Motor Skills and Level of Physical Activity in Young Children with Autism Spectrum Disorder

by

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This dissertation is dedicated to my husband, Michael James Farrell. Without your support over the past four years, this would not have been possible, thank you. I love you and can't wait for the next chapter in our lives together.

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List of Abbreviations and Acronyms

Actigprah GT3X+ - A small (4.6cm X 3.3cm X 1.5cm) and lightweight (19 grams) triaxial accelerometer (measuring activity in 3 planes), (Pensacola, FL).

APARQ – Australian Physical Activity Recall Questionnaire (APARQ), (Booth, Okely, Denney-Wilson et al .2006), is a questionnaire administered to adolescents which measures type of activity in both organized (i.e.: involves organized training/practice and organized competition) and non organized domains (i.e.: cycling or walking for transport or recreation, skate boarding, ball games with friends). Information regarding frequency, duration and context of participation is recalled during a typical week.

ASD (DSM V): Autism Spectrum Disorder (ASD), within the Diagnostic and Statistical Manual, Version Five (DSM V), is defined as a neurobiological disorder characterized by social communication deficits as well as restricted repetitive behaviors (American Psychological Association, 2013).

ASD (DSM IV): Autism Spectrum Disorder (ASD), within the Diagnostic and Statistical Manual, Version Four (DSM IV), is defined as a group of developmental disabilities characterized by the presence of abnormal or impaired development in social interaction, communication and restricted repetitive behavior (American Psychological Association, 2000).

AutR: Autism Spectrum Disorder with regression (symptoms persist and worsen over time).

AutNR: Autism Spectrum Disorder with no regression (symptoms remain relatively consistent over time).

ABA – Applied Behavioral Analysis (ABA) is one of the most widely used and accepted forms of treatment for individuals with Autism Spectrum Disorders (ASD). Although it is primarily researched and implemented in young children, it can be used across the lifespan. The ABA approach is both child and instructor (or parent) directed. In this treatment, many opportunities throughout the day (planned and natural) are used to provide opportunities to refine and acquire skills. Reinforcement is provided in abundance when behavior is deemed productive, no reinforcement is provided when behaviors are unrelated to learning outcome. Measurement of progress is ongoing, and reinforcement is gradually faded as progress continues. This type of approach can be used to target skills across a broad range of domains (Leaf & McEachin, 1999).

ADOS: Autism Diagnostic Observation Schedule (ADOS) (Lord, Rutter, DiLavore & Risi, 2002), consists of a semi-structured, standardized assessment that measures symptoms of Autism Spectrum Disorder (ASD) through a series of prompts designed to elicit a sample of communication, social interaction, and play, or imagination and is appropriate for young children through adults.

ADOS-2: Autism Diagnostic Observation Schedule, Version 2 (ADOS-2) (Lord, DiLavore & Gotham, 2012), consists of a semi-structured, standardized assessment that measures symptoms of Autism Spectrum Disorder (ASD) through a series of prompts designed to elicit a sample of communication, social interaction, and play, or imagination and is appropriate for toddlers (12 months of age) through adults.

ADI-R - Autism Diagnostic Instrument-Revised (ADI-R) (Lord, Rutter & Couteur, 1994), is a standardized parental interview for children and adults who have been referred for evaluation of Autism Spectrum Disorder (ASD), it provides categorical results in 3 different domains including language/communication, reciprocal social interactions and repetitive behaviors/interests.

AIMS: Alberta Infant Motor Scale (AIMS) (Piper, Pinnell, Darrah, Maguire & Byrne, 1992) is an observational assessment scale which measures the maturation in gross motor skills from birth through walking independently. Motor performance is characterized into 3 domains, weight-bearing, posture and antigravity movements.

BDI-2: Battelle Developmental Inventory -2 (BDI – 2) (Newborg, Stock, Wnek, Guidubaldi & Svinicki, 1984) is a standardized developmental assessment for children birth to 7 years. It evaluates early developmental milestones and consists of five domains, including; personal social, adaptive, communication, cognition and a motor domain.

CPRT: Classroom Pivotal Response Teaching (CPRT) (Stahmer, Suhreinrich, Reed, Schreibman, Bolduc, 2012) is a naturalistic behavioral intervention supported by scientific literature and has been developed for use in the classroom environment. CPRT has been adapted from Pivotal Response Training (PRT).

DSM IV: Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM IV).

DSM V: Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM V).

DD: Developmental disability

Early On: Offers early intervention services for young children and their families in Michigan with a developmental delay(s) and/or disabilities

I CAN – The I CAN program (Wessel, 1976) has been validated by the National Diffusion Network, U.S. Department of Education, it is a curriculum based assessment used to assess gross motor skills (i.e.: continuous bounce, kick, underhand roll, overhand throw, vertical jump and slide) for children with developmental delays. Information gathered from this assessment can be used for both instruction and planning of gross motor goals.

Get Skilled Get Active – This resource was created for teachers and professionals alike who were interested in building a program focused on specific movement skills. (New South Whales, Department of Education, 2000). The program focuses on twelve skills were recommended that children need acquire to be successful in motor programing from kindergarten through grade 6.

LD - Learning disabled

MSEL - Mullen Scale of Early Learning (MSEL) (Mullen, 1995), is an early learning standardized cognitive for children birth through 68 months. The *MSEL* consists of 4 cognitive scales including non verbal problem solving (visual discrimination and visual memory), fine motor (unilateral and bilateral manipulation as well as writing readiness), receptive language (comprehension and auditory memory) and expressive language (speaking ability and language formation, including verbalization of concepts). There is an additional subscale which measures gross motor skills but it is not represented in their overall cognitive score. Additionally, this subscale is only administered for children birth to 33 months of age.

NSP- National Standards Project (NSP) (National Autism Center, 2009), provides recommendations for education and behavioral interventions for individuals' with autism birth to twenty-two years of age.

NRC – National Research Council (NRC) (*National Research Council, Educating children with autism; Report of the committee on educational interventions in children with autism*, 2001), provides characteristics of effective intervention for children with autism birth to 8 years of age.

PA: Physical activity, defined by 5 categories including, SPA – Sedentary physical activity, LPA – Light physical activity, MPA – Moderate physical activity, MVPA – Moderate to vigorous physical activity, VPA – vigorous physical activity

PDD-NOS: Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS), a previously recognized subtype of Autism Spectrum Disorder (ASD), under the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM IV), characterized when there are "severe and pervasive impairments in the development of reciprocal social interaction associated with impairment in either verbal or nonverbal communication skills or with the presence of stereotyped behavior, interests, and activities, but criteria are not met for a other disorders…"

PDMS-2: Peabody Developmental Motor Scales, Version 2 (PDMS-2) (Folio & Fewell, 2000) is a standardized assessment developed to measure the motor skills for children birth through 71 months of age. The *PDMS-2* is comprised of 6 subtests including a reflex subtest, administered only to children < 24 months of age. The remaining 5 subtests are divided into gross motor, stationary (sustain control over body), locomotion (movement from one location to another), object manipulation (throw, catch and kick balls), and fine motor, grasping (ability to use hands), and visual-motor integration (use of visual perceptual skills while performing a eye-hand task).

PECS - Picture Exchange Communication System (PECS), is a form of augmentative and alternative communication which uses picture symbols as a method of communication. The use of PECS has been research extensively in children with Autism Spectrum Disorder (ASD), and has been noted as an emerging treatment by the National Standards Report (2009).

POPE - Playground Observation of Peer Engagement (POPE) (Frankel, Clarissa, Chang & Sugar, 2011) is a behavioral coding system includes 6 interactive states; solitary (participant plays alone with no peers within 3 feet), proximity (participant plays alone within 3 feet of peer not engaged in the same activity), onlooker (participant has an awareness of another child who is more than 3 feet away and not engaged in a similar activity), parallel (participant and peer engaged in similar activity but no engagement), parallel aware (participant and a peer are engaged in a same activity and both aware of each other), joint engagement (participant and peer are engaged in mutual social behavior) and games with rules (participant engages in a game or sport with rules)

PRT – Pivotal Response Treatment (or Teaching) (PRT) is a behavioral treatment for autism originally derived from applied behavior analysis (ABA). It is a treatment primarily used for preschool and elementary aged children, where the delivery of PRT occurs in a play based capacity. It is the goal of PRT to focus on ‘pivotal’ areas of development including motivation, response to multiple cues, self management and initiation of interactions. A key strategy in the PRT approach is motivation. By delivering reinforcements in a child’s natural environment, it has been shown that broad ameliorate in other developmental domains are produced including; social and communication skills, and overall behavior (Koegel, R. L., & Koegel, L. K, 2006).

TD: Typically developing

TEACCH: Treatment and Education of Autistic and Related Communication Handicapped Children (TEACCH) (Mesibov, Shea and Schopler 2004), is an intervention approach which promotes independence through the use of ‘structured teaching’, where the environment is constructed in an approach which is individualized, replete with visual supports.

TGMD-2 – Test of Gross Motor Development, Version 2 (TGMD-2) (Ulrich, 2000), is a standardized motor assessment appropriate for children aged 3 through ten years of age. The assessment consists of locomotor skills (run, gallop, leap, slide, hop, and jump) and object control skills (dribble, underhand roll, throw, catch, strike, kick).

VABS-2: Vineland Adaptive Behavioral Scales, Version 2, (VABS-2) (Sparrow, Cicchetti & Balla, 2005) is a standardized parent report measure of overall adaptive behavior for children birth through eighteen years of age. In addition to an overall composite score, domain scores can be determined for communication, daily living skills, socialization. Embedded within the socialization domain are gross and fine motor skills.

ABSTRACT

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Chair: Dale A. Ulrich

The research to date examining the motor skills in middle school and high school aged children with Autism Spectrum Disorder (ASD) suggests that significant motor delays are evident when comparisons are made to typically developing peers or normative data. Furthermore, the physical activity (PA) levels in adolescents with ASD have been shown to decrease with age. However, little is known regarding the motor skills or levels of physical activity in young children with ASD.

The purpose of this dissertation is to first determine a baseline measurement of motor skills and level of PA that characterizes young children with ASD. Knowledge from this research will help to define parameters for a motor skill intervention targeting young children with ASD.

Thirty-four children with ASD aged 2 to 5 participated in the first aim of this dissertation. The majority of study participants were found to be in the below average or poorer ranges based on normative data on a standardized motor assessment. In order to compare levels of PA, nineteen typically developing children were compared to the ASD group. Children with ASD were found to accumulate more mean minutes per day in moderate to vigorous PA, with both groups meeting current recommendations of sixty minutes of daily moderate to vigorous PA.

The secondary aim of the dissertation was to measure changes to both motor skills and levels of PA following an 8 week long motor skill intervention delivered to young children with ASD. Strategies from Classroom Pivotal Response Teaching (CPRT) were implemented as the framework for instruction. Nineteen participants' aged 4 – 6 participated in this study. Findings revealed that participants in the experimental group significantly improved their overall gross motor skills including both locomotor and object control skills. However, their levels of PA did not improve following the intervention.

Results from this intervention may be used to inform policy makers to include motor skill programming as part of the comprehensive early intervention services delivered to young children with ASD.

Chapter 1

The gross and fine motor skills in young children with Autism Spectrum Disorder

The prevalence of autism spectrum disorders (ASD) has risen dramatically over the past decade. In fact, ASD is now the highest among the developmental disabilities in the United States, with recent statistics estimating that 1 in every 68 children is diagnosed with the disorder(Center for Disease Control and Prevention, 2014). According to the Diagnostic and Statistical Manual V, ASD is a neurobiological disorder characterized by social communication deficits as well as restricted repetitive behaviors (American Psychological Association, 2013). The majority of autism research to date has focused on identifying core deficits in the social and communication domain (Flanagan, Landa, Bhat, & Bauman, 2012) as well as identifying and intervening on problem stereotypical behaviors (i.e.: hand flapping, body rocking) (Vismara & Rogers, 2010). This is despite recent evidence that suggests the motor domain may be among the first areas of development in children with ASD to demonstrate delays.

Qualitative differences in early movement behavior may be among the first indicators of ASD, as researchers have found that differences can be evident in infants as early as 3 to 6 months of age. In retrospective video of infants who were later diagnosed with autism (6 to 12 months of age), asymmetry was evident across several early movement skill behaviors including their lying posture and pattern of crawling (Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998). These findings can be supported by parental report of early movement milestones on a developmental inventory. Retrospective parental reports revealed that children with ASD (mean < 4 years) were significantly delayed when compared to their age matched typically developing peers (Ornitz, Guthrie, & Farley, 1977). Early movement milestones including, holding head erect while in the upright position, sitting up without support, moving around on hands and knees, pulling up without support and walking without support were significantly behind their age matched peers (Ornitz, et al., 1977). Next, a prospective study that measured infants at high risk for autism between 6 and 36 months of age found that head lag during a pull-to-sit task was significantly associated with autism spectrum disorders at 36 months of age (Flanagan, et al., 2012). Similar findings were revealed when the gross motor development in a cohort of infants at high and low risk for ASD was assessed at 3 and 6 months of age using the *Alberta Infant Motor Scale* (AIMS) (Bhat, Galloway, & Landa, 2012; Piper, Pinnell, Darrah, Maguire, & Byrne, 1992) significantly greater number of infants in the high risk group demonstrated delays in postural control at 3 and 6 months of age than the low risk group (Bhat, et al., 2012). Collectively, these findings are critical as they demonstrate that movement impairments are present as early as 3 to 6 months of age in infants at high risk for autism or who are later diagnosed with ASD (Bhat, et al., 2012; Flanagan, et al., 2012; Ornitz, et al., 1977; Teitelbaum, et al., 1998).

Comparison to typically developing peers and longitudinal research within the ASD population will enable researchers to determine the rate of development which characterizes this population. Group differences in early movement milestones were examined using home videos in two groups of children with ASD, those with ASD with regression (AutR) (mean age= 11.28) and ASD with no regression (AutNR) (mean age=12.68). In order to make inferences using a cross sectional design, these groups were age matched with either a developmental disability (DD) (mean age=12.28) or a typical developing group (TD) (mean age=9.95) (Ozonoff, et al., 2008). When compared to the DD and TD group, children in either the AutNR or AutR group demonstrated delays in the acquisition of several early movement milestones including: walking, sitting, and both prone and supine positions (Ozonoff, et al., 2008). Additionally, the period in development between one and two years of life was found to reflect the onset of the regression process in some children with ASD (Ozonoff, et al., 2008). In a longitudinal study conducted by Landa and Garrett-Mayer (2006), a group of infants and young children were assessed at 6, 14, and 24 months using the *Mullen Scale of Early Learning* (MSEL) (Mullen, 1995). Based on assessments and clinical judgment at 24 months, participants were categorized into one of three groups: unaffected, learning disabled (LD) or ASD. No significant differences were found in either the gross of fine motor scales when the ASD group was compared to the LD or unaffected groups at 6 months of age (Landa & Garrett-Mayer, 2006). However, when the ASD group was compared to the unaffected group at 14 months, significant differences were found in both their fine and gross motor skills. Furthermore, these differences remained significant between the ASD and unaffected groups at 24 months (Landa & Garrett-Mayer, 2006) suggesting the ASD group does not catch up in early motor development. Therefore, the period between 14 and 24 months appears to be a 'vulnerable period' where children with ASD demonstrate the greatest developmental delays and reduced trajectory compared to the unaffected and LD group (Landa & Garrett-Mayer, 2006).

