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Assessment of postural, locomotor, and physical fitness status in individuals with intellectual and developmental disabilities

Alana J. Turner
Mississippi State University, aturner4@coastal.edu

Assessment of postural, locomotor, and physical fitness status in individuals with intellectual and developmental disabilities

By

Alana Joy Turner

Approved by:

Harish Chander (Major Professor)
Chih-Chia Chen
Kasee K. Stratton-Gadke
Kayla Bates-Brantley
Adam C. Knight (Committee Member/Graduate Coordinator)
Teresa Jayroe (Dean, College of Education)

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Name: Alana Joy Turner

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Institution: Mississippi State University

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Committee Chair: Harish Chander

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Candidate for Degree of Doctor of Philosophy

Introduction: Postural control and locomotion deficits can be observed during the early years of childhood development and throughout life. For those with disabilities, these deficits can advance past the development years and into adolescence and adulthood while effecting quality of life and daily activity. Finding interactive rehabilitative activities to delay or limit these deficits is essential for people with disabilities to improve quality of life, inclusion, and overall movement. Adapted physical activity/sports like badminton and virtual reality could promote improvements in postural and locomotor status for young adults with intellectual and developmental disabilities like cerebral palsy (CP), intellectual disability (ID), and autism spectrum disorder (ASD). **Purpose:** The purpose of these studies is to assess the postural and locator status of young adults with intellectual and developmental disabilities after participating in a 12-week badminton program and an intensive virtual reality program. **Methods:** Study A will follow a multiple baseline approach to access postural control, locomotion and areas of physical fitness in young adults with IDD utilizing the immersive virtual reality game Fruit Ninja™ while study B will follow and repeated measures design accessing static postural control

for students in a comprehensive transition program for intellectual disabilities at a southeastern university.

DEDICATION

I would like to dedicate this dissertation to a few people. Firstly, to my parents Mark and Nita Turner. I want to thank them for their consistent and unending support throughout my academic career. I greatly appreciate the numerous phone calls and the drives to Starkville if I needed any assistance especially during comprehensive exams. Secondly, I would like to dedicate this dissertation to every child with a disability and his/her parents I have worked with through bike camps and adapted physical activity programs. They will never know the impact they have had on my life not only as a researcher but as a person. For them, I will continue to strive to create inclusive opportunities for physical activity and sports to improve all areas of life.

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TABLE OF CONTENTS

DEDICATION ii

ACKNOWLEDGEMENTS iii

LIST OF TABLES vii

LIST OF FIGURES viii

CHAPTER

I. INTRODUCTION 1

Purposes for Study A & B 4
Specific Aims & Manuscripts 4
Specific Aim 1 & Manuscript 1 4
Specific Aim 2 & Manuscript 2 5
Specific Aim 1 & Manuscript 3 5

II. REVIEW OF LITERATURE 7

Postural Control and Locomotion 7
Children with Disabilities-Posture/Locomotor Disabilities 10
Virtual Reality for Rehabilitation 16
Adapted Sport for Rehabilitation 21
Conclusions 22

III. METHODOLOGY 24

Study A 24
Participants 24
Study Design, Experimental Procedures, & Instrumentation 25
Study B 28
Participants 28
Study Design, Experimental Procedures, & Instrumentation 28
Limitations 30

IV. MANUSCRIPT 1 31

Manuscript 1: Effects of an Intensive, Immersive Virtual Reality Program-Fruit Ninja VR-Survival Mode® on Postural Control for Individuals with Intellectual and Developmental Disabilities- a Multiple Baseline Design 31
Abstract....31
Introduction 32
Methods 35
Participants 35
Study Design 35
Clinical Outcome Measures 36
Intervention....37
Data Analysis....37
Results 37
Eyes Open (EO)....38
Eyes Closed (EC) 42
Foam Eyes Open (FEO) 46
Foam Eyes Closed (FEC) 50
Single-Leg Eyes Open (1LEO) 54
Single-Leg Foam Eyes Open (1LFEO) 58
Discussion....61
Conclusions & Future Implications....65

V. MANUSCRIPT 2....67

Manuscript 2: Effects of Intensive, Immersive Virtual Reality for Individuals with Intellectual and Developmental Disabilities on Elements of Physical Fitness and Locomotion - A Multiple Baseline Design 67
Abstract....67
Introduction 68
Methods 70
Participants 70
Study Design, Experimental Procedures, and Instrumentation....71
Clinical Outcome Measures 72
Intervention....73
Data Analysis....73
Results 73
Locomotion-Timed Up & Go....74
Muscular Strength-Hand Grip Force....75
Flexibility- Modified Sit & Reach....77
Muscular Endurance- Sit to Stand....79
Discussion....81
Conclusions & Future Implications....84

VI. MANUSCRIPT 3....86

Manuscript 3: The Effects of an Inclusive Badminton Program on Postural Control for Individuals with Intellectual and Developmental Disabilities....86

Abstract......86
Introduction......87
Methods......89
Participants......89
Experimental Procedures......90
Data Analysis......90
Statistical Analysis......91
Results......91
Eyes Open (EO)......92
Eyes Closed (EC)......97
Foam Eyes Open (FEO)......98
Foam Eyes Closed (FEC)......101
Single-Leg Eyes Open (1LEO)......102
Discussion......103
Conclusion & Future Implications......106

VII. CONCLUSIONS......107

REFERENCES......108

LIST OF TABLES

Table 1 EF Deficits in ASD (Adapted from Demetriou et al., 2018) 15

Table 2 EF Deficits in ID (Adapted from Rodriques et al., 2019)..16

Table 3 Descriptive statistics- means and standard deviations. 66

Table 4 Descriptive Statistics. Means and standard deviations 85

LIST OF FIGURES

Figure 1 Postural Control Systems Theory 9

Figure 2 EO M/L Displacement Across Participants. 39

Figure 3 EO A/P Displacement Across Participants. 40

Figure 4 EO 95% Ellipsoid Area Across Participants....................41

Figure 5 EO Average Velocity Across Participants....................42

Figure 6 EC M/L Displacement Across Participants. 43

Figure 7 EC A/P Displacement Across Participants. 44

Figure 8 EC 95% Ellipsoid Area Across Participants. 45

Figure 9 EC Average Velocity Across Participants. 46

Figure 10 FEO M/L Displacement Across Participants. 47

Figure 11 EC A/P Displacement Across Participants. 48

Figure 12 FEO 95% Ellipsoid Area Across Participants. 49

Figure 13 FEO Average Velocity Across Participants. 50

Figure 14 FEC M/L Displacement Across Participants. 51

Figure 15 FEC A/P Displacement Across Participants. 52

Figure 16 FEC 95% Ellipsoid Area Across Participants. 53

Figure 17 FEC Average Velocity Across Participants. 54

Figure 18 1LEO M/L Displacement Across Participants. 55

Figure 19 1LEO A/P Displacement Across Participants. 56

Figure 20 1LEO 95% Ellipsoid Area Across Participants. 57

Figure 21 1LEO Average Velocity Across Participants. 58

Figure 22 1LFEO M/L Displacement Across Participants. 59

Figure 23 1LFEO A/P Displacement Across Participants. 60

Figure 24 95% Ellipsoid Area Across Participants. 61

Figure 25 Locomotion-TUG. Movement Time Across Participants. 75

Figure 26 Muscular Strength. Dominant Hand Grip Force Across Participants. 76

Figure 27 Muscular Strength. Non-Dominant Hand Grip Force Across Participants. 77

Figure 28 Flexibility. Modified Sit & Reach. Left Leg Distance Covered. 78

Figure 29 Flexibility. Modified Sit & Reach. Right Leg Distance Covered. 79

Figure 30 Muscular Endurance. Sit to Stand. Repetitions Across Participants. 80

Figure 31 EO Average M/L Displacement (in.) Time Main Effect for IDD during Pre-Test-Post-Test 93

Figure 32 95% EO Ellipsoid Area (in^2) Time-Main Effect for IDD during Pre-Test to Mid-Test 94

Figure 33 EO Average Velocity (ft/s) Time-Main Effect for IDD during Pre-Test to Mid-Test and Pre-Test Post-Test & Group X Time Interaction for IDD-BADM 95

Figure 34 EO Average Length (in.) Time-Main Effect for IDD during Pre-Test to Mid-Test and Pre-Test-Post-Test & Group X Time Interaction for IDD-BADM 96

Figure 35 EO Average A/P Displacement (in.) Time Main Effect for TD during Pre-Test-Post-Test 97

Figure 36 EC Average M/L Displacement (in.) Time Main Effect for TD during Pre-Test-Post-Test 98

Figure 37 FEO Average M/L Displacement (in.) Time Main Effect for IDD during Pre-Test-Post-Test 99

Figure 38 FEO Average A/P Displacement (in.) Time Main Effect for IDD during Pre-Test-Post-Test 100

Figure 39 FEO Average M/L Displacement (in.) Time Main Effect for TD during Pre-Test-Post-Test 101

Figure 40 FEC Average M/L Displacement (in.) Time Main Effect for TD during Pre-Test-Post-Test 102

Figure 41 1LEO Average A/P Displacement (in.) Group X Time Main Effect for IDD-BADM during Pre-Test-Post-Test 103

CHAPTER I

INTRODUCTION

Despite national proposals to increase the levels of physical activity (PA) of children during their school-aged years current research suggests that the vast majority of children are not meeting the minimum suggestion to participate in sixty minutes of PA each day (Obama, 2018; U.S. Dept. of Health & Human Services, 2008). Unfortunately, children with intellectual and developmental disabilities (IDD) experience notable lower levels of PA when compared to typical-development children (Tyler et al., 2014; Boyle et al., 2008). This is alarming since approximately 15% of the school-aged population are diagnosed with IDD (Boyle et al., 2008). According to the Centers of Disease Control and Prevention, in the United States about one in six, or about 15%, of children aged three through 17 years have one or more developmental disabilities (CDC, 2018). Developmental disabilities are a combination of conditions involving physical, learning, or behavior impairments. A few disabilities considered an IDD are: Down Syndrome (DS), Autism Spectrum Disorder (ASD), and even Global Developmental Delay (GDD). These conditions begin during the developmental phase and may impact daily functioning and can last throughout an individual's lifetime (CDC, 2018). When compared to their typically developing peers (TD), children with IDD experience a multitude of health disparities including greater risks of diabetes, obesity, hypertension, high cholesterol, and deficits in overall movement (Rimmer et al., 2010). With participation in daily PA, enhancements in these areas can be observed; however, parents frequently mention the lack of access to PA programming as the most significant barrier to participation that their children with IDD experience (Shields et al., 2012). PA participation for children with IDD include a plethora of researched benefits including improved aerobic capacity, increased gross motor functioning, and increased balance (Johnson, 2009). Yet, limited number of individuals with IDD participate in a sufficient amount of PA to receive benefits from the successive health outcomes. Finding alternate, motivating activities such as virtual reality exer-gaming (VR) and adapted physical activities could enhance a child's engagement with physical activity to receive benefits such as increased physical fitness and postural control.

Postural control is a motor skill derived from the interaction of multiple sensorimotor processes, including many biomechanical limitations and physiological systems such as movement and sensory strategies, orientation in space, control of dynamics, and cognitive processing (Horak, 2006). During a quiet stance, the central nervous system receives, combines, and organizes visual, somatosensory and vestibular information along with information from other systems, to ultimately produce a motor response to maintain an erect posture (Peterka, 2002). A deficiency in the postural control system may represent an underlying impairment in physiological subsystems; for example, abnormalities like a disability of an individual or combined sensory inputs can result in postural instability (Horak, 2006). Previous literature has highlighted the difficulties encountered by populations with sensory processing impairments when processing sensory information for postural control (Pavao et al., 2015). Although persons with ASD are reported to have problems modulating sensory information (e.g. Ben-Sasson et al., 2009, DSM-V), current research on postural strategies to sensory information have not been consistent in the ASD literature. In the eyes closed condition, Minshew et al. (2004) reported that participants with ASD exhibited reduced postural stability when compared to their typical developing participants. However, Travers et al. (2013) found no significant difference in standing postural control between adults with ASD and typical-development adults while performing the eyes closed condition. The findings to date lack synthesized evidence in relation to the effect of sensory information on postural control in the ASD population especially for the pediatric population. Therefore, the effect of sensory information on postural control in the ASD population remains unclear.

Further, as a therapeutic resource, virtual reality (VR) proposes the opportunity to intensify repetitive tasks and increase visual and auditory feedback, making VR a motivational tool for pediatric therapy without issuing any severe threat or physical restrictions to participants (Vivera et al., 2014). Previous literature has examined the effectiveness of VR physical activity on physiological, psychological and rehabilitative measures. For example, researchers suggested that VR could promote the lower limb function of patients who suffered from stroke (Iman, 2014). VR activity has also demonstrated a significant effect on the balance capability of stroke victims, individuals with Parkinson's disease (PD), and children with cerebral palsy (CP) (Juras et al., 2019). In addition, the effectiveness of VR in psychological treatment has been widely supported (Valmaggia, 2016). For instance, VR exercise has been observed to relieve anxiety and depression commonly observed with many individuals with disability (Zeng et al., 2017). As for rehabilitative effectiveness, VR technology in disease rehabilitation has been widely applied, mainly to improve lost motor skills caused by injury or illness (Zeng et al., 2017). Overall, VR has been frequently researched for rehabilitative purposes for many special populations; however, there is little research focusing on balance and physical fitness of children with ASD while applying VR exergaming as an intervention.

Purposes for Study A & B

The purpose of the investigation for Study A was to evaluate the effectiveness of an intensive, immersive virtual reality video game for postural control, locomotion, and physical fitness of young adults with IDD through a multiple baseline design. The purpose of the investigation for Study B was to assess the implementation of badminton as an adapted physical activity for students with IDD utilizing a repeated measures design with pre, mid, and post testing to measure potential improvements in postural control. For both studies, participants were students in a comprehensive transition program for intellectual disabilities at a southeastern university.

Specific Aims & Manuscripts

Study A

Specific Aim 1 & Manuscript 1

Effects of an Intensive, Immersive Virtual Reality Program-Fruit Ninja VR-Survival Mode® on Postural Control for Individuals with Intellectual and Developmental Disabilities- a Multiple Baseline Design

Specific Aim 1: To investigate the effects of effects of an intensive, immersive virtual reality program-Fruit Ninja VR-Survival Mode® on postural control for individuals with intellectual and developmental disabilities

H_0: The VR intervention will show significant difference in postural control performance during the intervention phase.

H_A: The VR intervention will show significant decreases in postural control performance during the intervention phase when compared to baseline.

Research Question: Will an intensive, immersive virtual reality (i.e. Fruit Ninja VR-Survival Mode®) improve postural control for individuals with intellectual and developmental disabilities?

Specific Aim 2 & Manuscript 2

Effects of Intensive, Immersive Virtual Reality Program-Fruit Ninja VR-Survival Mode® for Individuals with IDD on Elements of Physical Fitness and Locomotion - A Multiple Baseline Design

Specific Aim 2: To investigate the effects of effects of an intensive, immersive virtual reality program-Fruit Ninja VR-Survival Mode® on locomotion and physical fitness for individuals with intellectual and developmental disabilities

H_0: The VR intervention will show significant difference in locomotion ant physical fitness during the intervention phase.

H_A: The VR intervention will show significant decreases in movement time, increases in flexibility, increases in muscular endurance, and muscular strength during the intervention phase when compared to baseline.

Research Question: Will an intensive, immersive virtual reality (i.e. Fruit Ninja VR-Survival Mode®) improve locomotion and areas of physical fitness for individuals with intellectual and developmental disabilities?

Study B

Specific Aim 1 & Manuscript 3

The Effects of an Inclusive Badminton Program on Postural Control for Individuals with Intellectual and Developmental Disabilities

Specific Aim 1: To investigate the effects an inclusive badminton program on postural control for individuals with intellectual and developmental disabilities

H_0: The badminton intervention will show significant difference in postural control measurements.

H_A: The VR intervention will show significant decreases in postural control mechanisms for those with Intellectual and Developmental Disabilities.

Research Question: Will an inclusive badminton program (i.e. Fruit Ninja VR-Survival Mode®) improve postural control mechanisms for individuals with intellectual and developmental disabilities?

CHAPTER II

REVIEW OF LITERATURE

The purpose of this section is to investigate previous literature identifying special populations, such as, children with disabilities and more specifically children who exhibit postural and locomotor deficits. In addition to identifying children with physical, cognitive, and social deficits this chapter discusses current rehabilitation studies for this population, including, virtual reality and adapted physical activity programs like inclusive badminton to improve upon deficits. The first and second sections examine postural control and locomotion, different developmental, cognitive, and physical disabilities and deficits associated with each disability. The second section identifies new forms of rehabilitation- virtual reality and adapted physical activity programs.

Postural Control and Locomotion

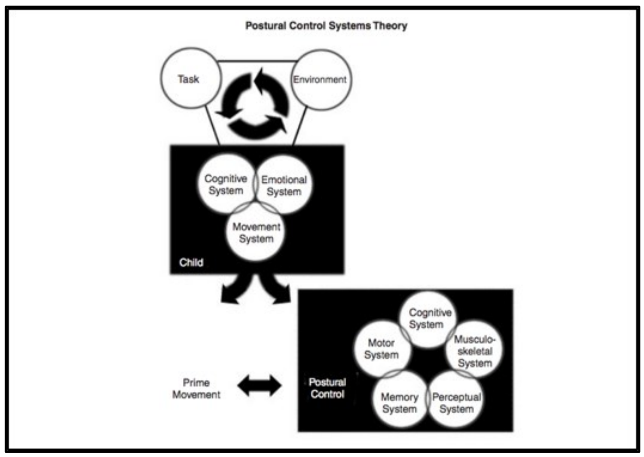
The Centers for Disease Control and Prevention (2017) reported about 1 in 6 (17%) children aged 3–17 years were diagnosed with a developmental disability, as reported by parents, during a study period of 2009-2017. These included Autism Spectrum Disorder (ASD), Attention-Deficit/Hyperactivity Disorder (ADHD), blindness, and Cerebral Palsy (CP), among others. One area that can be affected by a developmental disability is an individual’s postural control system. Horak and colleagues (2006) refer to postural control as a multifaceted skill maintained by multiple sensorimotor systems. Horak (2006) determined the factors responsible for postural control include higher center processing, control of dynamics, spatial orientation, biomechanical factors, and sensory/movement strategies. Previous research has also identified deficits in motor development (Provost et al., 2007), coordination and gross motor function (Jansiewicz et al., 2006), and the planning and performance of movement (Rinehart et al., 2006; Glazebrook et al., 2006) for children with ASD and developmental disabilities. Of particular importance are the identified deficits in the postural control system (Gepner, 2002; Molloy, 2003; Minshew et al., 2004; Kohen-Raz et al., 1992; Gepner et al., 1995). An undeveloped postural control system can be a limiting factor in the development of other motor skills, it may constrain the ability to develop mobility and manipulatory skills, and it is important concerning quality of life. The ability to maintain an erect posture is an essential skill necessary for typical motor development in humans.

Postural control observed in children with ASD and developmental disabilities appear to differ from that of typically developing (TD) children as well as children with intellectual disability (ID) (Molloy, 2003; Minshew et al., 2004; Kohen-Raz et al., 1992; Gepner et al., 1995). Children with developmental disabilities exhibit less age-related or milestone developments, less stable and variable postural control strategies, particularly in the mediolateral direction (Gepner et al., 1995). Additionally, both children with ASD and developmental disabilities have been observed to have decreased postural stability when compared to individuals with typical development under conditions where one or more sensory inputs had been removed or modified (Minshew et al., 2004; Kohen-Raz et al., 1992; Gepner et al., 1995).

The environment, task, and child embody different systems affecting movement. Within the child, the movement system can be divided into the control components for the primary movement and postural control as observed in Figure 1. Within postural control, the sensory, motor and musculoskeletal systems work in unison with other systems to produce efficient and safe postures and recovery of postures. These three systems have been examined to some extent in children with and without disabilities (Horak, 1996; Liu, 2001).

Figure 1

Postural Control Systems Theory



Postural Control Systems Theory. Adapted from Horack 1992 & Liu 2001.

Postural control during dynamic activities such as gait initiation requires the integration of multiple sensory and motor pathways so that the central nervous system (CNS) can coordinate the anticipatory/postural and planned movement components. Gait initiation (GI) is a functional task requiring voluntary disruption of the whole-body center of mass (COM) and a transition from a large base of support to a smaller base of support (BOS). GI has been reviewed to provide insight into dynamic postural control and the changes that occur in the control system through development, advancing age, and disability (Has, 2004&2005; Halliday et al., 1998; Martin et al., 2002). Horak (2006) mentions the main biomechanical restriction faced by the geriatric population is maintaining balance which is similar to children with developmental disabilities. The maintenance of balance requires an individual's COM to remain in the body's BOS, which represents where the body has direct contact with an external surface (Winter 1995). The BOS is comprised of the contact of the floor with the feet, and in some cases an assisted walking component like a cane or walker. Ultimately, when the COG exceeds the parameters of the BOS, postural instability occurs leading to falls and trips especially in a developing population. Further, the COM and Center of Pressure (COP) are constantly shifting anteriorly/posteriorly (A/P) and medially/laterally (M/L) to keep the body in an erect bipedal stance (Winter 1995). Due to the location of the COM of the human body, an inverted pendulum model was introduced to maintain balance in the A/P direction (Winter 1995). When the COM moves anteriorly to the COP, muscle activation from the plantar flexors including the gastrocnemius and soleus will realign the COM within the BOS (Winter 1995). Inversely, when the COM moves posteriorly to the COP, the dorsiflexors are activated to keep the COM within the parameters of the BOS. This constant shifting can be referred to as postural sway (Winter 1995). The increased amount of postural sway displacement can become a hindrance to the pediatric population.

Children with Disabilities-Posture/Locomotor Disabilities

According to the American Psychiatric Association (APA), an individual with Autism Spectrum Disorder (ASD) is diagnosed according to the following criteria: difficulty with communication with other individuals, repetitive behaviors or movements, symptoms that negatively influence the individual's ability to function properly in school, work environment, and other areas of life (NIMH, 2018). Moreover, ASD is known as a "spectrum" disorder because there is a wide variation in the type and severity of symptoms people experience (NIMH, 2018). The APA recently issued the Diagnostic and Statistical Manual of Mental Disorder, 5th Edition: DSM-5 (APA, 2013), which is the gold-standard for diagnosis of mental and behavioral conditions, including ASD. In the most recent edition of the DSM-5 (APA, 2013) locomotion deficiencies were not under the diagnosis criteria, but some gait abnormalities (lower extremity joint positioning, ground force reaction (GRF) asymmetries, and postural instability).

Recent studies have demonstrated that individuals with ASD also have motor impairments that inhibit locomotion such as poor postural control, gait abnormalities, and impairment in bilateral coordination (Shetreat-Klein, 2014). Sensory deficiencies were originally not part of the core definition of the disorder, but the DSM-5 categorization now includes the expression ‘‘hyper- or hypo-reactivity to sensory input or unusual interest in sensory aspects of the environment” (Doumas et al., 2015). Moreover, Doumas et al. (2015) hypothesized lack of sensorimotor activity such as, upright standing and postural control mechanisms, are linked to those with ASD. Eggleston et al. (2017) reported that postural instability appeared to be a symptom of gait asymmetry for children with ASD. Moreover, this study reported that children with ASD exhibited significant lower extremity joint position and ground reaction force asymmetries throughout the gait cycle (Eggleston et al., 2017). Gait symmetry is usually seen in children with TD and creates fluidity in an individual's movement. Further, motor impairments are affected by sensory deficiencies and can ultimately hinder a typical gait cycle by creating a compensatory gait which can lead to overall inefficient locomotion and poor movement quality.

Research has shown that cognitive deficits for children with ASD have impacted a complex cognitive construct known as Executive Function (EF) which influences several higher-level processes such as thought and behavior, developing throughout the lifespan (Johnston et al., 2019). EF encompass those cognitive processes that underlie goal-directed behavior and are orchestrated by activity within the prefrontal cortex (PFC; e.g., Olson & Luciana, 2008; Shimamura, 2000). EF consists of three areas: working memory, cognitive flexibility (shift), and inhibition (Johnston et al., 2019). Previous literature discusses that these areas or concepts are associated with stereotyped, repetitive behaviors, slower processing speeds, goal-oriented behavior, memory, attention, and even decision-making skills (Johnston et al, 2019). Overall, deficits in any of these areas of EF could impact a child's behavior and even communication skills.

Years of research suggests that children with ASD have deficits in social-emotional skills such as thinking about, understanding, and responding to others (Baron-Cohen, 2000). These deficits are often context-specific and multifaceted, including many social-emotional areas like perception and interpretation of social signals (Russo-Ponsaran et al., 2019). Russo-Ponsaran et al. (2019) conducted a study focusing on five domains of social-emotional functioning: facial emotion/recognition, social problem solving, theory of mind, delay of gratification, and frustration tolerance. Most of the scores reported from the study were significantly below GenEd population norms. Overall, if deficits are observed in social-emotional health areas, then it will be difficult for children with ASD to make relationships and communicate needs with peers, adults, and others.

Adaptive functioning is a multifaceted concept that includes age-appropriate skills to transition to the next phase of life (Matthews et al., 2015). Matthews et al. (2015) advocated for new interventions for adaptive functioning because Daily Living Skills (DLS) were significantly lower for people with ASD. Estes et al. (2015) reported that children at six, twelve, and 24 months with ASD had significantly lower Adaptive Behavior Composites (ABC) (provides an overall index of adaptive function) and Motor scores than their typical development control. In conclusion, adaptive functioning deficits are observed for children and people with ASD. It is important for children to not only learn language and communication skills but social skills and DLS should be dictated by societal demands.

Physical health can be divided into six sections: body composition, muscular endurance, muscular strength, flexibility, cardiovascular fitness, and skill-related fitness. Deficits in these areas of physical health can impact daily life for a person with ASD. For body composition, one study reported that children with ASD were 40% more likely to be obese than typical development children while 94% were reported to have a co-morbidity when compared to the 17% of children without ASD (Curtain et al, 2013). Rimmer et al. (2010) identified 42.5% of children with ASD to be overweight while 24.6% were obese. For skill-related fitness, locomotor and object-skills based on the Test of Gross Motor Development-2 (TGMD-2) (Berkely et al., 2010; Staples & Reid, 2010; Ulrich, 2000). The TGMD-2 assess locomotor skills such as running, hopping, galloping, leaping, jumping, overhead-throwing, underhand rolling, dribbling, kicking, and catching (Ulrich, 2000). These are skills essential to participation in physical education and active play. Further, Staples & Reid (2010) concluded that children with ASD performed movement skill at a level equivalent to children half their chronological age. In all, children with deficits in their motor function, can directly affect areas physical health and effect physical activity and exercise.

Exercise can be characterized as “activities that demonstrate an elevated breathing pattern and heart-rate to demonstrate a moderate to vigorous physical exertion has taken place” (Bittner et al., 2019). The Physical Activity Guidelines Advisory Board recommends that typical development and children with disabilities amass 60 minutes of moderate to vigorous physical activity a day for a minimum of 3 days a week, with aerobic exercise covering most of the time accumulated (Bittner et al., 2019). The Centers for Disease Control and Prevention (CDC) define aerobic exercise as “and activity in which the body’s large muscles move in a rhythmic manner for a sustained period of time” (Bittner et al., 2019). Further, past literature has shown benefits of aerobic exercise for children with ASD because it can be linked to improved outcomes such as decreases in stereotypical behavior, decreases in aggression, decreases in off-task behavior, increases in academic engagement, increases in social opportunities, improved attention, and increases in muscular endurance and strength (Bittner et al., 2019). Overall, it is important for children with ASD to participate in aerobic exercise because of improvements in specific areas where there may be deficits to promote better quality of life, socialization skills, physical fitness, and academic performance.

