A COMPARISON OF NINTENDO WII BALANCE TRAINING AND TRADITIONAL BALANCE TRAINING IN CHILDREN WITH DOWN SYNDROME

by

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ABSTRACT

The primary purpose of this study was to compare the effectiveness of a Nintendo Wii Fit balance intervention to a traditional balance intervention. Thirteen children (ages 4-6, 8 with Down syndrome (DS) and 6 typically developing (TD)) from an early childhood education program were selected to participate. Participants were randomly divided into either the Nintendo WiiFit or the traditional balance intervention group. Both groups trained 10 minutes per day, five days a week, for five weeks. Balance skills were tested three times (pre-test, post-test, and a retention test) using the Pediatric Balance Scale. Results showed a significant training effect on balance for all participants ($F(2,13) = 19.08$, $p < .01$). The balance scores improved significantly from baseline to post-testing ($p<0.01$). There was no significant difference between post-test and retention ($p=0.39$). There was no difference between participants who received the WiiFit training and those who received the traditional training ($F(2, 13) = 0.66$, $p=0.53$). The results of the study indicate that young children can improve balance abilities through a short-term training intervention. In addition, the WiiFit intervention was found to be a successful means to improve balance in young children with and without Down syndrome.

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INTRODUCTION

Down syndrome

According to the National Down syndrome Society one of every 691 babies in the United States is born with Down syndrome (DS) each year, making DS the most common genetic condition in the United States (National Down syndrome Society 2013). DS is a chromosomal mutation, which most commonly occurs when an individual has an extra copy of chromosome 21 (Wang, Long & Liu, 2012). There are three different types of DS, trisomy 21, translocation, and mosaicism. Trisomy 21 is the most common type of DS and it accounts for 95% of DS cases. It is usually caused by nondisjunction in cell division, which results in an embryo with three copies of chromosome 21 (National Down Syndrome Society 2013).

The extra chromosome present in DS leads to gene overexpression, which causes the symptoms of DS. Although these symptoms vary on a child-to-child basis, common physical features include upward slanting eyes, flattened facial features, oversized tongue, small head, and small body statue. In addition, children with DS commonly have features such as hypotonia, ligamentous laxity, motor delay, speech impairments, intellectual disability, and hearing and vestibular impairments. DS can also be characterized by several clinical symptoms including orthopedic, cardiovascular, neuromuscular, visual, cognitive and perceptual impairments (Gupta & Rao & Kumaran, 2011; Virji-Babul & Kerns & Zhou & Kapur & Shiffrar, 2006; Wang et al., 2012).

It is known children with DS experience delayed motor development, and typically reach developmental milestones later than those without DS (Gemus & Palisano & Russell & Rosenbaum & Walter & Galuppi & Lane, 2001; Gupta et al., 2011; Wang et al., 2012). The delayed attainment of developmental milestones, for children with DS, is attributed to ligamentous laxity in joints, decreased strength, hypotonia, and decreased postural control and balance (Connolly & Morgan & Russell & Fulliton, 1993; Gontijo & Mancini & Silva & Chages & Luz & Fonseca, 2008; Virji-Babul et al., 2006). Walking is a critical developmental milestone, and while typically developing toddlers initiate gait between 9-15 months, those with DS initiate gait approximately a year later, with an average onset of independent walking at 24 months (Gontijo et al., 2008; Motor development for individuals with Down syndrome 2013). In addition, children with DS often have irregular gait patterns, which has been connected to their decreased ability to attain static standing balance (Gomes & Barela, 2007).

Static Standing Balance

Static standing balance is a state of maintaining the position and momentum of the whole body center mass within the base of support without falling (Cherng, Lee & Su, 2003). Balance is essential for upright posture and successful performance in functional activities. Balance is a highly integrative system. It involves the integration of visual, somatosensory, and vestibular sensory systems within the central nervous system, and the coordination of a musculoskeletal response by motor adjustment systems (Cherng et al., 2003; Villarroya & González-Agüero & Moros-García & Marín, 2012). The gold standard for assessing standing static balance is the force platform (FP). Although the FP is an excellent tool to measure balance, they are extremely expensive, hard to transport and difficult to assemble (Clark & Bryant & Pua & McCrory & Bennell & Hunt, 2010). The Pediatric Balance Scale (PBS) is a far more affordable and accessible way to accurately measure balance. The PBS is commonly used to assess balance in children with developmental disabilities such as DS.