The previous studies which note the slowing of development when comparing infants and toddlers with ASD to comparison groups are important to consider as this will enable researchers to determine if a trajectory of motor development characterizes this population. Developmental trajectories in infants at high risk for autism, aged 6 to 36 months of age were assessed with the *MSEL* (Landa, Gross, Stuart, & Bauman, 2012). At 6 months of age, performance on early ASD indicators was similar but later diverged into four different patterns of developmental trajectories. Two of the trajectories were characterized by early motor delays when compared to normative developmental outcomes. Revealing in one trajectory that early fine motor delays are present as early as 6 months of age, with normative means falling below average in their gross and fine motor skills at 30 and 36 months of age respectively (Landa, et al., 2012). The second trajectory was characterized by a developmental slowing between 6 and 36 months as children continued to depart from developmental outcomes with pervasive delays including significant delays in fine motor development (Landa, et al., 2012). These findings are further supported by Lloyd and colleagues (2011) who reported that there appears to be a period throughout development where delays in toddlers with ASD become more pronounced. A large cross sectional analysis was conducted using the *MSEL* for toddlers and young children with ASD. The most prominent finding was that delays in motor skills increase with age, suggesting that relative to normative data, children continue to fall below what would be expected given their chronological age. In fact, by 31 to 36 months of age, children with ASD demonstrated a 9.18 month gross motor delay in what would have been anticipated for their chronological age. This can be compared to findings at 12 to 24 months where there was a 3.5 month gross motor delay (Lloyd, MacDonald, & Lord, 2011). Similar trends were found with fine motor skills, where the most significant differences were found at 31 to 36 months of age where children with ASD were 12.77 months behind what would be expected given their chronological age (Lloyd, et al., 2011). To determine if children with ASD display a change in motor performance throughout development, researchers measured a subset of 58 children longitudinally at two time points. There were significantly larger delays in gross and fine motor skills at 36 months compared to 12 months (Lloyd, et al., 2011). The results from this study underscore the importance of including movement skills to early screening of ASD, and similar to findings by Landa and Garrett-Mayer

(2006) and Landa et al. (2012) which suggest there may be a sensitive period where early intervention would be most beneficial.

The patterns of locomotion in children with ASD has recently emerged as a field of study which warrants attention. In a study conducted by Lloyd and colleagues (2011), it was found that based upon parental report on the *Autism Diagnostic Instrument-Revised* (ADI-R) (Lord, Rutter, & Couteur, 1994), young children with ASD fell within the normal range of independent walking, reaching this milestone at 13.73 months (compared to the average 12 months) (Payne & Isaacs, 2007). Similarly, based on retrospective parental reports, 47.2% of children with ASD were reported to walk independently at the same age that 97.4% of children in the typically developing group were walking without support (Ornitz, et al., 1977). Despite the similarity in findings revealing that the acquisition of independent walking is achieved within normal ranges, retrospective video analyses suggests qualitative differences in walking may characterize children with ASD. The walking gait in three groups of toddlers (mean age = 20.6 months) was analyzed using the Walking Observation Scale after 6 months of experience in independent walking (Esposito & Venuti, 2008). Qualitative differences were found when children with ASD were compared to both the typically developing, and cognitively impaired groups. The group of children with ASD demonstrated immature patterns of early walking (Esposito & Venuti, 2008). These differences were precipitated by a flat footed pattern, as opposed to a heel toe strike, little activation of the lower leg, impacting step length, and lastly, extraneous arm movement affecting the transfer of weight (Esposito & Venuti, 2008). Collectively these results suggest that once the skill of independent walking has been achieved among children with ASD, there are qualitative differences evident early in development (Esposito & Venuti, 2008).

Research examining the early movement milestones in children with ASD is pivotal and lends support for the inclusion of movement skills in the evaluation and programming of ASD. A large sample of toddlers, 17 through 36 months of age were grouped by disability according to DSM IV criteria, including, autism, Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS) (American Psychiatric Association, 2000)and atypical development (i.e.: those not meeting ASD criteria). Children were assessed using the *Battelle Developmental Inventory -2* (BDI – 2) (Matson, Mahan, Fodstad, Hess, & Neal, 2010; Newborg, Stock, Wnek, Guidubaldi, & Svinicki, 1984). The *BDI-2 evaluates* early developmental milestones and consists of five developmental areas, including a motor domain. A greater percentage of children with autism exhibited gross and fine motor impairments than in children with PDD-NOS (APA, 2004) or atypical development (Matson, et al., 2010). The atypical development group had significantly greater gross and fine motor skills than the toddlers with autism but not children with PDD-NOS (Matson, et al., 2010). Similar findings were revealed in a study that measured the motor skills of young children (aged 21-41 months) using the Peabody Developmental Motor Scales -2 (*PDMS-2*), a standardized motor assessment (Folio & Fewell, 2000; Jasmin, et al., 2009). Children were represented in three groups, including ASD, developmental delay and a typically developing group. Children with ASD had significantly poorer motor quotients when compared to typically developing children in the gross, fine and total (reflecting gross and fine quotients) quotients. These findings are further supported when young children aged 3 to 4 were administered the *PMDS-2* (Jasmin, et al., 2009). Mean motor quotients revealed that children with ASD demonstrated significant delays in both the gross and fine motor quotients when results were compared to normative data (Jasmin, et al., 2009). Therefore, the motor skills of young children with ASD warrant greater attention, particularly into the nature and scope of delays and how they may be characterized in different age groups.

The majority of research examining the early movement behavior of children at risk for, or with ASD has focused on retrospective parental report (Ornitz, et al., 1977; Ozonoff, et al., 2008), analysis of home videos (Chawarska, et al., 2007; Teitelbaum, et al., 1998) or early locomotion behavior (Esposito & Venuti, 2008; Ornitz, et al., 1977). Next, many studies to date have focused on the qualitative aspects of motor impairments where one single subtest or individual skill is examined within an assessment and therefore may influence overall results (Flanagan, et al., 2012; Landa & Garrett-Mayer, 2006; Landa, et al., 2012). Furthermore, only one study confirmed a diagnosis of ASD (Lloyd, et al., 2011) many times relying solely on parental reports. Based on recommendations from Provost and colleagues (2007), in order to comprehensively describe the motor abilities in young children with ASD, there is a critical need to assess the performance of individual skills within subtests on standardized motor assessments. Therefore, the current study serves to address some of the gaps in the literature by (1) examining the motor skills of young children with ASD, using a comprehensive, standardized motor assessment and (2) employing an objective diagnostic measure of ASD. As such, the primary aim of this study is to describe and compare the subscale performance in gross motor (stationary, locomotion, and object manipulation skills) and fine motor (grasping and visual motor integration) skills as measured by the *PDMS–2* in a sample of young children (aged 2 – 5) with ASD. It is hypothesized that the younger children will achieve significantly higher motor outcomes than the older children represented in this study. The secondary aim of this study is to examine the relationship between age and motor delay, controlling for nonverbal problem solving (measure of IQ) and severity scores in a sample of young children (aged 2 – 5) with

ASD. It is hypothesized that age will be a significant predictor of motor outcomes when controlling for either a measure of IQ or severity. This research will expand the current understanding of early motor skills among young children with ASD by describing performance skills across multiple subscales in both the gross and fine motor domain. Furthermore, results can be used as a baseline measure of gross and fine motor skills in children with ASD early in development. Recommendations for an evidence based motor skill intervention for young children with ASD will also be discussed.

METHOD

Participants

Recruitment occurred through local Early On programs in South East Michigan which provide services and support to children with developmental delays. To be included in this study, participants met ASD criteria based on the Autism Diagnostic Observation Schedule (ADOS) (Lord, Rutter, DiLavore, & Risi, 1999) were between 2 and 5 years of age, were able to participant in the motor skills assessment and lived within 50 miles of the testing center. The age range for this study was chosen since early intervention typically begins shortly after ASD diagnoses, which are reliable and stable beginning at 2 years of age (Cox, et al., 1999; Stone, et al., 1999). The upper age limit in this study was set in order to assist physical therapists, occupational therapists and adapted physical education teachers design and implement a movement skill program which addresses their delays upon entry into preschool or kindergarten.

Thirty-eight participants ranged in age from 24 to 68 months (mean age 47.42 ± 12.81). The sample was split into two groups (those who were receiving early on services and not yet enrolled in school and those enrolled in school and receiving early intervention services). The first group represented those aged 24 to 48 months (n=20; mean age 37.10 ± 7.17), and the second group included those who were 49 to 68 months (n=18; mean age 58.89 ± 5.95). The Mullen Scales of Early Learning (MSEL) (Mullen, 1995) was administered as the measure of IQ, however due to the language deficits that characterize this population, only one subtest (non verbal problem solving) was used as the predictor of IQ (see description of psychometric instruments below). The younger group achieved an age equivalent mean score of 23.25±15.39 (range 2-69); while the older group achieved a mean score of 36.65±19.47 (range 16-70) representing descriptive categories which range from very low to above average in both groups. The Vineland Adaptive Behavioral Scales -2 (VABS) (Sparrow, Cicchetti, & Balla, 2005) was administered as a measure of parental report of gross and fine motor skills. The younger group achieved a mean age equivalent score for fine motor skills of 29.00±9.46 (range 8-50) while the older group achieved a mean age equivalent score of 40.69±11.77 (range 11-70), descriptive categories ranging in both groups from below average to above average. The younger group achieved an age equivalent mean score in gross motor skills of 28.71±9.19 (range 16-55) and a mean age equivalent in the older group of 43.92±9.54 (range 22-70) with descriptive categories ranging in both groups from below average to superior. The calibrated severity scores derived from their overall *ADOS* raw score sum, was 7.1±2.2 (range 4-10) in the younger group and 6.9±1.2 (range 4-10) in the older group, with scores in both groups representing a diagnoses of Autism or Autism Spectrum Disorder.

Measures

All study participants were administered *MSEL*(Mullen, 1995)(Mullen, 1995)(Mullen, 1995)(Mullen, 1995)(Mullen, 1995)(Mullen, 1995) which is a standardized measure of cognitive functioning appropriate for children birth through 68 months. Evidence of the validity and reliability for children in this age range is reported in the *MSEL* manual (Mullen, 1995).The

MSEL consists of 4 cognitive scales including non verbal problem solving (visual discrimination and visual memory), fine motor (unilateral and bilateral manipulation as well as writing readiness), receptive language (comprehension and auditory memory) and expressive language (speaking ability and language formation, including verbalization of concepts). Although there is an additional subscale which measures gross motor skills it was not administered in this study due in part because the norms are only available for children birth to 33 months of age. First, the raw scores on the expressive language subtests were converted to age equivalents when possible and were used as a measure of language assisting researchers in selecting the most appropriate *ADOS* (Lord, et al., 1999)(Lord, et al., 1999)(Lord, et al., 1999)(Lord, et al., 1999)(Lord, et al., 1999)(Lord, et al., 1999) module. Next, non-verbal problem solving has been previously reported as a better representation of 'IQ' for young children with ASD (Luyster & Lord, 2009), therefore this scale was used in our analysis.

The *PDMS-2* is a standardized assessment developed to measure motor skills (Folio & Fewell, 2000). Evidence of the validity and reliability for children birth through 71 months of age is reported in the *PDMS-2* manual (Folio & Fewell, 2000). The *PDMS-2* is comprised of 6 subtests stationary (sustain control over body), locomotion (movement from one location to another), object manipulation (throw, catch and kick balls), grasping (ability to use hands), and visual-motor integration (use of visual perceptual skills while performing a eye-hand task) (Folio & Fewell, 2000). The reflex subtest was not used in this study because all of the children in this study were > 24 months of age. For the purpose of this study, the quotients, subtest standard score categories, and age equivalents were used in the analyses. The subtest standard scores were calculated based on raw totals in each sub domain, and can be classified into one of seven categories which range from 1 (very poor) to 7 (very superior). Motor quotients were computed by summing the subtest standard scores which comprise either the gross motor, fine motor or total motor skills, which are then converted into a quotient. The Gross Motor Quotient (GMQ) includes stationary, locomotion and object manipulation subtests while the Fine Motor Quotient (FMQ) includes grasping and visual-motor integration. The Total Motor Quotient (TMQ) combines the GMQ and FMQ. The age equivalents can be converted from the raw scores of each subtest. These age equivalents were used in this study as a way to confirm and compare their motor scores on the standardized *PDMS-2* assessment relative to parent report measures of motor skills on the *VABS.* The *PDMS-2* was administered and scored by a certified adapted physical education teacher with extensive experience in conducting motor assessments in young children with developmental disabilities. A secondary researcher live coded every administration of the *PDMS-2*. Percent agreement on assessments ranged from .92 - .1.00.

The *VABS-2* is a standardized parent report measure of overall adaptive behavior. Evidence of the validity and reliability for children birth through eighteen years of age is reported in the *VABS-2* manual (Sparrow, et al., 2005). In addition to an overall composite score, domain scores can be determined for communication, daily living skills, socialization. Embedded within the socialization domain are gross and fine motor skills, therefore this provided an additional measure of these skills. The *VABS-2* has correlated with fine and gross motor domains from the *PDMS-2* (Jasmin, et al., 2009) and *MSE*L (Lloyd, et al., 2011) and were used in this study as a way to provide further support for our observational findings on the *PDMS-2.*

Diagnostic instruments

The *ADOS* (Lord, et al., 1999) is a semi-structured, standardized assessment which measures symptoms of ASD through a series of prompts designed to elicit a sample of communication, social interaction, and play, or imagination. Evidence of the validity and reliability for young children through adults is reported in the *ADOS* manual (Lord, et al., 1999). The *ADOS* consists of 4 modules', a module is chosen based on developmental and expressive language levels, and independent from age or verbal IQ. This assessment quantifies the severity of ASD. Study participants received either a Module 1, for children who use little or no phase speech or a Module 2, for children who use phrase speech but are not yet fluent. Calibrated severity scores (CSS) were generated by raw scores on revised *ADOS* algorithms. Scores from the CSS range from one through ten, where zero to three does not meet ASD thresholds, four to five meets ASD classification and six to ten represent an Autism classification (Gotham, Pickles, & Lord, 2009). The *ADOS'* were conducted by two graduate level students who were trained and reliable to conduct the assessment for research purposes. Prior to the commencement of the study, three consecutive administrations exceeding 80% reliability was achieved. Furthermore, all *ADOS'* were video recorded, and afforded researchers with an opportunity to assess maintenance of reliability throughout the duration of the study, with consensus coding following every 5th administration (inter-rater reliability >80%).

Procedures

All study procedures were approved by the Institutional Review Board. Written informed consent was obtained from parents prior to their child's participation in the study. Each child who qualified to participate in this study had been previously diagnosed with ASD by a clinician or school psychologist according to DSM-IV (APA, 2000). All assessments were conducted over one day in a quiet and private laboratory with minimal distractions. First, the *MSEL* was administered to all study participants in order to obtain a measure of cognitive functioning. Next, the *ADOS'* were conducted to lend an additional layer of confidence to their diagnostic information. To measure gross and fine motor skills, the *PMDS-2* was administered to all study participants. Lastly, the *VABS* was administered over the phone by a trained researcher to provide support for the subjective findings on the *PDMS-2*.

Statistical Procedures

First, descriptive statistics were computed to describe demographic information. An alpha level of 0.05 was used to indicate statistical significance, and all analyses were performed using the SPSS software (Version 20).

The primary aim of this study was to describe and compare each groups subscale performance in gross motor (stationary, locomotion, and object manipulation skills) and fine motor (grasping and visual motor integration) skills as measured on the *PDMS–2*. Descriptive statistics were computed to describe central tendencies and variance in each subtest (ranging from 1 to 7) for each age group and the overall sample. In order to compare whether the two groups differed significantly from one another based on mean classifications from the subtests and quotients, two-sample t-tests were performed, and effect sizes were computed to describe the magnitudes of these differences.

For the secondary aim, the relationship between *PDMS-2* motor quotients and age was examined by regressing the quotient scores on the age group variable and calibrated severity score, essentially controlling for either calibrated severity scores or age when comparing the two groups. The relationship between age and motor delay when controlling for nonverbal problem solving was examined. First, a regression analysis was performed to examine whether or not the mean motor quotient scores differed by age group while controlling for nonverbal problem solving (*MSEL*).

Lastly, in order to support observations from the objectively measured *PDMS-2* scores, pearson product moment correlation analyses were performed to assess the linear associations between the gross and fine motor subtests and the *PDMS-2* and *VABS-2* scores, respectively.

RESULTS

Descriptive statistics are presented in Table 1.1. Mean subtest standard scores were computed for both groups in each of the five *PDMS-2* subtests, where scores ranged from 1 (very poor) to 7 (very superior) performance (classification scores of 6 and 7 not represented in tables since no one achieved these scores in this study). As seen in Table 1.2, on the *PDMS-2* stationary subtest, collectively, 71.1% of the study sample fell into the below average or lower classification (≤ 3). In the younger age group, 70.0% of the children were in the below average or lower classification, and 44.4% of the older age group scored in the poor or very poor classifications. In the object manipulation subtest 68.4% of all study participants scored in the below average or lower classification, with 55% of children in the younger group and 39.0% of children in the older group scoring in the poor or very poor classifications respectively. Similarly on the *PDMS-2* locomotion subtest, 76.3% of the entire sample of participants received a classification of below average or lower. When examining the two age groups, 45.0% of the participants in the younger group were classified in the poor or very poor classifications, while 44.4% of children in the older group fell into either the poor or very poor classification. Taken together, the gross motor subtest standard score classifications reveal that the majority of children represented in the total sample (> 68%) have classifications below average or lower.