Executive Function (EF) refers to the cognitive skills involved in problem-solving and goal-setting located in the prefrontal cortex (PFC) (Carlson et al., 2013). The three areas of EF include working memory, inhibition, and cognitive flexibility or shifting (Carlson et al., 2013). EF continues to adapt and improve into early adulthood; however, early advances are developed during the major developmental years such as the preschool years (Carlson et al., 2013). Researchers reported EF is influenced by both internal and external factors during development (sleep, language, socioeconomic status, caregiving, etc.) (Carlson et al., 2013). Overall, EF can be trained with changes to the brain's structure and function.

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition associated with deficits in social interactions, and restricted patterns of behaviors (Demetriou et al., 2018). Over the years, researchers reported deficits in Executive Function (EF) with impairments to the areas of mind and social cognition, social impairment, repetitive behavior movements, and overall quality of life (Demetriou et al., 2018). EF covers a broad range of higher-order domains such as goal-setting, planning, abstract reasoning, and even social regulation (Demetriou et al., 2018). Table 1 below highlights deficits in ASD.

The American Psychiatric Association (APA) and the American Association on Intellectual Developmental Disabilities (AAIDD) characterize Intellectual Disability (ID) by "significant limitations in intellectual functioning and adaptive functioning, originating before 18 years of age" (AAIDD, 2010; APA, 2013). The APA defines adaptive functioning into three main areas: communication, social skills, and personal independence (APA, 2013); while the AAIDD characterizes adaptive functioning as conceptual, social, and practical skills (AAIDD, 2010). For both characterizations of ID deficits are observed in EF since this area in the PFC houses these skills (Rodrigues et al., 2019). Deficits for ID are described in Table 2 below.

Table 1

EF Deficits in ASD (Adapted from Demetriou et al., 2018)

EF Area	**Developmental Stage Area of Brain**	**Deficits Observed**
Cognitive Flexibility (Shifting): to change or alternate between tasks and decision-making	Observed during early childhood; advances during adolescence Increased activation in left inferior and right mesial parietal cortex during "switching" task	Decreased performance on task for motor and sensory stereotypic behaviors
Inhibition: responsible for behavior regulations	Observed during early childhood; advances to adolescence Noted recruitment of ACC, OFC, inferior and middle gyri and higher activation of DLPFC	Reduced fronto-cerebellar connectivity Impaired performance on response inhibition task(s) for predicted motor and sensory stereotypic behaviors
Working Memory: the process to update and recall events of sequence over time	Observed in early childhood and advances during adolescence Increased activation of left and right PFC and left and right posterior parietal cortex (PPC)	Impaired working memory is related to deficits in communication and socialization skills Negatively correlated with restrictive and repetitive behaviors

Table 2

EF Deficits in ID (Adapted from Rodriques et al., 2019)

EF Area	Developmental Stage/ Area of Brain	Deficits Observed
Cognitive Flexibility (Shifting): to change or alternate between tasks and decision-making	- Observed during early childhood	- Deficits in dual tasking - Lowered attentional capacity
Inhibition: responsible for behavior regulations	- Observed during early childhood	- Slower information processing speeds than typical development individual - Deficits in controlling impulsivity
- Working Memory: the process to update and recall events of sequence over time	- Observed during early childhood	- Deficits in planning and problem-solving skills

Virtual Reality for Rehabilitation

Virtual Reality (VR) is not considered a new concept but has developed over the years, becoming readily available to researchers, rehabilitative professionals, and even the general consumer. VR is characterized as an experience that embraces the senses such as sight, hearing, and touch and is considered an alternative to reality, creating a three-dimensional environment (Pope, 2018). The term “virtual reality” was coined by Jaron Lanier of the Visual Programming Lab (VPL) in the late 1980s but can be traced back to the mid-1960s to Ivan Sutherland’s research with head-mounted displays at MIT and Harvard University funded by the Advanced Research Projects Agency of the US Department of Defense (Schroeder, 1993). This paper titled “The Ultimate Display” which embraced the idea that one day the computer would provide a view into virtual worlds (Alqahtani, 2017).

The different types of VR systems are categorized according to the “level of immersion” the system provides ranging from semi-immersive (two-dimensional display) to fully immersive (Alqatani, 2017). The first type of VR is the fully-immersive VR which requires the user to wear a head-mount display which encases the audio and visual perception of the user (Alqahtani, 2017). Typically, the user will also engage with the virtual environment through hand-held controllers or gloves (Alqahtani, 2017). Moreover, fully-immersive VR eliminates sensory feedback from the outside environment so the user is fully immersed into the video environment (Alqahtani, 2017). Another type of VR is a non-immersive system which involves a display screen such as a desktop monitor or television and does not include a head-mount display (Alqahtani, 2017). Non-immersive is the more common type of VR and can involve a gaming console, keyboards, and controller like a video game (Alqahtani, 2017). The non-immersive system is the least intrusive version of VR and more economically sufficient when compared to the fully-immersive version (Alqahtani, 2017). Lastly, semi-immersive VR provides the user with a partially virtual environment (Alqahtani, 2017). The semi-immersive environment allows users to have the perception of being in a different reality through a digital image, but will permit the user to remain connected to their physical setting (Alqahtani, 2017). Semi-immersive VR is used in more educational or training scenarios like pilot simulation training which partially replicates a functional, real-world situation (Alqahtani, 2017).

Many research centers, universities, and companies are financing billions of dollars into creating VR content, and already millions of people have access to VR technology (Solomon, 2014; Somaiya, 2015; Wohlesen, 2015). As the public begins to gain access to VR, children are increasingly more likely to come in contact with this type of technology throughout their daily lives (Bailey & Bailenson, 2017). Further, immersive VR has positively impacted adults' thoughts, behaviors, and attitudes, and now research with immersive VR is being used for children in therapies and even education (Bailey & Bailenson, 2017). For example, most research for VR with children has been in a medical or clinical setting for pain management (Shahrbanian et al., 2012), assessing ADHD and Autism Spectrum Disorder (Bellani et al., 2011; Pollak et al., 2009), and educational trainings of life skills for children with hearing impairments (Vogel et al., 2004). Overall for this section of the paper, the positive benefits and potential drawbacks of virtual reality for children will be addressed.

When children engage with an immersive environment, they can be transported psychologically to another location. Research with VR as a pain distraction tool suggests VR has the unique capability to make a virtual environment seem life-like to a child. Many studies report immersive VR can reduce children's physical and emotional pain during cancer treatments (Gershon et al., 2004), burn and would care (Hoffman et al., 2011; Van Twiller, Bremer, & Faber, 2007), dental care (Aminabadi et al. 2012), and during vaccinations (Koller & Goldman, 2012; Hough-Telford et al., 2016; Mack, 2017; Silverber et at., 2017). With the use of VR, pain management can be achieved in a clinical or hospital setting where anxiety is typically increased for children.

Children with disabilities are more likely to develop health-related issues than typical development children. With co-morbidities, obesity and cardiovascular problems seem to be an issue for children with disabilities. Several studies have reported that VR or exergaming increased physical activity, increased duration and intensity of physical activity time (McMahon et al., 2020), improved physical activity motivation (Finklestein et al., 2014), improved arm function, ambulation, and postural control (Chen et al. 2017). Chen et al. (2017) reported that VR would be a good use for therapy clinics or even for children at home as a home-based therapy kit.

For children with Autism Spectrum Disorder (ASD), deficits in social communication and interaction are a diagnosis for the disorder. Training social interactions and life skills through VR could be used as a training tool to allow children to learn socialization and valuable daily skills. VR training has improved emotion and expression regulation (Ip et al., 2018), improved communication skills (Taaryadi & Kurniawan, 2018), developed daily life skills (driving) (Wade et al., 2016), resulted in improvements in social understanding (Cheng et al., 2016), and increased social competence (Stitcher et al., 2014).

With the many benefits of VR for children to use for several aspects of daily life, there are a few disadvantages for VR use. Newbutt et al. (2020) reported issues such as: expensive pricing, bulkiness of equipment, difficult set-up, limited content, hardware limitations, hard on neck/back, and not entirely interactive. Like all new technology, some is met with resistance. With the proper training and instructional set-up, these challenges could be avoided.

VR, whether it is immersive, non-immersive, or semi-immersive, has applications in a real-world setting from education/training to physical activity. This section of the review addresses the many forms of application for VR for typical developing adults and children to those with disabilities.

In the field of medicine, education and training are the pillars of the career. Education and trainings adapt according to improvements in research and even during environmental factors like a pandemic. Singh et al. (2020) reported advantages of VR training and education in the medical field during the Coronavirus (COVID-19) pandemic such as VR to aid in complex operations (helps plan for intricate surgeries and unique cases with no precedence), VR for treatment of psychological disorders (treating fear, phobias, and pain), and VR for pain management (helps COVID-19 patients with chronic pain by distraction). Silva et al. (2018) also describes the advantages of VR in the cardiovascular medical field for education, pre-procedural planning, and patient interaction. For example, HoloAnatomy is a VR tool used to change the medical student curriculum by introducing a better visualization and comprehension of the body systems and organs to aid in dissections and operations (Silva et al., 2018). Training of surgeons for specialized surgeries and patient interaction could benefit children with disabilities due to rare conditions.

Rehabilitation applications of VR for children first appeared in the literature for the management of pain after experiencing burns (Hoffman et al., 2000a; Hoffman et al., 2000b). VR rehabilitation then shifted towards children with cerebral palsy, however children with other disabilities have also been studied (Sandlund et al., 2009). Physical therapists have incorporated VR into their rehabilitative process with customized active video games or mass-produced commercial video games. The commercial and active video games were originally produced for recreation, but were adapted for physical therapy which take advantage of the motion-sensing movements of the games. Commercial games include the Kinect™, Nintendo™, or Wii™.

Multiple studies incorporated the games for rehabilitation because they are safe, engaging, encouraging, functional, and fun task-oriented practice to facilitate improvements for motor function (Bermudez et al., 2016; Fehlings et al., 2013; Monge-Pereira et al., 2014; Tatla et al., 2013).

Active video games (non-immersive) have increased in interest among researchers for promoting physical activity among children (Foley & Madison, 2010). Due to technological advances, children spend an increased amount of time in sedentary activities like watching television and playing non-active video games (Foley & Madison, 2010). Non-active, screen-based games have decreased the amount of active behaviors of a child and increase the risk of obesity and hypertension (Pardee et al., 2007; Proctor et al., 2003). Also, increased screen time such as watching television has reported to increase exposure to food advertisements and consumption of less nutritional snack foods (Briddle, 2007). Interventions to decrease the amount of screen time have been unsuccessful because of the lack of interest and value in the activity (38). Subsequently, researchers have begun to incorporate technology into new interventions. One of these interventions is active video games. These are games that involve full-body movements that allow the players to physically interact with the screen presented to them. Maloney et al. (2008) and Murphy et al. (2006) reported significant increases in cardiovascular fitness, decreases in arterial pressure, and decreased weight gain when compared to the control group while participating in 12 weeks of Dance, Dance Revolution.

Adapted Sport for Rehabilitation

Badminton is a popular sport worldwide that requires fast and powerful shots and agile footwork (Teu et al, 2005). It is one of the fastest racket sports in the world (Teu et al., 2005). In addition, badminton players must react to the moving shuttlecock and adjust their body position rapidly and continuously throughout the game (Faude et al., 2017). They must maintain their center of gravity (COG) within the base of support (BOS) while performing very rapid and asymmetrical upper limb movements (Chang et al., 2013). Therefore, superior body balance is crucial for badminton skill advancement, sports performance (Chang et al., 2013), and injury prevention (Yung et al., 2007). However, the badminton players' balance ability and physical fitness has not yet been fully examined for children with intellectual, developmental, and physical disabilities such as ASD, CP, and DS. Previous literature reported that when standing on the non-dominant leg with their eyes closed, badminton players postural sway decreased over time (Masu et al., 2014). Furthermore, Yuksel et al. (2015) revealed that 8 weeks of badminton training can improve dynamic functional balance performance in typical-development children. Agility-type footwork such as the ability to alter direction over short distances is essential in both defending and attacking maneuvers during badminton training and competitions (Downy et al., 1980; Singh et al., 2011). Agility, which is defined as a rapid whole-body movement with a change of velocity or direction in response to a stimulus (Sheppard et al., 2006), is a crucial variable for outstanding performance in badminton competitions (Guclcover et al., 2011). Agility training during badminton could not only improve balance for children with disabilities but could improve physical fitness and postural control mechanisms for this population.

Conclusions

Finding alternatives to traditional physical activity and rehabilitation is needed for children with development disabilities to improve physical fitness, postural control, and locomotion Moreover, VR and adapted sports such as badminton are valid tools to help children with disabilities improve daily life from skills training to physical activity. Moreover, there are still many unanswered questions with VR and adapted sports concerning real-life applications for children with disabilities and their development. As researchers, how we choose to use VR and adapted sport as rehabilitative tools can determine the effectiveness of VR and adapted physical activity for enhancing a child's life.

CHAPTER III

METHODOLOGY

Study A

Immersive virtual reality (VR) is a new tool for rehabilitation and training purposes for individuals with disabilities, such as people with cerebral palsy and Down Syndrome, to improve movement and socialization. For young adults with IDD, VR has mainly been used to improve socialization, even though recent studies have provided evidence these young adults with IDD display postural and locomotion deficits. Therefore, VR could be used as a rehabilitative method to improve postural control, locomotion, and areas of physical fitness for young adults with IDD. The purpose of this study was to evaluate the effects of intensive, immersive VR video game on postural control, locomotion, and areas of physical fitness for young adults with IDD.

Participants

Participants were students in a comprehensive transition program for intellectual disabilities at a southeastern university. Exclusion criteria were the following: (1) individuals who receive any kind of medical treatment that is known to have an effect on physical condition or had any kind of major surgery for the past year prior to the beginning of this study, (2) having a history of cerebrovascular or coronary arterial disease, uncontrolled hypertension, or impairment of a major organ. Three male young adults were recruited (mean age = 19.67 y, SD = 0.58 y). Participant 1 (P1) was 20 years old and had hemiplegic cerebral palsy (CP) and intellectual disability (ID). Participant 2 (P2) was 20 years old and had autism spectrum disorder

(ASD) and intellectual disability (ID). Participant 3 (P3) was 19 years old with autism spectrum disorder (ASD) and intellectual disability (ID). Written informed consent or assent was obtained as appropriate from the participant and/or parent(s) of each participant.

Study Design, Experimental Procedures, & Instrumentation

A single-subject multiple-baseline design (MBD) using A-B-A with 1-hour follow-up was used. Previous literature has stated that the postural control system can recover and find equilibrium in typical development individuals within 30 minutes of a resting period. All assessments during the 3 study phases: (1) baseline phase (BP)—between 5 and 11 assessments the day (24 hours) before the intervention; (2) intervention phase (IP)—a total of 120 minutes (eight 15 minute intervals) of immersive, virtual reality video- Vive Pro Fruit Ninja®- Survival mode over two days; and (3) follow-up phase (FUP)—1 hour after the intervention. The present study was defined as a nonrandomized, non-concurrent, controlled MBD that provides generalizability with the design consisting of 3 subjects, behaviors, or settings. The baseline, intervention, and FUPs were arranged to support a decision of causality and generalizability. Standardized measurement conditions were ensured for repeated participants testing with consistency in both location and during the same time of day. The static balance outcome measures were administered consecutively in the following order utilizing an AMTI® force plate platform (Waterton, MA): Bilateral: (EO), eyes closed (EC), foam eyes open (FEO), foam eyes closed (FEC); Unilateral: dominant leg eyes open (1LEO) and dominant leg foam eyes open (1LFEO). Participants had 5-10 minutes of rest after outcome variables were measured before starting the next session of VR. The locomotion and physical fitness outcome measures were administered consecutively in the following order: Timed Up & Go (TUG), 30 second Sit to Stand, modified Sit & Reach for left and right legs, and hand grip force of dominant and non-dominant hands. Participants had 5-10 minutes of rest after outcome variables were measured before starting the next session of VR.

An AMTI® force plate platform (Waterton, MA) was used to determine change in the following postural sway variables under varying conditions: average anterior/posterior displacement (in.) (A/P), average medial/lateral displacement (in) (M/L), 95% ellipsoid area (in^2), and average velocity (ft/s). Each participant completed the balance trials in a pre-determined time interval for each condition through previous literature standards (citation): EO- 20 seconds, EC- 10 seconds, FEO- 20 seconds, FEC- 10 seconds, 1LEO- 10 seconds, and 1LFEO- 10 seconds.

The Timed Up & Go (TUG), dominant and non-dominant hand grip strength, Sit & Reach, and Sit to Stand were used to determine change in different aspects of dynamic balance and physical fitness and emphasized during intervention. The TUG test assesses dynamic balance and mobility by requiring participants to sit in a chair with 90° of bilateral knee flexion then walk three meters to a designated mark on the floor, turn 180° and walk back to the chair and sit down as quickly as possible. Researchers associate the TUG test with the ability to be independent in the community while requiring higher demands on dynamic balance, coordination, strength, and anticipatory postural control. Muscular strength refers to the maximal amount of force the participant can exert and hand grip strength utilizes a hand grip dynamometer and quantifies muscular strength by the amount of hand grip force of the dominant and non-dominant hand while maintaining the elbow at 90° of flexion. Past literature associates muscle grip strength by increasing the amount of force produced or reporting decreases in strength which could relate to muscular fatigue. Flexibility is described as the range of motion of a specific joint and is tested by the modified Sit & Reach test. Participants removed their shoes and placed one foot in the sit and reach apparatus, keeping that knee fully extended and the other leg in knee flexion. They reached forward as far as they could with two hands, holding the stretch for 3 s. The distance was recorded in centimeters and both legs were tested. Flexibility allows the muscles to move more efficiently, creating greater stability for the joint. Lastly, for muscular endurance the 30 second Sit to Stand test measures the maximum number of repetitions an individual can rise to a full stance (knees at full extension) from a seated position on a chair, without utilizing the arms. The number of completed stances were recorded. This test is highly correlated with strength of the lower limbs. All three components of musculoskeletal functioning are necessary to maintain proper posture, independence, and participation in active leisure pursuits (Winnick & Short, 2014). However, children with IDD have decreased levels of musculoskeletal functioning in comparison to their typically developing peers (Golubović et al., 2012), which impacts their levels of participation.

The IP consisted of 120 minutes of VR-based video games on two consecutive days. Daily interventions were delivered in two 60-minute sessions divided into four 15-minute intervals of VR. Participants were allowed to rest for 5-15 minutes before the next interval of VR which the participants engaged in a seated quiet activity of their choice. An HTC Vive Pro™ (HTC America, Inc. Seattle, WA, USA) head-mount display (HMD) was utilized for the IP. A commercially available VR game (Fruit Ninja VR-Survivor Mode) (Halfbrick Pty Ltd, Valve Cooperation©, 2016) was selected due to the characteristics of the game and similarities for balance training protocol such as: dynamic standing balance, coordination and timing requiring participants to perform weight shifting in standing, single-leg stance, reaching away from the center of gravity, squats and jumps, and side-steps.

Study B

Adapted physical activity can be used to foster an inclusive environment while reducing the risk of chronic illness among young adults with disabilities. Badminton is a racquet sport that has become popular across the world. Because the sport is applicable to various player levels, badminton is now considered a Special Olympics Unified Sport. Many Unified or adapted sports research studies tend to examine inclusion and socialization. However, not many studies have observed the effects of adapted sports on biomechanical measurements and physical fitness. Therefore, the purpose of this study was to explore the effects of badminton on physical fitness and postural control for students with disabilities.

Participants

Sixteen male and female participants (74.19kg± 9.8kg, 171.96cm± 5.4cm; 21.7± 1.8 years of age; 9 females and 7 males; 8 with IDD and 8 TD) were recruited from Mississippi State University (Mississippi State, MS). Participants were placed into four groups: 2 groups participating in the badminton intervention (4 students with IDD (IDD-BADM) and 4 typical-development participants (TD-BADM)) and 2 control groups not participating in the badminton intervention (4 students with IDD (IDD-CONTR) and 4 typical development students (TD-CONTR)).

Study Design, Experimental Procedures, & Instrumentation

A within-subjects repeated-measure design was used for this study. After obtaining consent from typical development participants and parental permission and participant assent for those with IDD, a familiarization of the study included a Par-Q+ (Physical Activity Questionnaire Plus) to ensure participants were ready for exercise along with collection of anthropometrics. Participants completed three testing days (pre-test, mid-test, and post-test) within a 12-week badminton adapted physical education class utilized as a physical activity intervention. The pre-tests occurred one week before the badminton intervention. Mid-tests were 6 weeks after the start of the intervention, while post-testing followed one week after the intervention. All testing days including balance tests on an AMTI force-plate under the following conditions: Bilateral stance: eyes open (EO)- 20 seconds, eyes closed (EC)-10 seconds, foam eyes open (FEO)- 20 seconds, foam eyes closed (FEC)- 10 seconds and unilateral stance on participant's dominant leg (1LEO)- 10 seconds. The adapted physical education class followed the Special Olympics Individual Badminton Skills Assessment and the Badminton World Federation (BWF) guidelines and was designed as a bi-weekly 50-minute badminton adapted physical education class under the following structure: 5 minutes of dynamic warmup, 40 minutes of badminton instruction by a Certified Adapted Physical Education instructor and two graduate teaching assistants for 12 weeks (24 sessions), and a 5-minute cool-down of static stretching.

Center of pressure (COP) measurements were taken during the static balance assessments, derived from the force platform, and were analyzed to quantify postural sway as a measure of postural stability. COP excursions were used to calculate postural sway variables [average displacements in the medial-lateral (M/L) and anterior-posterior (A/P) directions (M/L-DISP and A/P-DSIP) (in.), average 95% ellipsoid area (in^2), and average velocity (ft/s). All postural sway dependent variables were calculated for the three testing conditions (pre, mid, post, POST1 and POST2) and two group types ((IDD-BADM, IDD-CONTR) (TD-BADM, TD-CONTR)) during all six static balance conditions (EO, EC, EOF, ECF, 1LEO).

The dependent COP postural sway variables from the force-plate balance were analyzed using a between subjects 2 x 3 [2 (IDD-BADM x IDD-CONTR) x 3 (Pre-test x Mid-test x Post-test)] Repeated Measures Analysis of Variance (RM ANOVA) 2 x 3 [2 (TD-BADM x TD-CONTR) x 3 (Pre-test x Mid-test x Post-test)] Repeated Measures Analysis of Variance (RM ANOVA) independently. Post-hoc pairwise comparisons were performed with a Bonferroni correction if main effect significance was identified. All statistical analysis was performed using SPSS 21 (IBM® SPSS® V20.0, Armonk, New York 10504-172) at alpha level at $p \leq 0.05$.

Limitations

Several limitations applied to both of these studies. For Study A, a screening process included individuals with high-functioning intellectual and developmental disabilities with a one hour FUP. For Study B, training sessions occurred biweekly and some participants did not attend all classes. However, participants did not miss more than two classes throughout the 12-week study. Nonetheless, this study aimed to explore the postural and locomotor deficits of individuals with disabilities while utilizing exercise interventions to lessen deficits. More research is needed on new technology and adapted sports and physical activity to improve balance, locomotion, and quality of life for children with disabilities.

CHAPTER IV

MANUSCRIPT 1

Manuscript 1: Effects of an Intensive, Immersive Virtual Reality Program-Fruit Ninja VR-Survival Mode® on Postural Control for Individuals with Intellectual and Developmental Disabilities- a Multiple Baseline Design

Abstract

Purpose: To examine static postural control or balance in young adults with intellectual and developmental disabilities (IDD) following an intensive, immersive virtual reality (VR) intervention video game- Fruit Ninja®- Survival Mode. **Methods:** Single-subject, multiple baseline design with 4 young adults. Outcomes included static balance measurements: bilateral stance- eyes open (20s), eyes closed (10s), foam eyes open (20s), foam eyes closed (10s), and unilateral stance- eyes open (10s) and foam eyes open (10s). Assessments were recorded 3 to 11 times at baseline, 8 times during intervention, and 1 time at follow-up 1 hour following intervention. Sway measurements included: average A/P displacement (in), average M/L displacement (in), average 95% ellipsoid area (in^2), and average velocity (ft/s). Total of 120-minute VR intervention was completed for 2 consecutive days. Visual and statistical analyses were used. **Results:** Visual analysis showed static bilateral and unilateral stance were maintained throughout the intervention and during follow-up. **Conclusions:** Postural control for young adults with intellectual and developmental disabilities showed a maintenance of balance with intense, short duration VR intervention. Keywords: Balance, Intellectual and development disability, Virtual reality

Introduction

According to the American Association on Intellectual Developmental Disabilities (AAIDD), Intellectual Developmental Disabilities (IDD) are characterized by "significant limitations in intellectual functioning and adaptive functioning, originating before eighteen years of age." The Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013) states an individual is diagnosed under the following criteria: (a) deficits in intellectual functioning; (b) deficits in three domains of adaptive functioning including conceptual (academic), social, and practical abilities; and (c) symptom onset occurring during the developmental period. (AAIDD, 2010; APA, 2013). Adaptive function aligns with three categories: communication, social skills, and personal independence (APA, 2013). These areas are also referenced as conceptual, social, and practical skills (AAIDD, 2010). Within the general population, 1-3% of individuals are diagnosed with IDD (Harris, 2006; King et al., 2009, Maulik et al., 2011).

For individuals with IDD, falls are relevant for this population. In early literature, a fall is defined as "when the vertical line which passes through the center of mass (COM) of the human body comes to lie beyond the base of support (BOS) and correction does not take place in time" (Issacs, 1985). Tinetti (1998) redefined a fall in more general terms as "an event which results in a person coming to rest unintentionally on the ground or other lower level, not as a result of a major intrinsic event (such as stroke) or overwhelming hazard." Fall prevention requires adamant training to a complex known as the postural control system consisting of organization and integration of the visual, somatosensory, and vestibular systems (Horak, 2006). As persons with IDD present an array of varying disabilities with deficits to their postural control system (ataxia, movement disorders, vestibular disorders, sensory limitations), these individuals are more prone to falls when compared to typical development peers (Willgoss et al., 2010). Past literature has reported the fall prevalence for adults with ID is over 40% (Smulders et al., 2013) with over two per year for each person (Pal et al., 2014; Van Hanegem et al., 2014) which insinuates that falls for adults with ID is higher than their age matched peers without disabilities. Further, the incidence of falls for the elderly is around 33% while falls among older adults with IDD is around 57% (Willgross et al., 2010).

From all the above-mentioned data, 32% of falls for individuals with IDD lead to injury or even death (Chiba et al., 2009; Willgoss et al., 2010). Falls can also lead to psychological issues for the individual experiencing falls and to their caregivers (Payette et al., 2016). Due to these psychological stressors, individuals with IDD begin to avoid physical activity increasing the likelihood of sedentary life choices for this population (Chang et al., 2004; Chiba et al., 2009; Harlein et al., 2009; Rebenstein & Josephson, 2006). Fall prevention efforts through intensive physical activity training for persons with IDD may decrease willing cooperation because of difficulty motivating and persuading them to participate, so finding a motivation program is highly needed (Lotan, 2007; Temple, 2007). Previous literature has proposed virtual video games as a potential appealing physical fitness activity for individuals with IDD. (Yalon-Chamovitz & Weiss, 2008).