Balance in Children with Down syndrome

Young children with DS exhibit significant deficits in maintaining static standing balance and are typically 1-3 years behind children of the same chronological age and IQ (Connolly et al., 1993; Galli & Rigoldi & Mainardi & Tenore & Onorati & Albertini, 2008; Villarroya et al., 2012; Wai-Yiwang &Yun-Hueiju, 2002). These balance deficits can be attributed to the symptoms of DS, including ligamentous laxity, hypotonia, and short stature, which all negatively affect the ability to control the balance of the body (Gupta et al., 2011; Wai-Yiwang et al, 2002). Individuals with DS are also more likely to maintain an inactive lifestyle, which contributes to even worse postural control (Wai-Yiwang et al., 2002). Balance deficits can lead to difficulties with functional tasks that are involved in many activities of daily living. Galli et al. (2008) suggested a link between balance deficits and delays in achieving motor developmental milestones. Therefore improving postural stability in children with DS should increase their physical capacity to participate in daily-exercise and other social activities (Galli et al., 2008).

Many children with DS participate in intervention programs such as physical therapy or occupational therapy to help build motor skills, increase muscular strength, and improve deficits in balance (Gupta et al, 2011). Recently an emphasis has been placed on the importance of early intervention (EI) for those with developmental disorders such as DS. Its main goals are to decrease developmental delays, remediate prevailing deficiencies, prevent functional deterioration, and promote the well-being of the child (Hadders & Blauw, 2005; Rahman 2010).

Virtual Reality

Although traditional EI programs are a successful source of intervention for children with developmental disabilities, they are expensive and often considered monotonous and boring (Blasius & Brumels & Cortright & Oumedian & Solberg, 2008; Clark et al., 2010). In the past few years, there has been an increase in the use of virtual reality (VR) as a means for therapy. VR is a computer technology that uses interactive stimulations created with computer software to present users with "opportunities to engage in environments that appear to be and feel similar to real world objects and events" (Rahman 2010). Virtual reality based therapy stimulates real-life learning and allows the user to interact, move, and manipulate virtual objects. Using VR systems in therapy allows for increased intensity of training and provides the users with augmented and direct sensory feedback (Clark et al., 2010; Rahman 2010).

There are many benefits to using VR as a means of therapy. The main benefit of VR technology for the disabled is the ability of the user to safely engage in a range of activities free from the limitations imposed by their disability (Wilson, Foreman, & Stanton, 1997; Wuang, Chiang, Su, Wang, 2011). The gaming industry has created a large variety of VR systems that are portable, inexpensive, widely available to the public, and can be used in a variety of settings such as the home and school (Clark et al., 2010). In 2006, Nintendo released their first VR system, the Nintendo Wii. Then in 2008 they released the Nintendo WiiFit game, a fitness videogame that includes aerobic training, strength training, and yoga games. Since its release, the Nintendo WiiFit game has become increasingly popular and widespread as a means for therapy (Hine, Hummer, 2010). Researches have found that when compared to traditional balance training programs, the Nintendo Wii Fit is perceived as less strenuous and more enjoyable (Brumels, Basius, Cortright, Oumedian, Brent, 2008).

Review of the Literature

The scientific evidence supporting the benefits of virtual reality on balance in the disabled population is plentiful (Vernadakis, Gioftsidou, Antoniou, Ioannidis, Giannousi, 2012; Wilson et al, 1997). Rahman (2010) examined the effectiveness of the Nintendo Wii Fit in thirty children ages ten to thirteen with DS. He divided the children into two separate groups. The control group participated in only the traditional balance training, while the experimental group participated in the traditional training and additional Nintendo Wii Fit training. The program lasted six weeks, with two training sessions per week. The results revealed that Nintendo Wii Fit improved motor proficiency, visual integrative abilities, and sensory integrative functions for children with DS. There was a high significant difference found when comparing the post-intervention mean values of balance. Therefore Rahman concluded that the Nintendo Wii Fit as a VR therapy could improve balance of children with DS (Rahman 2010).

