and Lateral Movement Test, pre and post-test for both experimental and control groups (mean ± standard deviation).

Group	Illinois Agility Run (seconds)		Stork Stand (seconds)		Lateral Movement Test (moves complete)	
	Pre	Post	Pre	Post	Pre	Post
Experimental	30.43 ± 3.95	26.91 ±1.70	2.43 ± 1.02	2.46 ± 0.85	22.00 ± 3.70	23.43 ± 4.43
Control	25.67 ± 3.45	26.81 ± 3.42	2.38 ± 0.84	2.71 ± 1.28	24.86 ± 4.91	27.57 ± 7.04

4.1 Agility

There was no main effect of time (p = .19) for the Illinois Agility Run. The average time to complete the test was higher during the pre-test (28.05 ± 4.34 sec) than the post-test (26.86 ± 2.59 sec); however this difference was not found to be significant. There was also no main effect of group (p = 0.13).

There was a statistically significant interaction between group and time, $F_{(1, 12)} = 7.34$, $p = 0.02$. There was a significant decrease in performance time between the pre (30.43 ± 1.23 sec) and post-test (26.91 ± 1.70 sec) for the experimental group. This decrease in time was greater than the difference in performance time between the pre

(25.67 ± 3.45 sec) and post-test (26.81 ±3.42 sec) of the control group as demonstrated in Figure 1.

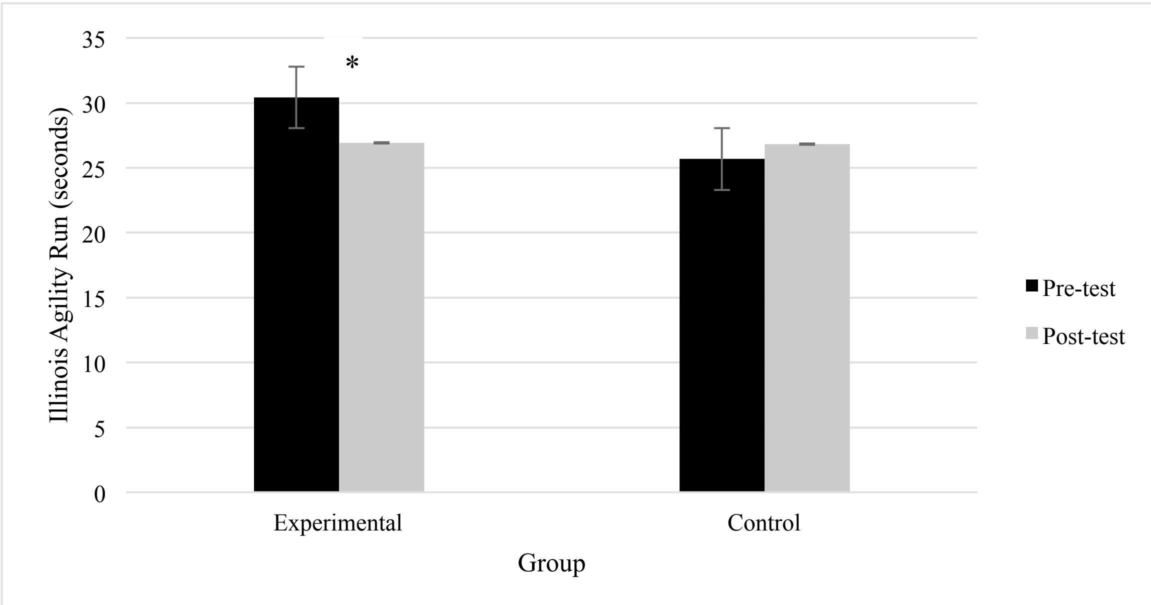

Figure 1. Bars represent average completion times of the Illinois Agility Run for pre and post-tests of both experimental and control groups. Asterisks (*) represent significant differences at $p < 0.05$ as seen between the pre and post-test of the experimental group. Vertical bars represent standard errors.

4.2 Balance

There was no main effect for time ($p = 0.40$). The post-test average time (2.58 ± 1.05 sec) was equivalent to the pre-test (2.405 ± 0.90 sec). There was no also main effect of group ($p = 0.84$). There was no interaction between group and time during the performance of the Stork Stand ($p = 0.45$). The average time of the control group (pre-test: 2.38 ± 0.84 sec, post-test: 2.71 ± 1.28 sec) was equal to the experimental group (pre-test: 2.43 ± 1.02 sec, post-test: 2.46 ± 0.85 sec).