To compare the differences between the younger and older group based on mean classifications in the gross motor subtests and quotient, two sample t-tests were performed (see Table 1.1). There were no significant differences between the younger and older group in the stationary [t(1,36)=1.17, *p*=0.25], locomotion [t(1,36)=-0.63, *p*=0.56] or object manipulation [t(1,36) = - 1.03, *p*=0.31.] subtest classifications. Similarly, there were not significant differences between the younger and older group on the gross quotient [t(1,36)=-0.43,*p*=0.85].

Next, despite 68.4% of total study participants being classified as below average or lower in the grasping subtest standard score, 31.6% were classified as average. Further results revealed that 40% of the younger group was classified as average compared to 22.2% of children in the older group who received a classification of average. Lastly results for the visual motor subtest standard score show 71.1% of the study participants were classified as below average or poorer, with 65.0% of the youngest group in the poor or very poor classification and 55.5% of the older group in the poor or very poor classifications. When considering overall fine motor classification results, although the grasping subtest revealed the highest percentage of children within the average classification, the results paralleled those in the gross motor results, with the majority of study participants (> 68%) classified in the below average or poorer categories.

To compare the differences between the younger and older group based on mean classifications in the fine motor subtests and quotient, two sample t-tests were performed (see Table 1.1). There were no significant differences between the younger and older group in the grasping [t(1,36)=1.57, *p*=0.12] or visual motor [t(1,36)=-0.13,*p*=0.89]. Similarly, there were not significant differences between the younger and older group on the fine motor quotient [t(1,36)=0.37,*p*=0.70]. Finally, there were no significant differences between groups when examining the total motor quotient [t(1,36)=-0.03,*p*=0.79].

Table 1.3 presents results from the linear regression analysis examining the relationship of *PDMS-2* and age controlling for calibrated severity of ASD. Although significant differences were not found between age groups on the 3 motor quotients from the *PDMS-2,* there was a significant relationship between the calibrated severity scores and all 3 motor quotients for both age groups. For every 1 unit increase in the calibrated severity score, there is a 2.70 unit decrease in expected gross motor quotient [B = -2.70, *SE* = 1.24, $p < .05$]. Results for the fine motor quotient revealed a similar relationship, where for every 1 unit increase in the calibrated severity score, there is a 3.07 unit decrease in the expected fine motor quotient [B = -3.07, *SE* = 1.41, $p <.05$]. There was also a significant relationship between the total motor quotient and the calibrated severity score [B = - 3.10, *SE* = 1.30, $p < .05$]. For every 1 unit increase in their calibrated severity score, there is a 3.10 expected decrease in their total motor quotient.

Table 1.4 presents results from the linear regression analysis examining the relationships between the three quotients (gross, fine and total) and age group when controlling for nonverbal problem solving. There was a significant difference between age groups on the total motor quotient [$F(1, 34) = 6.30$, $p < .05$] and fine motor quotient [$F(1, 34) = 6.43$, $p < .05$] scores, but not on the gross motor quotient. The results reveal that when nonverbal problem solving is controlled for, the younger group achieved an adjusted mean total motor quotient score 8.90 units greater than the older group. Similarly, the younger group achieved an adjusted mean fine motor quotient score that is 10.54 units greater than the older group. Meaning that when controlling for non-verbal problem solving, age is a significant predictor of total and fine motor quotients.

Finally, when testing the validity of the *PDMS-2* gross motor subtests, these subtests were found to have a positive linear association with the *VABS*-2 gross motor subtest, revealing a significant and positive correlation with the stationary ($r = 0.70$, $p < .001$), locomotion ($r = 0.64$, $p < .001$) and object manipulation ($r = .65$, $p <.001$) subtests. Similarly, the *PDMS-2* fine motor subtests were significantly and positively correlated to the fine motor subtest, including grasping ($r = 0.55$, $p < .05$) and object manipulation ($r = 0 .67$, $p < .001$) tasks of the *VABS-2* fine motor subtest.

DISCUSSION

By using the *PDMS-2* to assess motor skills, we were able to describe and compare performance on individual sub domains. Based on the five *PDMS-2* sub domains, children with ASD in this study exhibited pervasive motor skill delays which are evidenced in both the gross and fine motor skills. Sixty-eight percent of the children in this study scored below average or lower in gross and fine motor subtest classification. These results are similar to findings from Provost and colleagues (2007) who revealed that 60% of young children with ASD met the requirements for early intervention service based on motor deficits alone without the consideration of any other ASD symptoms such as deficits in the social and communication domains.

Contrary to our hypothesis, that younger children would achieve higher motor outcomes than older children, the differences in mean classification scores found between the younger and older age groups in this study were not statistically significant. However, the results may suggest that despite an inherent increase in services for the older group upon entry into school, there doesn't appear to be a meaningful change in their motor skills. It should be assumed that the school aged children in this sample would be receiving more frequent services including adapted physical education, physical and occupation therapy and an increase in social opportunities which should result in additional opportunities for involvement in movement skill activities. Therefore, it can be suggested that the existing therapies and motor skill services which the older children in this sample were receiving did not adequately address their delays given the consistency of poor gross and fine classifications. These findings are important and should be taken into consideration when determining intervention and therapy options for young children with ASD.

In order to determine if there is a motor skill development trajectory specific to young children with ASD, longitudinal research is needed. Very few studies to date offer longitudinal data on motor skill development throughout early childhood. Longitudinal findings from Lloyd and colleagues (2011) revealed that when young children with ASD were measured at two time points, one year apart, children fell further behind their chronological age at the second time point; these findings were found in both gross and fine motor skills. Although the scope of the current study does not allow us to make such conclusions, it is interesting that when nonverbal problem solving is controlled for, the younger group achieved a significantly higher adjusted mean score in both the total and fine motor quotient when compared to the older group. Meaning that age is a significant predictor of motor outcomes. These results are intriguing and should lend support for additional research examining how the motor trajectory may change longitudinally while controlling for a measure of IQ independent of language deficits (e.g.: nonverbal problem solving). Longitudinal research will also allow researchers to examine if there is a cascading effect of motor delays throughout development. For example, determining if early motor delays in object manipulation (ball skills) impact future participation in an organized sport? Or, examining if fine motor delays result in a decrease in functional independence later in development? Taken together, longitudinal research will allow us to examine if the delays found in the motor domain early in development will eventually become meaningful deficits (Staples & Reid, 2010).

Next, it was hypothesized that age would be a significant predictor of motor outcomes when controlling for CSS, the findings from our study would support this hypothesis. When calibrated severity scores are controlled for, higher severity scores are related to poorer motor outcomes, on all three motor quotients and in both age groups. These results are critical given past research has demonstrated that more advanced motor skills have been shown to be related to a decrease in ASD severity as the child developments (Sutera, et al., 2007). Despite the relationship between motor skills and ASD severity, to our knowledge there are no intervention studies which target age appropriate motor skills as the primary aim in young children with ASD. Future motor behavior researchers should focus on creating interventions which implement evidence based practices to maximize important motor outcomes. This type of intervention has the potential to simultaneously enhance both motor skills and result in additional changes to developmental areas such as the communication (Bhat, et al., 2012) and social domains (MacDonald, Jaszewski, Esposito, & Ulrich, 2011).

Owing to the behavioral difficulties that can occasionally be encountered during the evaluations for children with ASD, a few modifications were made to the administration of assessments. For example, if the examiners felt that the child was off task or not aware (i.e.: lack of eye contact) during the demonstration of any of the skills, an additional demonstration was provided. Furthermore, frequent reinforcers (i.e.: stickers) were administered following the desired behavior. Finally, language was used that was developmentally appropriate for each child, for example, if a child was non-verbal, then along with the verbal instruction, the Picture Exchange Communication Schedule (PECS) (visual schedule represented in pictures) were used as an additional way to deliver instruction. There are a few limitations in this study. First, the examiners were not blind to the ASD diagnoses of the children. However, given the expertise and clinical experience of the researchers, this knowledge was not anticipated to alter any of the objective measurements. Lastly, the generalizability of this study is limited due to the cross sectional nature of this data

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Table 1.1 Descriptive data and baseline differences

	24-48(n=20) mean±SD (range)	49-68 (n=18) mean±SD (range)	*p*	ES
Gender	M=14, F=6	M=15, F=3	0.317	0.20
Race/ethnicity	C=13, AA=2, A=2, H=1, O=2	C=14, A=2, O=2	0.708	0.34
Chronological age at testing	37.10±7.17	58.89±5.95	<0.01*	0.86
Calibrated Severity Score	7.1±2.2 (4-10)	6.9±1.2 (4-10)	0.678	0.05
MSEL nonverbal age equivalent	23.25±15.39 (2-69)	36.65±19.47 (16-70)	0.251	0.36
VABS-2 Fine motor age equivalent	29.00±9.46 (8-50)	40.69±11.77 (11-70)	<0.01*	0.48
VABS-2 Gross motor age equivalent	28.71±9.19 (16-55)	43.92±9.54 (22-70)	<0.01*	0.63
PDMS-2 Stationary classification	3.10±0.97 (1-5)	2.72±1.02 (1-4)	0.253	0.18
PDMS-2 Object manip. classification	2.55±1.05 (1-5)	2.89±0.96 (1-4)	0.313	0.34
PDMS-2 Locomotion classification	2.60±1.23 (1-4)	2.83±1.04 (2-5)	0.563	0.10
PDMS-2 Grasping classification	2.70±1.26 (1-4)	2.06±1.26 (1-4)	0.121	0.24
PDMS-2 Visual motor classification	2.45±1.15 (1-4)	2.50±1.15 (1-4)	0.894	0.02
PDMS-2 Gross quotient	74.95±13.69 (49-97)	76.89±13.65 (43-94)	0.854	0.07
PDMS-2 Fine quotient	74.05±15.24 (46-99)	72.17±15.95 (46-100)	0.702	0.06
PDMS-2 Total motor quotient	72.10±14.65 (48-98)	72.28±14.34 (49-92)	0.798	0.01

M=Male; F=Female; C=Caucasian; AA=African American; A=Asian; I=American Indian; H=Hispanic or Latino; O=Other; MSEL=Mullen Scales of Early Learning; VABS-2=Vineland Adaptive Behavior Scales; PDMS-2=Peabody Developmental Motor Scales-2; ES= Effect size; *p*=Level of significance; *Indicates a significance ($p \leq 0.05$)

Table 1.2 Percentages of children in each age group with ASD scoring in specific *PDMS-2* classifications for subtests

	Very poor (1)	Poor (2)	Below Average (3)	Average (4)	Above Average (5)	Range
Stationary						
24-48 mo.(n=20)	10.0	5.0	55.0	25.0	5.0	1-5
49-68 mo. (n=18)	11.1	33.3	27.8	27.8	0.0	1-4
Locomotion						
24-48 mo.(n=20)	20.0	25.0	35.0	20.0	0.0	1-4
49-68 mo. (n=18)	0.0	44.4	27.8	22.2	5.6	2-5
Object Manip.						
24-48 mo.(n=20)	20.0	35.0	15.0	25.0	5.0	1-5
49-68 mo. (n=18)	11.1	27.8	27.8	33.3	0.0	1-4
Grasping						
24-48 mo.(n=20)	25.0	20.0	15.0	40.0	0.0	1-4
49-68 mo. (n=18)	50.0	16.7	11.1	22.2	0.0	1-4
Visual Motor.						
24-48 mo.(n=20)	20.0	45.0	5.0	30.0	0.0	1-4
49-68 mo. (n=18)	22.2	33.3	16.7	27.8	0.0	1-4

Table 1.3 Estimated linear regression models for *PDMS-2* Motor Quotients where age group and CSS are the predictor variables

Quotient	*B (SE)*	*t*	*p*
GMQ Intercept	96.54(9.51)	10.15	<.001*
24-48 mo	-0.12(4.31)	-0.03	0.977
49-64 mo	0		
CSS	-2.70(1.24)	-2.18	<.041*
FMQ Intercept	94.53(10.84)	8.72	<.001*
24-48 mo	3.95(4.91)	0.81	0.426
49-68 mo	0		
CSS	-3.07(1.41)	-2.18	<.042*
TMQ Intercept	94.81(9.98)	9.51	<.001*
24-48 mo	1.90(4.52)	0.42	0.676
49-64 mo	0		
CSS	-3.10(1.30)	-2.39	<.032*

SE=Standard error; TMQ=Total motor quotient; GMQ=Gross motor quotient; FMQ=Fine motor quotient; CSS=Calibrated severity score; *p*=Level of significance; * Indicates a significance ($p \leq 0.05$)

Table 1.4 Estimated linear regression models for *PDMS-2* Motor Quotients where age group and IQ are the predictor variables

Quotient	*B (SE)*	*t*	*p*
GMQ Intercept	56.79(4.38)	12.96	<.001*
24-48 mo	6.12(3.60)	1.70	0.098
49-64 mo	0		
IQ	0.52(0.10)	5.24	<.001*
FMQ Intercept	49.18(5.05)	9.73	<.001*
24-48 mo	10.54(4.16)	2.54	<.050*
49-68 mo	0		
IQ	0.62(0.11)	5.40	<.001*
TMQ Intercept	49.05 (4.31)	11.38	<.001*
24-48 mo	8.90 (3.55)	2.51	<.051*
49-64 mo	0		
IQ	0.61(0.10)	6.26	<.001*

SE=Standard Error; CSS=Calibrated severity score; TMQ=Total motor quotient; GMQ=Gross motor quotient; FMQ=Fine motor quotient; IQ=Mullen Scale of Early Learning, Non Verbal Problem Solving; *p*=Level of significance; *Indicates a significance ($p \leq 0.05$)

Chapter 2

The physical activity in young children with and without Autism Spectrum Disorder

There are currently 12.5 million children and adolescents who are obese in the United States (Center for Disease Control and Prevention, 2012). Most startlingly, however is that the prevalence of obesity is has tripled since 1980 (CDC, 2012). Therefore, it is imperative to identify and intervene on possible modifiable factors contributing to the obesity epidemic. Over the past decade there has been a significant decline in the physical activity (PA) levels in youth across the United States, as such, the levels of PA in children has recently surfaced as a health priority (Obama, 2010). Although there are no specific PA guidelines for children with disabilities, best practices recommend that preschool aged children participate in 60 minutes of structured and 60 minutes of unstructured PA every day (National Association for Sport and Physical Education, 2012). Furthermore, the World Health Organization (WHO) (2003) recommends that children and youth participate in a minimum of sixty minutes of moderate to vigorous PA every day. Recent findings reveal that both typically developing children as well as children with disabilities are falling below recommended guidelines (Kim, 2009; Tucker, 2008). Special populations were one population that was targeted in the Let's Move Campaign (2010), a national campaign to combat obesity, as an underrepresented and underserved community. Since Autism Spectrum Disorder (ASD) is the fastest growing developmental disability in the United States (CDC, 2012), there is a growing need for research examining and intervening on the factors contributing to the potential health disparities which characterizes this population.

According to the Diagnostic and Statistical Manual V, ASD is a neurobiological disorder characterized by social communication deficits as well as restricted repetitive behaviors (American Psychological Association, 2013). Since the PA patterns of children are established early in development it is imperative to examine the status of PA in young children with ASD. Next, the relationship between motor skills and levels of PA has been examined as a potential factor contributing to sedentary behavior in typically developing children (Barnett, Van Beurden, Morgan, Brooks, & Beard, 2009; Fisher et al., 2005; Williams et al., 2008; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006), despite these findings this relationship has been relatively underexplored in young children with ASD.