While previous studies have demonstrated the effectiveness of the Nintendo Wii Fit as a means of therapy (Brumels et al., 2008; Rogers, Slimmer, Amini, & Park, 2010), there is limited knowledge of this technologies effectiveness in young children with DS. The purpose of this study is to compare the effectiveness of a Nintendo Wii Fit balance intervention to a traditional balance intervention, in young children with Down syndrome. It is predicted that the Nintendo Wii Fit intervention will result in greater improvements in balance for this population.

METHODS

Participants

Thirteen children diagnosed with DS (two boys and eleven girls) aged 4-6 years old were recruited from the Kinder Frogs School on the TCU campus. Exclusion factors included children with cardiovascular conditions, dual diagnoses, and functional vision or hearing loss. No attempts were made to differentiate between distinction of DS by translocation, trisomy 21, or mosaiscm. Children who used ankle foot orthotics were not allowed to wear these devices during the training or testing. Children were allowed to continue use of any hearing or visual aids during the training and testing. Approval from the institutional review board was attained prior to the study. The children's parents were informed of the study and they signed a university approved consent form before beginning the study. Following parental consent the children were give verbal assent of their comprehension and willingness to participate in the study.

Apparatus

Pediatric Balance Scale

The Pediatric Balance Scale (PBS) is a modified version of the Berg Balance Scale, and is used to assess balance for young children with mild to moderate disabilities. The relative and absolute reliability of PBS has been previously established (Franjoine, Gunther, & Taylor, 2003). PBS is composed of 14 different subtests, increasing in difficulty as the test progresses. The items tested in the PBS are carried out in the following order: sitting to standing, standing to sitting, transfers, standing unsupported, sitting unsupported, standing with eyes close, standing with feet together, standing with one foot in from, standing on one foot, turning 360 degrees, turning to look behind, retrieving object from flood, placing alternate foot on stool, and reaching forward with outstretched arm (Franjoine et al., 2003). Each item is scored on the standard criterion-based 0 to 4 point scale. The lowest score 0, is chosen when the child cannot complete the task at all. Scores of 1, 2, and 3 signifying increasing proficiency in the task, and a score of 4 is chosen when the child is able to complete the move accurately. All 14 scores are added together to produce the final score for the test; a score of 56 is the maximum score that can be obtained from this test (Her, Woo, & Ko, 2012).

Nintendo Wii

The Nintendo Wii is a VR gaming system that was released in 2006. It utilizes wireless controllers that interact with the user through a motion detection system. An infrared light sensor mounted on the top of the TV captures and reproduces the movements performed by the user and an onscreen avatar mimics these motions (Hine & Hummer, 2010; Rahman 2010; Wuang et al., 2011). Sensors embedded into the controllers are able to respond to changes in speed, direction, and acceleration, allowing the user to fully interact within the games (Wuang et al., 2011). The Nintendo WiiFit game includes training games and body tests to improve individual's static and dynamic balance, and also has the capabilities to tract an individual's progress over time. This game utilizes a thin Balance Board (Hine et al., 2010).

Nintendo WiiFit Balance Board

The Nintendo WiiFit Balance Board is an accessory product that is used in the Nintendo WiiFit game. The board is approximately 20 inches wide by 12 inches long and it can support up to 330 pounds (Wuang et al., 2011). The board contains four pressure transducers located in the corners of board, which are able to assess force distribution and the resultant movements in center of pressure. These sensors tract the users movements throughout the game and communicate through Bluetooth technology to the Nintendo Wii Console to provide instant feedback to the user (Clark et al., 2010; Rahman 2010; Wuang et al., 2011).