Virtual Reality (VR) is not considered a new concept but has developed over the years, becoming readily available to researchers, rehabilitative professionals, and even the general consumer. VR is characterized as an experience that embraces the senses such as sight, hearing, and touch and is considered an alternative to reality, creating a three-dimensional environment (Zeng, 2018). When individuals with IDD engage with an immersive environment, they can be transported psychologically to another location. Research with VR as a pain distraction tool suggests VR has the unique capability to make a virtual environment seem life-like to a person with an intellectual disability. Many studies report immersive VR can reduce physical and emotional pain during cancer treatments (Gershon et al., 2004), burn and would care (Hoffman et al., 2011; Van Twiller, Bremer, & Faber, 2007), dental care (Aminabadi et al. 2012), and during vaccinations (Koller & Goldman, 2012; Hough-Telford et al., 2016; Mack, 2017; Silverber et at., 2017) for persons with IDD. With the use of VR, pain management can be achieved in a clinical or hospital setting where anxiety is typically increased for this population.

Individuals with disabilities are more likely to develop health-related issues than typical development peers. With co-morbidities, obesity and cardiovascular problems seem to be an issue for people with disabilities. In previous studies, VR or exergaming increased physical activity, increased duration and intensity of physical activity time (McMahon et al., 2020), improved physical activity motivation (Finklestein et al., 2014), improved arm function, ambulation, and postural control (Chen et al. 2017). Chen et al. (2017) reported that VR would be a good use for physical therapy clinics or even for individuals with IDD at home as a home-based therapy kit.

Despite the balance deficits that are common yet limiting for those with IDD, the use of an intensive, immersive virtual reality gaming system has not been proposed for young adults with IDD to improve postural control through a single-subject multiple baseline approach. While VR continues to be readily available, cost efficient, easy-to-play, and motivating approach, previous research has yet to explore the use of an immersive VR gamified program to affect postural control issues in individuals with IDD. Therefore, the purpose of this study was to observe the effects of an intensive, immersive VR video game to improve static balance for individuals with IDD through a multiple baseline approach. The researchers hypothesized that static balance would improve for each individual throughout the intervention phase when compared to the baseline phase.

Methods

Participants

Participants met the following inclusion criteria: (1) between the ages of 18-30, participants were students in a comprehensive transition program for intellectual disabilities at a southeastern university. Exclusion criteria were the following: (1) individuals who receive any kind of medical treatment that is known to have an effect on physical condition or had any kind of major surgery for the past year prior to the beginning of this study, (2) having a history of cerebrovascular or coronary arterial disease, uncontrolled hypertension, or impairment of a major organ. Three male young adults were recruited (mean age = 19.67 y, SD = 0.58 y). Participant 1 (P1) was 20 years old and had hemiplegic cerebral palsy (CP) and intellectual disability (ID). Participant 2 (P2) was 20 years old and had autism spectrum disorder (ASD) and intellectual disability (ID). Participant 3 (P3) was 19 years old with autism spectrum disorder (ASD) and intellectual disability (ID). Written informed consent or assent was obtained as appropriate from the participant and/or parent(s) of each participant.

Study Design

A single-subject multiple-baseline design (MBD) using A-B-A with 1-hour follow-up was used. Previous literature has stated that the postural control system can recover and find equilibrium in typical development individuals within 30 minutes of a resting period. All assessments during the 3 study phases included the following: (1) baseline phase (BP)—between 5 and 11 assessments the day (24 hours) before the intervention; (2) intervention phase (IP)—a total of 120 minutes (eight 15 minute intervals) of immersive, virtual reality video- Vive Pro Fruit Ninja®- Survival mode over two days; and (3) follow-up phase (FUP)—1 hour after the intervention.

The present study was defined as a nonrandomized, non-concurrent, controlled MBD with clear-cut results that provides generalizability with the design consisting of 3 subjects, behaviors, or settings. The baseline, intervention, and FUPs were arranged to support a decision of causality and generalizability. Standardized measurement conditions were ensured for repeated participants testing with consistency in both location and during the same time of day. The static balance outcome measures were administered consecutively in the following order utilizing an AMTI® force plate platform (Waterton, MA): Bilateral: (EO), eyes closed (EC), foam eyes open (FEO), foam eyes closed (FEC); Unilateral: dominant leg eyes open (1LEO) and dominant leg foam eyes open (1LFEO). Participants had 5-10 minutes of rest after outcome variables were measured before starting the next session of VR.

Clinical Outcome Measures

An AMTI® force plate platform (Waterton, MA) was used to determine change in the following postural sway variables under varying conditions: average anterior/posterior displacement (in.) (A/P), average medial/lateral displacement (in) (M/L), 95% ellipsoid area (in^2), and average velocity (ft/s). Each participant completed the balance trials in a pre-determined time interval for each condition through previous literature standards (citation): EO- 20 seconds, EC- 10 seconds, FEO- 20 seconds, FEC- 10 seconds, 1LEO- 10 seconds, and 1LFEO- 10 seconds.

Intervention

The IP consisted of 120 minutes of VR-based video games on two consecutive days. Daily interventions were delivered in two 60-minute sessions divided into four 15-minute intervals of VR. Participants were allowed to rest for 5-15 minutes before the next interval of VR in which the participants engaged in a seated quiet activity of their choice. An HTC Vive Pro™ (HTC America, Inc. Seattle, WA, USA) head-mount display (HMD) was utilized for the IP. A commercially available VR game (Fruit Ninja VR-Survivor Mode) (Halfbrick Pty Ltd, Valve Cooperation©, 2016) was selected due to the characteristics of the game and similarities for a balance training protocol such as: dynamic standing balance, coordination and timing requiring participants to perform weight shifting in standing, single-leg stance, reaching away from the center of gravity, squats and jumps, and side-steps.

Data Analysis

Guidelines recommended for rigorous analysis of Single Subject Research Design following What Works Clearinghouse™ standards through visual analysis.

Results

All participants completed all study phases and fully complied with the intervention. Baseline data stability was achieved for all outcome measures for each participant allowing for clear comparisons across the various phases. Data are graphed for each static balance condition: (EO, EC, FEO, FEC, 1LEO, 1LFEO) according to the postural sway dependent variable reported (average A/P displacement, average M/L displacement, 95% ellipsoid area, average velocity) (Figures 2-24). Overall, across participants for each dependent variable, data showed great variability from baseline to intervention to the follow-up phase. The researchers explain why this was observed in the Discussion section. Below are the conditions with detailed results across participants.

Eyes Open (EO)

There was much variability during the IP phase with a gradual downward trend in the beginning of the IP then a more rapid upward trend towards sessions 11-15. All participants tended to stay within the same level between BL and IP. During the FUP, all participants remained within the same level of the IP. During the IP, overlap of results occurred for all participants, varying at different sessions. For the FUP, P1and P2 showed an increase in ellipsoid area while P3 showed a decrease in area size after the IP. For average velocity, all participants showed a few areas of overlap between BL and IP with P2 demonstrating the most overlap. Across all participants, level remained the same with an indirect immediacy of effect once each participant entered the IP.

Figure 2

EO M/L Displacement Across Participants.

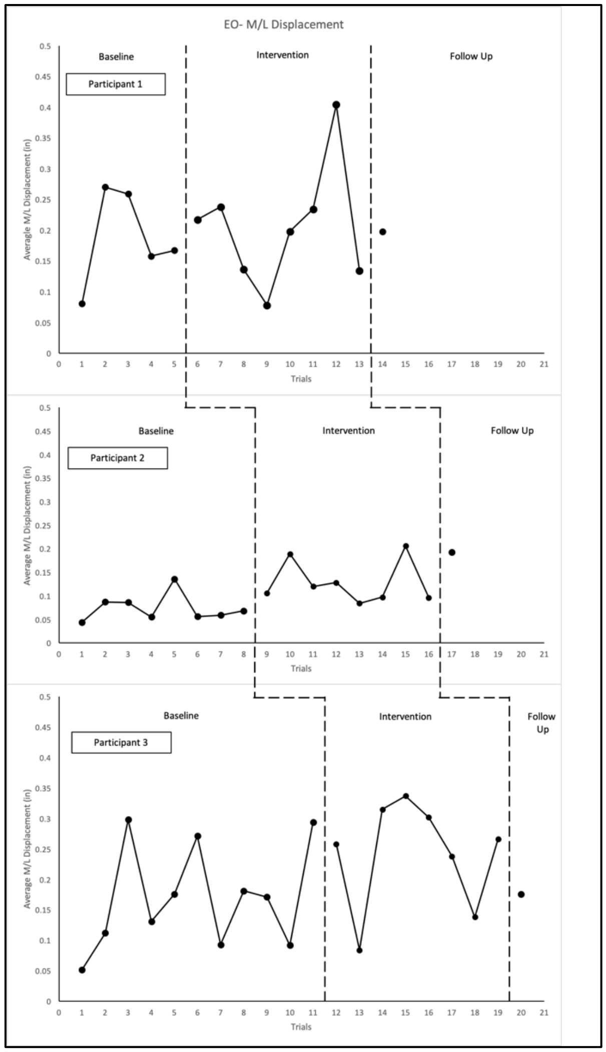


Figure 3

EO A/P Displacement Across Participants.

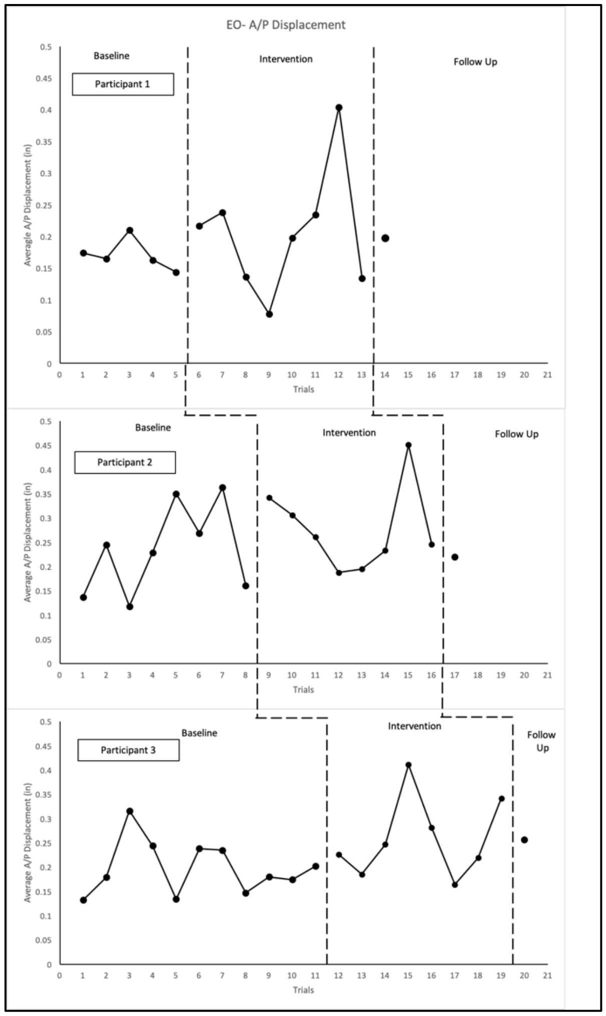


Figure 4

EO 95% Ellipsoid Area Across Participants

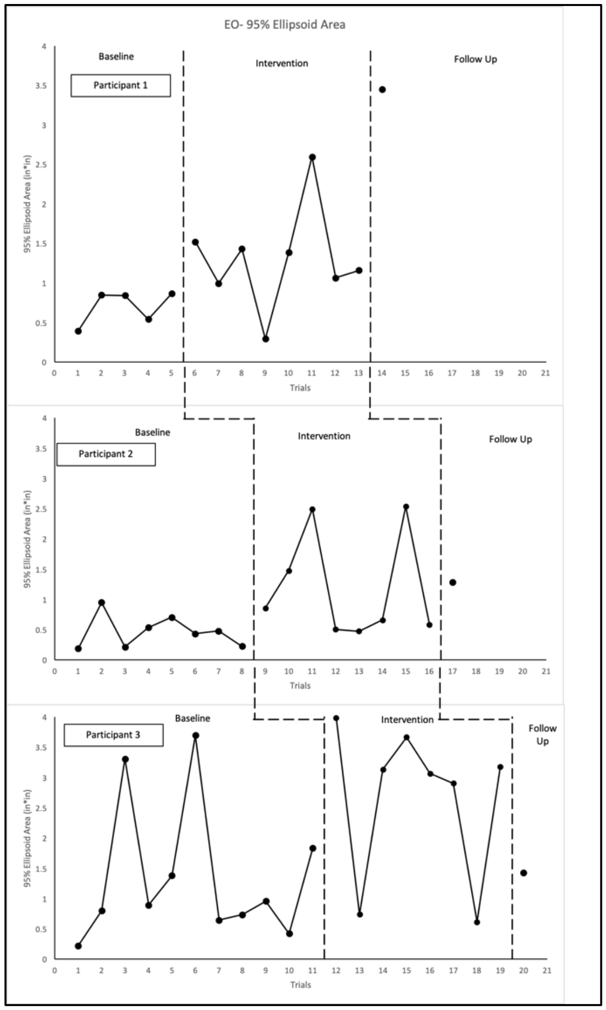
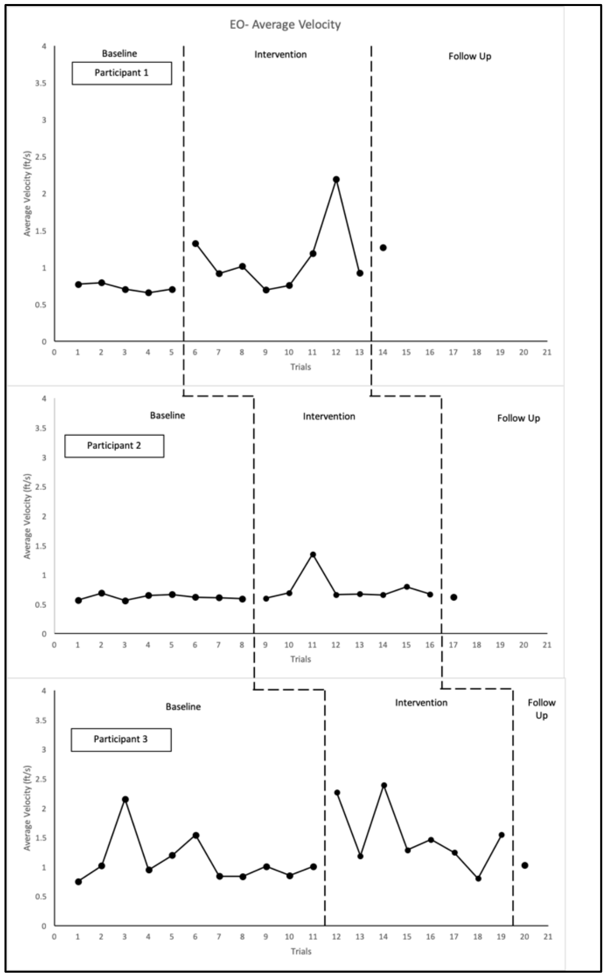


Figure 5

EO Average Velocity Across Participants



Eyes Closed (EC)

Despite an outlier during the IP (P1-session 8), P1 showed the same level, trend, and low variability for 95% ellipsoid area. P2 presented a slight upward trend towards session 13 then began to decrease towards the end of IP. Overall, visual analysis for P1, P2, and P3 showed high amount of overlap and variability for each stage.

Figure 6

EC M/L Displacement Across Participants.

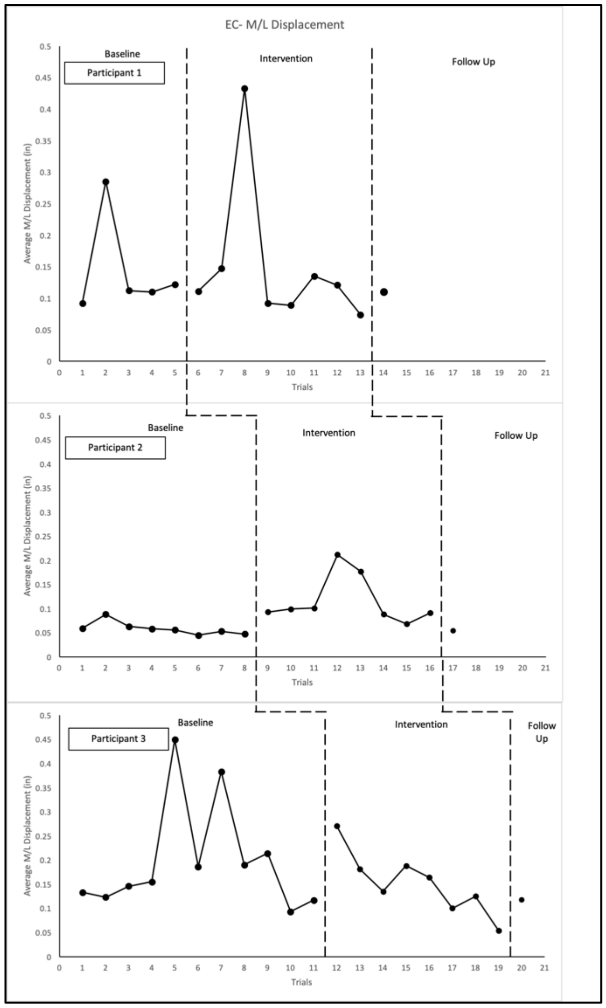


Figure 7

EC A/P Displacement Across Participants.

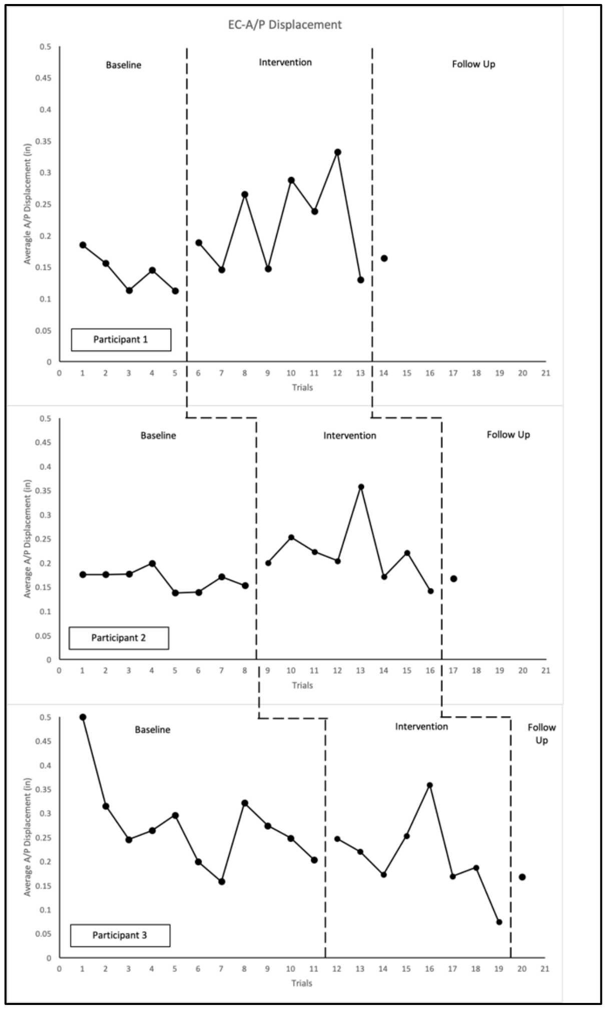


Figure 8

EC 95% Ellipsoid Area Across Participants.

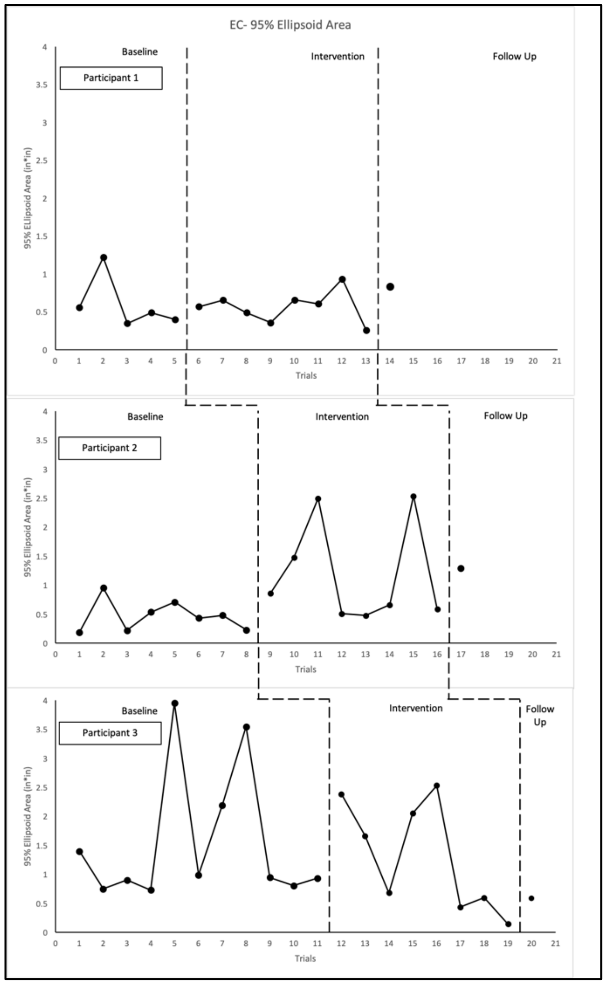
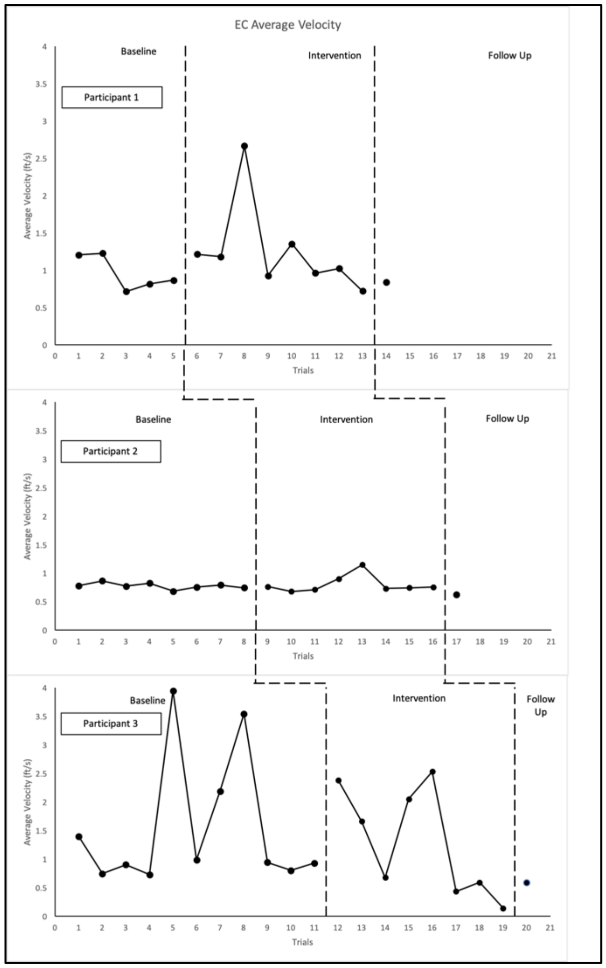


Figure 9

EC Average Velocity Across Participants.



Foam Eyes Open (FEO)

The FEO condition revealed similar level, trend, overlap and variability for P1 and P2 for all variables. Across all participants, the FUP for average M/L and A/P displacement presented similar data points when compared to BL and IP. In 95% ellipsoid area (P1 & P3) and average velocity (P1, P2, & P3) showed similar levels, trends, and overlap from BL to IP. For 95% ellipsoid area, P2 demonstrated a slight increase in level compared to P1 and P3. FUP for average M/L and A/P displacement, 95% ellipsoid area, and average velocity fell within measures of the IP and BL phases.

Figure 10

FEO M/L Displacement Across Participants.

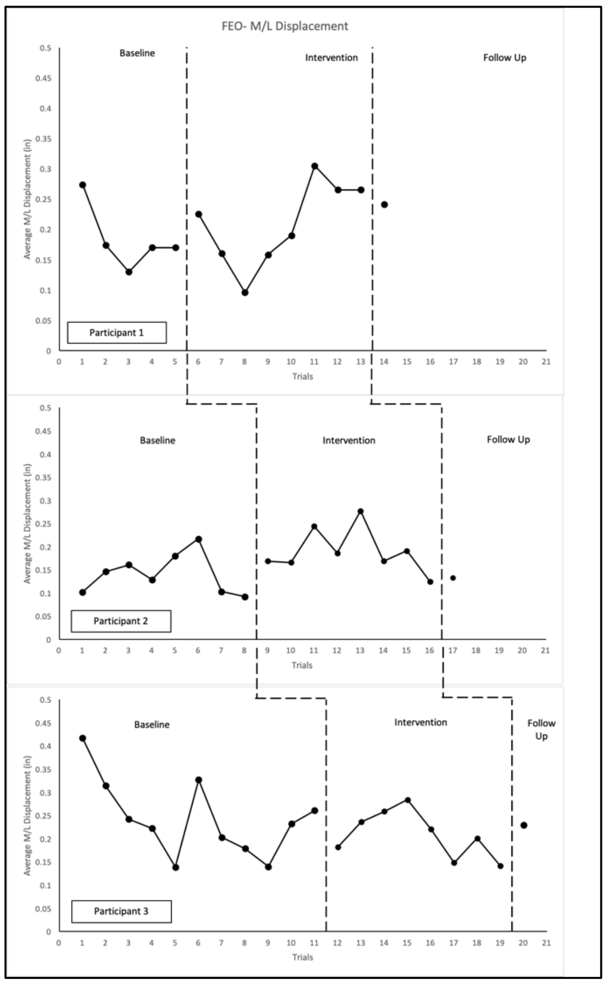


Figure 11

EC A/P Displacement Across Participants.

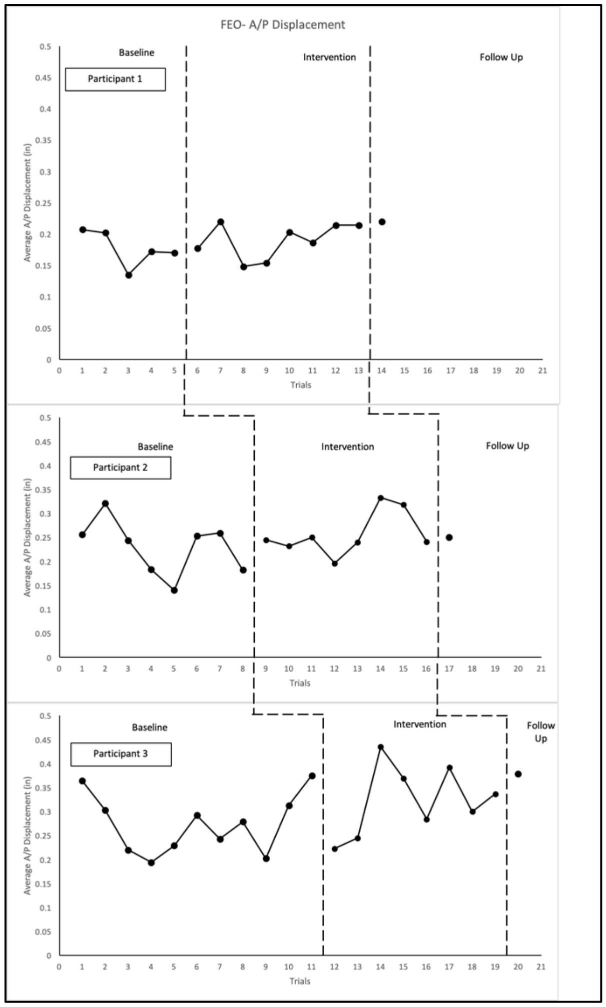


Figure 12

FEO 95% Ellipsoid Area Across Participants.