4.3 Coordination

There was a trend observed for a main effect of time ($p = 0.06$) on the performance of the Lateral Movement Test. The average moves complete for the pre-test was 23.43 ± 4.43 moves and the post-test was 25.5 ± 6.05 moves. There was also no main effect of group (p = 0.20). There was no interaction between group and time during the Lateral Movement Test (p = 0.54). The experimental group (pre-test: 22.00 ± 3.70 moves, post-test: 23.43 ± 4.43 moves) performance over time was the same as the control group (pre-test: 24.86 ± 4.91 moves, post-test: 27.57 ± 7.04 moves).

4.4 Agility Difference Scores

The agility data was further analyzed by performing an independent t-test to compare the difference in scores between the pre and post tests for both groups as listed in Table 2. This test was performed because the pre-tests of the groups were very different but the absolute values of the post-tests were equal. While the experimental group did have a significant improvement over time (pre-test: 30.43 ± 1.23 sec, post-test: 26.91 ± 1.70 sec), the t-test determined whether or not the improvement over time for the experimental group was significant compared to the difference over time for the control group. The t-test determined that the experimental group mean test (pre to post) difference time (3.52 ± 4.04 sec) was determined to be significantly different than the control group mean test difference time (-1.14 ± 2.09 sec) at p = 0.02. Figure 2 demonstrates the difference in improvement between the two groups.

Table 2. Illinois Agility Run results in seconds.

Experimental Group			Control Group		
Pre	Post	Difference	Pre	Post	Difference
36.9	28.25	8.65	26.4	28.94	-2.54
28.4	28.2	0.2	31.1	31.66	-0.56
30.31	28.15	2.16	25.25	24.16	1.09
27.28	23.87	3.41	28.15	29.43	-1.28
33.44	25.6	7.84	25.47	23.78	1.69
25.18	27.8	-2.62	22.87	27.22	-4.35
31.5	26.5	5.00	20.46	22.47	-2.01

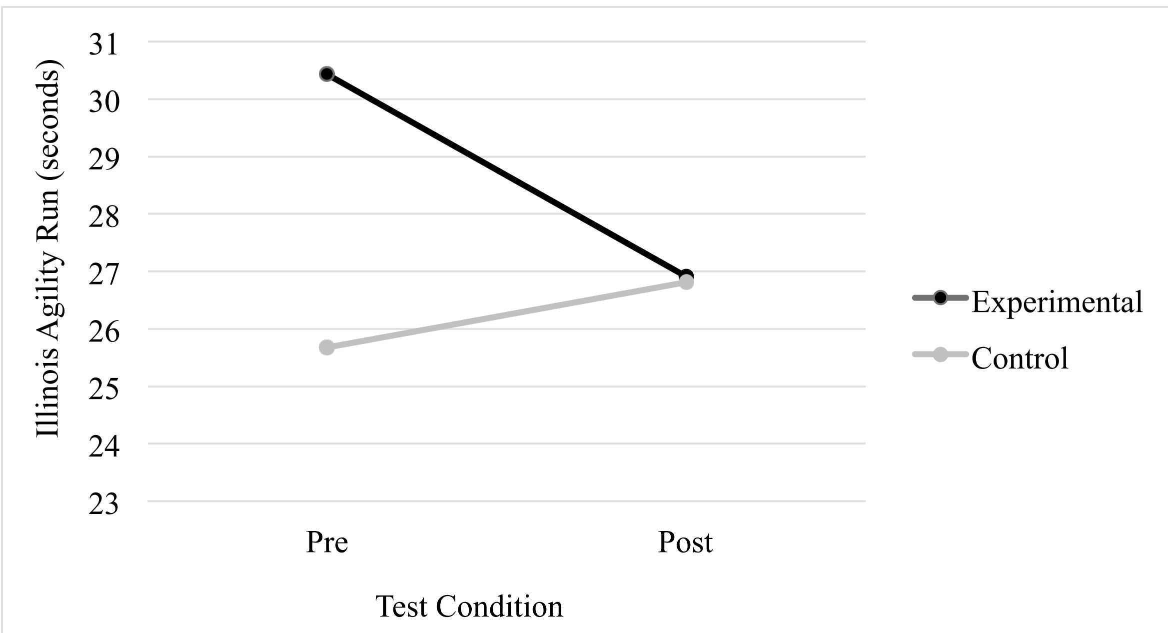

Figure 2. Line graph represents performance of Illinois Agility Run over time for both experimental and control groups.