Procedures

Balance ability was individually assessed three times throughout the study using the PBS: pretest, posttest, and retention test (see Appendix A). The training and assessments all took place in the Kinderfrogs School by trained technicians. The participants had their baseline balance abilities assessed during the pretest at the beginning of the study.

Participants were then randomly divided into two groups of seven and six students each. One group was assigned to the Nintendo WiiFit method of intervention, and the other group to the traditional method of intervention. Both groups participated in their balance intervention method for five weeks, training five times per week for fifteen minutes each day. At the end of the five weeks, all participants had their balance assessed by the PBS, to determine any changes in balance from their initial score on the PBS. A two-week washout period followed, where the participants did not partake in either type of balance intervention. The participants then had their balance assessed at the end of this washout period, to determine the retention rate of the specific intervention method.

Nintendo WiiFit Intervention

The Nintendo WiiFit intervention involved the use of four Nintendo Wii Fit games as a training mechanism to improve balance: Soccer Heading, Tight-Rope

Walking, Penguin Slide, and Ski Slalom. Before the intervention began the participants attended a familiarization session on how to operate the Nintendo Wii technology and its tools. Each child individually participated in a 10 minute Nintendo Wii Fit yoga session to familiarize themself with the Nintendo Wii nunchuck and the procedures for getting on and off the Nintendo Wii Balance Board (Vernadakis et al., 2012).

Soccer Heading, Tight-Rope Walking, Penguin Slide, and Ski Slalom were the games chosen for this study because of the movements the player must perform in order to successfully maneuver the game. Soccer Heading and Penguin slide require "full lateral weight shifting of the center of gravity over base of support"; Tight-Rope Walking and Ski Slalom require "anterior-posterior weight shifting of the center of gravity over base of support" (Vernadakis et al., 2012).

The Nintendo Wii was set up in the same way prior to each training session. The Nintendo Wii Balance Board was placed approximately two meters away from the television screen and the children were required to wear the Wii nunchuck's safety strap around their wrists. The children were instructed to maintain both feet on the Nintendo Wii Balance Board at all times. At the start of each Nintendo Wii Fit training period the children participated in a five-minute Nintendo Wii Fit Yoga session, which served as a dynamic warm up for the children. After the warm up session, the children played the four selected Nintendo Wii Fit games in the following order, Soccer Heading, Ski Slalon, Penguin Slide, and Tight-Rope Walking. The child spent approximately three minutes playing each game.

Traditional Balance Intervention

The traditional balance intervention involved the use of four activities that have been shown to improve balance in children with developmental disabilities. They completed the following exercises: three sets of 10 horizontal and vertical jumps, balance beam walks, throwing and catching balls/beanbags outside of their base of support, and jumping on a mini trampoline (Gupta et al., 2011; Tatla, Radomski, Cheung, Maron, & Jarus, 2012). All of the necessary equipment was set up prior to the training session, and the children completed the activities in the same order during each session. At the start of each training session the children participated in a five-minute warm up of dynamic stretching.

Design and Analysis

There are two independent factors (IF) in this study, type of balance intervention and testing time. The IF balance intervention has two means: Wii Fit training and traditional training. The second IF, testing time has 3 means: pretest, post test, and retention test 1. Following randomization, a preliminary Independent T-test was conducted to determine if there are differences between the two groups at baseline. No significant difference was found between the two groups at baseline, and therefore a 2 x 5 repeated measures analysis of variance (ANOVA) was used to analyze the scores from the PBS.

RESULTS

Selected participant characteristics are shown in Table 1. The population had a mean height 40.8 $\pm$ 1.839 inches and a mean weight of 41.31 $\pm$ 6.925 pounds. BMI percentile had the greatest variability in the population with a mean percentile of 80.34 $\pm$ 17.99 %. Four children were considered normal weight, five were considered overweight, and two were considered obese.

Table 1. Selected Participant Demographics.