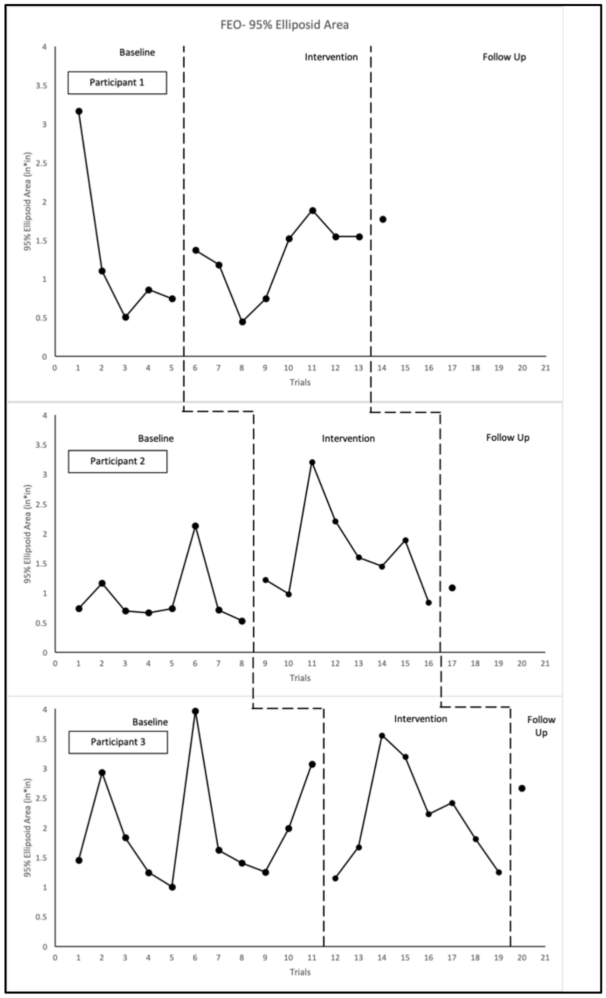
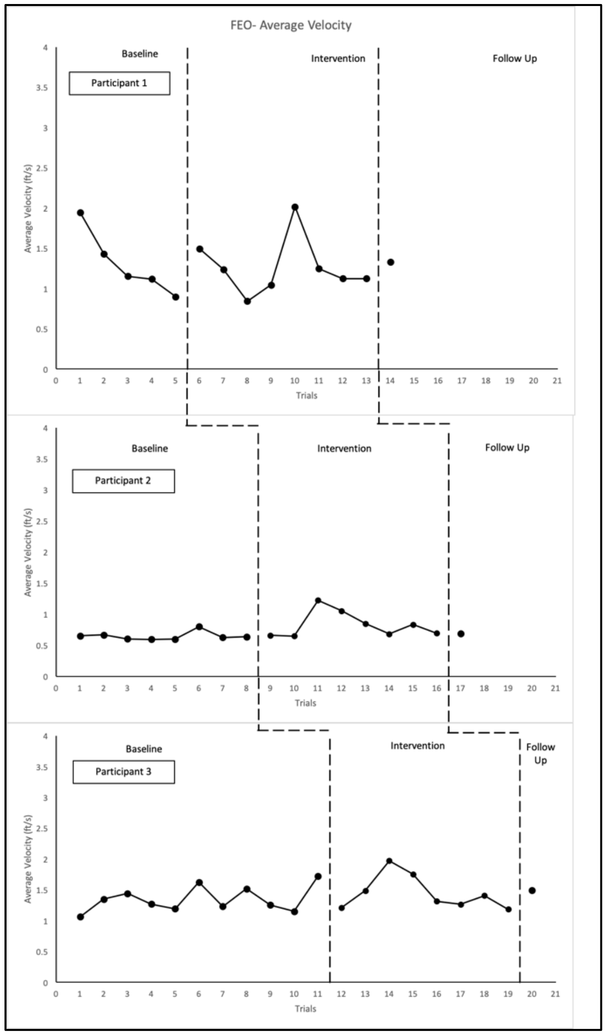


Figure 13

FEO Average Velocity Across Participants.



Foam Eyes Closed (FEC)

Across all participants, all variables showed similar trends, level, overlap, and from BL to FUP.

Figure 14

FEC M/L Displacement Across Participants.

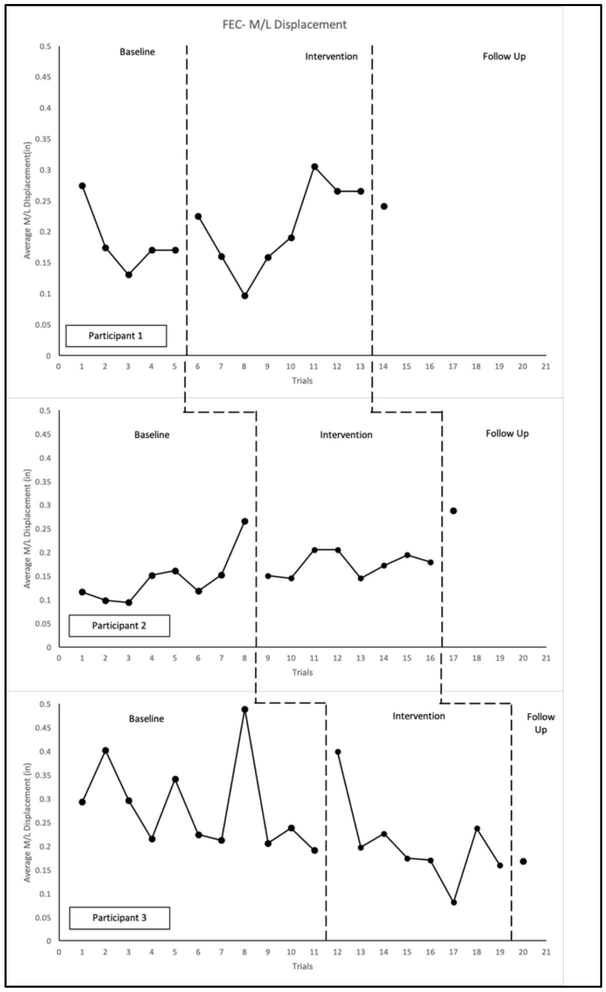


Figure 15

FEC A/P Displacement Across Participants.

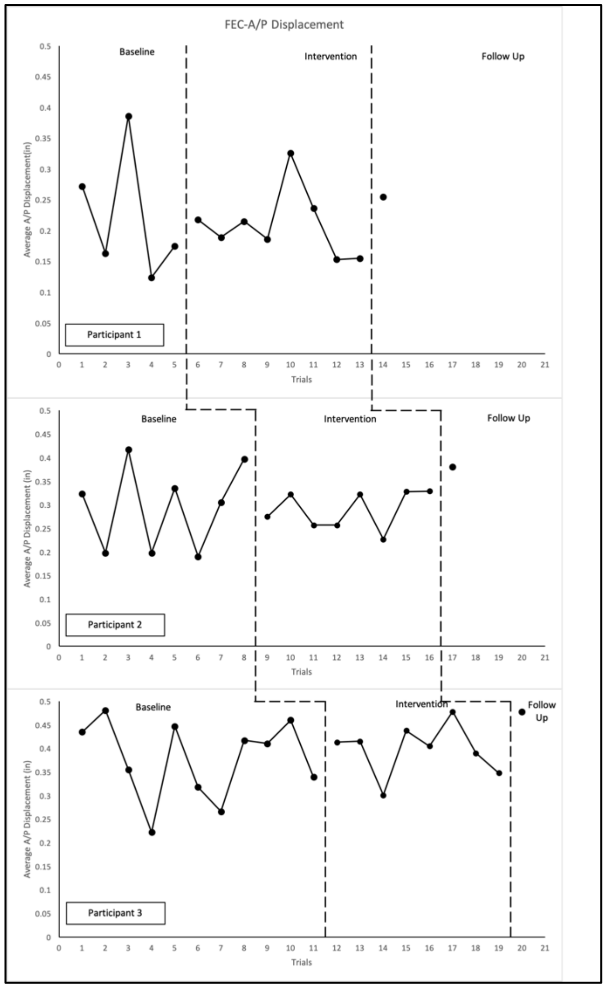


Figure 16

FEC 95% Ellipsoid Area Across Participants.

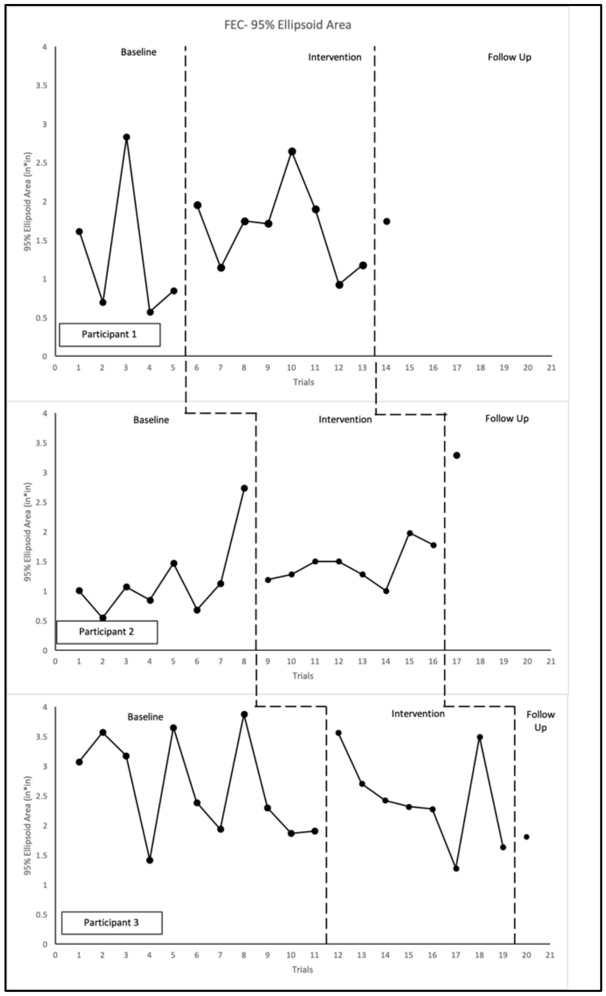
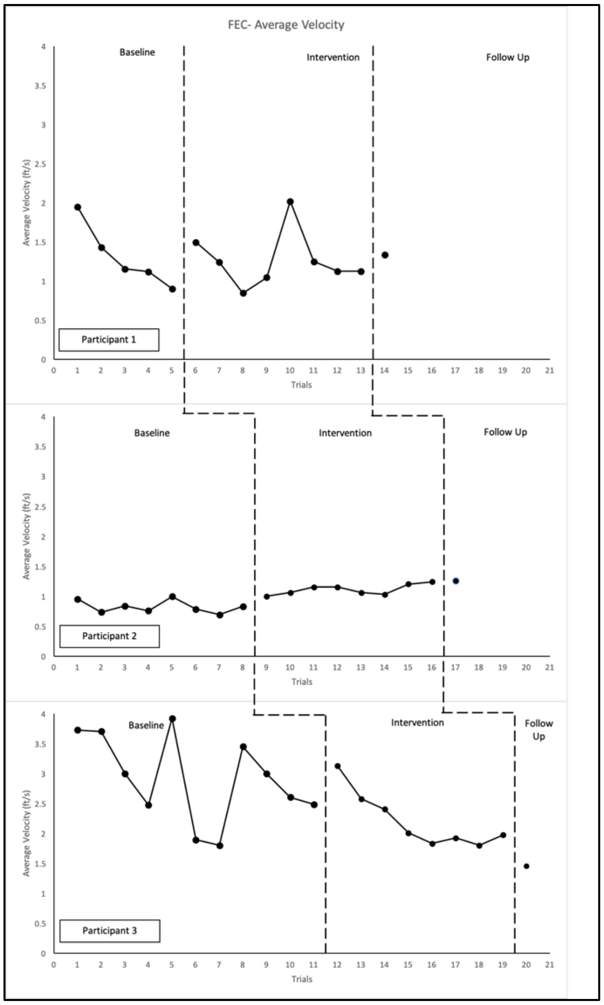


Figure 17

FEC Average Velocity Across Participants.



Single-Leg Eyes Open (1LEO)

During the 1LEO condition, all participants showed similar traits for visual analysis such as trends, overlap, and level for all variables

Figure 18

1LEO M/L Displacement Across Participants.

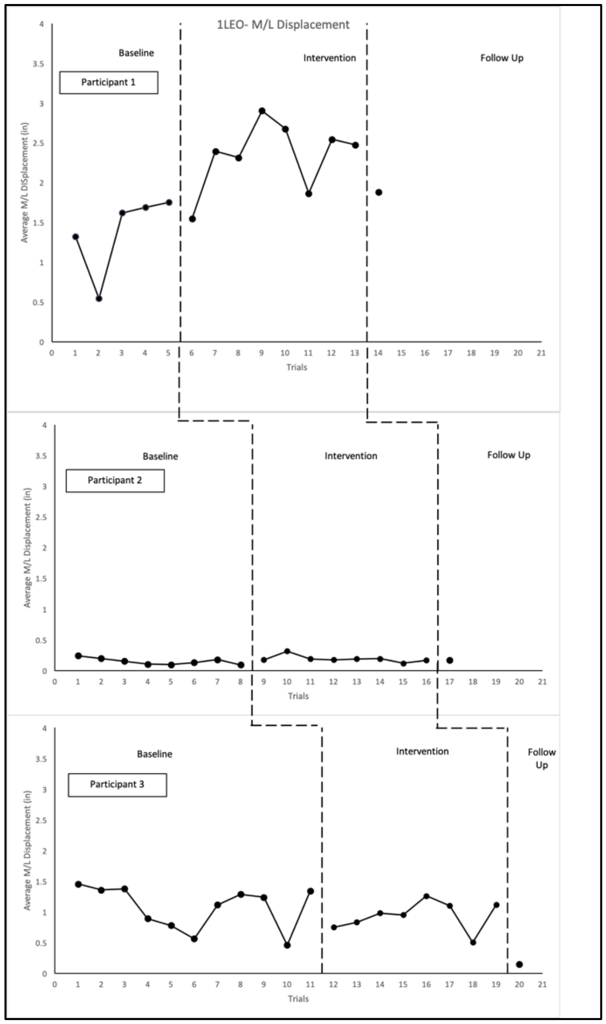


Figure 19

1LEO A/P Displacement Across Participants.

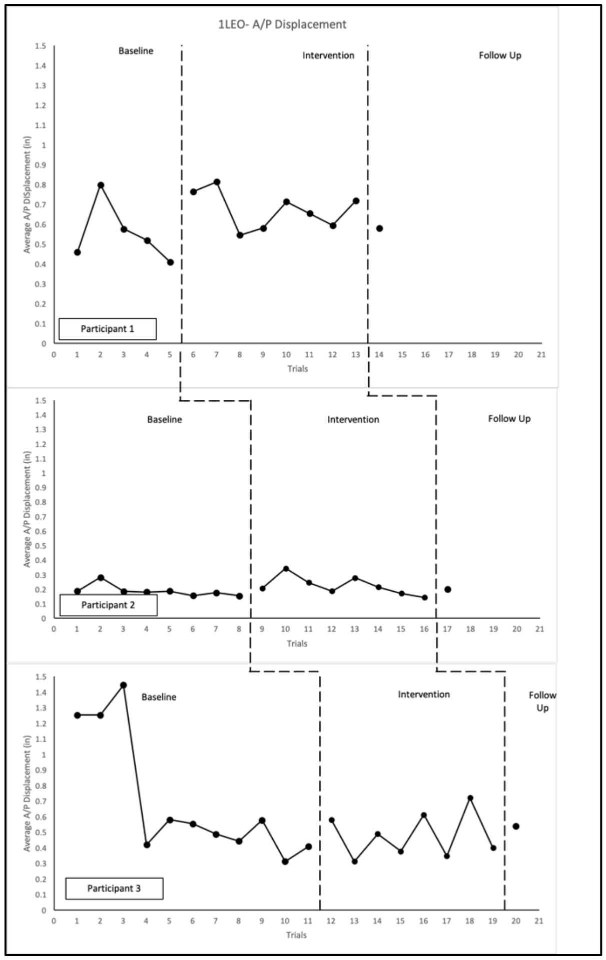


Figure 20

1LEO 95% Ellipsoid Area Across Participants.

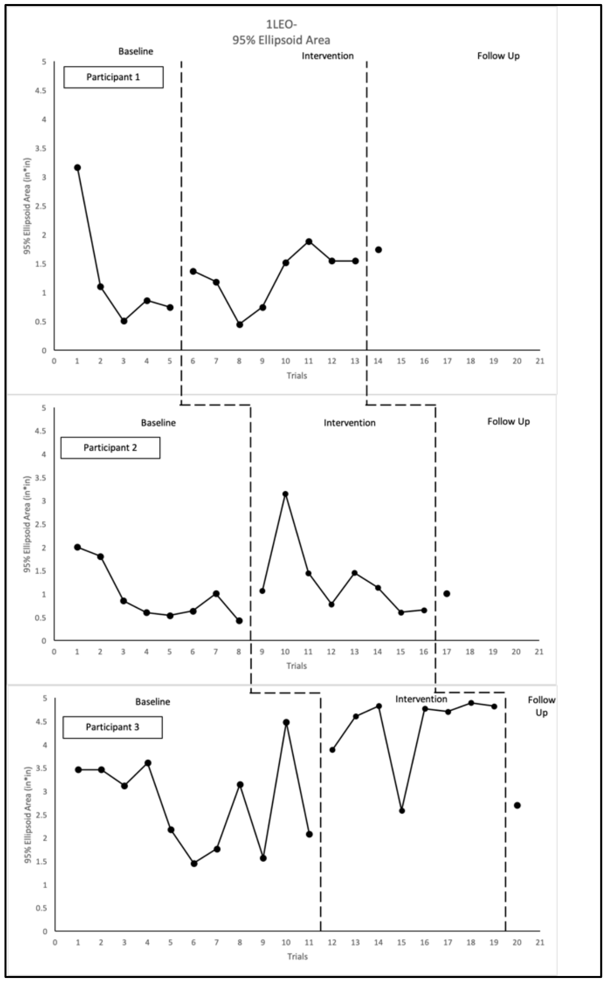
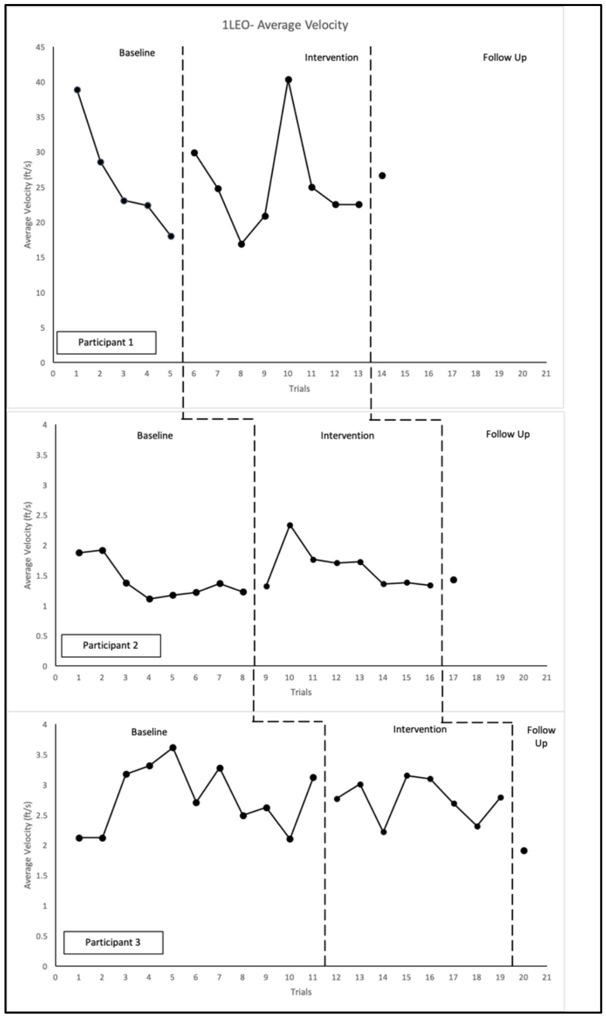


Figure 21

1LEO Average Velocity Across Participants.



Single-Leg Foam Eyes Open (1LFEO)

P1, P2, and P3 all had similar trends, levels, overlap, and immediacy of effect for average A/P and M/L displacement, 95% ellipsoid area, and average velocity form BL to FUP.

Figure 22

1LFEO M/L Displacement Across Participants.

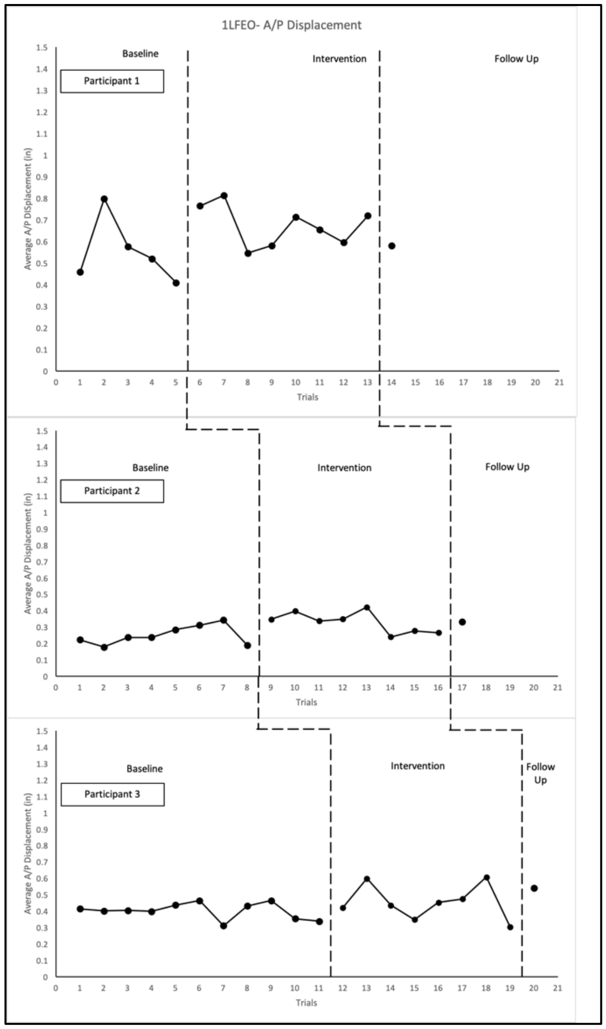


Figure 23

1LFEO A/P Displacement Across Participants.

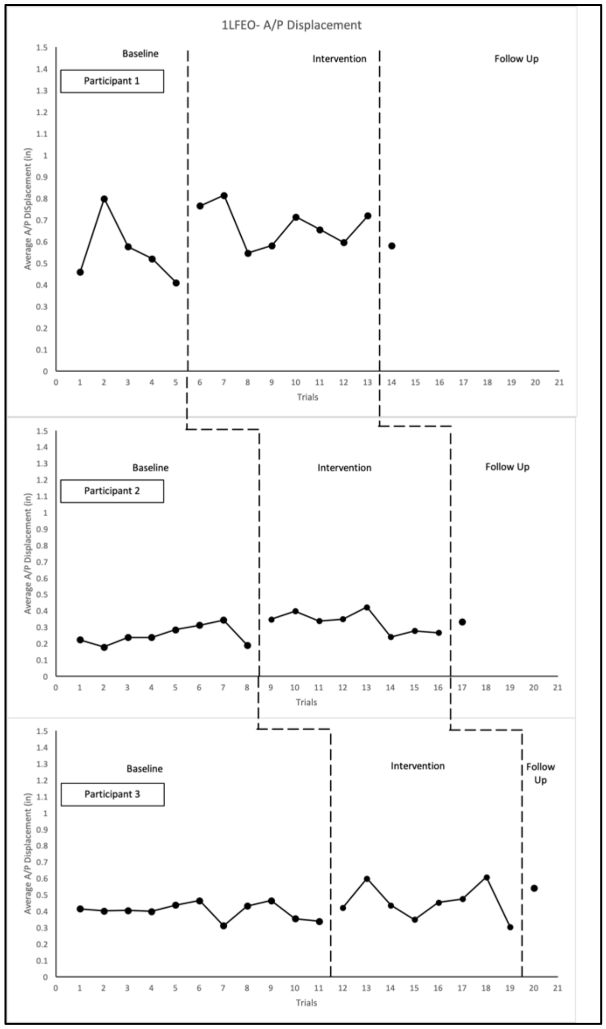
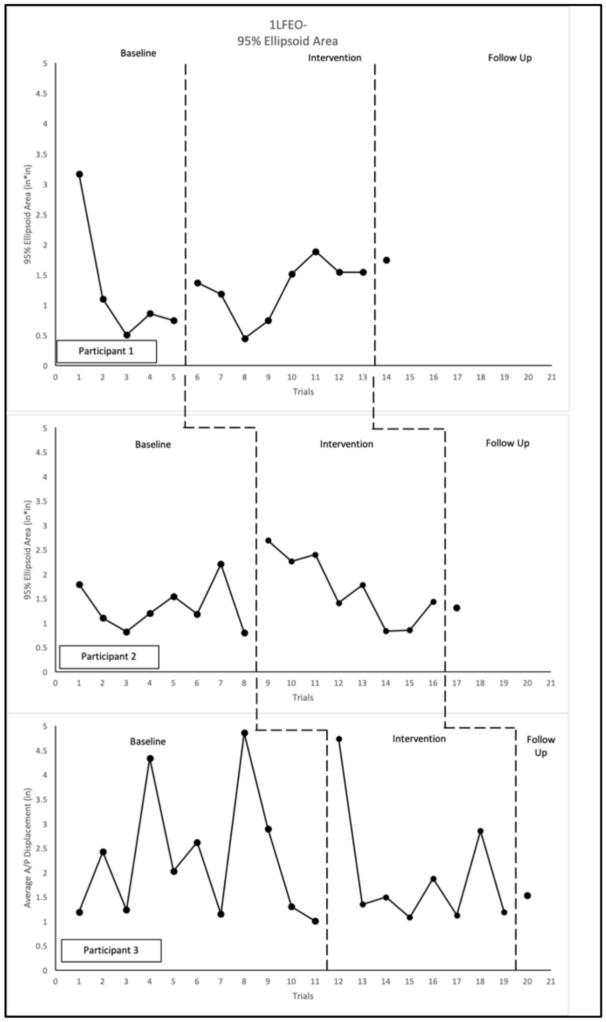


Figure 24

95% Ellipsoid Area Across Participants.



Discussion

We examined the effect of an intensive, immersive VR intervention on static balance for young adults with IDD. We hypothesized static bilateral/unilateral balance performance variables would be improved in these young adults. Results from our study support two major findings. First, our data suggest that static balance during bilateral and unilateral stance was extremely variable across all participants for all variables and conditions. Second, postural sway measures did not decline or worsen throughout the VR training intervention.

When compared to typical-development peers after VR exposure, it has been observed that individuals with IDD have concerning issues with static postural control such as an increase of sway amplitude (Chen & Tsai, 2015), ellipsoid area (Doumas et. al, 2015), A/P and M/L displacement (Fournier et al., 2010), and larger sway area for flat and foam surfaces (Molloy et al., 2003). Issues during standing postural control can lead to further delay in motor skills, falls, and lowered rates of physical activity participation (Hynes & Block, 2022). Results from this study and others suggests that exercise interventions like Tai Chi (Sarabzadeh et al., 2019), Taekwondo (Kim et al., 2006), and simulated horse-riding (Wuang et al., 2012) can show improvements and maintenance of balance skills. However, most of these interventions can be timely and costly which can take place from six to twelve weeks at the least. Also, due to location and availability of the trainers, coaches, and researchers these interventions may not be accessible for this population. However, with a VR video game that is commercially available to the general public, this study suggests that an immersive VR video game could be a balance rehabilitation tool to maintain balance instead of experiencing deficits. Balance training through a VR video game like Fruit Ninja VR®-Survival Mode that incorporates balance training techniques challenging the postural control system such as weight shifting in standing, single-leg stance, reaching away from the center of gravity, squats and jumps, and side-steps could be beneficial for this population especially for motivation. Results from this study also suggest an intensive, immersive VR video game balance training program could be beneficial to train in short time intervals to maintain balance. For example, young adults with IDD typically have lower levels of fitness including a sedentary lifestyle (Lotan et al., 2007), low levels of motivation (Halle, Gabler-Halle, & Chung, 1999), including psychological and physiological issues (Fernhall & Tymeson, 1988). Moreover, Fruit Ninja VR®-Survival Mode could serve as a motivating, short-interval training modality to maintain balance yet keep the attention and motivation for this population.