Data from the National Health and Nutrition Examination Survey (NHANES) reported that obesity rates for children with disabilities are significantly higher than in children without disabilities (CDC, 2010). Since increasing PA has become a national priority for special populations in the United States (Obama, 2010), it is critical that research can keep up with the demand for information and initiation of PA programming. The research to date examining the PA levels and patterns of youth with ASD is scarce and contradictory. In fact, there is research to date that suggests children with ASD are meeting PA guidelines as defined by the CDC (2008). In a large cross sectional study examining the objective PA patterns in youth with ASD, both the younger (aged 9-11) and the older (aged 12-18) group met the current requirements of sixty minutes of daily moderate to vigorous PA (MVPA) (MacDonald, Esposito, & Ulrich, 2011). However, authors caution interpretation, as there was an age-related decline in PA patterns, with participants in the older group spending a significant more amount of mean time per day in sedentary ($p \leq 0.001$) and a significant less amount of time in moderate to vigorous ($p < 0.05$) PA (MacDonald, et al., 2011). Similar findings were revealed when the objective measurement of PA patterns were compared in youth with ASD aged 10 – 19 were divided into 3 groups for cross sectional analysis, including an elementary school (ES) , middle school (MS) and a high school (HS) group (Pan & Frey, 2006). Significant differences between all three school levels and weekly and school day PA patterns were revealed. Results from total weekly PA revealed that children in ES were more active overall than adolescents in HS (+309.3 minutes) and spent a significant more amount of time in MVPA compared to those in HS (+92.9 minutes) or MS (+57.4 minutes) ($p < .001$) (Pan & Frey, 2006). Next, when selected periods of the school day were measured, youth in ES were found to be more active (+331.7 minutes) and spent more time in MVPA than both those in HS (24.8) and in MS (+17.3) groups ($p < .001$) (Pan & Frey, 2006). Collectively these findings are important as they demonstrate that elementary school aged children are more physically active than children in either middle school or high school, with significant differences found in MVPA (Pan & Frey, 2006). Furthermore, younger children with ASD are significantly more physical inactive when compared to older children (MacDonald, et al., 2011).

Despite previous reports of children with ASD meeting minimum guidelines for PA, there is research to support that both children with ASD and an age matched typically developing group are not meeting these guidelines. One such study measured the objective PA patterns in two groups of children ranging in age from 3 - 11, and included a group of children with ASD (mean age 6.6) as well as a typically developing group (mean age 6.7) (Bandini et al., 2012). After controlling for age and sex, the typically developing children accumulated a significant greater adjusted mean score for total activity counts in moderate activity during the weekday than in children with ASD ($p <.05$) (Bandini, et al., 2012). Not surprisingly the typically developing group also achieved a significantly higher amount of time spent in moderate activity during the weekdays than children with ASD (*p* < .05) (Bandini, et al., 2012). Most interesting however was that only 43% of typically developing children met the minimum requirement of 60 minutes of daily MVPA, as compared with just 23% of children with ASD (*p* < .06) (Bandini, et al., 2012). Measuring habitual PA (meaning daily/weekly PA) assists researchers in determining whether children are meeting minimal daily or cumulative thresholds for PA. However, it is also important to examine whether or not differences exist during opportunities of unstructured play (recess) or structured PA (physical education). In a study conducted by Pan (2008), the PA patterns of children with ASD and without disabilities aged 7 to 12 were measured. Overall findings revealed significant differences between both groups (*p* < .01) during recess time (Pan, 2008). Children with ASD spent just 27.70% of time engaged in PA at a moderate intensity or higher compared to children without disabilities who spent 36.15% of recess time at a moderate or higher intensity (Pan, 2008). Next, PA variables including, counts per minute, steps per minute, percentages in moderate or higher intensity levels, and the duration of a bout in MVPA, were measured during a middle school physical education class (Pan, Tsai, & Hsieh, 2011). It was found that the children with ASD (mean age 14.19) were in general less physically active than children without ASD (mean age 14.10) (Pan, et al., 2011). Although most of the relationships between the PA variables were not significant (with the exception of steps/min) it is interesting to note that when comparisons to typically developing peers are made, children with ASD appear to be less physically active than their peers (Pan, et al., 2011).The need for further objective measurement of PA in young children with ASD is of critical importance as it may shed light on an often overlooked need for school based interventions to increase PA early on in development.

There are host health disparities associated with physical inactivity including, an elevated body mass index, high levels of blood pressure (Gaya et al., 2009), and type II diabetes (Hu, Li, Colditz, Willett, & Manson, 2003). Therefore, examining potential factors contributing to physical inactivity are critical as it may lend support for the increase of interventions targeting PA. One potential factor, which has been researched extensively in the typically developing population, is the relationship between PA and motor skills (Barnett, et al., 2009; Fisher, et al., 2005; Williams, et al., 2008; Wrotniak, et al., 2006). Despite methodological differences examining this relationship, several common trends can be extracted from this research. First, there appears to be a discrepancy between children in high and low motor proficiencies. Meaning that children who are in the highest quartile of motor proficiency (as measured by a standardized motor assessment) spend significantly more time in moderate to vigorous activity (MVPA) and vigorous physical activity (VPA) and significantly less time in sedentary behavior than children in lower quartiles (Williams, et al., 2008; Wrotniak, et al., 2006), Therefore, there appears to be a threshold of motor proficiency which this relationship is most important, children who exhibit high levels of motor proficiency are also the most active, however this relationship ceases to exist for children represented in any of the lower tertiles. In a separate study, the motor skills as measured by the Test of Gross Motor Development -2 (*TGMD-2*) (Ulrich, 2000), were found to be positively correlated with levels of PA measured by accelerometers in preschool aged boys but not girls (Cliff, Okely, Smith, & McKeen, 2009). In fact, the object control skills (striking, dribbling, catching, kicking, overhand throwing and underhand rolling) in boys were positively associated with PA outcomes including the percent of time spent in MPA and MVPA and total PA (Cliff, Okely, et al., 2009). However for girls the object control standard score was not related to PA outcomes (Cliff, Okely, et al., 2009). Despite the gender differences in this study, the results do support previous research examining the relationship between PA and motor skills.

Next, longitudinal research examining the relationship between motor skills and levels of PA will enable researchers to determine when children would most benefit from intervention. One such study examined the relationship between motor proficiency using Get Skilled Get Active (New South Whales, Department of Education) and PA through a self-reported questionnaire called the Australian Physical Activity Recall Questionnaire (APARQ) (Barnett, et al., 2009). Motor skill proficiency, primarily object control skills in the primary school years was positively associated with levels of PA during adolescence (Barnett, et al., 2009). In fact, object control skills were positively associated with both participation in MVPA and VPA during adolescence (Barnett, et al., 2009). Next, proficiency in object control skills were positively associated with the amount of time spent in organized PA opportunities for adolescence (Barnett, et al., 2009). This finding is of critical importance as it suggests that targeting motor skills early on in development has the potential to result in an increase in social opportunities associated with an increase in PA. Despite the research which supports the need for early motor skill interventions as a potential vehicle to increase the PA in typically developing children, there is a paucity of literature available examining this relationship in children with ASD.

Taken together, relatively little is known regarding the factors contributing to PA in children with ASD. This is concerning since there is cross sectional research which suggests the PA levels of children with ASD appear to decline throughout development (MacDonald, et al., 2011; Pan & Frey, 2006). To date there remains several gaps in the literature, first to our knowledge there are no studies that have examined the PA levels in young children with ASD. Examining the PA levels of children early in development may lend support for the inclusion of

PA programming before entry into kindergarten. Next, there are no studies that examine the relationship between motor skills and levels of levels of PA in a group of young children with ASD as well as typically developing age comparison group. As such, the primary aim of this study is to objectively measure the current PA levels of young children (aged 2 – 5) with ASD and to compare their results to a typically developing group. It is hypothesized that the typically developing children will achieve significantly more mean minutes per day in moderate to vigorous PA and fewer mean minutes per day in sedentary or light PA. The secondary aim of this study is to examine the relationship between objectively measured PA and motor skills in young children with and without ASD. It is hypothesized that children (typically developing and children with ASD) who are more physically active will achieve greater motor outcomes. Results can be used as a baseline measure of PA levels in young children with and without ASD early in development.

METHODS

Participants

Recruitment occurred through local Early On programs in South East Michigan which provide services and support to children with developmental delays. To be included in this study, participants met ASD criteria based on the Autism Diagnostic Observation Schedule (*ADOS*) (Lord, Rutter, DiLavore, & Risi, 1999) were between 2 and 5 years of age, were able to participant in the motor skills assessment and lived within 50 miles of the testing center. Additionally, children were included in this study if they met PA monitoring guidelines based on recommended wear time adherence parameters for this age range (Cliff, Reilly, et al., 2009). The age range for this study was chosen since early intervention typically begins shortly after ASD diagnoses, which are reliable and stable beginning at 2 years of age (Cox et al., 1999; Stone et al., 1999). The upper age limit in this study was set in order to assist physical therapists, occupational therapists and adapted physical education teachers design and implement a movement skill program which addresses their delays upon entry into preschool or kindergarten.

The ages of the participants ranged from 24 to 68 months (mean age 45.72 ± 12.28). The sample was split into 2 groups, the ASD group, n = 34 (mean age 47.42 ± 12.814), and typically developing group, n = 19 (mean age 42.50 ± 10.78). This was a convenience sample so the participants were not matched based on any of the variables however descriptive statistics are presented below. The Mullen Scales of Early Learning (MSEL) (Mullen, 1995) was administered as the measure of IQ, when it was possible to calculate their full scale IQ, the ASD group achieved a mean score of 35.09 ±16.80 (range 4-67), representing a descriptive category within the very low range. While the typical group achieved a mean score of 105.50±21.81 (range 75-162) representing descriptive categories which ranged from very low to below average. The *ADOS* was administered as the confirmation of diagnoses of Autism Spectrum Disorder to the ASD group only. The calibrated severity scores derived from their overall *ADOS* raw score sum, was 6.6±1.2, with scores representing a diagnoses of Autism or Autism Spectrum Disorder.

Measures

All study participants were administered the *MSEL* which is a standardized measure of cognitive functioning appropriate for children birth through 68 months. Evidence of the validity and reliability for children in this age range is reported in the *MSEL* manual (Mullen, 1995). The *MSEL* consists of 4 cognitive scales including non-verbal problem solving (visual discrimination and visual memory), fine motor (unilateral and bilateral manipulation as well as writing readiness), receptive language (comprehension and auditory memory) and expressive language (speaking ability and language formation, including verbalization of concepts). Although there is an additional subscale which measures gross motor skills it was not administered in this study due in part because the norms are only available for children birth to 33 months of age. The raw scores on the expressive language subtests were converted to age equivalents and were used as a measure of language assisting researchers in selecting the most appropriate *ADOS* module. If a child's score fell within basal norms (t-scores of at least 20 on each subscale), full scale IQs were calculated using both verbal and non-verbal subtest age equivalents. If it was not possible to calculate IQ scores (t-scores fell below 20 on each subscale), then Ratio IQs were calculated. The non-verbal ratio IQs were calculated by taking the mean of non-verbal subtests age equivalents. Once the mean of the non-verbal subtests were calculated, a non-verbal mental age could be interpreted. The non-verbal mental age was divided by the chronological age and multiplied by 100 in order to obtain non-verbal ratio IQ. The same procedures for verbal ratio IQs were conducted. Ratio IQ's have been previously cited as a method to describe IQ for children with ASD (Lloyd, MacDonald, & Lord, 2011; Richler, Bishop, Kleinke, & Lord, 2007).

The Peabody Developmental Motor Scales – 2 (PDMS-2) is a standardized assessment developed to measure motor skills (Folio & Fewell, 2000). Evidence of the validity and reliability for children birth through 71 months of age is reported in the *PDMS-2* manual (Folio & Fewell, 2000). The *PDMS-2* is comprised of 6 subtests stationary (sustain control over body), locomotion (movement from one location to another), object manipulation (throw, catch and kick balls), grasping (ability to use hands), and visual-motor integration (use of visual perceptual skills while performing a eye-hand task) (Folio & Fewell, 2000). The reflex subtest was not used in this study because all of the children in this study were > 24 months of age. For the purpose of this study, the quotients were used in the analyses. Motor quotients were computed by summing the subtest standard scores which comprise either the gross motor, fine motor or total motor skills, which are then converted into a quotient. The Gross Motor Quotient (GMQ) includes stationary, locomotion and object manipulation subtests while the Fine Motor Quotient (FMQ) includes grasping and visual-motor integration. The Total Motor Quotient (TMQ) combines the GMQ and FMQ. The *PDMS-2* was administered and scored by a certified adapted physical education teacher with extensive experience in conducting motor assessments in young children with developmental disabilities. A secondary researcher live coded every administration of the *PDMS-2*. Percent agreement on assessments ranged from .92 - .1.00.

Physical Activity Measurement

Physical activity was measured with an Actigprah GT3X+ (Pensacola, FL), a small (4.6cm X 3.3cm X 1.5cm) and lightweight (19 grams) triaxial accelerometer (measuring activity in 3 planes) device. Accelerometers have been previously reported as a valid and reliable assessment of objectively PA in young children and preschoolers (Pate, Almeida, McIver, Pfeiffer, & Dowda, 2012; Puyau, Adolph, Vohra, & Butte, 2012; Trost et al., 1998). Data was collected during the spring months which represented a cold to moderate period in the region where participants resided. Participants were instructed to wear the monitor during all waking hours around their waist above their right iliac crest. Placement consideration was based on previous research supporting PA measurement in children (Cliff, Reilly, & Okely, 2009). Next, a method found to increase wear time adherence in children with disabilities includes the administration of a social story (i.e., a story of a superhero character who wears a magic belt), therefore all families were read and provided with a social story to take home (Hauck, 2011). Finally, parents were given a log to record the times of the day when the monitor was taken off, for example, taking a shower, changing, or comfort. Monitors were returned by priority mail following a seven-day wear period.

All accelerometer data were downloaded with ActiLife 6 Software. In keeping with recommendations from an evidence guided protocol for objectively measuring habitual PA in young children (Cliff, Reilly, et al., 2009) participants were included in the analysis if they met a minimum of 3 days of monitoring with 3hrs of wear time per day. A 15 second epoch was employed based on previous research supporting the frequent and intermittent movements which typically characterizes this age population (Pate, et al., 2012). Next, although specific recommendations for cut-point definitions are lacking for this population (Cliff, Reilly, et al., 2009) validated and published cut points for young children by Pate et al. (2006) were used. Therefore, data was reduced and classified into one of five PA categories, sedentary physical activity (SPA) (counts of < 799), light physical activity (LPA) (800 -1679), moderate physical activity (MPA) (1680 – 3367), vigorous physical activity (VPA) (≥ 3368) . Moderate to vigorous physical activity was calculated as the mean of the sum of MPA and VPA (MVPA)(Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006).

Diagnostic instruments

The *ADOS* (Lord, et al., 1999) is a semi-structured, standardized assessment which measures symptoms of ASD through a series of prompts designed to elicit a sample of communication, social interaction, and play, or imagination. Evidence of the validity and reliability for young children through adults is reported in the *ADOS* manual (Lord, et al., 1999). The *ADOS* consists of 4 modules', a module is chosen based on developmental and expressive language levels, and independent from age or verbal IQ. This assessment quantifies the severity of ASD. Study participants received either a Module 1, for children who use little or no phase speech or a Module 2, for children who use phrase speech but are not yet fluent. Calibrated severity scores (CSS) were generated by raw scores on revised *ADOS* algorithms. Scores from the CSS range from one through ten, where zero to three does not meet ASD thresholds, four to five meets ASD classification and six to ten represent an Autism classification (Gotham, Pickles, & Lord, 2009). The *ADOS'* were conducted by two graduate level students who were trained and reliable to conduct the assessment for research purposes. Prior to the commencement of the study, three consecutive administrations exceeding 80% reliability was achieved. Furthermore, all *ADOS'* were video recorded, and afforded researchers with an opportunity to assess maintenance of reliability throughout the duration of the study, with consensus coding following every 5th administration (inter-rater reliability >80%).

Procedures

All study procedures were approved by the Institutional Review Board. Written informed consent was obtained from parents prior to their child's participation in the study. All assessments were conducted over one day in a quiet and private laboratory with minimal distractions. First, each child who qualified to participate in this study had been previously diagnosed with ASD by a clinician or school psychologist according to DSM-IV (American Psychiatric Association, 2000). First, the *MSEL* was administered to all study participants in order to obtain a measure of language to assist researchers in choosing the appropriate *ADOS* module. Next, in order to support this previous Dx, at study entry participants met either ASD or Autism cut off criteria on the *ADOS*. The *ADOS'* were conducted to lend an additional layer of confidence to their diagnostic information. To measure gross and fine motor skills, the *PMDS-2* was administered to all study participants. Next, the protocol for wearing an accelerometer was explained to parents and when appropriate to the children.