	Minimum	Maximum	Mean ± Std. Deviation
Age (years)	4.10	6.70	5.18 ± 0.838
Height (in)	38.00	44.50	40.80 ± 1.839
Weight (lbs)	32.00	58.20	41.31± 6.925
BMI %	35.50	99.50	80.34 ± 17.99

At baseline no statistically significant differences were found between the Nintendo WiiFit group and the traditional group in balance abilities (Figure 1). At time 2, following the five weeks of intervention, there was no statistically significant difference found between either of the two groups (Figure 2). Finally following the two-week washout period there was no statistically significant difference found between either group (Figure 3).

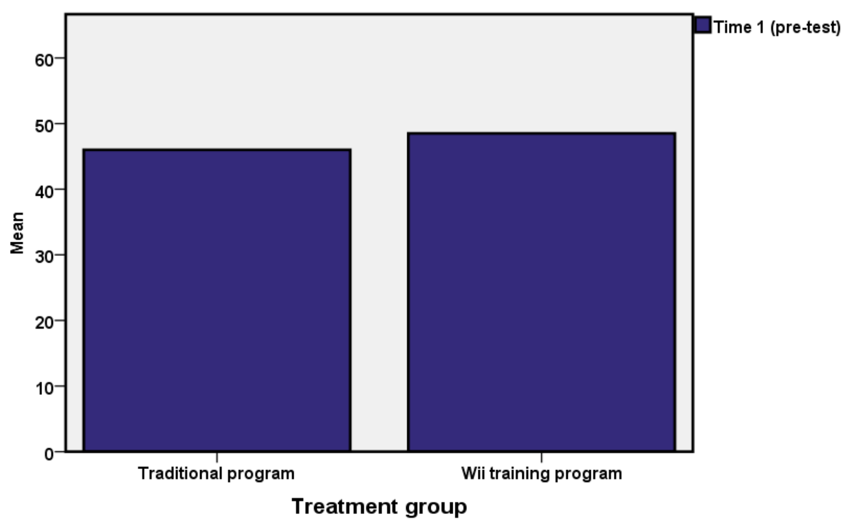


Figure 1. Traditional vs. Nintendo Wii Program Pre-Test

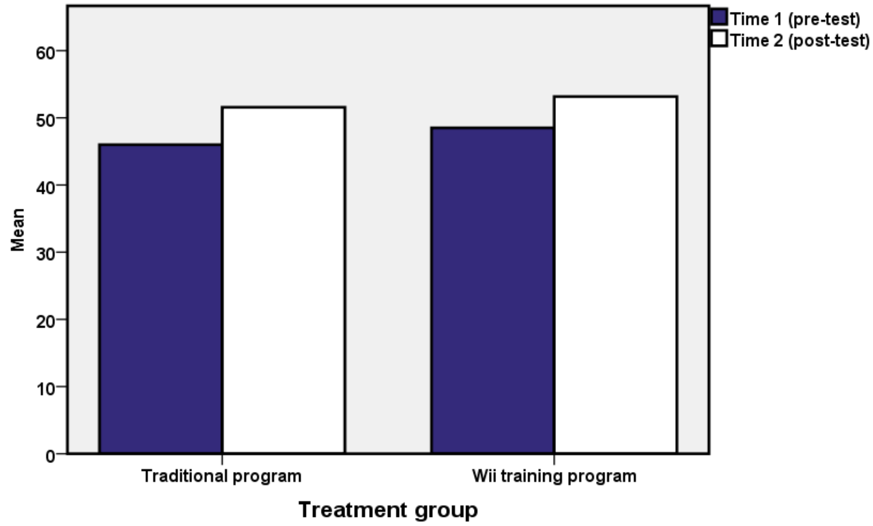


Figure 2. Traditional vs. Nintendo Wii Post-Test

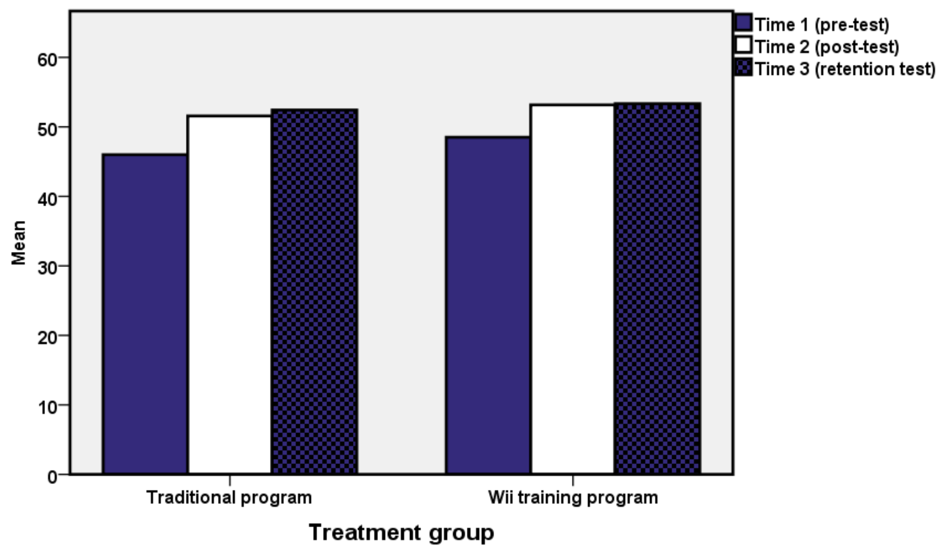


Figure 3. Traditional vs. Nintendo Wii Retention Test