Unlike most previous literature, this study did not report improvements in postural control after VR balance training. J. Porter, K. Kohm & A. Robb (2020) reported similar results for postural control measurements for typical developing adolescents after exposure to VR video games. Further, deficits in postural sway variable could be due to the quick transition and changing of environments from a virtual to real-world setting. This type of transition isn't providing reliable feedback to the postural control system and mainly the vestibular system. For example, if the vestibular system is experiencing quick transitions between environments, the postural control system will heavily rely on the visual and somatosensory to correct an individual's balance. For individuals with IDD, these two systems may also have deficits which could cause overcorrection to an individual's balance performance, delaying the process to find postural equilibrium.

The gold standard for static balance testing is typically performed on a force platform apparatus under a pre-set time measurement under different conditions, challenging the visual, vestibular, and somatosensory systems. After conducting this study, the researchers realized that traditional static balance testing may be too sensitive for some research designs like single subject design (SSD) which was demonstrated in the baseline phases for all participants. For example, when an individual becomes unbalanced, their COP is thrown outside of their BOS. To regain equilibrium, and individual typically sways in the opposite direction to place their COP back within their BOS. If this does not occur a stepping strategy will be adopted to prevent a fall.

The constant translation of the COP can be extremely variable based on the individual and their disability. This was the outcome for this study. For future studies, a different type of static balance test like the Balance Error Scale Scoring (BESS) should be used due to the less variable nature of the test.

Previous literature has documented deficits in balance skills of persons with IDD (Bonavolonta et al., 2019; Willgoss et al., 2010), and these findings reinforce the importance of developing regular physical activity programs for this population (CDC, 1997; Lotan, 2006; Rimmer, 2004). Given co-morbidities associated with lowered levels of physical fitness, a sedentary lifestyle (Draheim et al., 2002) and falls (Chiba et al., 2009; Willgoss et al., 2010), the need for adequate programs is dire. For young adults with IDD, there are several hindrances to physical activity programs such as the physical environment, especially for those who reside in rural locations (Ruuskanen & Parkatti, 1994; Temple, 2007). In addition, young adults with IDD often receive poor support and encouragement for participating in physical activity from family, guardians, and caregivers (Heller et al., 2002). A main factor in exercise participation is the need to find the activity engaging and entertaining (Temple, 2007) while also motivating an individual with IDD (Gignac, 2003). Findings from this study and others (Booth et al., 2014; Lotan et al., 2009, 2011) suggest that VR video games address these issues. The ability of VR to motivate individuals with IDD while gaining exercise compliance with enjoyment of physical activity is likely to play an important role in achieving physically activity goals while improving areas of fitness and balance skills (Da Cunha et al., 2018; Lotan et al., 2009, 2011; McMahon & McMahon, 2016).

These results suggest that immersive, interactive VR video gaming could be a viable option for individuals with IDD to maintain balance skills. This result has important implications for young adults with IDD and emphasizes the significance of incorporating virtual gaming as an effective gamified maintenance resource for populations with complex balance deficits when compared to traditional exercise programs. Previous literature findings recommend VR gaming is an effective and easy way to implement physical activity for this population (Yalon-Chamovitz & Weiss, 2008).

Conclusions & Future Implications

An efficient postural control system is necessary for an improved quality of life, yet significantly impacts and contributes to issues with participation restrictions in young adults with IDD. Physical activity or exercise intervention programs for young adults with IDD should address balance deficits as a main factor to physical limitations in order to improve functional motor skills which could lead to more inclusivity among peers in sports and daily activities. The results from this study suggests that immersive, intensive VR video gaming could be a physical activity alternative for young adults with IDD to maintain balance skills instead of engaging in traditional video gaming, leading to a sedentary lifestyle. This study has important clinical implications for physical therapists, for it contributes to previous literature that VR video games maintain or improve balance for individuals with IDD. This new intervention tool could be used in clinics for more engaging therapy tools for children/young adults with IDD or even used as an at-home therapy tool to maintain skills between therapy sessions. Further research should address the effects of dynamic balance skills during an intensive, immersive VR study. Moreover, additional research would be beneficial to identify intensity level of VR to discover long-term benefits of physical activity at varying intensity levels.

Table 3

Descriptive statistics- means and standard deviations.

Condition	*Baseline (BL)*	*Intervention Phase (IP)*	*Follow-Up (FUP)*
EO			
A/P DISP (in.)	0.14± 0.08	0.19± 0.19	0.19±0.01
M/L DISP (in.)	0.86± 1.40	0.25± 0.25	0.27±0.05
95% EA (in*in)	1.05± 1.33	2.14± 1.98	2.05±1.21
VELOCITY(ft/s)	0.86± 0.36	1.14± 0.53	0.97±0.33
EC			
A/P DISP (in.)	0.14±0.10	0.14±0.08	0.09±0.03
M/L DISP (in.)	0.21±0.09	0.22±0.07	0.17±0.00
95% EA (in*in)	1.02±1.29	1.10±1.16	0.42±0.16
VELOCITY(ft/s)	1.10±0.45	1.12±0.47	0.81±0.06
FEO			
A/P DISP (in.)	0.20±0.08	0.20±0.06	0.20±0.06
M/L DISP (in.)	0.24±0.07	0.26±08	0.28±0.08
95% EA (in*in)	1.55±1.02	1.86±1.23	1.84±0.79
VELOCITY(ft/s)	1.18±0.38	1.14±0.40	1.17±0.42
FEC			
A/P DISP (in.)	0.22±0.10	0.20±0.06	0.24±0.06
M/L DISP (in.)	0.31±0.12	0.32±0.07	0.37±0.11
95% EA (in*in)	2.26±1.93	1.89±0.85	2.27±0.88
VELOCITY(ft/s)	2.01±1.27	1.53±0.59	1.35±0.10
1LEO			
A/P DISP (in.)	0.48±0.53	0.91±1.06	0.74±0.99
M/L DISP (in.)	0.34±0.14	0.43±0.20	0.42±0.20
95% EA (in*in)	2.18±1.98	1.72±0.98	1.53±0.45
VELOCITY(ft/s)	7.38±10.46	9.72±11.95	9.83±14.54
1LFEO			
A/P DISP (in.)	1.10±0.78	1.17±1.03	1.18±1.41
M/L DISP (in.)	0.38±0.14	0.49±0.16	0.45±0.12
95% EA (in*in)	1.75±1.13	1.65±0.89	1.53±0.23
VELOCITY(ft/s)	7.55±10.36	9.85±11.87	10.15±14.28

CHAPTER V

MANUSCRIPT 2

Manuscript 2: Effects of Intensive, Immersive Virtual Reality for Individuals with Intellectual and Developmental Disabilities on Elements of Physical Fitness and Locomotion - A Multiple Baseline Design

Abstract

Purpose: To examine areas of physical fitness and locomotion in young adults with intellectual and developmental disabilities (IDD) following an intensive, immersive virtual reality (VR) intervention video game- Fruit Ninja- Survival Mode®. **Methods:** Single-subject, multiple baseline design with 4 young adults. Outcomes included dynamic balance and physical fitness measurements: muscular strength, muscular endurance, flexibility, and the locomotion. Assessments were recorded 3 to 11 times at baseline (24 hours prior to intervention), 8 times during intervention, and 1 hour at follow-up 1 hour following intervention. Physical fitness measurements included: hand grip force (kg), sit-to-stand repetitions (# of repetitions), sit-and-reach length (cm), and Timed Up & Go (TUG) -movement time (s). Total of 120-minute VR intervention was completed for 2 consecutive days. Visual and statistical analyses were used. **Results:** Visual analysis showed improvements in flexibility and movement time for all participants, while some participants improved in all areas of physical fitness and locomotion and all participants-maintained scores throughout BL and IP. **Conclusions:** Locomotion and physical fitness areas were improved and maintained for young adults with intellectual and

developmental disabilities with an intense, short duration VR intervention. Keywords: Balance, Physical fitness, Intellectual and development disability, & Virtual reality

Introduction

According to The American Psychiatric Association (APA) and the American Association on Intellectual Developmental Disabilities (AAIDD), Intellectual Developmental Disabilities (IDD) are characterized by "significant limitations in intellectual functioning and adaptive functioning, originating before eighteen years of age" (AAIDD, 2010; APA, 2013). Adaptive function aligns with three categories: communication, social skills, and personal independence (APA, 2013). These areas are also referenced as conceptual, social, and practical skills (AAIDD, 2010). Within the general population, 1-3% of individuals are diagnosed with IDD (Harris, 2006; King et al., 2009, Maulik et al., 2011). A few disabilities considered an IDD are: Down Syndrome (DS), Autism Spectrum Disorder (ASD), and even Global Developmental Delay (GDD) (APA, 2013). These conditions that begin during the developmental phase may impact daily functioning, and can last throughout an individual's lifetime (CDC, 2018). When compared to their typical-development peers, individuals with IDD experience a multitude of health disparities including greater risks of diabetes, obesity, hypertension, high cholesterol, and deficits in overall movement (Rimmer et al., 2010).

The American Psychiatric Association (APA, 2000) states that those with intellectual disability (ID) have complications resulting in motor deficits. Previous literature has reported that individuals with IDD show many issues with fine and gross motor skills (Kioumourtzoglou, Batsiou, Theodorakis, & Mauromatis, 1994) and lowered levels of physical fitness (Carmeli, Imam, & Merrick, 2012). Compared to typical development peers, individuals with IDD have poor motor coordination and integration (Henderson, Morris, & Ray, 1981), slower reaction times (Amemiya, 1982), deficits in postural stability (Blomqvist, Olsson, Wallin, Wester, & Rehn, 2013; Carmeli, Barchad, Lenger, & Coleman, 2002), and decreases of muscular strength (Angelopoulou, Tsimaras, Christoulas, Kokaridas, & Mandroukas, 1999; Blomqvist et al., 2013; Carmeli, Ayalon, Barchad, Sheklow, & Reznick, 2002; Horvat, Croce, Pitetti, & Fernhall, 1999). Motor disorders suggest that young adults with IDD may have difficulty participating in physical activity and exercise. For individuals with IDD, physical activities must be under medical supervision or with precautions to avoid accidents such as falls as a result of their lowered levels of physical fitness. (Winter, Bastiaanse, Hilgenkamp, Evenhuis, & Echteld, 2012; Winter, Magilsen, van Alfen, Penning, & Evenhuis, 2009). The need to find a safe and effective form of physical activity for this population to improve areas of postural control and physical fitness is warranted.

Virtual Reality (VR) is not considered a new concept but has developed over the years, becoming readily available to researchers, rehabilitative professionals, and even the general consumer. VR is characterized as an experience that embraces the senses such as sight, hearing, and touch and is considered an alternative to reality, creating a three-dimensional environment (Zeng, 2018). When individuals with IDD engage with an immersive environment, they can be transported psychologically to another location. Research with VR as a pain distraction tool suggests VR has the unique capability to make a virtual environment seem life-like to a person with an intellectual disability. Many studies report immersive VR can reduce physical and emotional pain during cancer treatments (Gershon et al., 2004), burn and would care (Hoffman et al., 2011; Van Twiller, Bremer, & Faber, 2007), dental care (Aminabadi et al. 2012), and during vaccinations (Koller & Goldman, 2012; Hough-Telford et al., 2016; Mack, 2017; Silverber et at.,

2017) for persons with IDD. With the use of VR, pain management can be achieved in a clinical or hospital setting where anxiety is typically increased for this population.

Despite the balance and physical fitness deficits that are common yet limiting for those with IDD, the use of an intensive, immersive virtual reality gaming has not been proposed for young adults with IDD to improve locomotion and areas of physical fitness through a single-subject multiple baseline approach. While VR continues to be readily available, cost efficient, easy-to-play, and motivating approach previous research has yet to explore the use of an immersive VR gamified program to affect dynamic balance and fitness issues in individuals with IDD. Therefore, the purpose of this study was to observe the effects of an intensive, immersive VR video game to improve locomotion and physical fitness for individuals with IDD through a multiple baseline approach. The researchers hypothesized that locomotion and physical fitness would improve for each individual throughout the intervention phase when compared to the baseline phase.

Methods

Participants

Participants met the following inclusion criteria: (1) between the ages of 18-30, participants were students in a comprehensive transition program for intellectual disabilities at a southeastern university. Exclusion criteria were the following: (1) individuals who receive any kind of medical treatment that is known to have an effect on physical condition or had any kind of major surgery for the past year prior to the beginning of this study, (2) having a history of cerebrovascular or coronary arterial disease, uncontrolled hypertension, or impairment of a major organ. Three male young adults were recruited (mean age = 19.67 y, SD = 0.58 y). Participant 1 (P1) was 20 years old and had hemiplegic cerebral palsy (CP) and intellectual disability (ID).

Participant 2 (P2) was 20 years old and had autism spectrum disorder (ASD) and intellectual disability (ID). Participant 3 (P3) was 19 years old with autism spectrum disorder (ASD) and intellectual disability (ID). Written informed consent or assent was obtained as appropriate from the participant and/or parent(s) of each participant.

Study Design, Experimental Procedures, and Instrumentation

A single-subject multiple-baseline design (MBD) using A-B-A with 1-hour follow-up was used. Previous literature has stated that the postural control system can recover and find equilibrium in typical development individuals within 30 minutes of a resting period. All assessments during the 3 study phases: (1) baseline phase (BP)—between 5 and 11 assessments the day (24 hours) before the intervention; (2) intervention phase (IP)—a total of 120 minutes (eight 15 minute intervals) of immersive, virtual reality video- Vive Pro Fruit Ninja®- Survival mode over two days; and (3) follow-up phase (FUP)—1 time after the intervention.

The present study was defined as a nonrandomized, non-concurrent, controlled MBD with that provides generalizability with the design consisting of 3 subjects, behaviors, or settings. The baseline, intervention, and FUPs were arranged to support a decision of causality and generalizability. Standardized measurement conditions were ensured for repeated participant testing with consistency in both location and during the same time of day. The locomotion and physical fitness outcome measures were administered consecutively in the following order Timed Up & Go (TUG), 30 second Sit to Stand, modified Sit & Reach for left and right legs, and hand grip force of dominant and non-dominant hands. Participants had 5-10 minutes of rest after outcome variables were measured before starting the next session of VR.

Clinical Outcome Measures

The Timed Up & Go (TUG), dominant and non-dominant hand grip strength, Sit & Reach, and Sit to Stand were used to determine change in different aspects of dynamic balance and physical fitness and emphasized during intervention. The TUG test assesses dynamic balance and mobility by requiring participants to sit in a chair with knee flexion at 90° then walk three meters to a designated mark on the floor, turn 180° and walk back to the chair and sit down as quickly as possible. Researchers associate the TUG test with the ability to be independent in the community while requiring higher demands on dynamic balance, coordination, strength, and anticipatory postural control. Muscular strength refers to the maximal amount of force the participant can exert and hand grip strength utilizes a hand grip dynamometer and quantifies muscular strength by the amount of hand grip force of the dominant and non-dominant hand while maintaining the elbow at 90° of flexion. Past literature associates muscle grip strength by increasing the amount of force produced or reporting decreases in strength which could relate to muscular fatigue. Flexibility is described as the range of motion of a specific joint and is tested by the modified Sit & Reach test. Participants removed their shoes and placed one foot in the sit and reach apparatus, keeping that knee straight and the other leg bent. They reached forward as far as they could with two hands, holding the stretch for 3 s. The distance was recorded in centimeters and both legs were tested. Flexibility allows the muscles to move more efficiently, creating greater stability for the joint. Lastly, for muscular endurance, the 30 second Sit to Stand test measures the maximum number of repetitions an individual can rise to a full stance (knees at full extension) from a seated position on a chair, without utilizing the arms. The number of completed stances were recorded. This test is highly correlated with strength of the lower limbs. All three components of musculoskeletal functioning are necessary to maintain proper posture, independence, and participation in active leisure pursuits (Winnick & Short, 2014). However, children with IDD have decreased levels of musculoskeletal functioning in comparison to their typically developing peers (Golubović et al., 2012), which impacts their levels of participation.

Intervention

The IP consisted of 120 minutes of VR-based video games on two consecutive days. Daily interventions were delivered in two 60-minute sessions divided into four 15-minute intervals of VR. Participants were allowed to rest for 5-15 minutes before the next interval of VR in which the participants engaged in a seated quiet activity of their choice. An HTC Vive Pro™ (HTC America, Inc. Seattle, WA, USA) head-mount display (HMD) was utilized for the IP. A commercially available VR game (Fruit Ninja VR-Survivor Mode) (Halfbrick Pty Ltd, Valve Cooperation©, 2016) was selected due to the characteristics of the game and similarities for the balance training protocol such as: dynamic standing balance, coordination and timing requiring participants to perform weight shifting in standing, single-leg stance, reaching away from the center of gravity, squats and jumps, and side-steps.

Data Analysis

Guidelines recommended for rigorous analysis of Single Subject Research Design following What Works Clearinghouse™ standards through visual analysis.

Results

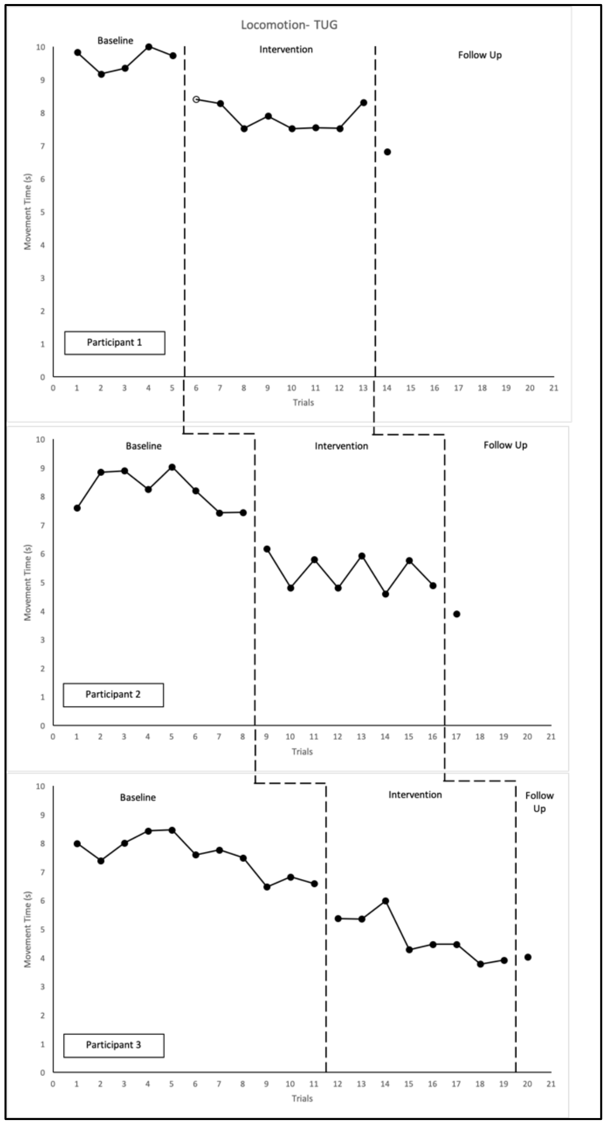
The participants completed all study phases and fully complied with the intervention. Baseline (BL) data stability was attained for each outcome measure for all participants, therefore clear comparisons were reported across the various phases. Data are graphed for each outcome measure (Figures 1, 2, 3, and 4) for locomotion, muscular strength, muscular endurance, and flexibility.

Locomotion-Timed Up & Go

Across all participants a gradual, consistent change evidenced by the downward trend throughout the IP. All participants established an immediate change in level and trend early in the intervention followed by incremental improvements in the IP. All participants showed statistically significant changes from the BP to the IP and a direct immediacy of effect once entering the intervention.

Figure 25

Locomotion-TUG. Movement Time Across Participants.



Muscular Strength-Hand Grip Force

While hand grip force for the dominant and non-dominant hands initially showed significant improvements, P1 and P2 showed increases in level with an upward trend while P3 maintained throughout the IP (Figure 2). All participants showed a direct immediacy of effect when entering the IP.

Figure 26

Muscular Strength. Dominant Hand Grip Force Across Participants.

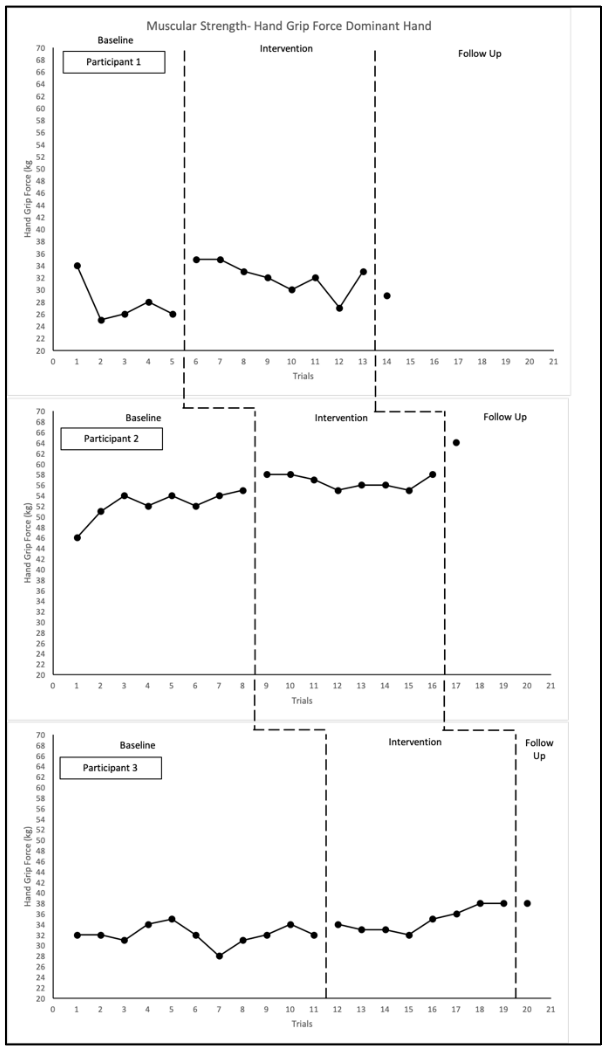
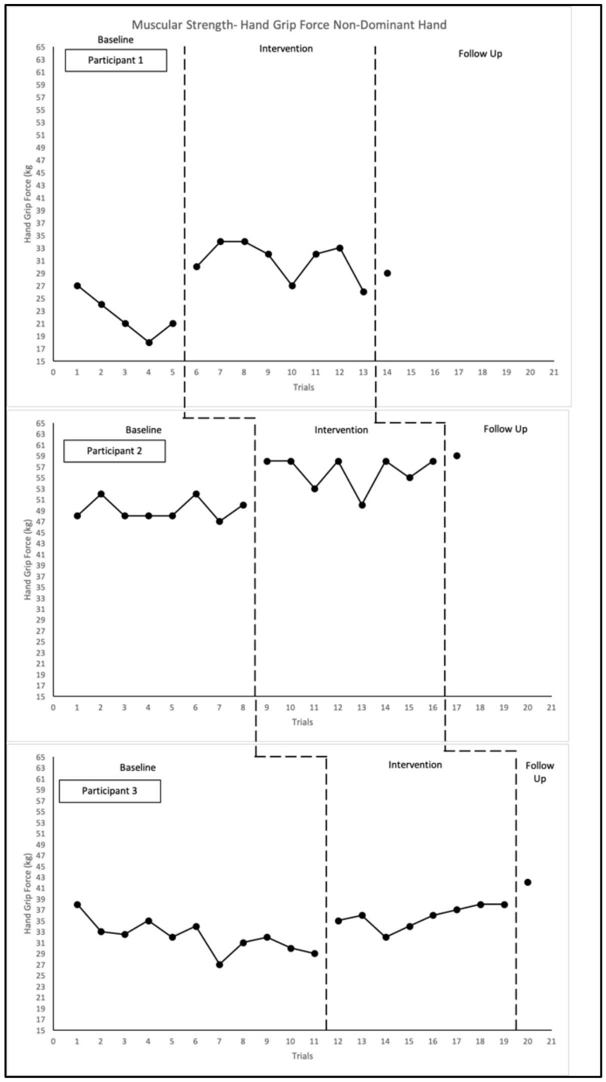


Figure 27

Muscular Strength. Non-Dominant Hand Grip Force Across Participants.



Flexibility- Modified Sit & Reach

In P1, the Sit & Reach scores were characterized by a change in level and trend for both the left and right leg. P3 showed an increasing trend in the IP that was most evident in the first few days and that leveled off and increased towards the end of the intervention for both legs. P2 also reported increases in level and an upward trend in distance covered for both legs and maintained flexibility throughout the IP. All participants maintained means during the FUP.

Figure 28

Flexibility. Modified Sit & Reach. Left Leg Distance Covered.

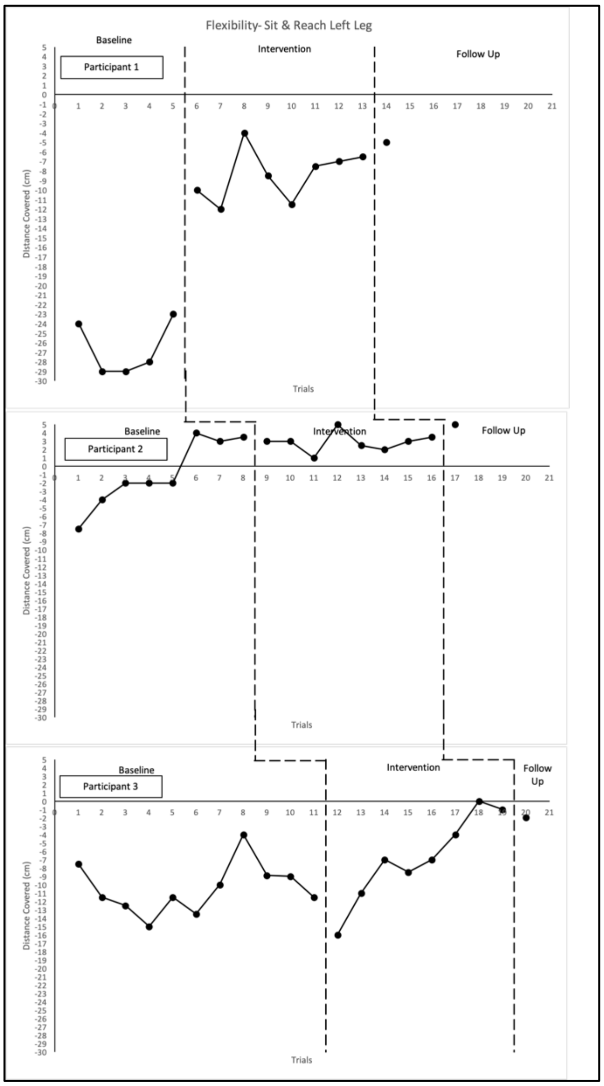
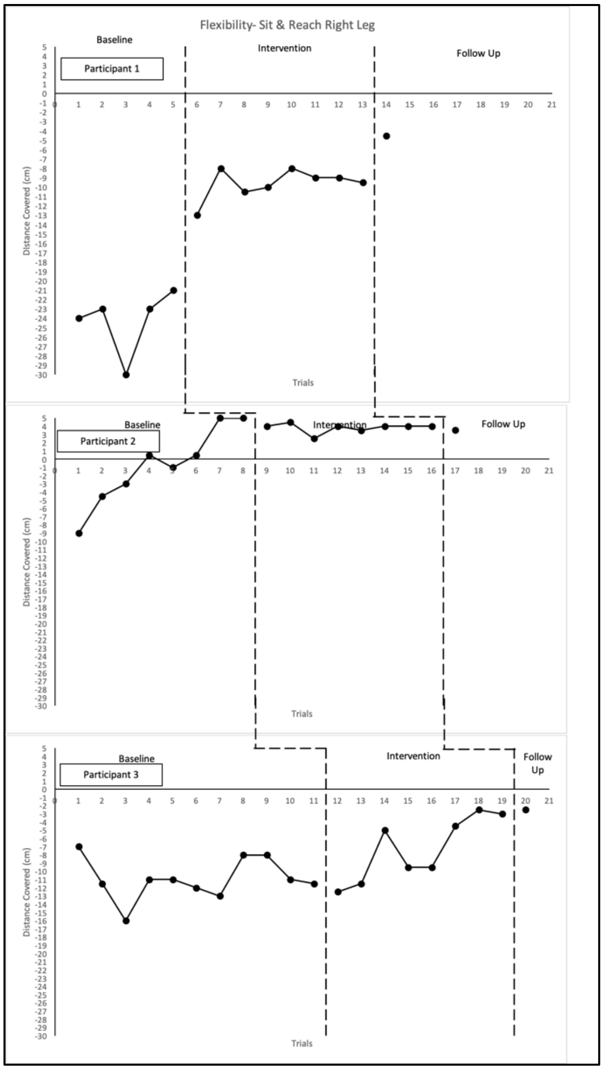


Figure 29

Flexibility. Modified Sit & Reach. Right Leg Distance Covered.