4.5 Statistical Power

A power analysis was performed using Cohen's D for all variables. This test was done to calculate effect sizes and to determine the magnitude of the reported results. The calculated Cohen's D value for the agility data was 0.04. This value is close to zero indicating that both groups performed the same. The Cohen's D value calculated for the balance data was -0.23, indicating the control group performed better than the experimental group. The coordination data yielded a -0.70 Cohen's D value also demonstrating a better performance from the control group compared to the experimental group. These values indicate that the exergaming intervention resulted in very low effects or did not demonstrate any effect at all.

Chapter 5: Discussion and Conclusion

The purpose of this thesis was to determine whether or not the use of exergaming could enhance the development of the psycho-motor component of physical literacy, specifically the skills of agility, balance, and coordination among children aged six to nine years old. This was done by comparing the performances of pre and post-tests of the Illinois Agility Run, Stork Stand, and Lateral Movement Test between an experimental (exergaming) group and control group. Exergaming has previously been reported to increase energy expenditure, improve balance in the elderly and be a useful aid during physical therapy (Fitzgerald, Trakarnratanakul, Smyth & Caulfield, 2010; Lange, Flynn & Rizzo, 2009; O'Huiginn et al., 2009, &Vander Schee & Boyles, 2010). Other research has concluded that exergaming increases energy expenditure compared to sedentary video games and that participants generally enjoy exergame use (Fitzgerald et al., 2010 & Graves, Ridgers & Stratton, 2008). While no research has evaluated the effects of exergaming on the improvement of agility, balance or coordination, the results of this thesis observed an improvement in agility but none in balance or coordination.

The participant performances of the Illinois Agility Run demonstrated an improvement in agility over time for the experimental group while the control group showed little improvement. Even though, the experimental group showed a greater improvement over time, both groups had very different pre-test values, but similar post-test values. To determine whether or not the improvement demonstrated by the experimental group was significant, a t-test was performed to compare the mean difference time between pre and post-test performances for both groups. The t-test determined that the experimental group mean test difference time was in fact significant. This difference demonstrates that the exergaming training of the experimental group contributed to the improvement in agility.

The exergaming training included 12 sessions over a seven and a half week period. The consistent exergame training over this period of time was conducive to eliciting an improvement in agility. This finding is similar to other studies that used exergaming in rehabilitation settings, where it was also observed that the exergame use helped improve patient recovery (e.g., O'Huiginn, et al., 2009). Another study, by Fitzgerald et al. (2010), demonstrated positive results to improve elderly balance after 12 sessions of exergaming training was completed over a four week period. The exergames selected here appear to positively impact agility. The games that were chosen were Wii Fit, Wii Sports and Just Dance. As reported by Sheehan & Katz (2010), these games support the development and enhancement of the psycho-motor component of physical literacy and related skills such as agility.

There were no observed improvements in balance or coordination and according to the power analysis performed, the control group in fact performed better than the experimental group during both tests. The lack of improvement in balance is contrary to existing research. Fitzgerald et al. (2010) observed an improvement in elderly balance after participants used exergames for 12 sessions over a four-week period. The difference in results could be due to the balance tests used; different measures of balance may not be measuring the exact same construct. Fitzgerald et al. (2010) used the Star-Excursion balance test to evaluate dynamic balance while in the current study the balance beam and the Stork Stand balance tests were used to evaluate dynamic and static balance respectively. The balance beam test was chosen because this dynamic balance test in commonly used in physical education settings to train and test dynamic balance among children (Jensen & Hirst, 1980) and thus has high external validity. From the observations during data collection, the balance beam test is indeed simple and straightforward but perhaps too easy for the six to nine age group of the participants. The Stork Stand was chosen for this study because it is commonly used in physical education to evaluate a student's static balance and considered a valid and reliable tool for measuring static balance (Ribadi, Rider &Toole, 1987). Most participants found this test difficult. Many could not stand on their dominant foot while on the ball of their foot for very long; an indication that this test may not be appropriate for the participant age group, which could have impacted the results of this test.

The disparity between the current results and those of the balance study could also be due to the two different populations investigated. This thesis used children between the ages of six and nine and the balance improvements in the Fitzgerald et al. (2010) study were found in the elderly. The elderly participants in Fitzgerald el al.'s study may had poorer base-line balance and thus greater ability for improvement in the balance test.