Statistical Procedures

First, descriptive statistics were computed to describe demographic information. An alpha level of 0.05 was used to indicate statistical significance, and all analyses were performed using the SPSS software (Version 20). Preliminary analysis revealed that there were no significant differences in PA based on autism severity, IQ or gender, therefore gender was combined for subsequent analysis.

The primary aim of this study was to describe and compare the levels of PA in young children with ASD and a typically developing group of similar age. In order to compare whether the two groups differed significantly from one another based on mean time spent in each of the five PA levels (SPA, LPA, MPA, MVPA and VPA), two-sample t-tests were performed. Since PA recommendations are typically cited as minutes spent in moderate to vigorous PA (MVPA), it was calculated as the mean of the sum of MPA and VPA.

The secondary aim of this study was to examine the relationship of motor quotients as measured on the *PDMS-2* to levels of PA (in each of the 5 PA categories) in young children with ASD and a typically developing group. T-tests were computed first to test whether the two groups differed significantly from one another based on average gross (stationary, locomotion and object manipulation), fine (grasping and visual motor integration) and total (gross and fine) motor quotients from the *PDMS-2.* Next, analysis of covariance (ANCOVA) was used to compare the two groups in terms of mean PA outcomes after controlling for the relationships of motor skills with the various PA outcomes. Because all relationships between motor skills and levels of PA in each group (for all five PA categories) were statistically similar, the interactions of motor quotient and group were dropped in order to do a comparison between the two groups examining levels of PA.

Lastly, the relationships between calibrated severity scores and levels of PA were examined using linear regression analyses for the ASD group only. This was done by regressing PA categories on the calibrated severity score, for each PA outcome separately.

RESULTS

Descriptive statistics are presented in Table 2.1. The mean time spent wearing the monitor differed by number of days and hours per day, therefore we conducted an ANCOVA to control for wear time. The ANCOVA results are presented in table 2.2. Children with ASD spent significantly less time per day in the mean SPA category when compared to the typically developing group [t (52) = 4.57, $p < .001$]. This is in contrast to the daily mean LPA category, where the ASD group spent a significantly greater amount of time in this category than the typically developing group [t (52) = -5.25, $p < .001$]. Next, results from the daily mean MPA category revealed that children with ASD spent significantly more time in MPA than the typically developing group [t (52) = -4.02, $p < .001$]. Similarly, results from the daily mean MVPA category reveal that the ASD group spent a significant more amount of time in this category when results are compared to the typically developing group [t (52) = -3.81, $p < .001$]. Finally, the ASD group spent significantly more time in VPA than their typically developing age group [t (52) = -2.56, $p < .05$].

The relationships between levels of PA and motor skills were examined next. Mean subtest standard scores on the *PDMS-2* were first calculated for both groups, results were then computed to overall fine, gross or total motor quotients. The typically developing group achieved a significantly greater gross [t(52) = 5.72, $p < .001$], fine [t(52) = 4.12, $p < .001$] and total [t (52) = 5.83, $p < .001$] motor quotient when compared to the ASD group. See table 2.1. The ANCOVA results reveal that there are no significant relationships between motor quotients and any of the PA categories (when calculated as daily means), in either group. Specifically, there was no significant relationship in the gross [F (1, 52) = 0.019, $p = 0.89$], fine [F (1, 52) = 0.807, $p = 0.373$] or total motor [F (1, 52) = 0.242, $p = 0.625$] quotient and their SPA means per day. Similarly, there was no significant relationships between the LPA means per day and their gross [F (1, 52) = 0.762, $p = 0.387$], fine [F (1, 52) = 0.056, $p = 0.814$] or total motor [F (1, 52) = 0.462, $p = 0.50$] quotients. Next, the daily mean MPA results reveal no significant relationship between gross [F (1, 52) = 0.085, $p = 0.772$], fine [F (1, 52) = 0.14, $p = 0.905$] or total motor [F (1, 52) = 0.70, $p = 0.793$] quotients. The MVPA daily means reveal no significant differences in either the gross [F (1, 52) = 0.142, $p = 0.708$], fine [F (1, 52) = 0.107, $p = 0.745$] or total motor [F (1, 52) = 0.182, $p = 0.672$] quotients. Finally, the VPA daily means reveal no significant differences in either the gross [F (1, 52) = 0.265, $p = 0.609$], fine [F (1, 52) = 0.626, $p = 0.433$], or total motor [F (1, 52) = 0.566, $p = 0.455$] quotients.

Next, group differences in PA after controlling for motor quotients were examined. The ANCOVA results revealed that even after controlling for motor skills, there is still a significant difference between groups in all categories ($p < 0.05$). See table 2.3. Specifically, after controlling for each motor quotient in SPA, there was a significant difference in PA after controlling for the gross [F (1, 52) = 5.70, $p < 0.05$], fine [F (1, 52) = 5.77, $p < 0.05$] and total motor [F (1, 52) = 4.82, $p < 0.05$] quotients. Similarly, after controlling for motor quotients in LPA, there was a significant difference in PA after controlling for the gross [F (1, 52) = 12.88, $p < 0.01$], fine [F (1, 52) = 12.48, $p < 0.01$] and total motor [F (1, 52) = 12.10, $p < 0.01$] quotients. Next, the MPA results reveal a significant relationship in PA between groups after controlling for gross [F (1, 52) = 6.59, $p < 0.05$], fine [F (1, 52) = 7.60, $p < 0.01$] or total motor [F (1, 52) = 6.60, $p < 0.05$] quotients. The MVPA reveals significant differences in PA between groups after controlling for the gross [F (1, 52) = 6.88, $p < 0.05$], fine [F (1, 52) = 8.17, $p < 0.05$] and total motor [F (1, 52) = 7.14, $p < 0.05$] quotients. Finally, when controlling for motor quotients, results from VPA reveals significant differences in PA when controlling for the gross [F (1, 52) = 4.84, $p < 0.05$], fine [F (1, 52) = 5.59, $p < 0.05$], and total motor [F (1, 52) = 5.64, $p < 0.05$] quotients.

Table 2.4 presents results from the linear regression analyses examining the relationships of daily mean time spent in each of the 5 PA categories, with calibrated severity of ASD. Linear regression results reveal that calibrated severity scores are not related to any of the five PA categories ($p > 0.05$). For every 1 unit increase in the calibrated severity score, there is a 5.78 minute increase in expected SPA daily means [B = 5.78, *SE* = 6.78, $p = 0.401$]. Next, results from LPA reveal that for every 1 unit increase in the calibrated severity score, there is a 0.98 minute decrease in expected daily means [B = -0.98, *SE* = 1.98, $p = 0.622$]. Similarly, in MPA, for every 1 unit increase in calibrated severity score, there is a 1.19 minute unit decrease in what would be expected for their means per day [B = -1.19, *SE* = 2.08, $p = 0.571$]. Results for the MVPA category reveal a similar relationship, whereby for every 1 unit increase in calibrated severity score, there is a 1.89 minute unit decrease in what would be expected for their daily means [B = -1.89, *SE* = 2.82, $p = 0.509$]. Finally, there is a 1.39 minute unit decrease in what would be expected in their means per day VPA category [B = -1.39, *SE* = 1.88, $p = 0.468$].

DISCUSSION

Despite both groups meeting or exceeding minimum MVPA recommended guidelines, it is important to note that the majority of their time was spent in sedentary PA. This is concerning since low levels of PA early in life has been cited as a factor contributing to the obesity epidemic (Tennefors, Coward, Hernell, Wright, & Forsum, 2003). Additionally, physical inactivity across every population is associated with a number of negative health outcomes (Gaya, et al., 2009; Hu, et al., 2003). Furthermore, the presence of these conditions may create more health barriers for participation in regular PA.

Physical activity levels and patterns begin to develop early on in life, therefore there is an unprecedented need to begin to understand some of the factors contributing to this behavior early on in development. Recent studies have found that motor skill delays that are evident early on in life can and can persist and worsen throughout early childhood (Lloyd, et al., 2011). Unfortunately the same pattern is found in PA levels for children with ASD, with cross sectional research supporting the fact that older children with ASD are significantly more physically inactive when compared to younger children (MacDonald, et al., 2011; Pan & Frey, 2006). It was hypothesized that the typically developing group would achieve significantly more mean minutes per day in MVPA and fewer minutes in SPA and LPA when compared to the children with ASD. Although the current study findings would suggest that children with ASD spend more time in MVPA than their typically developing peer and spend less time in LPA and SPA, it is still unknown how their PA trajectory may change throughout development. Future studies should consider longitudinal research examining this trajectory throughout development.

Previous reports of PA measurement during selected periods (including structured and unstructured play time) have resulted in children with ASD accumulating fewer minutes in MVPA (Bandini, et al., 2012; Pan, 2008). Therefore, more comprehensive measurement into how young children with ASD are accumulating their PA is needed. For example, future PA research for children with ASD should consider an observational period where coding is occurring while simultaneously wearing a PA monitoring device. This may assist researchers in determining whether or not the accumulation of PA was due to a hallmark characteristic of ASD called stereotypy (repetitive behavior) or if it was due to movement through space that was purposeful.

There is some research to support that in preschool aged children, those who achieve the highest quartile of motor proficiency spend significantly more time in MVPA and VPA and significantly less time in SPA than children in lower quartiles (Williams, et al., 2008; Wrotniak, et al., 2006). Therefore, it was hypothesized that children (both typically developing and children with ASD) who were more physically active would achieve greater motor outcomes. Current study results would suggest that there is no relationship between motor skills and levels of PA, in either typically developing children or children with ASD in any of the five PA categories. It is important to note that the children enrolled in this study were significantly younger than previous research in this area, therefore perhaps the entry into preschool marks a sensitive period where this relationship emerges.

Finally, the National Standards Project (NSP) (National Autism Center, 2009) is an initiative which seeks to provide parents, caregivers, educators and service providers with pertinent information regarding treatment and practice options for individuals with ASD (aged birth through 22). Although the primary focus of the NSP is to provide recommendations for established treatment methodology, the NSP (2009) also cites emerging treatments. Emerging treatments have been shown to produce positive behavioral outcomes but do not yet have sufficient research to be considered established (NSP, 2009). Physical exercise was named one of twenty-two emerging treatments for children and young adults with ASD (NSP, 2009). Although findings from this study would suggest that children are meeting recommended PA guidelines, perhaps the more important finding is how much time each group spent in sedentary PA. Interventions to reduce this behavior early on in development may curb the trajectory of PA decline throughout development. Play based interventions have previously been cited as a type of intervention young children with ASD would enjoy and benefit from (Lloyd et al. 2011). Finally, in keeping with recommendations from the National Association for Sport and Physical Education (2012) and NSP (2009) early intervention services should include a motor behavior component.

Due to the wide spectrum of behaviors that examiners encountered throughout the evaluations, several modifications were made to individualize the delivery of instruction throughout the study. First, frequent reinforcers were used throughout the assessments that included the administration of stickers, high fives and when appropriate food, the examiners only administered these techniques after several attempts of the standardized methods failed. Next, since a demonstration is a component in many of the assessments that were delivered, examiners made sure to use language that was developmentally appropriate, for example, gaining the student's attention prior to the delivery of instruction and using shortened sentences. Finally, examiners repeated instruction for a second or third time when necessary.

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Table 2.1 Descriptive data for both groups

	ASD (n=34) mean±SD (range)	TD (n=19) mean±SD (range)	*p*	ES
Gender	M=25,F=9	M=11,F=8	0.181	0.61
Race	A=4, B=2, H=1, W=23, O=4	A=2, B=4, H=2, W=11	0.546	0.32
SES	HS=5, SC=7, ASC=7, B=9, PB=6	HS=1, B=10, PB=8	0.781	0.41
Age	47.42 ± 12.814 (24-68)	42.50 ± 10.78 (26-62)	0.313	0.26
CSS	6.6±1.2 (4-10)	-	-	-
Full Scale IQ	35.09 ±16.80 (4.44-67.10)	105.50±21.81 (75.69-162.03)	<0.001***	0.86
NVRatioIQ	43.16±18.14 (6.66-78.21)	-	- -	- -
VRatioIQ	27.97±17.51 (1.78-71.05)	-		
PDMS Gross Quotient	75.87±13.52 (49-97)	98.45±15.71 (79-139)	<0.001**	0.61
PDMS Fine Quotient	73.16±15.39 (46-109)	90.25±14.30 (70-118)	<0.001**	0.49
PDMS Total Quotient	72.18±14.30 (48-98)	94.55±13.06 (74-116)	<0.001**	0.63
% SPA	73.61±5.96 (62-85)	80.89±4.55 (72-87)	< 0.01**	0.57
% LPA	13.16±2.17 (10-18)	10.11±1.59 (8-13)	<0.01**	0.62
%MPA	9.56 ±2.46) (5-15)	6.87±2.08 (5-11)	< 0.01**	0.51
% MVPA	13.22 ±4.52 (6-24)	9.00±3.20 (5-16)	<0.05*	0.47
% VPA	3.66±2.44 (1-12)	2.13±1.16 (1-5)	<0.05*	0.37
Mean Min. Wear Time	784.81±70.41 (661.19-924.42)	822.15±152.75 (662.07-1050.43)	<0.05*	0.16

M=Male; F=Female; ASD=Autism spectrum disorder; TD=Typical development; M=male; F=Female; A=Asian; B=Black; H=Hispanic; W=White; O=Other; HS=High school; SC=Some college; ASC=Associates; B=Bachelor degree; PB=Post bachelor degree; CSS=calibrated severity score; Full Scale IQ = Mullen IQ scores; NVRatioIQ= Mullen Non verbal ratio IQ; VRatioIQ=Verbal ratio IQ; SPA=Sedentary physical activity; LPA=Light physical activity; MPA=Moderate physical activity; MVPA=moderate to vigorous physical activity; VPA= Vigorous physical activity; ES=Effect size; *p*=Level of significance; *p<.05; **p<.001; ***p<.0001

Table 2.2 ANCOVA results controlling for wear time in the 5 physical activity categories

	Typically Developing (n = 19)	Autism Spectrum Disorder (n = 34)	F (df)
Mean time SPA	655.59	577.57	191.92***
Mean time LPA	82.41	103.35	19.46***
Mean time MPA	56.74	75.16	13.51***
Mean time MVPA	65.45	89.52	9.34***
Mean time VPA	17.40	28.70	1.09*

SPA=Sedentary physical activity; LPA=Light physical activity; MPA=moderate physical activity; MVPA=Moderate to vigorous physical activity; VPA= Vigorous physical activity; F=F test; df=degrees of freedom; *p*=Level of significance; **p*<.05; ***p*<.001; ****p*<.0001

Table 2.3 Group differences in means per day physical activity categories after adjusting for motor skills as measured by *PDMS -2*

	F (df)
SPA	
Fine motor quotient	F(1, 52) =5.77*
Gross motor quotient	F(1, 52) = 5.70*
Total motor quotient	F(1, 52) = 4.82*
LPA	
Fine motor quotient	F(1, 52) = 12.49*
Gross motor quotient	F(1, 52) = 12.88*
Total motor quotient	F(1, 52) = 12.10*
MPA	
Fine motor quotient	F(1, 52) = 7.60*
Gross motor quotient	F(1, 52) = 6.84*
Total motor quotient	F(1, 52) = 6.59*
MVPA	
Fine motor quotient	F(1, 52) = 8.17*
Gross motor quotient	F(1, 52) = 6.88*
Total motor quotient	F(1, 52) = 7.14*
VPA	
Fine motor quotient	F(1, 52) = 6.29*
Gross motor quotient	F(1, 52) = 4.84*
Total motor quotient	F(1, 52) = 5.59*

SPA=Sedentary physical activity; LPA=Light physical activity; MPA=moderate physical activity; MVPA=Moderate to vigorous physical activity; VPA=Vigorous physical activity; df= degrees of freedom; F=F test; *p*=Level of significance; **p*<.05; ***p*<.001; ****p*<.0001

Table 2.4 Estimated linear regression models for PDMS-2 Motor Quotients where CSS is the predictor variable