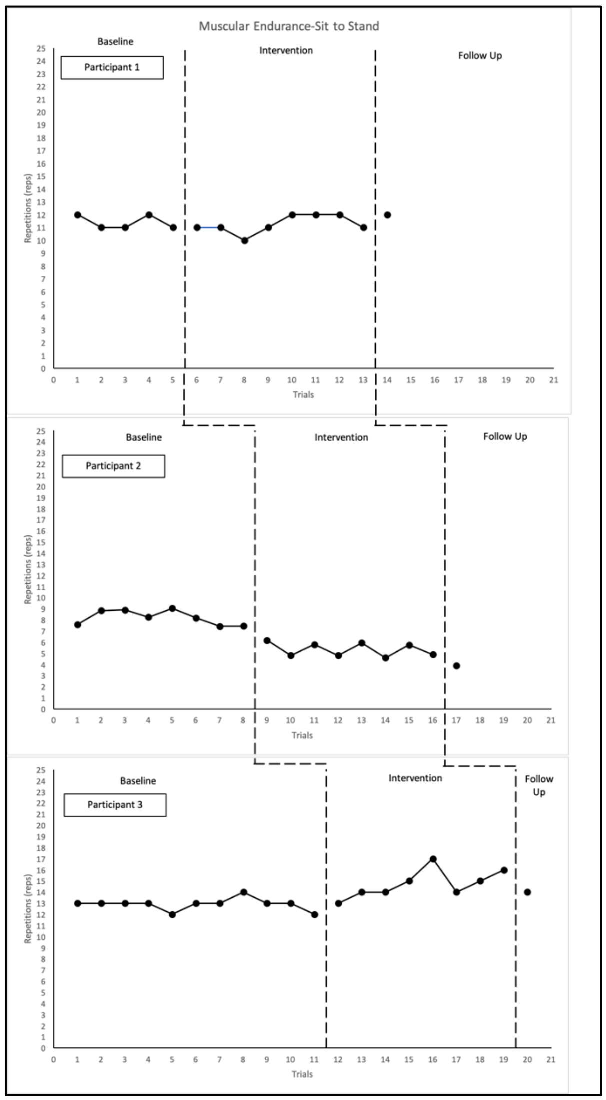


Muscular Endurance- Sit to Stand

Visual analysis revealed 2 patterns in the CB&M scores in response to the intervention. P3 showed a gradual, consistent upward trend and increase in level throughout the IP. A more rapid response was seen in P2 with an immediate change in level and trend early in the intervention followed by increasing improvements throughout the IP. P1 maintained means from BL to IP.

Figure 30

Muscular Endurance. Sit to Stand. Repetitions Across Participants.



Discussion

We examined the effect of an intensive, immersive VR intervention on locomotion and areas of physical fitness for young adults with IDD. We hypothesized that locomotion and physical fitness variables would be improved in these young adults. Our data suggest that locomotion, flexibility, and muscular strength significantly improved while muscular endurance was maintained during an intensive, immersive VR intervention.

These results suggest that immersive, interactive VR video gaming could be a physical activity alternative for individuals with IDD to improve dynamic balance, flexibility, and muscular strength. This result has important implications for young adults with IDD and emphasizes the significance of incorporating virtual gaming as an effective gamified option for improving locomotion and areas of physical fitness for populations with fitness and balance deficits when compared to traditional exercise programs. Previous literature findings recommend VR gaming is an effective and easy way to implement physical activity for this population (Yalon-Chamovitz & Weiss, 2008).

Other studies also support the present results from this study for locomotion and adapted exercise interventions. For instance, 4 adolescents with CP participated in an immersive, intensive VR program through a multiple-baseline approach. Visual analysis revealed improvements in mobility and dynamic balance through the Community Balance and Mobility Scale (CB&M) after a short term intensive VR program (Brien & Sveistrup, 2011). Our results are similar to this study in stating that dynamic balance improved for this population. In another study, 31 individuals with mild to moderate IDD participated in a twelve 30-minute bi-weekly VR (SeeMe) program and found improvements in locomotion skills among adults utilizing a dynamic balance test-Timed Up & Go (TUG) (Lotan & Weiss, 2021). Both studies support that

VR could be used as an adaptive physical activity to improve dynamic balance or locomotion for individuals with IDD.

Son, Jeon, & Kim (2016) reported significant increases in trunk flexibility after a 16-week walking program for individuals with ID. Wu et al. (2010) reported similar results in the Sit & Reach test to the current study; however, unlike the current study, the jogging, walking, and dancing intervention duration was over 24 weeks verses our study over two days. Results from this study and others suggests that exercise interventions like Tai Chi (Sarabzadeh et al., 2019), Taekwondo (Kim et al., 2006), and simulated horse-riding (Wuang et al., 2012) can show improvements and maintenance of balance skills and flexibility. However, most of these interventions can be timely and costly which can place from six to twelve weeks at the least. Also, due to location and availability of the trainers, coaches, and researchers these interventions may not be accessible for this population. However, with a VR video game that is commercially available to the general public, this study suggests that an immersive VR video game could be a program to improve range of motion of the lower extremity while increasing flexibility. Flexibility improvements from training through a VR video game like Fruit Ninja VR®-Survival Mode that incorporates functional training techniques while challenging the postural control system such as weight shifting in standing, single-leg stance, reaching away from the center of gravity, squats and jumps, and side-steps could be beneficial for this population, especially for motivation. Results from this study also suggest an intensive, immersive VR video game balance training program could be beneficial to improve flexibility and range of motion.

Muscular endurance and muscular strength may not have shown the changes initially hypothesized, as the complex movements elicited by the VR program, Fruit Ninja®- Survival Mode, did not specifically target constant concentric and eccentric muscle control required for the 30 second Sit to Stand test and hand grip force. The VR program targeted more balance focused training aimed at over ground balance and ambulatory skills such as weigh shifts and unilateral balance skills. Further, the amount of high intensive intervals of the VR program could have played a role of neuromuscular fatigue which could in turn directly affect the results of the muscular endurance test. Borji et al. (2013) reported that when compared to typical development peers, individuals will IDD demonstrated a greater force decline following high intensity intermittent exercise. Wouters, Evenhuiss, and Hilgenkamp (2020) presented individuals with IDD have low physical fitness levels such as muscular endurance and strength. Therefore, a short, intensive physical activity intervention may not be beneficial to see immediate improvements for this population. However, scores from the Sit to Stand and hand grip force tests did not decline over time which could indicate the VR intervention could serve as a maintenance tool for young adults with IDD.

Previous literature has documented deficits in dynamic balance and physical fitness levels of young adults with IDD (Bonavolonta et al., 2019; Willgoss et al., 2010; Bouzas, Ayan, & Martinez-Lemos, 2018), and these findings reinforce the importance of creating adapted exercise programs for this population (CDC, 1997; Lotan, 2006; Rimmer, 2004). Given co-morbidities associated with decreased levels of physical fitness, a sedentary lifestyle (Draheim et al., 2002) and falls (Chiba et al., 2009; Willgoss et al., 2010), adequate programming is needed. For young adults with IDD, there are limitations to exercise programs such as physical environment, especially for those who reside in rural locations (Ruuskanen & Parkatti, 1994; Temple, 2007). In addition, young adults with IDD often receive poor support and encouragement for participating in physical activity from family, guardians, and caregivers (Heller et al., 2002). A main factor in exercise participation is the need to find the activity engaging and entertaining (Temple, 2007) while also motivating an individual with IDD (Gignac, 2003). Findings from this study and others (Booth et al., 2014; Lotan et al., 2009, 2011) suggest that VR video games address these issues. The ability of VR to motivate individuals with IDD while gaining exercise compliance with enjoyment of physical activity is likely to play an important role in achieving physically activity goals while improving areas of physical fitness and locomotion (Da Cunha et al., 2018; Lotan et al., 2009, 2011; McMahon & McMahon, 2016).

Conclusions & Future Implications

An efficient postural control system and functional fitness is necessary for an improved quality of life, while impacting the daily lives of young adults with IDD. Physical activity or exercise intervention programs for young adults with IDD should address balance and physical fitness deficits as factors to physical limitations in order to improve functional motor skills which could lead to more inclusivity among peers in sports and daily activities. The results from this study suggests that immersive, intensive VR video gaming could be a physical activity alternative for young adults with IDD to improve dynamic balance skills and areas of physical fitness instead of engaging of traditional video gaming, leading to a sedentary lifestyle. This study has important clinical implications for physical therapists, for it contributes to previous literature that VR video games improve balance and fitness for individuals with IDD. This new intervention tool could be used in clinics for more engaging therapy tools for children/young adults with IDD or even used as an at-home therapy tool to maintain motor skills between therapy sessions. Further research should address the effects of muscular strength and endurance during an intensive, immersive VR study. Moreover, additional would be beneficial to identify intensity level of VR to discover long-term benefits of physical activity at varying intensity levels.

Table 4

Descriptive Statistics. Means and standard deviations

Variable/Test	*Baseline (BL)*	*Intervention Phase (IP)*	*Follow-Up (FUP)*
Locomotion *TUG (s)*	8.20± 1.0	5.97± 1.52	4.90± 1.65
Muscular Strength *Hand grip force (kg)*			
Dominant	37.92±10.78	41.21±11.38	43.67±18.16
Non-Dominant	35.73±10.75	40.92±11.39	43.33±15.04
Muscular Endurance *Sit to Stand (reps)*	12.71±1.43	14.96±3.61	16.67±6.43
Flexibility *Sit & Reach (cm)*			
Left Leg	-10.62±9.95	-4.10±6.07	-0.67±-1.17
Right Leg	-10.33±9.25	-4.35±6.44	5.13±4.16

CHAPTER VI

MANUSCRIPT 3

Manuscript 3: The Effects of an Inclusive Badminton Program on Postural Control for Individuals with Intellectual and Developmental Disabilities

Abstract

Purpose: To examine static postural control/balance in young adults with intellectual and developmental disabilities (IDD) and typical development young adults before, during and after an inclusive badminton intervention. **Methods:** Four young adults with IDD (IDD-BADM) and four typical development young adults (TD-BADM) who participated in the intervention, and four young adults with IDD (IDD-CONTR) and four typical development young adults (TD-CONTR) as controls were tested one week before the intervention, 6 weeks into the intervention, and one week after the intervention. Repeated measures design (pre, mid, post) static balance measurements included the following: bilateral stance- eyes open (20s), eyes closed (10s), foam eyes open (20s), foam eyes closed (10s), and unilateral stance- eyes open (10s) and foam eyes open (10s). Sway measurements included: average A/P displacement (in), average M/L displacement (in), average 95% ellipsoid area (in^2), and average velocity (ft/s). **Results:** Significant time and group x time interaction were reported for EO, EC, FEO, and 1LEO for all groups. **Conclusions:** An inclusive badminton program improved static postural control for those with intellectual and developmental disabilities. However, no significant differences were

reported for typical development peers. Keywords: Balance, Intellectual and development disability, Badminton

Introduction

According to The American Psychiatric Association (APA) and the American Association on Intellectual Developmental Disabilities (AAIDD), Intellectual Developmental Disabilities (IDD) are characterized by "significant limitations in intellectual functioning and adaptive functioning, originating before eighteen years of age" (AAIDD, 2010; APA, 2013). Adaptive function aligns with three categories: communication, social skills, and personal independence (APA, 2013). These areas are also referenced as conceptual, social, and practical skills (AAIDD, 2010). Within the general population, 1-3% of individuals are diagnosed with IDD (Harris, 2006; King et al., 2009, Maulik et al., 2011). A few disabilities considered an IDD are: Down Syndrome (DS), Autism Spectrum Disorder (ASD), and even Global Developmental Delay (GDD) (APA, 2013). These conditions that begin during the developmental phase, may impact daily functioning, and can last throughout an individual's lifetime (CDC, 2018). When compared to their typical-development peers, individuals with IDD experience a multitude of health disparities including greater risks of diabetes, obesity, hypertension, high cholesterol, and deficits in overall movement (Rimmer et al., 2010). With deficits in overall movement, the postural control system can be impacted. Postural control is the ability to maintain postural equilibrium by constant adjustment of one's center of mass (COM) within their base of support (BOS) (Polluck et al., 2000). Sensorimotor issues, such as decreases in postural control (Kohen-Raz et al., 1992; Memari et al, 2013; Minshew et al., 2004), poor limb coordination (Sacrey et al., 2014), gait (Fournier et al., 2013; Rinehart et al., 2006), and reduced anticipatory postural adjustments of motor actions (Martineau et al., 2004; Schmitz et al., 2003), frequently are seen in individuals with developmental disabilities and are considered symptoms supporting a diagnosis of IDD like ASD (APA, 2013). Many levels of motor control mechanisms are utilized to maintain postural equilibrium and induce movements have been implicated in IDD, such as sensory integration, sensory organization, and feedforward and feedback processes. Continued control of motor behaviors includes the coordination of several joints simultaneously (Massion, 1994). The coordination of the body as a multi-joint segment allows the individual to initiate complex movements like grasping and reaching and making adjustments to their balance used for the gait process (Horak, 2006). Also, feedforward processes ensure the individual can maintain control of fluid motor behaviors since they are involved in preparing and executing quick movements based on the sensory feedback readily available (Horak, 2006; Ghez & Gordon, 1991). The current study aimed to evaluate an inclusive adapted physical activity of postural control in individuals with IDD.

Badminton is a popular sport worldwide that requires fast and powerful shots and agile footwork (Teu et al, 2005). It is one of the fastest racket sports in the world (Teu et al., 2005). In addition, badminton players must react to the moving shuttlecock and adjust their body position rapidly and continuously throughout the game (Faude et al., 2017). They must maintain their center of gravity (COG) within the base of support (BOS) while performing very rapid and asymmetrical upper limb movements (Chang et al., 2013). Therefore, superior body balance is crucial for badminton skill advancement, sports performance, (Chang et al., 2013) and injury prevention (Yung et al., 2007). However, the badminton players' balance ability and physical fitness has not yet been fully examined for children with intellectual, developmental, and physical disabilities such as ASD, CP, and DS. Previous literature reported that when standing on the non-dominant leg with their eyes closed, badminton players postural sway decreased over time (Masu et al., 2014). Furthermore, Yuksel et al. (2015) revealed that 8 weeks of badminton training can improve dynamic functional balance performance in typical-development children. Agility-type footwork such as the ability to alter direction over short distances is essential in both defending and attacking maneuvers during badminton training and competitions (Downy et al., 1980; Singh et al., 2011). Agility, which is defined as a rapid whole-body movement with a change of velocity or direction in response to a stimulus, (Sheppard et al., 2006) is a crucial variable for outstanding performance in badminton competitions (Guclcover et al., 2011). Agility training during badminton could not only improve balance for children with disabilities but could improve postural control mechanisms for this population. Therefore, the purpose of this study was to evaluate the implementation of inclusive badminton as an adapted physical activity for young adults with IDD to improve areas of postural control.

Methods

Participants

Sixteen male and female participants (74.19kg± 9.8kg, 171.96cm± 5.4cm; 21.7± 1.8 years of age; 9 females and 7 males; 8 with IDD and 8 TD) Participants met the following inclusion criteria: (1) between the ages of 18-30, (2) participants were students in a comprehensive transition program for intellectual disabilities at a southeastern university. Participants were placed into four groups: 2 groups participating in badminton intervention (4 students with IDD (IDD-BADM) and 4 typical-development participants (TD-BADM)) and 2 control groups not participating in the badminton intervention (4 students with IDD (IDD-CONTR) and 4 typical development students (TD-CONTR)).

Experimental Procedures

A within-subjects repeated-measure design was used for this study. After obtaining consent from typical development participants and parental permission and participant assent for those with IDD, a familiarization of the study included a Par-Q+ (Physical Activity Questionnaire Plus) to ensure participants were ready for exercise along with collection of anthropometrics. Participants completed three testing days (pre-test, mid-test, and post-test) within a 12-week badminton adapted physical education class utilized as a physical activity intervention. The pre-tests occurred one week before the badminton intervention. Mid-tests were 6 weeks after the start of the intervention, while post-testing followed one week after the intervention. All testing days including balance tests on an AMTI force-plate under the following conditions: Bilateral stance: eyes open (EO)- 20 seconds, eyes closed (EC)-10 seconds, foam eyes open (FEO)- 20 seconds, foam eyes closed (FEC)- 10 seconds and unilateral stance on participant's dominant leg (1LEO)- 10 seconds. The adapted physical education class followed the Special Olympics Individual Badminton Skills Assessment and the Badminton World Federation (BWF) guidelines and was designed as a bi-weekly 50-minute badminton adapted physical education class under the following structure: 5 minutes of dynamic warmup, 40 minutes of badminton instruction by a Certified Adapted Physical Education instructor and two graduate teaching assistants for 12 weeks (24 sessions), and a 5-minute cool-down of static stretching.

Data Analysis

Center of pressure (COP) measurements were taken during the static balance assessments, derived from the force platform, and were analyzed to quantify postural sway as a measure of postural stability. COP excursions were used to calculate postural sway variables [average displacements in the medial-lateral (M/L) and anterior-posterior (A/P) directions (M/L-DISP and A/P-DSIP) (in.), average 95% ellipsoid area (in^2), and average velocity (ft/s). All postural sway dependent variables were calculated for the three testing conditions (pre, mid, post) and two group types ((IDD-BADM, IDD-CONTR) (TD-BADM, TD-CONTR)) during all six static balance conditions (EO, EC, EOF, ECF, 1LEO).

Statistical Analysis

The dependent COP postural sway variables from the force-plate balance were analyzed using a between subjects 2 x 3 [2 (IDD-BADM x IDD-CONTR) x 3 (Pre-test x Mid-test x Post-test)] Repeated Measures Analysis of Variance (RM ANOVA) 2 x 3 [2 (TD-BADM x TD-CONTR) x 3 (Pre-test x Mid-test x Post-test)] Repeated Measures Analysis of Variance (RM ANOVA) independently. Post-hoc pairwise comparisons were performed with a Bonferroni correction if main effect significance was identified. All statistical analysis was performed using SPSS 21 (IBM® SPSS® V20.0, Armonk, New York 10504-172) at alpha level at $p \leq 0.05$.

Results

Individuals with IDD whom participated in the badminton intervention (IDD-BADM) and controls for these participants (IDD-CONTR), typical-development partners (TD-BADM) and controls for these individuals (TD-CONTR) completed three testing periods over 12 weeks of the inclusive badminton intervention: pre-testing (before intervention), mid-testing (6 weeks during intervention), and post-testing (after intervention) under the following conditions: bilateral stance (Eyes Open(EO), Eyes Closed(EC), Foam Eyes Open(FEC), and Foam Eyes Closed(FEC)) and unilateral stance on dominant leg (Single-Leg Eyes Open(1LEO)). Significant main results are listed for each group under these conditions. Tables and graphs follow the results.

Eyes Open (EO)

Significant time main-effects were reported for both IDD-BADM and IDD-CONTR for 95% ellipsoid area [F (2, 4.227), (p= 0.041), (η_p^2 = 0.413)] with pairwise comparisons from pre-mid (p= 0.046), average velocity [F (1.093, 12.374), (p= 0.010), (η_p^2 = 0.673)] with pairwise comparisons from pre-mid (p =0.002) pre-post (p =0.028), and average length [F (1.094, 12.379), (p= 0.010), (η_p^2 = 0.674)] with pairwise comparisons pre-mid (p =0.002) and pre-post ((p =0.028). Significant group x time interaction was shown for IDD-BADM for average velocity [F (1.094, 7.422), (p= 0.030), (η_p^2 = 0.533)] with pairwise comparisons from pre-mid (p =0.001) and LSD (0.336), pre-post (p =0.001) and LSD (0.374), average length [F (1.094, 7.422), (p= 0.030), (η_p^2 = 0.533)] with pairwise comparisons pre-post (p =0.007) and LSD (7.483). For both IDD-BADM and IDD-CONTR the ellipsoid area decreased from pre-mid testing, revealing an increase in static balance. In addition, average velocity and average length decreased for both IDD groups from pre-mid testing; however, from pre-post testing IDD-BADM continued to decrease velocity while IDD-CONT increased velocity, with decreases in balance performance for the control group. No significant time, group, nor group x time interactions were found for average displacement in the M/L or A/P directions. Significant time main-effects were reported for both TD-BADM and TD-CONTR for average displacement in the M/L direction [F (2, 15.814), (p= 0.000), (η_p^2 = 0.725)] with pairwise comparisons pre-mid (p =0.003) and pre-post (p =0.001) and the average displacement in the A/P direction [F (2, 10.494), (p= 0.002), (η_p^2 = 0.636)] pre-mid (p =0.010) and pre-post (p =0.020). Both TD groups exhibited improvements in balance performance in the M/L direction from pre-mid testing and overall pre-post testing. Yet, both TD groups revealed decreases in balance performance from pre-mid testing and pre-post testing for the A/P direction. No significant t time, group, nor group x time main effects were found for 95% ellipsoid area, average velocity, or average length.

Figure 31

EO Average M/L Displacement (in.) Time Main Effect for IDD during Pre-Test-Post-Test

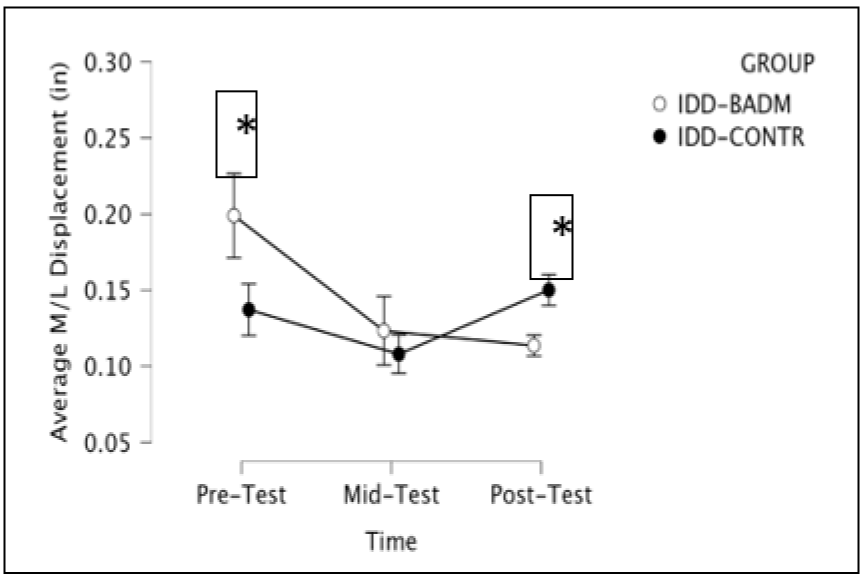


Figure 32

95% EO Ellipsoid Area (in^2) Time-Main Effect for IDD during Pre-Test to Mid-Test

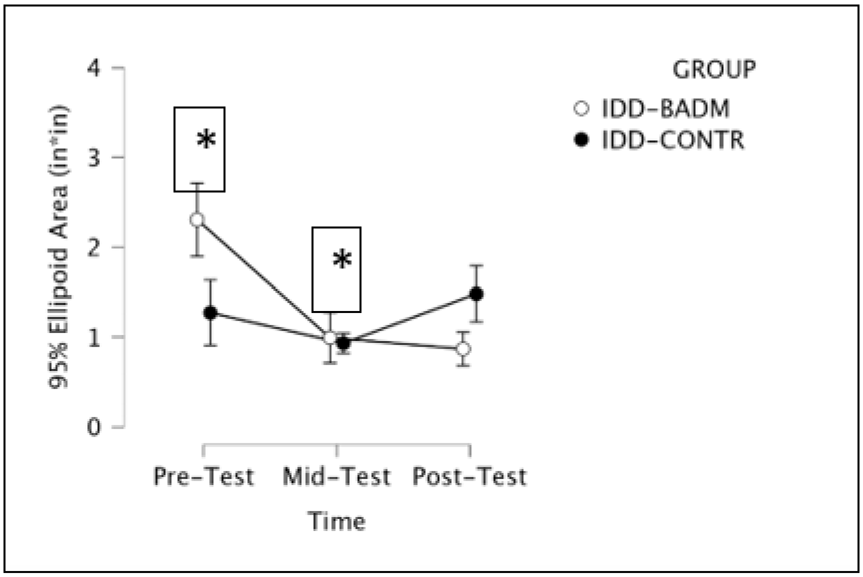


Figure 33

EO Average Velocity (ft/s) Time-Main Effect for IDD during Pre-Test to Mid-Test and Pre-Test Post-Test & Group X Time Interaction for IDD-BADM

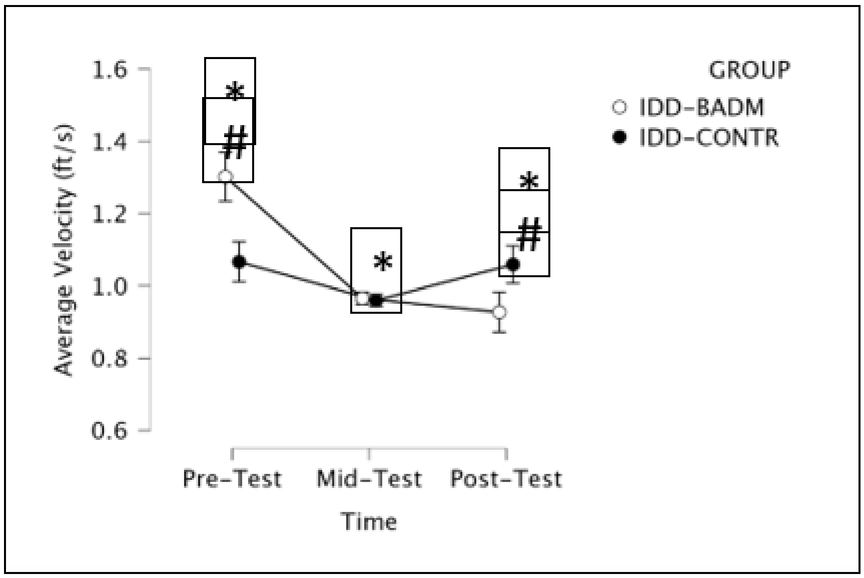


Figure 34

EO Average Length (in.) Time-Main Effect for IDD during Pre-Test to Mid-Test and Pre-Test-Post-Test & Group X Time Interaction for IDD-BADM