At all three time points the TD children had statistically significantly higher PBS scores than their peers with DS (Figure 4). At baseline the TD children scored an average of 10 points higher on the PBS then the children with DS. At time point two (post-test) the TD children scored an average of 4 points higher on the PBS then the children with DS.

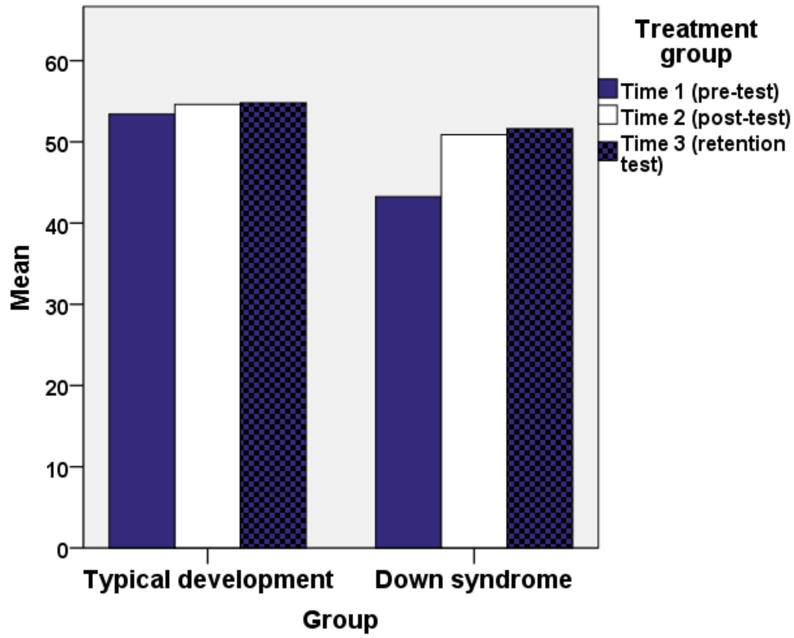


Figure 4. Typical Development vs. Down syndrome

<u>DISCUSSION</u>

Nintendo WiiFit vs. Traditional

The hypothesis that the Nintendo WiiFit Intervention would be more effective than the Traditional Intervention in improving balance abilities was not supported. There was no statistically significant difference found between the Nintendo WiiFit intervention and the Traditional intervention at any of the three time points (pre-test, post-test, retention test). Following five-weeks of intervention, all thirteen subjects that participated in the study saw improvements in their balance abilities. All of the children were also able to maintain their improved balance scores following the 2-week washout period with no training.