PA Category	Beta (SE)	T	*p*
SPA Mean per day			
Intercept	533.53(53.02)	10.06	<0.001***
CSS	5.78(6.78)	0.85	0.401
LPA Mean per day			
Intercept	110.82(15.38)	7.12	<0.01**
CSS	-0.98(1.98)	-0.49	0.622
MPA Mean per day			
Intercept	84.24(16.28)	5.17	<0.01**
CSS	-1.19(2.08)	-0.57	0.571
MVPA Mean per day			
Intercept	103.87(22.06)	4.70	<0.01**
CSS	-1.89(2.82)	-0.67	0.509
VPA Mean per day			
Intercept	39.28(14.75)	2.66	0.012
CSS	-1.39(1.88)	-0.735	0.468

SPA=Sedentary physical activity; LPA=Light physical activity; MPA=Moderate physical activity; MVPA=Moderate to vigorous physical activity; VPA=Vigorous physical activity; SE=Standard error; *p* =Level of significance *p<.05; **p<.001; ***p<.0001

Chapter 3

The effects of an early motor skill intervention using research supported strategies on motor skills and levels of physical activity in young children with Autism Spectrum Disorder

The incidence of Autism Spectrum Disorder (ASD) has risen dramatically over the past decade, with current estimates that it affects 1 out of every 68 individuals (Center for Disease Control and Prevention, 2014) . With revised ASD screening procedures for toddlers with Autism Spectrum Disorder (Lord, Luyster, Gotham, & Guthrie, 2012), the identification of ASD symptoms can be detected as early as twelve months of age (Lord, et al., 2012). As a result, there has been an increasing awareness on the importance of early intervention. To date, there are a number of evidence based practices which have been shown to promote the best possible outcomes for children with ASD (Dawson, et al., 2010; Mesibov, Shea, & Schopler, 2004; Vismara & Rogers, 2010). According to the National Standards Project (NSP) (National Autism Center, 2009) evidence based practices can be defined as the combination of four aspects, research findings (academic rigor), professional judgment (by a series of experts), values and preferences (interests of all parties involved in the treatment needs to be taken into consideration) and capacities (professionals need to be equipped with qualifications to deliver services). The majority of research examining the evidenced based practices in children with ASD has focused on the social and communication domain, this is despite motor skills being named as 1 of 8 domains to be targeted in the educational curriculum for children birth through 8 years of age (National Research Council, 2001). There are no known interventions adopting best practices from either the NSP (2009) or National Research Council (NRC) (2001), which target motor skills as the primary outcome in young children with ASD. Furthermore, the evidenced based research available within the motor domain for individuals with ASD is replete with limitations.

Among recommendations from the NRC (2001), intervention for young children with ASD should be intensive (meaning delivered daily, year round), begin early in development, adopt a low child to instructor ratio, and should include systematic instruction. However, oftentimes in a school physical education setting, researchers and teachers alike are limited by the frequency and duration of each instructional session. Therefore, it is common practice to adopt one or two strategies from a more comprehensive evidence based treatment program such as Applied Behavioral Analysis (ABA) or Pivotal Response Treatment (PRT). As such, when single strategies are adopted from a larger more comprehensive program, they will be referred from herein as research-supported strategies.

One such study incorporated a research-supported strategy called prompting and fading within an adapted physical education class. Prompting can be understood as manually or physically guiding a child through a particular action (Lovaas, 1981). If a prompt elicits an appropriate response, this should be followed by a reward, which is meaningful to the child. Prior research has found that utilizing a specialized visually based communication system called the Picture Exchange Communication System (PECS), while implementing prompting and fading, can enhance learning outcomes (Yoder & Lieberman, 2010). The effects of a visual support system on 'time on task' behavior and 'time off task' behavior in a group of 4 elementary school students aged 5 to 9 with ASD was measured in an inclusive physical education environment (Fittipaldi-Wert, 2007). This study included daily sessions lasting twenty to thirty minutes, where twelve sessions were used to collect preliminary baseline data, eleven sessions were dedicated to the intervention, and 1 to 3 sessions were used to measure maintenance. Although the study conducted by Fittipaldi-Wert (2007) does not utilize the PECS system specifically, the visual prompts implemented within the gymnasium environment function in the same way PECS does within a social studies or math class. Findings revealed that the time on task at baseline without prompts was 36.70%; however during the intervention which employed prompts, the percent of time on task increased to 63.40%, resulting in an overall 26.70% total increase in time on task (Fittipaldi-Wert, 2007). Similarly, the total mean percentage for all study participants' time off task behaviors during baseline was 29.88% compared to 15.23% after the implementation of the prompts during intervention, resulting in an overall decrease of 14.65% (Fittipaldi-Wert, 2007). Although study findings lend support for visual prompting as a method to increase 'time on' or decrease 'time off' behavior, other study characteristics such the intensity and frequency of the intervention fail to conform with any guidelines recommended by the NRC (2001) for elementary school students. Lastly, methodological considerations such as a lack of control group make results from this study difficult to generalize.

In addition to visual prompting, multiple prompting methods can be used in tandem with one another (Collier & Reid, 1987; Reid, Collier, & Cauchon, 1991). Two prompting strategies were compared to teach 6 boys with ASD aged 7 to 10 a bowling skill task (Collier& Reid 1987). The first instructional strategy included extensive physical, visual and verbal prompts; however, the second instructional strategy minimized the emphasis of such prompts. Both groups met twice weekly for twenty to twenty-five minutes until three hundred and thirty two bowing task trials were achieved (approximately thirty trials were conducted in each session). Findings revealed that the group of participants instructed with the extensive use of prompts achieved a significantly higher performance than the participants in the de-emphasized prompt group ($p<$

0.05) (Collier & Reid, 1987). Although study findings can lend support for the use of prompts in an instructional session for physical education, the scope of the intervention was narrow, targeting a single bowling skill task. Furthermore, the intensity and duration of the intervention (thirty trials per session until three hundred and thirty two trials were achieved) falls considerably short of the recommendations outlined by the NRC (2001). Next, although the opportunity for generalization of skills were suggested among the characteristics of effective interventions (NRC, 2001), no mention of the generalization of this skill into a recreational setting was noted.

In a separate study the type of prompt (visual *or* physical) was examined to determine the most productive method when instructing children with ASD how to perform a bowling skill motor task (Reid, et al., 1991). The physical strategy included verbal directions along with manual guidance throughout the task, whereas the visual strategy included verbal directions along with a visual demonstration of the task. The study included 4 participants with ASD aged eleven to fifteen. Participants met 2 to 3 times per week for twenty to twenty-five minutes each session. Participants concluded the study when one hundred and twenty trials were completed; authors note that approximately twenty to thirty trials per session were achieved. It was found that children performed significantly better on the bowling skill task when the instructional strategy included a physical prompt. Children receiving the physical prompt increased their improvements through the task analysis demonstrating a greater improvement in the number of sequences which were achieved when compared to the group receiving the visual prompt ($p \leq 0.05$) (Reid, et al., 1991). However, authors caution that teasing apart a method superior to another may be counterproductive, since learning trajectories and variability among children with ASD may exist (Reid, et al., 1991). The limitations in this study are similar to those from

Collier & Reid (1987), with the outcomes measured in a single skill domain (bowling skill task), an intervention which spans over a relatively short duration (lasting until one hundred and twenty trials were completed) and the lack of a follow up measurement which would determine maintenance of skill.

Studies that implement research supported strategies such as prompting, can lead to positive motor behavior outcomes in children with ASD. However, methodological considerations in these studies make replication and generalization difficult. In a separate study, the use of a reward was found to increase skill acquisition. The gross motor skill performance in a group of twenty-eight middle school children aged ten to fourteen with ASD and cognitive impairment were compared following a 6 week period (Weber & Thorpe, 1989). Six motor skill tasks based on the *I-CAN* Assessment of Gross Motor Skills (continuous bounce, kick, underhand roll, overhand throw, vertical jump and slide) (Wessel, 1976) were presented at random under two teaching conditions. Under the constant practice condition, participants were introduced to only 1 of the 6 motor skills tasks during each thirty minute session. In the distributed condition, all six experimental tasks were presented during the session, along with 3 additional motor skill tasks (which participants had already successfully mastered). Under this condition, participants spent 2 to 3 minutes working on any one of the 6 motor tasks, before either taking a break or continuing to refine a preexisting motor skill. Results from this study demonstrate that participants receiving the distributed practice technique had significantly greater scores on the *I-CAN* compared to the participants receiving the constant practice technique ($p=0.001$) (Weber & Thorpe, 1989). Authors suggest that the participants in the distributed condition may have viewed the breaks as a reward, where they were able to have a break or work on pre existing motor skills, which they enjoyed. Study findings were later replicated in a group of twelve male children with Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS) (American Psychiatric Association, 2000) aged eleven to fifteen (Weber & Thorpe, 1992). The distributed technique was found again to be superior to the constant technique with significant differences at post intervention between the groups total motor scores (p=0.001) (Weber & Thorpe, 1989, 1992). While this type of instructional strategy produced favorable results from pre to post intervention, the introduction of this type of programming, is relatively late in development based on recommendations from the NRC (2001), suggesting that motor skills should be targeted earlier in development (≤ 8 years of age). Next, because both interventions (Weber & Thorpe, 1992) were conducted within the parameters of a typical school setting, neither benefitted from a small group instruction or 1:1 ratio which is recommended as a characteristic of an effective educational intervention (NRC, 2001). Furthermore, both studies fall considerable short of the recommendations from NRC (2001) for intensive instruction defined as 5 days per week, twenty-five hours per week year round. Lastly, ongoing monitoring of the interventions effectiveness (Smith, et al., 2007) or generalizations of skills (NRC, 2001) were never considered.

The length of time required for research-supported strategies to result in positive change is a topic of much debate among researchers. Factors such as the rate of skill acquisition, task requirements, type of environment (school gymnasium, community recreation setting, school classroom), or service provider characteristics, can influence when and how learning goals are achieved. One study measured the motor skill acquisition in 7 students with ASD aged fifteen to sixteen in an inclusive physical education environment. The intervention was conducted over a 2 week period that included 4 sessions, each lasting forty five minutes (Hutzler & Margalit, 2009). Participants learned new motor skill tasks, which focused on the acquisition of field hockey skills. Research supported strategies including verbal, visual and physical prompts, positive reinforcement and peer supports were implemented. Following just 2 lessons, participants increased their field hockey skill acquisition by 8.4% (Hutzler & Margalit, 2009). Study findings suggest that by coupling instructional techniques along with research-supported strategies, motor skill acquisition were plausible after 2 lessons in an *inclusive* physical education setting. Although opportunities for supported interaction with typically developing peers is a characteristic outlined by the NRC (2001), the intensity and frequency of this intervention fall considerably short of the recommendations by the NRC (2001).

An inclusive environment has been shown to have a positive effect on peers without disabilities and to enhance the social interactions of those with disabilities (Block & Obrusnikova, 2007). However, in addition to supported interaction with typically developing peers, there are other environmental factors to consider when building an intervention. In order to facilitate the variety of individual learning needs in children with ASD, prior research would support that environmental adjustments are critical (Hume & Odom, 2007; Pan, 2010). In the Treatment and Education of Autistic and Related Communication Handicapped Children (TEACCH) manual, Mesibov, Shea and Schopler (2004) describe ways in which the environment can be structured; this includes 5 characteristics defined by: routines, individual work systems, physical organization, visual structures, and schedules. The effectiveness of a 10-week water exercise swimming program was implemented using many of TEACCH strategies. The intervention was delivered to a group of 16 male participants with ASD aged 7 to 9, with outcome measures were assessed in both the aquatic and social domain. Several modifications were made to the organization of the pool and pool deck environment, including the establishment of clear boundaries, and visual schedules that include a task analysis (breakdown of individual skill components). The children receiving the intervention improved their aquatic skills ($p < 0.01$) and decreased their antisocial behaviors problems ($p < 0.01$) following the intervention (Pan, 2010). Although this is one of the only studies which measure outcomes across multiple domains (recreation/leisure and social), the study fails to emphasis the generalization of skills (i.e.: how the social changes may be maintained in a classroom setting). Furthermore, because this study was delivered as part of a physical education program, limitations for the opportunity of intensive and daily instruction in a small group or 1:1 ratio were not plausible, thereby failing to conform to many of the characteristics outlined by the NRC (2001).

The National Standards Report (2009) provides recommendations for education and behavioral interventions for individuals' birth to twenty-two years of age. Within this report, several treatments were also identified as having 'emerging evidence'. Structured teaching was identified as having emerging evidence suggesting that implementation of such a technique may produce favorable results. One such study implemented a structured teaching strategy to promote play skills and independent work in 3 participants with ASD ranging in age from six to twenty (Hume & Odom, 2007). An individual work system was tailored for each participant where information on task options, amount of work to be completed, a signal that work is done and instructions for the next activity, were visually communicated to each participant (Hume & Odom, 2007). The individual work system was found to be an effective strategy in increasing either play functioning or independent work for all 3 participants. A decrease in teacher prompting and an increase in the volume of objects manipulated or used during free play were also noted (Hume & Odom, 2007). Although research findings have most immediate relevance in a classroom, many of the strategies can be integrated into a gymnasium environment.

Strategies to enhance a gymnasium environment may be the labeling of walls, where each wall represents a different meaning (i.e. between activity, lining up, sitting down, waiting etc.) (Staples, Todd, & Reid, 2006). Despite findings by Hume and Odom (2007), very few intervention studies to date implement any of these environmental strategies.

Given the review of available intervention research targeting motor skills in individuals with ASD, it is clear that there is evidence to suggest that when research supported strategies are incorporated into a motor skill intervention the results manifest in positive behavioral change. However, there are many limitations to what is currently known. None of the studies reviewed meet the NRC (2001) recommendations for intensity or frequency, with many interventions lasting a few days or weeks (Collier & Reid, 1987; Hutzler & Margalit, 2009; Reid, et al., 1991). Next, most interventions target a single skill area (i.e.: underhand roll) (Collier & Reid, 1987; Reid, et al., 1991). Furthermore, despite research that highlights the importance for maintenance or follow up measurement (Smith, et al., 2007), only two of the studies reviewed incorporated this into their methodology (Fittipaldi-Wert, 2007; Pan, 2010). Although the NRC (2001) identified 'early' intervention as a characteristics of effective interventions, the majority of interventions to date focus on middle or high school students, to our knowledge there is only one intervention targeting young children with ASD (Fittipaldi-Wert, 2007). Lastly, too few studies integrate only one or two research supported strategies within the context of a physical education class or motor behavior intervention (Collier & Reid, 1987; Fittipaldi-Wert, 2007; Reid, et al., 1991; Todd & Reid, 2006; Weber & Thorpe, 1989, 1992), thereby potentially limiting the opportunity for a greater increase in skill acquisition.

Pivotal Response Treatment (PRT) has been identified as an effective behavioral treatment for individuals with ASD (NSP, 2009), however a common criticism is that it is difficult to implement in an educational setting (Stahmer, Suhrheinrich, Reed, Schreibman, & Bolduc, 2011). As a result, Classroom Pivotal Response Teaching (CPRT) (Stahmer, et al., 2011) was developed by researchers and teachers alike for everyday implementation into the classroom. Briefly, there are 8 key components to the CPRT program. The components can be grouped by antecedent (student attention, clear and appropriate language, easy and difficult tasks, shared control, multiple cues) and consequence strategies (direct reinforcement, contingent consequence, reinforcement of attempts). Classroom Pivotal Response Teaching targets core areas that upon intervention manifest in positive behavior change (Stahmer, et al., 2011). However, core areas can also refer to any developmental domain that upon intervention can result in immediate changes and have a cascading influence on secondary developmental domains. For example, when a motor skill intervention is found to increase motor skills, and where a change in the motor domain results in an increased opportunity for social skills. This type of evaluation of outcomes (across multiple domains) was noted by Smith et al.(2007) as an important consideration when planning and conducting an intervention study.

Therefore, the primary aim of this study was to measure the effectiveness of an early and intensive motor skill intervention employing strategies from CPRT on motor skills and levels of physical activity in preschool aged children with ASD. It is hypothesized that the children who receive the intervention will achieve significantly higher motor outcomes; spend more time in moderate to vigorous PA and less time in sedentary or light PA, than those who do not receive the intervention. The secondary aim of this study was to measure changes in socialization behavior in the experimental group only following an early and intensive motor skill intervention in preschool aged children with ASD. It is hypothesized that children who receive the intervention will spend more time engaged in socially interactive states that result in an increase in peer awareness or interaction and less time in isolation (see description of interactive states in methods). Recommendations for physical education and physical activity programming for young children with ASD will also be discussed.