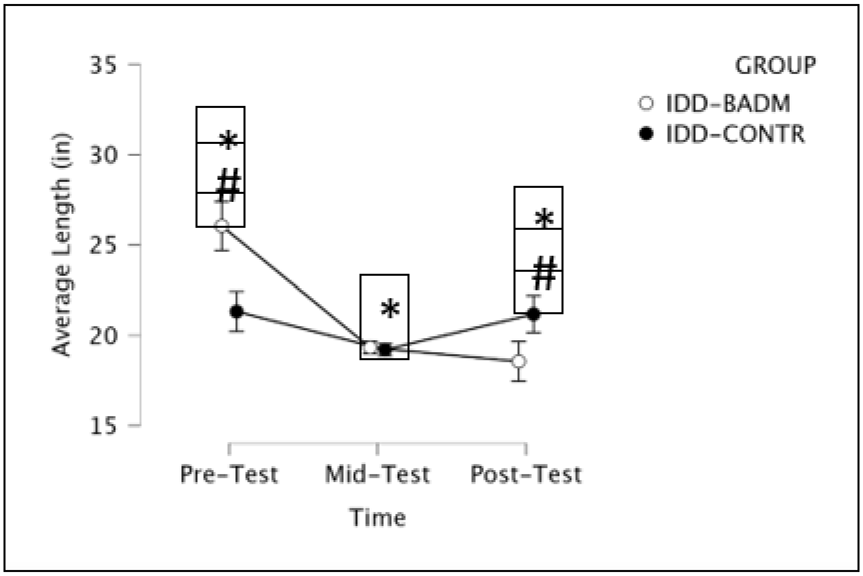
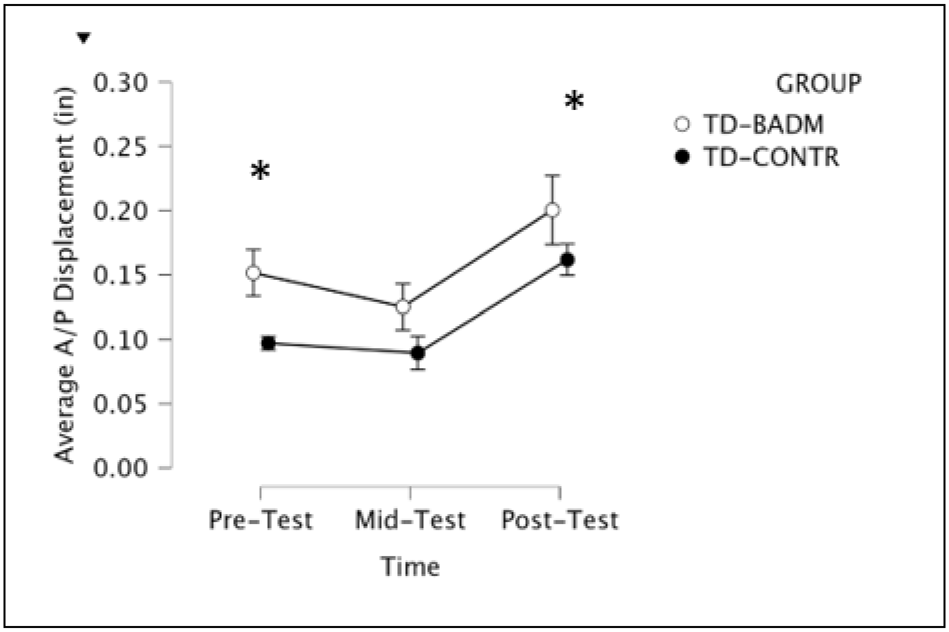


Figure 35

EO Average A/P Displacement (in.) Time Main Effect for TD during Pre-Test-Post-Test

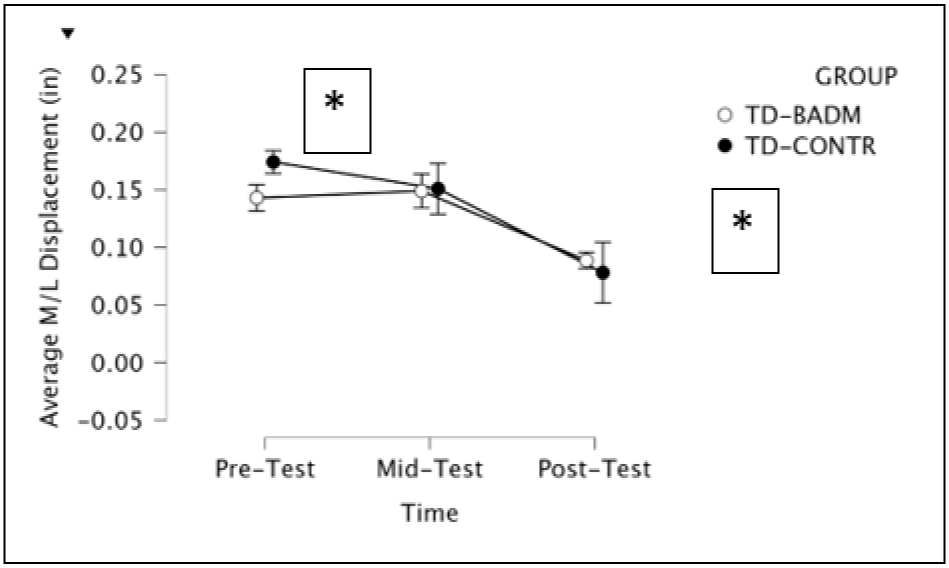


Eyes Closed (EC)

Significant time-main effects were reported for both TD-BADM and TD-CONTR in average displacement in the M/L direction [F (2, 12.146), (p= 0.001), (η_p^2 = 0.669)] with pairwise comparisons from pre-mid (p =0.002) and pre-post (p =0.020). Both TD groups decreased M/L displacement from pre-mid testing and pre-post testing, resulting in an improvement of balance measurements. No significant time, group, nor group x time main effects were found for 95% ellipsoid area, average velocity, or average length or in the A/P direction. Further, no significant time, group, nor group x time interaction were found for IDD-BADM or IDD-CONTR.

Figure 36

EC Average M/L Displacement (in.) Time Main Effect for TD during Pre-Test-Post-Test



Foam Eyes Open (FEO)

Significant time main effects were analyzed for IDD-BADM and IDD-CONTR in average displacement in the M/L direction [F (2, 3.942), (p= 0.048), (η_p^2 = 0.396)] with pairwise comparisons from pre-mid (p =0.032), significantly decreasing postural sway from pre-mid testing, and average displacement in the A/P direction [F (2, 5.708), (p= 0.018), (η_p^2 = 0.488)] with pairwise comparisons from pre-mid (p =0.032) which revealed improvements in balance performance through decreasing displacement in the A/P direction. No significant main effects for time, group, nor group x time interactions were found for 95% ellipsoid area, average velocity, or average length.

Significant time main effects were reported for TD-BADM and TD-CONTR in average displacement in the M/L direction [F (2, 11.416), (p= 0.002), (η_p^2 = 0.655)] with pairwise comparisons from pre-post (p =0.019) and mid-post (p =0.001), demonstrating decreases in M/L sway from pre-post testing and mid-post testing, while average displacement in the A/P direction [F (2, 13.709), (p= 0.001), ($\eta_p^2 = 0.696$)] with pairwise comparisons from pre-post (p =0.010) and mid-post (p= 0.007) presented increases in sway from pre-post testing. No significant main effects for time, group, nor group x time interactions were found for 95% ellipsoid area, average velocity, or average length.

Figure 37

FEO Average M/L Displacement (in.) Time Main Effect for IDD during Pre-Test-Post-Test

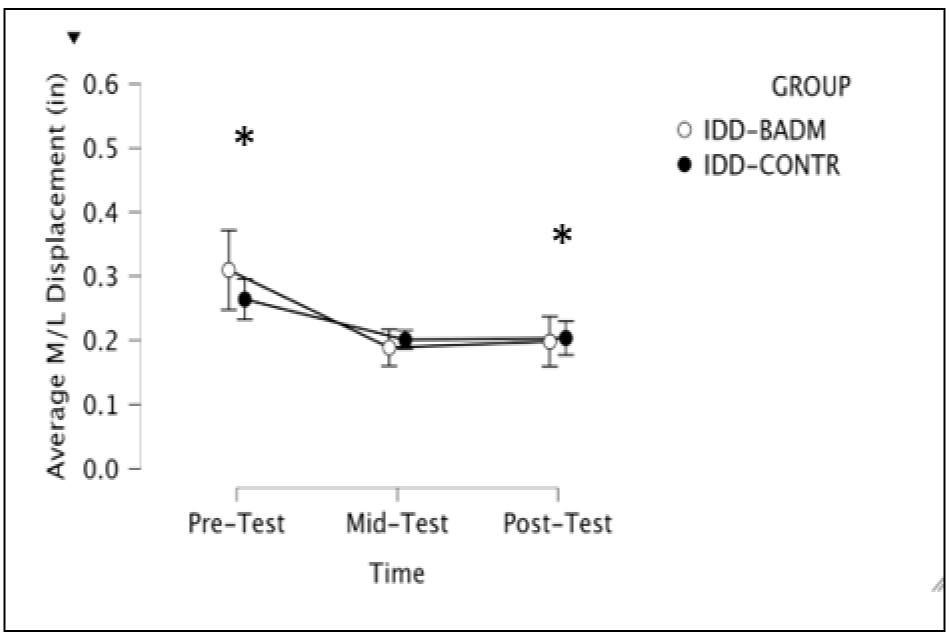


Figure 38

FEO Average A/P Displacement (in.) Time Main Effect for IDD during Pre-Test-Post-Test

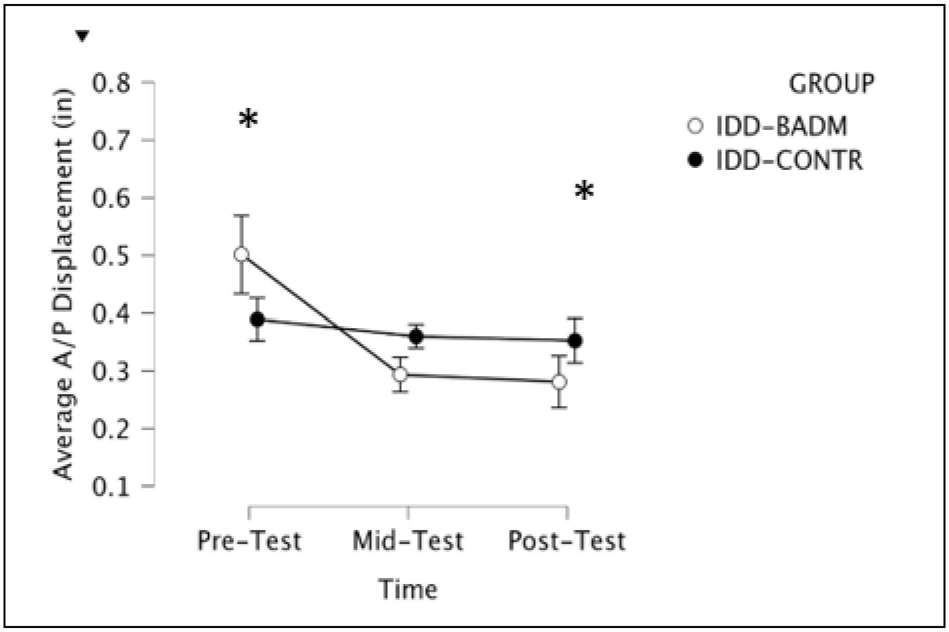
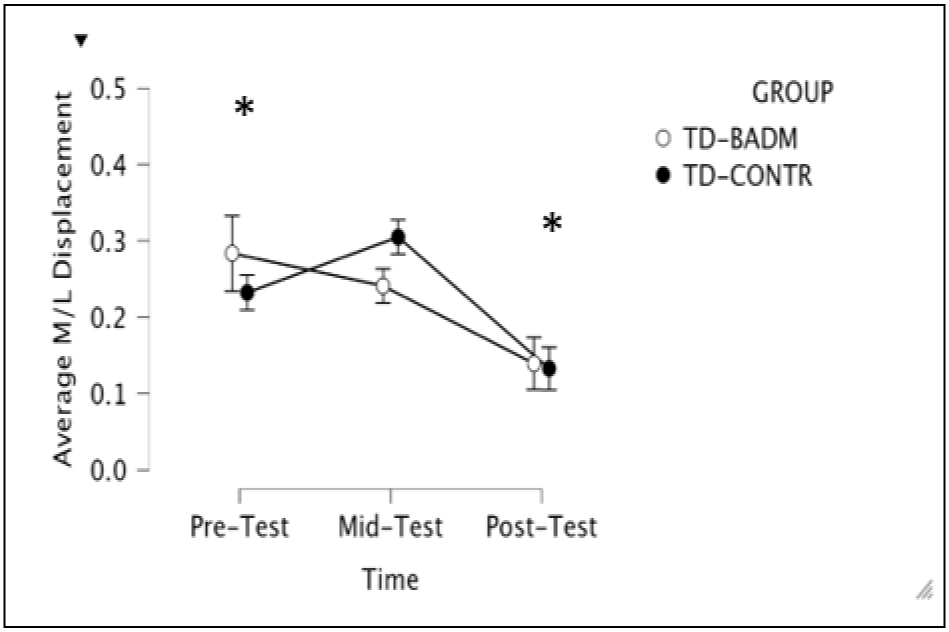


Figure 39

FEO Average M/L Displacement (in.) Time Main Effect for TD during Pre-Test-Post-Test



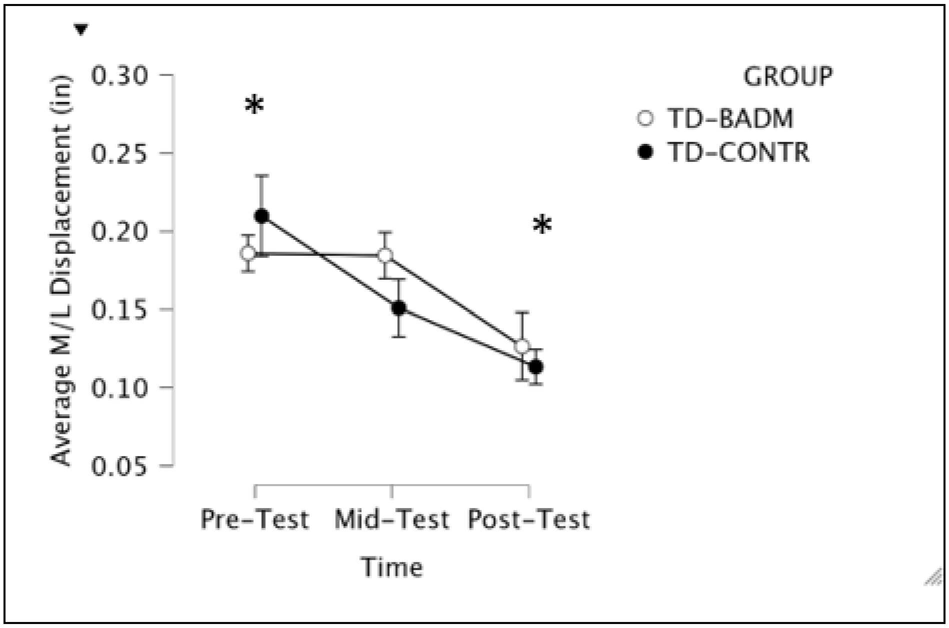
Foam Eyes Closed (FEC)

For IDD-BADM and IDD-CONTR, no significant main effects for time, group, nor group x time interactions were found for average displacement in the M/L or A/P directions, 95% ellipsoid area, average velocity, or average length.

Significant time main effects were found for TD-BADM and TD-CONTR in average displacement in the M/L direction [F (2, 9.489), (p= 0.003), (η_p^2 = 0.613)] with pairwise comparisons from pre-post (p =0.007) and mid-post (p =0.023) exhibited decreases in displacement revealing improvements in balance measures. No significant main effects for time, group, nor group x time interactions were found for average displacement in the A/P direction, 95% ellipsoid area, average velocity, or average length.

Figure 40

FEC Average M/L Displacement (in.) Time Main Effect for TD during Pre-Test-Post-Test

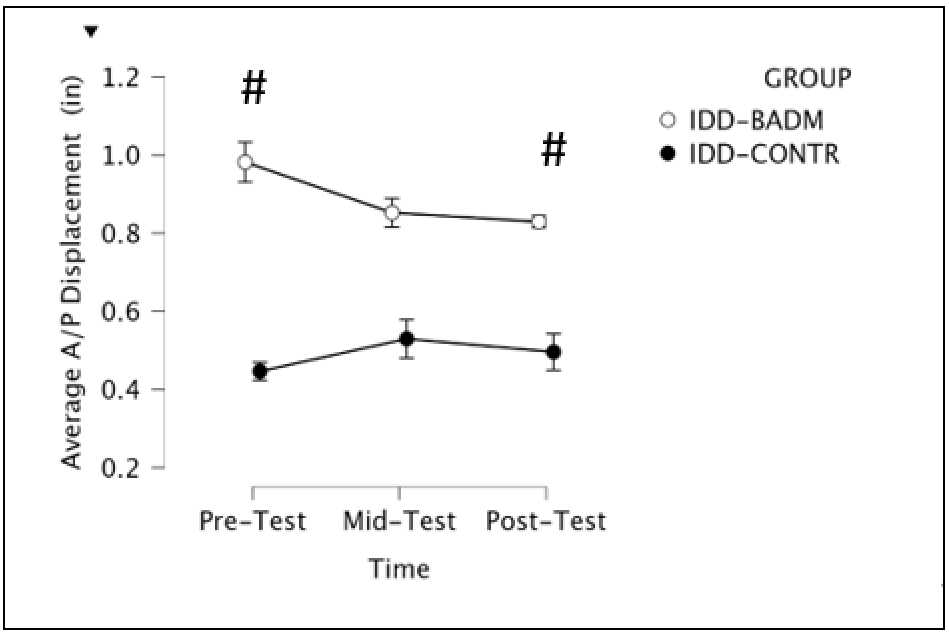


Single-Leg Eyes Open (1LEO)

Significant time x group interactions were reported for IDD-BADM in average displacement in the A/P direction [F (2, 4.621), (p= 0.033), (η_p^2 = 0.957)] with pairwise comparisons from pre-post (p =0.022). IDD-BADM had significantly less A/P displacement from pre-post testing when compared to the control group, showing improvements in postural sway variables over time for the intervention group. However, no significant main effects for time, group, nor group x time interactions were found for average displacement in the M/L direction, 95% ellipsoid area, average velocity, or average length. IDD-CONTR, TD-BADM, and TD-CONTR reported no significant main effects for time, group, nor group x time interactions were found for average displacement in the A/P direction, 95% ellipsoid area, average velocity, or average length.

Figure 41

1LEO Average A/P Displacement (in.) Group X Time Main Effect for IDD-BADM during Pre-Test-Post-Test



Discussion

This study was performed to evaluate the effects of an inclusive badminton intervention on postural control in young adults with intellectual and developmental disabilities; through this program, we attempted to develop an adapted, inclusive physical activity program for the prevention of falls in such individuals.

The results of this study suggest that badminton may be effective in improving postural balance in young adults with intellectual and developmental disabilities. However, for typical development peers, postural control was maintained across the 12 weeks, but no significant differences were observed for TD-BADM when compared to TD-CONTR.

In this study, we observed that the average value of postural sway, for A/P displacement, M/L displacement, 95% ellipsoid area, sway velocity, and length under the following conditions EO, EC, FEO, FEC, 1LEO. Significant time main effects were observed under EO, EC, FEO, and 1LEO for the IDD and TD groups. Significant group main effects for IDD-BADM were reported under EO and 1LEO conditions presenting considerably lower sway measurements in the adolescents with intellectual disabilities whom participated in the badminton intervention when compared to the matched controls.

For the EO condition, time main effects were reported for the IDD groups with decreases in static, quiet stance for average 95% ellipsoid area from pre-mid testing, average velocity from pre-mid testing, and average length from pre-mid testing and pre-post testing with all sway variables decreasing which in turn demonstrates balance improvements. Group x time interactions were shown for IDD-BADM for average velocity and average length from pre-mid testing and pre-post testing. The IDD-BADM showed greater decreases of COP sway variable for average velocity and average length when compared to their matched controls. Time main effects in average M/L and A/P displacement for both TD groups were reported. While M/L displacement decreased over the 12 weeks for both groups, A/P displacement during EO and FEO increased for both groups after 12 weeks, which reveals balance degraded over time for those participating in the intervention and those that did not. These findings for A/P displacement decrements could be related to the time frame of the data collection of the post-tests. Upon entry into the lab, participants had to report how they were feeling based on a 5-point pictorial Likert scale. Participants reported higher level scores than in pre-testing. The higher-level scores could be correlated with tiredness and fatigue due to emotional stress from external factors like final examinations and lack of sleep which justifies the possible higher sway increases in the A/P direction for the TD participants and controls.

During the EC, FEO, and FEC, both TD groups showed decreases in average M/L displacement from pre-post testing as time main effects. Also, in the FEO condition, both IDD groups decreased average sway displacement in the M/L and A/P directions from pre-post testing. For TD-BADM and IDD-BADM, these results are similar to those of Chang et al., 2013 and Wong et al., 2019 could be related to the type of progression through the 12 weeks of the intervention as the skills intensified from static position underhand serving to more dynamic movements such as a forehand and backhand, focusing on weight shifts in the medial and lateral directions and agility. However, we could not control for TD-CONTR, so their improvements could be related to their own physical activity throughout the semester.

For 1LEO, IDD-BADM reported group x time interaction for average A/P displacement from pre-post testing, decreasing the A/P direction of their COP when compared to IDD-CONTR after the 12-week intervention. These results align with the type of movements and skills that are acquired from playing badminton. For instance, badminton players react to the moving shuttlecock and adjust their body position rapidly and accordingly throughout the game (Faude et al., 2007). Badminton players are constantly shifting their center of gravity (COG) outside and within their base of support (BOS) while performing very quick, unilateral upper limb movements (Chang et al., 2013). This constant movement of the COG with asymmetrical upper body movement while playing badminton over the course of 12-week biweekly classes is challenging and trains the postural control system by integrating and organizing changing sensory information while utilizing a feedforward process for quick response times especially for those with postural control deficits. This type of intervention is also training anticipatory postural adjustments which assists in the A/P displacement of the individual's COP while moving forwards and backwards throughout the court and while the individual is making contact with the shuttlecock with rapid change of the six degrees of freedom of the unilateral glenohumeral joint of the upper extremity. Even though these are training dynamic balance movements, static balance like during the 1LEO condition is also being challenged or training and improving.

Conclusion & Future Implications

For young adults with IDD, postural control and balance deficits are observed and reported for this population resulting in falls and limited physical activity participation. Inclusive badminton is an adapted physical activity to improve static postural control. Results from this study demonstrate that badminton could be an efficient form of physical activity to increase postural control for those with IDD. However, this study did not find significant group differences for the typical development peers when compared to controls. This could be related to the design of the class. The typical development peers were more involved in coaching and instructing the participants with IDD rather than participating in the badminton drills themselves. Some limitations could be the small sample size of all groups which could contribute to the results and participants could have participated in other balance training programs throughout the study but were instructed not to. Other interventions such as Tai Chi and virtual reality video-gaming could be beneficial postural training interventions to improve balance and decrease the prevalence of falls for this population.

CHAPTER VII

CONCLUSIONS

For the individuals with intellectual and developmental disabilities, deficits are reported for areas of postural control, locomotion, and physical fitness. Decrements in these areas can result in lowered quality of life levels with decreases in functional mobility, limited joint range of motion, increases in a sedentary lifestyle, limited participation in physical activity with peers, and even lead to co-morbidities. Finding physical activity alternatives for this population is crucial to improve all areas of health and wellness from emotional to physical health. Exercise interventions such as inclusive badminton could serve as an exercise intervention to improve postural control for young adults with IDD in a group setting, while new types of technology like immersive VR can improve areas of physical fitness and locomotion while maintaining postural control for individuals with IDD. Both sport-related adapted physical activities in a group setting and individual video immersive video games could be used as a proficient form of balance training for this population to engage interest and ultimately motivate young adults with IDD to become more physically active and improve areas of postural control which could lead to a higher quality of life.

REFERENCES

1. Amemiya, M. (1982). An analysis of simple reaction time in mentally retarded and nonretarded children matched on mental age: Examination using intertrial interval as a variable. Shinrigaku Kenky, 53(4), 193–199.
2. American Association of Intellectual and Developmental Disabilities. (2010). Definition, classification, and systems of support (11th ed). Washington, DC.
3. American Psychiatric Association, editor. Diagnostic and Statistical Manual of Mental Disorders (DSM-5®): American Psychiatric Publishing; 2013.
4. American Psychiatric Association. (2000). Diagnostic and statistical manual of mental disorders (4th ed. (DSM-IV)). Washington, DC: American Psychiatric Association.
5. Aminabadi, N. A., Erfanparast, L., Sohrabi, A., Oskouei, S. G., & Naghili, A. (2012). The impact of virtual reality distraction on pain and anxiety during dental treatment in 4–6 year-old children: A randomized controlled clinical trial. Journal of Dental Research, Dental Clinics, Dental Prospects, 6, 117–124.
6. Angelopoulou, N., Tsimaras, V., Christoulas, K., Kokaridas, D., & Mandroukas, K. (1999). Isokinetic knee muscle strength of individuals with mental retardation, a comparative study. Perceptual and Motor Skills, 88(3 Pt 1), 849–855. http://dx.doi.org/10.2466/pms.1999.88.3.849
7. Auxter, D. (1966). Muscular fatigue of mentally retarded children. The Training School Bulletin, 63, 5–10.

8. Ben-Sasson, A., Hen, L., Fluss, R., Cermak, S. A., Engel-Yeger, B., & Gal, E. (2009). A meta-analysis of sensory modulation symptoms in individuals with autism spectrum disorders. Journal of Autism and Developmental Disorders, 39(1), 1–11. doi:10.1007/s10803-008-0593-3.
9. Bittner, M., GOUDY, L., DILLON, S. R., MCNAMARA, S., & ADAMS, D. (2018). EXERCISE IDENTIFIED AS AN EVIDENCE-BASED PRACTICE FOR STUDENTS WITH AUTISM SPECTRUM DISORDER. Palaestra, 32(1).
10. Blomqvist, S., Olsson, J., Wallin, L., Wester, A., & Rehn, B. (2013). Adolescents with intellectual disability have reduced postural balance and muscle performance in trunk and lowerlimbs compared to peers without intellectual disability. Research in Developmental Disabilities, 34(1), 198–206. http://dx.doi.org/10.1016/ j.ridd.2012.07.008
11. Bonavolonta, V., Cataldi, S., Greco, E., & Fischetti, F. (2019). The effectiveness of physical and sport activities in children and adolescents with learning and developmental disabilities: State of the art didactic implications and future research. Italian Journal of Health Education, Sport and Inclusive Didactics (Giornal Italiano di Educazione Alla Salute, Sport e Didattica Indage), 3(4). https://doi.org/10.32043/gsd.v3i4.151
12. Booth, V., Masud, T., Connell, L., & Bath-Hextall, F. (2014). The effectiveness of virtual reality interventions in improving balance in adults with impaired balance compared with standard or no treatment: A systematic review and meta-analysis. Clinical Rehabilitation, 28(5), 419–431. https://doi.org/10.1177/026921551350938.