The results indicated that coordination did not significantly improve over time for either the experimental or control groups. There is no existing research to compare the interaction between exergaming training and the improvement in coordination; however the use of the coordination test used could be a reason there was no difference found between groups. The Lateral Movement Test (Schilling & Kiphard, 1976) is one part of a test battery that determines coordination among children and was chosen for this study because it was deemed the most reliable coordination test. The test's validity was reported with coefficients that ranged from 0.50 and 0.60 and reliability range between 0.65 and 0.87 (Lacy & Hastad, 2006). Although the selection of this measure tool was based on a review of the physical education literature, it may be that the use of another test that measures coordination may have yielded more positive results.

The absence of observed improvements in balance or coordination could be attributed to the limitations of this thesis. One of these limitations is the small sample size used. Every effort was made to recruit as many participants as possible but due to time constraints, limited resources and sporadic participant attendance, the sample size used for this study was small. To avoid the small sample size, a more hands on approach should have been used during the recruitment of the participants. A future recommendation of working with organizations would be to negotiate with the organization to let the researcher be more involved in the recruitment process. Another recommendation would be to choose to work with an organization that has a history of consistent participant attendance. While a small sample size was not ideal for this study, a statistical power analysis performed indicated that more participants would not make a difference to the results obtained.

One confounding factor in this study is the nature of the Nintendo Wii gaming experience. While the Nintendo Wii games are deemed exergames, this game system requires the use of a hand held controller that transmits the player's movements to the main game console. This feature may have limited or discouraged the player to use their whole body to play the game. It is possible to play these exergames with limited physical movement as one can "trick" the system by, for example, flicking one's wrist rather than moving the entire arm or body. In attempt to mimic the freedom children would have at home when playing Nintendo Wii, the participants of the study were not instructed on how to play will full body movement.

Another limitation of this thesis could be bias in terms of equivalent groups due to already existing differences between the experimental and control groups. While the groups were matched in age and gender, the control group consistently presented better pre-test scores than the experimental group suggesting that the two groups were not comparable from the start of the study. This was demonstrated in the agility results where the control group's agility pre-test times lower compared to the pre-test times of the experimental group.

A third limitation of this thesis was the nature of the exergaming training. Originally it was intended that participants complete the training over a four week period but due to scheduling conflicts and time constraints, participants took longer to complete the training. Participants completed 12, 30-minute exergaming sessions over a seven and a half week period In order for the training to be more effective, in future research training should take place consistently three times a week for four weeks. Additionally, children typically do not play exergames on a consistent or scheduled basis. Therefore even sporadic use may be of benefit to anyone using exergaming. The games used during the exergame training also included unavoidable and unnecessary rest periods. The intermittent nature of the games was due to the time it took to set-up or switch games which further reduced any potential effects. It is also important to note that while other studies have stated that exergaming increases energy expenditure and is an enjoyable way to participate in physical activity, all research also states that exergaming is not a replacement for physical activity but rather a complement.

A fourth limitation of this thesis arose during the testing portion of the data collection. The data was collected by the primary researcher and a research assistant, each with specific roles during data collection to maintain consistency. However, human error is unavoidable while using a stopwatch to measure time or counting movements during the tests. Another limitation of the testing was the possible learning effect of the tests. While participants only completed one trial of the Illinois Agility Run during the pre-test, any improvement during the post-test could be attributed to the participant becoming more efficient at remembering and running the pattern of the test. The same could be said of the Stork Stand and Lateral Movement Test because multiple trials were completed during these tests.

Although the results of this thesis only demonstrated an improvement in agility and none in balance or coordination, anecdotally, the participants in the exergaming group all expressed enjoyment during the training. In many cases, the participants wanted to continue longer even when their training session was complete and were also disappointed when all training was finished. While participant enjoyment was not measured during this thesis, it should be noted that enjoyment is an important part when children decide to participate in physical activity. The number one reason to participate in sports as stated by children is because it's fun (Active for Life, 2013). It is recommended that future research determine a widely accepted method of measuring physical literacy so that other studies will have a consistent tool of measurement.

Other research should also examine the use of the X-Box Kinect exergaming system and its potential for physical activity benefits. The X-Box Kinect exergaming system detects whole body movements through a sensor, rather than ones generated through a hand-held remote controller like the Nintendo Wii system.

Conclusion

Technology today is always evolving. Future exergames or exergaming systems will surely be created or other ways of combining technology and physical activity. While technology today is part of the reason for the increase in sedentary behaviours such as screen technology use, any ways to increase physical activity levels in children should be explored. The presented thesis explored the idea of enhancing a child's physical literacy with the use of exergaming and while this research was inconclusive, more research is necessary to further explore this exercise adherence tool.

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