METHODS

Participants

Recruitment occurred through local Early On programs in South East Michigan which provide services and support to children with developmental delays. To be included in this study, participants met ASD criteria based on the Autism Diagnostic Observation Schedule - 2 (*ADOS*-2) (Lord, et al., 2012) were between 4 and 6 years of age, could participant in the motor skills assessment and lived within 50 miles of the testing center. Next, children were enrolled into the experimental group if parents did not have scheduled absences that would result in participants missing 3 or more days of the intervention. If 3 or more days of the intervention were going to be missed, children were invited to enroll into the control group. An exclusion criteria for both the control and experimental group was the participation in any other motor or physical activity programming throughout the duration of the intervention. The experimental group participated in the intervention, while the control group was instructed to conduct business as usual throughout their summer months. The 4-6 year old age range was chosen for this study in order to assist physical therapists, occupational therapists, and adapted physical education teachers design and implement a motor skill program for children with ASD upon entry into preschool or kindergarten.

The participants in experimental group (n=11, 9 boys) were 58.44±7.32 months in age and participants in the control group (n=9, 6 boys) were 60.54±7.34 months in age. Body Mass

Index (BMI) was calculated as a percent for both the experimental and control group, with the experimental group achieving a BMI percentile of 61.70±25.53 (range 25–94) and 54.61±34.03 (range 4-98) in the control group. The Mullen Scales of Early Learning (MSEL) (Mullen, 1995) was administered as the measure of IQ, the experimental group achieved a mean cognitive score (sum of subtests) of 184.91±32.45 (range 132-246), while the control group achieved a mean cognitive score of 138.22±56.80 (range 80–237) representing descriptive categories which range from very low to above average in both groups. The Vineland Adaptive Behavioral Scales -2 (VABS-2) (Sparrow, Cicchetti, & Balla, 2005) was administered as a measure of overall adaptive behavior, the experimental group achieved a mean composite scores (sum of subtests) of 88.11±11.14 (range 73-110) while the control group scored 82.11±13.43 (range 60 – 101) with descriptive categories ranging low to adequate in both groups. The calibrated severity scores derived from their overall *ADOS-2* raw score sum, was 6.0±0.9 (range 4-9) in the experimental group and 6.9±2.9 (range 5-10) in the control group, with scores in both groups representing a diagnoses of Autism or Autism Spectrum Disorder.

Measures

All study participants were administered the *MSEL* which is a standardized measure of cognitive functioning appropriate for children birth through 68 months. Evidence of the validity and reliability for children in this age range is reported in the *MSEL* manual (Mullen, 1995). The *MSEL* consists of 4 cognitive scales including non verbal problem solving (visual discrimination and visual memory), fine motor (unilateral and bilateral manipulation as well as writing readiness), receptive language (comprehension and auditory memory) and expressive language (speaking ability and language formation, including verbalization of concepts). Although there is an additional subscale which measures gross motor skills it was not administered in this study due in part because the norms are only available for children birth to 33 months of age. The raw scores on the expressive language subtests were converted to age equivalents and were used as a measure of language assisting researchers in selecting the most appropriate *ADOS-2* module. Since full scale IQs could be calculated for every child in the study, both the verbal and non-verbal subtest age equivalents were used in our analysis.

The Test of Gross Motor Development *(TGMD-2)* (Ulrich, 2000) is a standardized assessment developed to measure fundamental motor skills including locomotor skills (running, galloping, hopping, hopping, leaping, horizontal jumping, and sliding) and object control skills (striking a stationary ball, stationary dribble , catching, kicking, overhand throw and underhand roll). Evidence of the validity and reliability for children aged 3 to 10 is reported in the *TGMD-2* manual (Ulrich, 2000). The *TGMD-2* can be administered for the purpose of identifying children who would qualify for services such as Adapted Physical Education and is therefore appropriate for use in young children with ASD who typically exhibit gross motor delays early in development (Lloyd, MacDonald, & Lord, 2011). For the purpose of this study, the raw scores and quotients were used in the analyses. Raw scores were calculated by summing the totals from each of the two subtests. Motor quotients are a composite of the results from both the locomotor and object control subtests and provide the most reliable score for the *TGMD-2* (Ulrich, 2000). The *TGMD-2'* were administered and scored by a certified adapted physical education teacher with extensive experience in conducting motor assessments in young children with developmental disabilities. A secondary researcher coded live video recordings of every administration of the *TGMD-2*. Percent agreement on assessments ranged from .85 - .1.00.

The Peabody Developmental Motor Scales – 2 *(PDMS-2)* is a standardized assessment developed to measure motor skills (Folio & Fewell, 2000). Evidence of the validity and reliability for children birth through 71 months of age is reported in the *PDMS-2* manual (Folio & Fewell, 2000). The *PDMS-2* is comprised of 6 subtests however only 3 represent those in the gross motor domain. Therefore, the stationary (sustain control over body), locomotion (movement from one location to another), object manipulation (throw, catch and kick balls), were administered to study participants'. The gross motor quotient and raw scores were used in the analyses. Raw scores were generated by summing the totals in each of the motor subtests. The gross motor quotient was computed by summing the 3 gross motor subtests standard scores and converting this score into a quotient. The *PDMS-2'* were administered and scored by a trained physical therapist with extensive experience in conducting motor assessments in young children with developmental disabilities. Furthermore, a secondary researcher coded live video recordings of every administration of the *PDMS-2*. Percent agreement on assessments ranged from .94 - .1.00.

The *VABS-2 is* a standardized parental; report measure of overall adaptive behavior. Evidence of the validity and reliability for children birth through eighteen years of age is reported in the *VABS-2* manual (Sparrow, et al., 2005). The overall composite scores were used to describe the adaptive behavior in our sample. The *VABS-2* was administered by two researchers with previous experience administering parental questionnaires.

For participants in the experimental group only, the Playground Observation of Peer Engagement (POPE) (Frankel, Gorospe, Chang, & Sugar, 2011) was administered. The *POPE* includes 6 interactive states; solitary (participant plays alone with no peers within 3 feet), proximity (participant plays alone within 3 feet of peer not engaged in the same activity), onlooker (participant has an awareness of another child who is more than 3 feet away and not engaged in a similar activity), parallel (participant and peer engaged in similar activity but no engagement), parallel aware (participant and a peer are engaged in a same activity and both aware of each other), joint engagement (participant and peer are engaged in mutual social behavior) and games with rules (participant engages in a game or sport with rules). Peer interactions were coded for fifteen minutes, where 1 minute intervals were recorded for fifteen minutes, with the first fourty seconds spent observing the state of interaction, and the final twenty seconds designated for coding the behavior. The percent of time spent during fifteen minutes within in each of the six socially interactive states were the interval used in the analyses. Two researchers trained to assess the *POPE* to young children live coded participant social behavior every two weeks throughout the intervention.

Diagnostic instruments

The *ADOS-2* (Lord, et al., 2012) is a semi-structured, standardized assessment which measures symptoms of ASD through a series of prompts designed to elicit a sample of communication, social interaction, and play, or imagination. Evidence of the validity and reliability for use with toddlers through adults is reported in the *ADOS-2* manual (Lord, et al., 2012). The *ADOS-2* consists of 5 modules'; a module is chosen based on developmental and expressive language levels, and independent from age or verbal IQ. This assessment quantifies the severity of ASD. Study participants received either a Module 1, for children who use little or no phase speech or a Module 2, for children who use phrase speech but are not yet fluent. Calibrated severity scores (CSS) were generated by raw scores on revised *ADOS-2* algorithms. Scores from the CSS range from one through ten, where zero to three does not meet ASD thresholds, four to five meets ASD classification and six to ten represent an Autism classification (Gotham, Pickles, & Lord, 2009). The *ADOS-2'* were conducted by two graduate level students who were trained and reliable to conduct the assessment for research purposes. Prior to the commencement of the study, three consecutive administrations exceeding 80% reliability was achieved. Furthermore, all *ADOS-2'* were video recorded, and afforded researchers with an opportunity to assess maintenance of reliability throughout the duration of the study, with consensus coding following every 5th administration (inter-rater reliability >80%).

Physical Activity Measurement

Physical activity was measured with an Actigprah GT3X+ (Pensacola, FL), a small (4.6cm X 3.3cm X 1.5cm) and lightweight (19 grams) triaxial accelerometer (measuring activity in 3 planes) device. Accelerometers have been previously reported as a valid and reliable assessment of objectively physical activity in young children and preschoolers (Pate, Almeida, McIver, Pfeiffer, & Dowda, 2012; Puyau, Adolph, Vohra, & Butte, 2012; Trost, et al., 1998). Data was collected during the summer months which represented a warm period in the region where participants resided. Participants were instructed to wear the monitor during all waking hours around their waist above their right iliac crest. Placement consideration was based on previous research supporting PA measurement in children (Cliff, Reilly, & Okely, 2009). Next, a method found to increase wear time adherence in children with disabilities includes the administration of a social story (i.e., a story of a superhero character who wears a magic belt), therefore all families were read and provided with a social story to take home (Hauck, 2011). Finally, parents were given a log to record the times of the day when the monitor was taken off, for example, taking a shower, changing, or comfort. Monitors were returned by priority mail following a seven day wear period.

All accelerometer data were downloaded with ActiLife 6 Software. In keeping with recommendations from an evidence guided protocol for objectively measuring habitual physical activity in young children (Cliff, et al., 2009) participants were included in the analysis if they met a minimum of 3 days of monitoring with 3hrs of wear time per day. A 15 second epoch was employed based on previous research supporting the frequent and intermittent movements which typically characterizes this age population (Pate, et al., 2012). Next, although specific recommendations for cut-point definitions are lacking for this population (Cliff, et al., 2009) validated and published cut points for young children by Pate et al. (2006) were used. Therefore, data was reduced and classified into one of five physical activity categories, sedentary physical activity (SPA) (counts of < 799), light physical activity (LPA) (800 -1679), moderate physical activity (MPA) (1680 – 3367), vigorous physical activity (VPA) (≥ 3368) . Moderate to vigorous physical activity was calculated as the mean of the sum of MPA and VPA (MVPA)(Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006).

Intervention

This study adopted its intervention methodology and curriculum content from current literature reviewing best practices of evidence based research and motor skills in children with ASD. First, the NRC (2001) reviewed educational interventions for children birth to 8 years of age, within this report, characteristics of effective interventions were recommended, and therefore many of these were integrated within this study. Next, the recommendations from the National Standards Project (2009), which reviewed the educational and behavioral treatments for individuals' birth to twenty-two years of age, were also implemented into this study. Furthermore, guidelines from a model developed by Smith et al. (2007) for research in psychosocial interventions in autism were also considered. Finally, the intervention curriculum content was created to target the gross motor skills on the *TGMD-2*. This assessment was selected as it is designed to use assessment equipment and movement skills which are common and familiar to children ranging from three to thirteen years of age (Ulrich, 2000).

The introduction of an intervention should be established early in development, therefore the 4 to 6 year old age range was chosen for this research in order to provide children with a repertoire of motor skills upon entry into preschool. Next, the ratio of participant to trainer was 1:1, enabling a constant dyad of instruction and feedback between the participant and trainer. The current intervention was 5 days per week, for twenty hours per week lasting for 8 weeks. The intervention was founded on the research supported strategies from Classroom Pivotal Response Teaching (CPRT) (Stahmer, et al., 2011).

Briefly, CPRT (PRT for a classroom environment) is a behavioral intervention that is implemented in a naturalistic setting. Learning opportunities within CPRT can occur within the child's natural environment and parents, service providers (occupational therapist, physical therapist, adapted physical education teacher) or peers act as the principal intervention agent (Koegel & Kern Koegel, 2006). A primary goal of CPRT is to provide children with structured individualized instruction that places a focus on student motivation. Therefore modifications were made to the way in which the skill was instructed and when appropriate acquired. For example, for a lower functioning child a skill was broken down into a task analysis, where each component is first successfully learned individually and then combined to form the overall skill. However, during the same lesson, for a more advanced student, the instructor could provide a task card (Alexander & Schwager, 2012) to the child, where steps to each activity are written out, and it becomes the goal of the child to experience the thrill of achieving the tasks independently. Therefore, the way in which the structured techniques are delivered may vary, but the learning outcomes result in positive changes.

Next, monitoring of the intervention implementation was conducted on a daily basis by the principal investigator (PI) through direct observation. These checks were conducted to ensure that the delivery of the CPRT strategies remained consistent between participants and throughout the 8-week long motor skill intervention. Next, a 4-week maintenance measurement following the intervention was chosen to measure the sustainability of change to both motor skills and levels of PA in research participants.

The motor skills on the *TGMD-2* represent an age appropriate repertoire of skills commonly found in the children aged three to thirteen years of age (Ulrich, 2000). Therefore, targeted instruction on each of its two subtests, object control (i.e. throw, catch, kick, and strike) and locomotor skills (i.e.: run, gallop, slide, jump), were delivered through CPRT strategies.

Finally, there were two informational sessions were meant to provide trainers with the necessary instructional techniques to deliver the 8 components of CPRT within the context of the intervention. The PI of this intervention was a certified adapted physical education teacher and had previous training and extensive experience in the implementation of research supported strategies and motor skill programming. All trainers were undergraduate students with previous work with children with disabilities and were interested in pursuing a graduate degree in pediatrics or a related field.

Procedures

All study procedures were approved by the Institutional Review Board. Written informed consent was obtained from parents prior to their child's participation in the study. Each child who qualified to participate in this study had been previously diagnosed with ASD by a clinician or school psychologist according to DSM-IV (American Psychiatric Association, 2000). All assessments were conducted over one day in a quiet and private laboratory with minimal distractions. First, the *MSEL* was administered to all study participants in order to obtain a measure of cognitive functioning. Next in order to support this previous Dx, at study entry participants met either ASD or Autism cut off criteria on the *ADOS-2*. The *ADOS-2'* were conducted to lend an additional layer of confidence to their diagnostic information. Next, to measure motor skills, the *PMDS-2* and *TGMD-2* were administered to all study participants. Following the administration of the motor assessments, the protocol for wearing an accelerometer was explained to parents and when appropriate to the children. Next, the *VABS-2* was administered by a researcher to provide a measure of overall adaptive behavior. For those in the experimental group, one week following the pre measures, participants began the summer motor intervention. Each participant attended the study 5 days a week for 4 hours each day, lasting for 8 weeks. The *POPE* was administered to the experimental group every other week throughout the intervention. One week following the intervention both the control and experimental group returned for a post intervention data collection to measure the changes in motor skills and physical activity. In order to measure the sustainability in changes to motor skills, and level of physical activity the experimental and control group returned for a second follow up measurement 4 weeks after the motor skill intervention.

Statistical Procedures

First, descriptive statistics were computed to describe central tendencies and variance for all demographic variables for each age group and the overall sample (at the onset of data collection). An alpha level of 0.05 was used to indicate statistical significance, and all analyses were performed using the SPSS software (Version 21). In order to compare whether the two groups differed significantly from one another based on gender, race, age, social economic status, calibrated severity score, BMI percentile, cognitive t-score, and adaptive behavior composite, two-sample t-tests were performed. To compare group differences in race and gender and SES, chi-square tests were performed. Effect sizes were computed to describe the magnitudes of these differences. The t- tests and chi squared tests were supplemented with additional post hoc tests comparing distributions between the two groups, including the non-parametric Mann-Whitney U test.

To examine the primary aim of this study, changes to motor skills and levels of physical activity, a general linear model analysis was conducted to examine the within group differences at each time point. This analysis was chosen due to the missing data at time point 2, as it allowed the errors in the linear model to have unique variance at each time point and unique covariance across the time points (given the longitudinal nature of the study). Predictors in this model included the time point (time 1 was pre intervention, time 2 post intervention and time 3 four week maintenance), group (control or experimental), and the time-point by group interaction (to assess differences in change over time between the two groups). When no group by time interactions were present, Bonferroni tests were conducted to examine the main effects post hoc. Additional paired t-tests were used to examine the magnitudes of differences across time between both groups.