13. Borji Rihab, Sonia Sahli, Nidhal Zarrouk, Firas Zghal, Haithem Rebai. Neuromuscular fatigue during high-intensity intermittent exercise in individuals with intellectual disability. Research in Developmental Disabilities,Volume 34, Issue 12, 2013, Pages 4477-4484. https://doi.org/10.1016/j.ridd.2013.09.025.
14. Boyle CA, Boulet S, Schieve LA, et al. Trends in the prevalence of developmental disabilities in US children, 1997e2008. Pediatrics. DOI: 2011;127:1034e1042.
15. Brien, M., & Sveistrup, H. (2011). An intensive virtual reality program improves functional balance and mobility of adolescents with cerebral palsy. Pediatric Physical Therapy: The Official Publication of the Section on Pediatrics of the American Physical Therapy Association, 23(3), 258–266. https://doi.org/10.1097/PEP.0b013e318227ca0f.
16. Carey DP. Eye–hand coordination: eye to hand or hand to eye? Curr Biol 2000;10:R416–9.
17. Carlson, S. M., Zelazo, P. D., & Faja, S. (2013). Executive function. In P. D. Zelazo (Ed.), Oxford library of psychology. The Oxford handbook of developmental psychology (Vol. 1): Body and mind (p. 706–743). Oxford University Press.
18. Carmeli, E., Barchad, S., Lenger, R., & Coleman, R. (2002). Muscle power, locomotor performance and flexibility in aging mentally-retarded adults with and without Down's syndrome. Journal of Musculoskeletal and Neuronal Interactions, 2(5), 457–462.
19. Carmeli, E., Imam, B., & Merrick, J. (2012). The relationship of pre-sarcopenia (low muscle mass) and sarcopenia (loss of muscle strength) with functional decline in individuals with intellectual disability (ID). Archives of Gerontology and Geriatrics, 55(1), 181–185. http://dx.doi.org/10.1016/j.archger.2011.06.032

20. CDC. (1997). National center for chronic disease prevention and health promotion, guidelines for school and community programs to promote lifelong physical activity among young people. The Journal of School Health, 67(6), 202–219. https://doi.org/10.1111/j.1746-1561.1997.tb06307.x

21. Chang WD, Chang WY, Lee CL, et al. Validity and reliability of wii fit balance board for the assessment of balance of healthy young adults and the elderly. J Phys Ther Sci 2013;25:1251–3.

22. Chang, J. T., Morton, S. C., Rubenstein, L. Z., Mojica, W. A., Maglione, M., Suttorp, M. J., Roth, E. A., & Shekelle, P. G. (2004). Interventions for the prevention of falls in older adults: systematic review and meta-analysis of randomized clinical trials. BMJ (Clinical Research ed.), 328(7441), 680. https://doi.org/10.1136/bmj.328.7441.680

23. Chen, F., & Tsai, C. (2015). A light fingertip touch reduces postural sway in children with autism spectrum disorders. Gait and Posture, 43(1), 137–140. doi:10.1016/j.gaitpost.2015.09.012.

24. Chiba, Y., Shimada, A., Yoshida, F., Keino, H., Hasegawa, M., Ikari, H., Miyake, S., & Hosokawa, M. (2009). Risk of fall for individuals with intellectual disability. American Journal on Intellectual and Developmental Disabilities, 114(4), 225–236. https://doi.org/10.1352/1944-7558-114.4:225-236

25. Cuesta-Vargas, A. I., Paz-Lourido, B., & Rodriguez, A. (2011). Physical fitness profile in adults with intellectual disabilities: Difference between levels of sport practice. Research in Developmental Disabilities, 32(2), 788–794. http://dx.doi.org/10.1016/j.ridd.2010.10.023

26. Da Cunha, R. D., Neiva, F. W., & da Silva, R. L. D. S. (2018). Virtual reality as a support tool for the treatment of people with intellectual and multiple disabilities: A systematic literature review. Revista de Informa´tica Te orica e Aplicada, 25(1), 67–81.

27. Dane S, Hazar F, Tan Ü. Correlations between eye-hand reaction time and power of various muscles in badminton players. Int J Neurosci 2008;118:349–54.

28. Demetriou, E. A., Lampit, A., Quintana, D. S., Naismith, S. L., Song, Y. J. C., Pye, J. E., ... & Guastella, A. J. (2018). Autism spectrum disorders: a meta-analysis of executive function. Molecular psychiatry, 23(5), 1198-1204.

29. Doumas, M., McKenna, R., & Murphy, B. (2015). Postural control deficits in autism spectrum disorder: The role of sensory integration. Journal of Autism and Developmental Disorders. doi:10.1007/s10803-015-2621-4.

30. Downey JC, Brodie D. Get Fit for Badminton: A Practical Guide to Training for Players and Coaches. Pelham, London: 1980.

31. Draheim, C. C., Williams, D. P., & McCubbin, J. A. (2002). Prevalence of physical inactivity and recommended physical activity in community-based adults with mental retardation. Mental Retardation, 40(6), 436–444. https://doi.org/10.1352/ 0047-6765(2002)040<0436:POPIAR>2.0.CO;2

32. Enoka, R. M., & Duchateau, J. (2008). Muscle fatigue: What, why and how it influences muscle function. Journal of Physiology, 586(1), 11–23.

33. Esposito PE, MacDonald M, Hornyak JE, Ulrich DA. Physical activity patterns of youth with Down syndrome. Intellect Dev Disabil. DOI: 2012;50:109e119.

34. Faude O, Meyer T, Rosenberger F, et al. Physiological characteristics of badminton match play. Eur J Appl Physiol 2007;100:479–85.

35. Faude O, Meyer T, Rosenberger F, et al. Physiological characteristics of badminton match play. Eur J Appl Physiol 2007;100:479–85.

36. Fernhall, B., & Tymeson, G. T. (1988). Validation of a cardiovascular fitness field test for adults with mental retardation. Adapted Physical Activity Quarterly, 5, 49–59.

37. Fournier KA, Kimberg CI, Radonovich KJ, Tillman MD, Chow JW, Lewis MH, et al. Decreased static and dynamic postural control in children with autism spectrum disorders. Gait Posture. 2010;32(1):6–9.

38. Gandevia, S. C. (2001). Spinal and supraspinal factors in human muscle fatigue. Physiological Reviews, 81(4), 1725–1789.

39. Gepner B, et al. Postural effects of motion vision in young autistic children. Neuroreport 1995;6(8):1211–4.

40. Gepner B, Mestre DR. Brief report: postural reactivity to fast visual motion differentiates autistic from children with Asperger syndrome. J Autism Dev Disord 2002;32(3):231–8.

41. Gershon, J., Zimand, E., Pickering, M., Rothbaum, B., & Hodges, L. (2004). A pilot and feasibility study of virtual reality as a distraction for children with cancer. Journal of the American Academy of Child & Adolescent Psychiatry, 43, 1243–1249. doi:10.1097/01.chi.0000135621.23145.05.

42. Ghez C, Hening W, Gordon J. Organization of voluntary movement. Curr Opin Neurobiol. 1991;1(4):664–71.

43. Gignac, M. A. (2003). Leisure time physical activity and well-being: learning from people living with arthritis. Research Quarterly for Exercise and Sport, 30(11), 2299–2301.

44. Glazebrook CM, Elliott D, Lyons J. A kinematic analysis of how young adults with and without autism plan and control goal-directed movements. Motor Control 2006;10(3):244–64.

45. Gucluover A, Demirkan E, Kutlu M, et al. The comparison of some physical and physiological features of elite youth national and amateur badminton players. J Phys Educ Sports Sci 2012;6:244–50.

46. Halle, J. W., Gabler-Halle, D., & Chung, Y. B. (1999). Effects of a peer mediated aerobic conditioning program on fitness levels of youth with mental retardation: Two systematic replications. Mental Retardation, 37, 435–448.

47. Halliday SE, et al. The initiation of gait in young, elderly, and Parkinson's disease subjects. Gait Posture 1998;8(1):8–14.

48. Harlein, J., Dassen, T., Halfens, R. J. G., & Heinze, C. (2009). Fall risk factors in older people with dementia or cognitive impairment: A systematic review. Journal of Advanced Nursing, 65(5), 922–933. https://doi.org/10.1111/j.1365-2648.2008.04950.x

49. Harris, J. C. (2006). Intellectual disability: Understanding its development, causes, classification, evaluation, and treatment (pp. 42–98). Oxford University Press.

50. Hass CJ, et al. The influence of Tai Chi training on the center of pressure trajectory during gait initiation in older adults. Arch Phys Med Rehabil 2004;85(10):1593–8.

51. Heller, T., Ying, G-s., Rimmer, J. H., & Marks, B. A. (2002). Determinants of exercise in adults with cerebral palsy. Public Health Nursing, 19(3), 223–231. https://doi.org/10.1046/j.0737-1209.2002.19311.x

52. Henderson, S. E., Morris, J., & Ray, S. (1981). Performance of Down syndrome and other retarded children on the Cratty Gross-Motor Test. American Journal of Mental Deficiency, 85(4), 416–424.
53. Hoffman HG, Doctor JN, Patterson DR, Carrougher GJ, Furness TA 3rd. Virtual reality as an adjunctive pain control during burn wound care in adolescent patients. Pain. 2000; 85(1–2):305–309. [PubMed: 10692634]
54. Hoffman HG, Patterson DR, Carrougher GJ. Use of virtual reality for adjunctive treatment of adult burn pain during physical therapy: a controlled study. The Clinical journal of pain. 2000; 16(3):244–250. [PubMed: 11014398]
55. Horak FB. Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls. Age Ageing. 2006;35(Suppl 2):ii7–ii11.
56. Horak, F. B. (1992). Motor control models underlying neurologic rehabilitation of posture in children. In: H. Forssberg, H. Hirschfeld (Eds.), Movement Disorders in Children. Medicine & Sport Science, Basel, Karger, 36, 21-30.
57. Horak, F. B. (2006). Postural orientation and equilibrium: What do we need to know about neural control of balance to prevent falls? Age Ageing, 35, ii7–ii11. doi:10.1093/ageing/afl077.
58. Horvat, M., Croce, R., Pitetti, K. H., & Fernhall, B. (1999). Comparison of isokinetic peak force and work parameters in youth with and without mental retardation. Medicine and Science in Sports and Exercise, 31(8), 1190–1195.
59. Hough-Telford C, Kimberlin DW, Aban I, Hitchcock WP, Almquist J, Kratz R, et al. Vaccine delays, refusals, and patient dismissals: a survey of pediatricians. Pediatrics 2016;138(3):241-3.

60. Hynes, J., Block, M. Effects of Physical Activity on Social, Behavioral, and Cognitive Skills in Children and Young Adults with Autism Spectrum Disorder: a Systematic Review of the Literature. Rev J Autism Dev Disord (2022). https://doi.org/10.1007/s40489-022-00319-5

61. Imam, B.; Jarus, T. Virtual Reality Rehabilitation from Social Cognitive and Motor Learning Theoretical Perspectives in Stroke Population. Rehabil. Res. Pr. 2014, 2014, 1–11. [CrossRef]

62. Isaacs B. Falls. In Exton-Smith AN, Weksler ME eds. Practical Geriatric Medicine. New York: Churchill Livingstone, 1985; 154–60.

63. Jansiewicz EM, et al. Motor signs distinguish children with high functioning autism and Asperger's syndrome from controls. J Autism Dev Disord 2006;36(5):613–21.

64. Johnson CC. The benefits of physical activity for youth with developmental disabilities: a systematic review. Am J Health Promot. 2009;23:157e167.

65. Juras, G.; Brachman, A.; Michalska, J.; Kamieniarz, A.; Pawłowski, M.; Hadamus, A.; Białoszewski, D.; Błaszczyk, J.; Słomka, K.J. Standards of Virtual Reality Application in Balance Training Programs in Clinical Practice: A Systematic Review. Games Health J. 2019, 8, 101–111.

66. Kim, Y., Todd, T., Fujii, T., Lim, J.-C., Vrongistinos, K., & Jung, T. (2016). Effects of taekwondo intervention on balance in children with autism spectrum disorder. Journal of Exercise Rehabilitation, 12(4), 314–319. https://doi.org/10.12965/jer.1632634.317

67. King, B. H., Toth, K. E., Hodapp, R. M., & Dykens, E. M. (2009). Intellectual disability. In B. J. Sadock, V. A. Sadock, & P. Ruiz (Eds.), Comprehensive textbook of psychiatry. (9th ed., pp. 3444–3474). Lippincott Williams & Wilkins. ISBN: 978-0-7817-6899-3.

68. Kioumourtzoglou, E., Batsiou, S., Theodorakis, Y., & Mauromatis, G. (1994). Selected motor skills of mentally retarded and nonretarded individuals. Perceptual and Motor Skills, 78(3 Pt 1), 1011L 5.

69. Kohen-Raz R, Volkmar F, Cohen D. Postural control in children with autism. J Autism Dev Disord. 1992;22(3):419–32.

70. Koller D, Goldman RD. Distraction techniques for children undergoing procedures: a critical review of pediatric research. *J Pediatr Nurs* 2012;27(6):652-81. Epub 2011 Oct 13.

71. Liu, W. Y. (2001). Anticipatory postural adjustments in children with cerebral palsy and children with typical development during forward reach tasks in standing. Philadelphia, PA, MCP Hahnemann University (Dissertation, pp. 111-173).

72. Lotan, M. (2006). Physical activity for individuals with down syndrome: A review with clinical implications. International Journal of Disability and Human Development, 5(4), 387–391. https://doi.org/10.1515/IJDHD.2006.5.4.337

73. Lotan, M. (2007). Quality physical intervention activity for persons with down syndrome. ScientificWorldJournal, 7, 7–19. https://doi.org/10.1100/tsw.2007.20

74. Lotan, M., & L. Weiss, P. (2021). Improving Balance in Adults With Intellectual Developmental Disorder via Virtual Environments. *Perceptual and motor skills*, *128*(6), 2638-2653

75. Lotan, M., Yalon-Chamovitz, S., & Weiss, P. L. (2009). Improving physical fitness of individuals with intellectual and developmental disability through a virtual reality intervention program. Research in Developmental Disabilities, 30(2), 229–239. https://doi.org/10.1016/j.ridd.2008.03.005

76. Lotan, M., Yalon-Chamovitz, S., & Weiss, P. L. (2011). Training caregivers to provide virtual reality intervention for adults with severe intellectual and developmental disability. Journal of Physical Therapy Education, 25(1), 15–19. https://doi.org/10.1097/00001416-201110000-00004

77. Mack H. Pilot study shows VR goggles reduce fear, pain in children during vaccination. *Mobile Health News* 2017 Jan 25. Available from: www.mobihealthnews.com/content/pilot-study-shows-vr-goggles-reduce-fear-pain-children-during-vaccination. Accessed 2017 Aug 11.

78. Martin M, et al. Gait initiation in community-dwelling adults with Parkinson disease: comparison with older and younger adults without the disease. Phys Ther 2002;82(6):566–77.

79. Martineau J, Schmitz C, Assaiante C, Blanc R, Barthelemy C. Impairment of a cortical event-related desynchronisation during a bimanual load-lifting task in children with autistic disorder. Neurosci Lett. 2004;367(3):298–303.

80. Masu Y, Muramatsu K, Hayashi N. Characteristics of sway in the center of gravity of badminton players. J Phys Ther Sci 2014;26:1671–4.

81. Maulik, P. K., Mascarenhas, M. N., Mathers, C. D., Dua, T., & Saxena, S. (2011). Prevalence of intellectual disability: A meta-analysis of population-based studies. Research in Developmental Disabilities, 32(2), 419–436. https://doi.org/10.1016/j.ridd.2010.12.018

82. McMahon, A. K., & McMahon, D. D. (2016). Exercise technology interventions and individuals with IDD. Division of Autism and Developmental Disabilities Online Journal, 3, 42–53. https://doi.org/10.1016/j.ridd.2008.03.005

83. Memari AH, Ghanouni P, Gharibzadeh S, Eghlidi J, Ziaee V, Moshayedi P. Postural sway patterns in children with autism spectrum disorder compared with typically developing children. Res Autism Spectr Disord. 2013;7:325–32.

84. Minshew, N. J., Sung, K., Jones, B. L., & Furman, J. M. (2004). Underdevelopment of the postural control system in autism. Neurology, 63(11), 2056–2061.

85. Molloy, C. A., Dietrich, K. N., & Bhattacharya, A. (2003). Postural stability in children with autism spectrum disorder. Journal of Autism and Developmental Disorders, 33(6), 643–652.

86. Noterdaeme M, et al. Evaluation of neuromotor deficits in children with autism and children with a specific speech and language disorder. Eur Child Adolesc Psychiatry 2002;11(5):219–25.

87. Obama M. Let's move! raising a healthier generation of kids. Child Obes. 2012;8: 1.

88. Pal J., Hale L., Mirfin-Veitch B. & Claydon L. (2014) Injuries and falls among adults with intellectual disability: a prospective New Zealand cohort study. Journal of Intellectual and Developmental Disability 39, 35–44.

89. Pan CY, Frey GC. Physical activity patterns in youth with autism spectrum disorders. J Autism Dev Disord. 2006;36:597e606.

90. Pavao, S. L., Silva, F. P., Savelsbergh, G. J., & Rocha, N. A. (2015). Use of sensory information during postural control in children with cerebral palsy: Systematic review. Journal of Motor Behavior, 47(4), 291–301. doi:10.1080/00222895.2014.981498.

91. Payette, M. C., B elanger, C., L eveill e, V., & Grenier, S. (2016). Fall-related psychological concerns and anxiety among community-dwelling older adults: Systematic review and meta-analysis. PloS One, 11(4), e0152848. https://doi.org/10.1371/journal.pone.0152848

92. Peterka, R. J. (2002). Sensorimotor integration in human postural control. Journal of Neurophysiology, 88(3), 1097–1118.

93. Provost B, Lopez BR, Heimerl S. A comparison of motor delays in young children: autism spectrum disorder, developmental delay, and developmental concerns. J Autism Dev Disord 2007;37(2):321–8.

94. Reina AM, Adams EV, Allison CK, Mueller KE, Crowe BM, Puymbroeck Mv, et al. Yoga for functional fitness in adults with intellectual and developmental disabilities. Int J Yoga 2020;13:156-9.

95. Rimmer JH, Yamaki K, Lowry BD, Wang E, Vogel LC. Obesity and obesity-related secondary conditions in adolescents with intellectual/developmental disabilities. J Intellect Disabil Res. DOI: 2010;54:787e794.

96. Rimmer, J. H. (2004). The National Center on Physical Activity and Disability (NCPAD): Providing web-based resources on physical activity for people with disabilities. A lecture presented at the American Association for Mental Retardation (AAMR) Conference, Philadelphia, PA.

97. Rinehart NJ, et al. An examination of movement kinematics in young people with high-functioning autism and Asperger's disorder: further evidence for a motor planning deficit. J Autism Dev Disord 2006;36(6):757–67.

98. Rinehart NJ, Tonge BJ, Bradshaw JL, Iansek R, Enticott PG, McGinley J. Gait function in high-functioning autism and Asperger's disorder: evidence for basal-ganglia and cerebellar involvement. Eur Child Adolesc Psychiatry. 2006;15(5):256–64.

99. Rodrigues AR, Santos S, Rodrigues A, Estevens M, Sousa E (2019) Executive profile of adults with intellectual disability and psychomotor intervention' effects on executive functioning. Physiother Res Rep 2: DOI: 10.15761/PRR.1000122

100. Rubenstein, L. Z., & Josephson, K. R. (2006). Falls and their prevention in elderly people: What does the evidence show. The Medical Clinics of North America, 90(5), 807–824. https://doi.org/10.1016/j.mcna.2006.05.013

101. Ruuskanen, J. M., & Parkatti, T. (1994). Physical activity and related factors among nursing home residents. Journal of the American Geriatrics Society, 42(9), 987–991. https://doi.org/ 10.1111/j.1532-5415. 1994.tb06593.x

102. Sacrey L-AR, Germani T, Bryson SE, Zwaigenbaum L. Reaching and grasping in autism spectrum disorder: a review of recent literature. Front Neurol. 2014;5:6.

103. Sandlund M, McDonough S, Hager-Ross C. Interactive computer play in rehabilitation of children with sensorimotor disorders: a systematic review. Dev Med Child Neurol. 2009; 51(3):173–179. [PubMed: 19191834]

104. Sarabzadeh, M., Azari, B. B.,&Helalizadeh, M. (2019). The effect of six weeks of Tai Chi Chuan training on the motor skills of children with Autism spectrum disorder. Journal of Bodywork and Movement Therapies, 23(2), 284–290. https://doi.org/10.1016/j.jbmt.2019.01.007

105. Schmitz C, Martineau J, Barthélémy C, Assaiante C. Motor control and children with autism: deficit of anticipatory function. Neurosci Lett. 2003; 348(1):17–20.

106. Sheppard JM, Young WB. Agility literature review: classifications, training and testing. J Sports Sci 2006;24:919–32.

107. Shields N, Synnot AJ, Barr M. Perceived barriers and facilitators to physical activity for children with disability: a systematic review. Br J Sports Med. 2012;46:989e997.

108. Silverberg Z, Silverberg M, La Puma J. *Virtual reality and vaccination: see the sea and be pain-free?* Paper presented at: World Summit on Pediatrics; 2017 Jun 24; Rome, Italy.

109. Singh J, Raza S, Mohammad A. Physical characteristics and level of performance in badminton: a relationship study. J Educ Pract 2011;2:6– 10. (2011).

110. Smulders E., Enkelaar L., Weerdesteyn V., Geurts A. C. & van Schrojenstein Lantman-de Valk H. (2013) Falls in older persons with intellectual disabilities: fall rate, circumstances and consequences. Journal of Intellectual Disability Research 57, 1173–82.

111. Son S, Jeon B, Kim H. Effects of a walking exercise program for obese individuals with intellectual disability staying in a residential care facility. J Phys Ther Sci. 2016;28:788–793.

112. Temple, V. A. (2007). Barriers, enjoyment, and preference for physical activity among adults with intellectual disability. International Journal of Rehabilitation Research. Internationale Zeitschrift Fur Rehabilitationsforschung. Revue Internationale de Recherches de Readaptation, 30(4), 281–287. https://doi.org/10.1097/MRR.0b013e3282f144fb

113. Teu KK, Kim W, Tan J, et al. Using dual Euler angles for the analysis of arm movement during the badminton smash. Sports Eng 2005;8:171–8.

114. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. N Eng J Med 1988; 319: 1701–7

115. Travers, B. G., Powell, P. S., Klinger, L. G., & Klinger, M. R. (2013). Motor difficulties in autism spectrum disorder: Linking symptom severity and postural stability. Journal of Autism and Developmental Disorders, 43(7), 1568–1583. doi:10.1007/s10803-012-1702-x.

116. Tyler K, MacDonald M, Menear K. Physical activity and physical fitness of school-aged children and youth with autism spectrum disorders. Autism Res Treatment. 2014:1e6, 2014.

117. U.S. Department of Health and Human Services. Physical Activity Guidelines for Americans. 2008.

118. Valmaggia, L.; Latif, L.; Kempton, M.J.; Rus-Calafell, M.; Kemptom, M.J.; Maria, R.-C. Virtual reality in the psychological treatment for mental health problems: An systematic review of recent evidence. Psychiatry Res. Neuroimaging 2016, 236, 189–195.

119. Van Hanegem E., Enkelaar L., Smulders E. & Weerdesteyn V. (2014) Obstacle course training can improve mobility and prevent falls in people with intellectual disabilities. Journal of Intellectual Disability Research 58, 485–92.

120. Van Twillert, B., Bremer, M., & Faber, A. W. (2007). Computer-generated virtual reality to control pain and anxiety in pediatric and adult burn patients during wound dressing changes. Journal of Burn Care & Research, 28, 694–702. doi:10.1097/BCR.0B013E318148C96F.

121. Vieira, G.D.P.; De Araujo, D.F.G.H.; Leite, M.A.A.; Orsini, M.; Correa, C.L. Realidade virtual na reabilitação física de pacientes com doença de Parkinson. J. Hum. Growth Dev. 2014, 24, 31.

122. Whitt-Glover MC, O'Neill KL, Stettler N. Physical activity patterns in children with and without Down syndrome. Pediatr Rehabil. 2006;9:158e164.

123. Willgoss, T. G., Yohannes, A. M., & Mitchel, D. (2010). Review of risk factors andpreventative strategies for fall-related injuries in people with intellectual disabilities. Journal of Clinical Nursing, 19(15-16), 2100–2109. https://doi.org/10.1111/j.1365-2702.2009.03174.x

124. Winter DA, et al. Stiffness control of balance in quiet standing. J Neurophysiol 1998;80(3):1211–21.

125. Winter, C. F., Bastiaanse, L. P., Hilgenkamp, T. I., Evenhuis, H. M., & Echteld, M. A. (2012). Cardiovascular risk factors (diabetes, hypertension, hypercholesterolemia, and metabolic syndrome) in older people with intellectual disability: Results of the HA-ID study. Research in Developmental Disabilities, 33(6), 1722–1731. http://dx.doi.org/10.1016/j.ridd.2012.04.010

126. Winter, C. F., Magilsen, K. W., van Alfen, J. C., Penning, C., & Evenhuis, H. M. (2009). Prevalence of cardiovascular risk factors in older people with intellectual disability. American Journal on Intellectual and Developmental Disabilities, 14(6), 427–436.

127. Wong, T., Ma, A., Liu, K., Chung, L., Bae, Y. H., Fong, S., Ganesan, B., & Wang, H. K. (2019). Balance control, agility, eye-hand coordination, and sport performance of amateur badminton players: A cross-sectional study. Medicine, 98(2), e14134. https://doi.org/10.1097/MD.000000000001413.

128. Wouters M, Evenhuis HM, Hilgenkamp TIM. Physical fitness of children and adolescents with moderate to severe intellectual disabilities. Disabil Rehabil. 2020 Sep;42(18):2542-2552. doi: 10.1080/09638288.2019.1573932. Epub 2019 Apr 11. PMID: 30973765.

129. Wu, C. L., Lin, J. D., Hu, J., Yen, C. F., Yen, C. T., Chou, Y. L., et al. (2010). The effectiveness of healthy physical fitness programs on people with intellectual disabilities living in a disability institution: Six-month short term effect. Research in Developmental Disabilities, 31(3), 713–717. http://dx.doi.org/10.1016/ j.ridd.2010.01.013

130. Wuang, Y.-P., Wang, C.-C., Huang, M.-H., & Su, C.-Y. (2010). The effectiveness of simulated developmental horse-riding program in children with autism. Adapted Physical Activity Quarterly, 27(2), 113. https://doi.org/10.1123/apaq.27.2.11

131. Yalon-Chamovitz, S., & Weiss, P. T. (2008). Virtual reality as a leisure activity for young adults with physical and intellectual disabilities. Research in Developmental Disabilities, 29(3), 273–287. https://doi.org/10.1016/j.ridd.2007.05.004

132. Yuksel MF, Cengiz A, Zorba E, et al. Effects of badminton training on physical parameters of players. Anthropology 2015;21:542–7.

133. Yung PSH, Chan RHK, Wong FCY, et al. Epidemiology of injuries in Hong Kong elite badminton athletes. Res Sports Med 2007;15:133–46.

134. Zeng, N.; Pope, Z.; Lee, J.E.; Gao, Z. A systematic review of active video games on rehabilitative outcomes among older patients. J. Sport Health Sci. 2017, 6, 33–43.