These results show that the Nintendo WiiFit balance intervention was just as effective in improving balance scores as the Traditional methods that are currently being implemented in school and physical therapy. The children's abilities to maintain their balance improvements following the two-week washout period, leads the researchers to believe that both interventions caused lasting improvements in balance abilities for the children. The scientific evidence supporting the benefits of the Nintendo Wii on balance in the disabled population is plentiful (Brumels et al., 2008; Vernadakis et al., 2012; Wilson et al, 1997). This is one of the few studies that has examined the use of the Nintendo Wii as a means for therapeutic intervention in a younger disabled population. The positive benefits on balance abilities found in this study correspond to the results found by Rahman (2010) in a population of children aged ten-thirteen with DS. More research still needs to be completed on a younger population of children with DS.

Typical Development vs. Down syndrome

The TD children had statistically significant higher scores than the children with DS on the PBS at all three time points (Figure 4). At time 1 (pre-test) the typically developing children scored an average of ten points higher than their peers with DS. This result was to be expected, due to the various symptoms of DS that cause delays in maintaining static standing balance (Connolly et al., 1993; Galli et al., 2008; Villarroya et al., 2012; Wai-Yiwang et al., 2002). Following the 5 weeks of intervention, at the post-test, the children with DS were only an average of four points behind the typically developing children.

One of the main purposes of any intervention program in children with disabilities is to try to close the developmental gap between the children with disabilities and their TD peers (Hadders et al., 2005; Rahman, 2010). By implementing the two balance training interventions used in this study, the researchers were able to decrease the developmental gap between the children with DS and their TD peers. By closing the gap between the TD children and their peers with DS, the children with DS will be able to increase their participation in activities at school and at home (Brumels et al., 2008; Hadders et al., 2005; Rahman, 2010).

Limitations

The researchers were only able to recruit a small sample size, which did not allow for a control group. A second limitation was due to time restrictions in the Kinderfrogs school day. Although each child received individual attention, the researchers had to implement group-training sessions instead of individualized sessions. Finally the researchers did not monitor any outside training or interventions that the children were receiving outside of this study.

Implications

The results of the study indicate that the Nintendo WiiFit Intervention was just as effective as a means for improving balance in young children as the traditional methods the children are already receiving in school and in physical therapy. The Nintendo WiiFit intervention has many advantages to the Traditional intervention.

First, the children found the Nintendo WiiFit intervention to be more “fun” than the traditional intervention. The interactive mode of training created a high-energy environment that the children were able to thrive in. The interactive components of the Nintendo WiiFit lead higher motivation in the children. This is important because a higher motivation will lead the children to continue to want to participate in the activity day after day. The Nintendo WiiFit also has the capabilities to set goals. This also plays into the increased motivation and competitiveness of the children. When the children are able to set a goal, they become determined to reach that goal. Finally the Nintendo

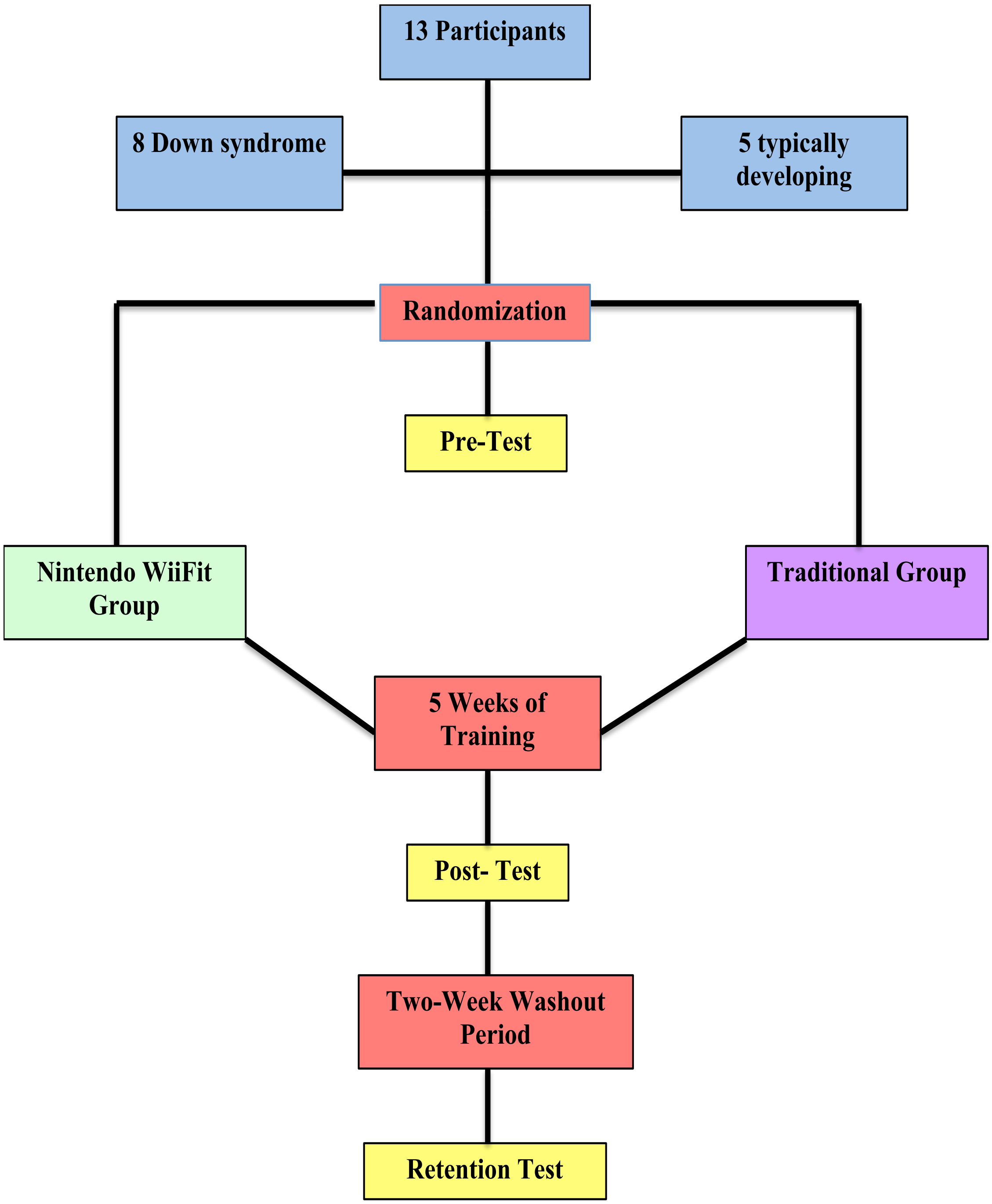
WiiFit has the ability to track the children's progress. Due to the various advantages of the Nintendo WiiFit Intervention, it is predicted that there will be a continued increase in its use as a means for therapeutic intervention (Brumels et al., 2008, Hine et al., 2010).

The study also indicates that a short training period of 15 minutes per day can make significant improvements in balance abilities. This result is important because it demonstrates that a little can go a long way. The researchers created a 'parent information sheet' that was distributed to all of the children who participated in the study's parents. The goal of this was to educate the parents about the significant improvements that can be made through the Nintendo WiiFit technology. The researchers hope that the parents will take the knowledge from this study and implement it in their homes.

Future Directions

More research needs to be completed examining the effects of the Nintendo Wii as a means for therapeutic intervention in young children with DS. Further research also needs to be done on the effect of varying the intensity of the intervention period. A longer intervention period, or longer training sessions each day should be implemented and it is expected that the children would see larger increases in balance abilities. Further research also needs to be done examining the effect of implementing a longer washout period following the intervention period. In doing so, the maximal washout period without declines in balance abilities could be found. Finally more research needs to be done exploring the various other virtual reality technologies that are on the market. Due to the success of this study, the use of the Nintendo Wii as a means for therapeutic intervention can be expected to continue to rise. This technology can be used to supplement traditional exercises and increase the motivational and fun aspects of therapy.

APPENDIX A


13 Participants
8 Down syndrome
5 typically developing
Randomization
Pre-Test
Nintendo WiiFit Group
Traditional Group
5 Weeks of Training
Post- Test
Two-Week Washout Period
Retention Test

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