In order to examine the secondary aim of this study, the effect of time on changes in socialization in the experimental group only, a general linear model was used. This enabled the errors to be correlated over time, allowing for the small amount of missing data in these variables. All models were fitted using the MIXED procedure in SPSS (Version 21).

RESULTS

Descriptive statistics revealed no significant differences in the experimental or control group at baseline on demographic variables, with exception to their *MSEL* cognitive score ($p<0.05$) (see table 3.1). Therefore, this variable was used as a covariate in the general linear model examining subsequent motor outcomes and physical activity.

The within group differences for each motor and PA variable were examined using a general linear model with the cognitive score as a covariate (see table 3.2). The time point by group interactions were significant in the models for the *TGMD-2* locomotor skill and object control raw scores as well as the quotient ($p\leq 0.01$), and therefore these interactions were examined in detail first. For the experimental group, there was a -16.82(SE=1.71) unit difference from time 2 (post intervention) to time 1 (pre intervention) ($p<0.001$), and a 0.27 unit difference from time 3 (post intervention maintenance) to time 2 ($p>0.05$) in the locomotor raw scores. In the control group the difference in locomotor raw units between time 2 and 1 was -3.67 (SE=1.89) ($p>0.05$) and 0.36 (SE=1.38) between time 3 and 2 ($p>0.05$) (see figure 3.1). There was therefore a larger increase in mean raw locomotor scores for the experimental group from time 1 to time 2.

For object control skills, there was a -18.27(SE=1.65) unit difference from time 2 to time 1 in the experimental group ($p<0.01$), and a 3.36(SE=1.18) unit difference between time 3 and time 2 ($p<0.05$). In the control group, there was a -2.56(SE=1.82) unit difference between time 2 and time 1 ($p>0.05$), and a 0.65(SE=1.38) unit difference between time 3 and 2 ($p>0.05$) (see figure 3.2). Therefore, there was a larger increase in mean raw object control scores for the experimental group from time 1 to time 2.

Lastly, in the *TGMD-2* gross quotient, for the experimental group, there was a -32.73(SE=3.51) unit difference between time 2 and time 1 ($p<0.01$), and a 5.73(SE=1.72) unit difference between time 3 and time 2 ($p>0.05$). In the control group, there was a -5.0(SE=3.88) unit difference between time 2 and time 1 ($p>0.05$), and a 2.35(SE=2.00) unit difference from time 3 to time 2 ($p>0.05$) when examining the *TGMD-2* gross quotient (see figure 3.3). In summary, the experimental group achieved a significantly larger increase in their gross quotient scores from time 1 to time 2.

Next, none of the time point by group interactions were significant for the *PDMS-2* or PA outcomes, and therefore main effects for both group and time were examined with bonferroni post hoc t-tests. For each of the *PDMS-2* dependent variables there was a significant main effect of time ($p<0.05$) but not group ($p>0.05$). First, there was a main effect of time [$F(2,18)=4.295, p<0.05$] with a significant increase in stationary raw scores between time 1 and 3, [$t(1,18)=-3.031, p<0.001$] (see figure 3.4). Similarly, for object manipulation raw scores, there was a main effect of time [$F(2,18)=4.178, p<0.05$] with significant increases between time 1 to 3 [$t(1,18)=-2.641, p<0.05$] (see figure 3.5). Next, for the locomotor raw scores, there was a main effect of time [$F(2,18)=9.595, p\leq0.001$] with significant increases from time 1 to time 3 [$t(1,18)=-3.260, p<0.01$] (see figure 3.6). Lastly, the *PDMS-2* gross quotient revealed a main effect of time [$F(2,18)=9.154, p<0.01$] with significant increases between time 1 and 3 [$t(1,18)=-4.616, p<0.001$] (see figure 3.7).

When examining the PA variables, there was a significant main effect of time in 4 of the 5 categories (light, moderate, moderate to vigorous, vigorous) ($p<0.05$) but no main effects for group were found in any of the categories ($p>0.05$). For light PA, there was a main effect of time [$F(2,18)=7.227, p<0.001$] with the number of mean minutes per day declining from between time

1 and 3 [t(1,18)=2.426,$p<0.05$] (see figure 3.9). Similarly, in moderate PA, there was a main effect of time [F(2,18)=5.633,$p\leq0.01$) where fewer mean minutes were spent in this category between time 1 and time 3 [t(1,18)=2.586,$p<0.05$] (see figure 3.10). In moderate to vigorous, there was a main effect of time [F(2,18)=6.303,$p<0.001$] with significant differences between time 1 and 3 [t(1,18)=2.981,$p<0.05$], where participants spent more time in mean moderate to vigorous PA between time 1 and time 3 (see figure 3.11). Lastly, in vigorous PA there was a main effect of time [F(2,18)=6.628,$p<0.01$], where participants spent less time in daily mean vigorous PA with significant differences between time 1 and 3 [t(1,18)=2.515,$p<0.05$] (see figure 3.12).

The between-group differences at each time point were examined next (see table 3.3). There were no significant differences in any of the *TGMD-2*, *PDMS-2* or PA variables between groups at baseline ($p>0.05$). There was a significant difference between the experimental and control groups in the mean *TGMD-2* locomotor and object control raw scores as well as the gross quotient, where the experimental group achieved significantly higher raw sums and quotient scores at both time 2 ($p\leq 0.05$) and time 3 ($p\leq 0.05$) respectively. There were no significant between-group differences in the experimental and control group on any of the *PDMS-2* raw scores or PA categories at any time point.

The effects of time for each of the six *POPE* dependent variables were examined in the experimental group only next (see table 3.4). The general linear models revealed that of the 6 *POPE* dependent variables, 3 were found to have significant time effects ($p\leq0.05$). Proximity and parallel aware both had a positive effect of time (a trend for increasing minutes), and these time effects were both found to be significant at the 0.10 level [F(4,6.14)=4.40, $p=0.052$] and [F(4,9.32)=3.50, $p=0.054$], respectively (see figure 3.15 and 3.16). Next, solitary also revealed an effect of time (a trend for decreasing minutes) [F(4,8.76)=7.94, $p<0.01$] (see figure 3.14). No trends were found for joint engagement [F(4,10.1)=1.5, $p>0.05$], parallel play [F(4,7.18)=0.82, $p>0.05$], or onlooking [F(4,2.37)=2.19, $p>0.05$] (see figures 3.13, 3.17 and 3.18). Too few minutes were accumulated in games throughout the intervention and therefore this analysis was unable to be run for this variable.

DISCUSSION

The differences in treatments for children with ASD are vast and are determined by a host of factors including; the severity of autism, age of individual, type of treatment setting and practicing philosophies of service providers. Early intervention employing practices that are evidence based have been shown to maximize the child's learning outcomes across a variety of domains (Odom, Collet-Klingenberg, Rogers, & Hatton, 2010). Furthermore, interventions implementing evidence based practices are now considered the gold standard for treatments of individuals' birth through twenty two years of age (NSP, 2009).

The current study adopted research supported strategies from CPRT to deliver a motor skill intervention for young children with ASD. To our knowledge, there are no studies to date that implement a comprehensive behavioral treatment within the motor domain for young children with ASD. Therefore, study findings may be used to inform policy makers and service providers to include motor skill programming as part of the early intervention services delivered to young children with ASD.

It was hypothesized that children who receive the intervention would achieve significantly higher motor outcomes than those who did not receive the intervention. Results suggest that this hypotheses was correct. Significant gains were made on the *TGMD-2* in the experimental group when examining pre to post intervention change, with overwhelmingly positive results in the gross quotient, object control, and locomotor raw scores ($p \leq 0.01$). Furthermore, the control group made no significant gains from pre to post intervention on any of the *TGMD-2* outcomes measures, including the gross quotient, object control, or locomotor raw scores ($p > 0.05$). Meaning that gains in the experimental group were a direct result of the intervention. Although age equivalents were not used in our analyses to make pre and post comparisons, it is interesting to note that the experimental group achieved significant differences from pre to post intervention on their age equivalents. At study entry the experimental group achieved a age equivalent of 1.82, while at post intervention the age equivalents increased to a mean age of 6.21 (see appendix 3.1 and 3.2 respectively). These findings are interesting and should be taken into consideration during school based interventions where evaluations are typically performed using an age equivalents.

Based on recommendations from Smith et al. (2007) a maintenance measurement was included to measure the effects of the intervention over time. No significant differences were found in either the experimental or control group between post intervention measurement (occurred immediately following the intervention) and the 4 week maintenance measurement on the *TGMD-2* gross motor quotient or locomotor skills ($p \geq 0.05$). No significant differences were found in the control group between the post intervention measurement and the 4 week maintenance measurement on the *TGMD-2* object control skills ($p \geq 0.05$). However, there was a significant difference between these time points in the experimental group object control raw scores ($p \leq 0.05$). Results suggest that despite significant gains in the experimental group following the intervention, ongoing intervention is needed to sustain these changes, highlighting the importance of continued early intervention/therapy. It is important to note that this length of maintenance was chosen so that there would not be any interference with participants' returning to school and resuming their regularly scheduled treatments. However, future research should consider a longer follow up period to determine if and how gains in the motor or social domain are sustained.

It is interesting to note that despite significant differences in the experimental group from pre to post intervention as measured in the *TGMD-2* ($p \leq 0.01$), changes did not appear to generalize to any of the subtests or overall gross motor quotients represented on the *PDMS-2*. Although generalization of motor skills from the *TGMD-2* to the *PDMS-2* was not an aim of this study, future motor behavior researchers should consider the evaluation of motor skills in a free play unstructured activity as this type of environment is where most of these skills are likely to emerge.

Next, as noted earlier, the PRT intervention strategy seeks to target pivotal 'core areas' which can include any developmental domain that upon intervention, results in immediate changes and has a cascading influence on secondary developmental domains. This type of intervention has the potential to simultaneously enhance both motor skill acquisition and result in a host of positive outcomes in the communication and social domains. A salient example of this type of interaction within the motor behavior domain occurs for example when an intervention targeting motor skill acquisition results in positive changes both within the child's movement skill repertoire as well as changes within social domain. The current study findings would support previous research by Pan et al. (2010), where changes in the motor domain appeared to positively affect the social domain. It was hypothesized that the children who receive the intervention would spend more time in socially interactive states throughout the duration of the intervention. The *POPE* was administered to the experimental group only, 3 interactive states were found to have an effect of time ($p \leq 0.05$). Both proximity and parallel aware are two socially interactive states that represent a positive exchange, each revealing a significant trend for increasing minutes throughout the intervention ($p \leq 0.05$). Solitary is a socially interactive state which represents a negative exchange, however a trend for decreasing minutes throughout the intervention was found ($p < 0.05$). Findings suggest that the acquisition of motor skills throughout the intervention, resulted in an overall increase in the frequency of positive social exchanges. Therefore future motor behavior researchers should focus on creating an intervention that addresses motor behavior with an embedded social or communication outcome measurement.

One further consideration is regarding the PA results from this study. Although it was hypothesized that the children who receive the intervention would achieve significantly more time in MVPA and less time in SPA or LPA, study findings do not support this. However, it is important to note that because this intervention was conducted over the summer months, the first monitoring period pre intervention was during a week that the participants were still in school, and therefore assuming typical PA behavior. The second and third monitoring period were following the intensive 8-week intervention, where many families in the experimental group took the opportunity to vacation. Therefore, current study results may have been impacted by atypical PA behavior during vacations that are associated with increased sedentary behavior due to travelling constraints. In contrast to what was found in the current study, Sowa and Meulenbroek (2012) examined the effects of physical exercise interventions on the social and motor gains in individuals with ASD (mean age 13.6, range 4 – 41.3), findings revealed that PA interventions had a positive effect on the motor and social gains in individuals with ASD. Although the age range in this review is outside the sample included in this study, overall analysis revealed post intervention improvement scores of 37.5% in behavioral changes (in both motor and social domains) (Sowa & Meulenbroek, 2012). It was found that motor interventions resulted in a mean of 40.38% improvement score in motor skills, similarly, social skill improvement scores improved by a mean of 39.51% (Sowa & Meulenbroek, 2012)). Although current study results would suggest that a motor skill intervention does not seem to reflect positive changes in PA (i.e.: an increase in moderate to vigorous or decreased sedentary), as noted earlier methodological considerations may be contributing to this findings. Alternatively, perhaps given findings from Sowa and Meulenbroek (2012), the relationship between variables (motor, PA or social) emerge later on in development. Therefore, additional ways to measure and facilitate this interaction should be considered when planning and developing a motor skill intervention for children with ASD.

Next, a few modifications to the delivery of instruction during the evaluation of assessments were administered in order to ensure that every child's best effort was recognized. First, a parental preference sheet was administered to the parents prior to the beginning of the evaluations; research assistants used this data to guide their method of reinforcers. Next, frequent breaks both within and between assessments were provided where participants could visit with their parents, have some water or receive their reinforcement (i.e.: stickers, time with personal electronic device etc.), taken together, this assisted in the transitions both within and between assessments. Next, if examiners felt that the participants were not following directions or unaware during the demonstration phase in any of the evaluations, a second or third demonstration was provided until examiners believed that participants had a clear understanding of task required.

In summary it is clear that when young children with ASD receive direct and intensive instruction on targeted motor skills delivered within evidence based framework, the results are overwhelmingly positive. Future research should also consider recommendations from both the NRC (2001) and NSP (2009) for the successful planning and implementation of an evidence based motor skill intervention for children with ASD.

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Table 3.1 Descriptive data and baseline differences

	Exp.(n=11) mean±SD (range)	Control (n=9) mean±SD (range)	*p*	ES
Gender	M=9, F=2	M=6, F=3	0.58	0.14
Race/Ethnicity	C=9, AA=2	C=7, H=1, O=1	0.69	0.24
Social Economic Status	SHS=1,SC=2, ASC=1,B=3,PB=4	HS=1,ASC=1,B=5, PB=2	0.34	0.12
Chronological age at testing	58.44±7.32 (50.00-70.00)	60.54±7.34 (50.00-68.00)	0.34	0.14
BMI percentile	61.70±25.53 (25.50-94.00)	54.61±34.03 (4.70-98.90)	0.34	0.11
Calibrated severity score	6.0±0.9 (4-9)	6.9±2.9 (5-10)	0.67	0.20
MSEL Cognitive t score	184.91±32.45 (132.00-246.00)	138.22±56.80 (80.00-237.00)	0.04*	0.45
VABS-2 Adaptive behavioral composite	88.11±11.14 (73.00-110)	82.11±13.43 (60.00-101.00)	0.38	0.24

M=Male; F=Female; C=Caucasian; AA=African American; H=Hispanic; O=Other; SHS=Some high school; SC=Some college; HS=High school; ASC=Associates; B=Bachelor; PB=Post bachelor; MSEL=Mullen Scales of Early Learning; PDMS-2=Peabody Developmental Motor Scales -2; TGMD-2= Test of Gross Motor Development-2;VABS-2=Vineland Adaptive Behavior Scales-2; ES= Effect size; *p*=Level of significance;*$p<.05$; **$p<.001$; ***$p<.0001$

Table 3.2 Estimated marginal means (standard errors in parenthesis) using raw scores on *TGMD-2* and *PDMS-2* and physical activity (PA) mean minutes per day, in general linear models incorporating cognitive score as covariate

DV	Intercept (SE)	Group (0=con. 1=exp.)	Mean difference (Estimated Mean)		
			T1-T2	T2-T3	T1-T3
TGMD-2					
Locomotor	6.28(7.30)	0	-3.67(1.89)	0.36(1.38)	-3.30(2.12)
		1	-16.82(1.71)***	0.27(1.19)	-16.55(1.88)***
Object control	5.89(6.91)	0	-2.56(1.82)	0.65(1.38)	-1.91(1.84)
		1	-18.27(1.65)***	3.36(1.18)*	-14.91(1.62)***
Gross quotient	60.15(9.86)	0	-5.0(3.88)	2.35(2.00)	-2.66(4.48)
		1	-32.73(3.51)***	5.73(1.72)*	-27.00(4.01)***
PDMS-2					
Locomotor	106.04(17.61)	0	-7.11(5.11)	-4.67(4.15)	-11.78(4.22)*
		1	-5.36(4.62)	-7.10(3.76)	-12.46(3.82)*
Object manip.	13.05(7.71)	0	-3.33(2.28)	0.22(1.11)	-3.11(2.40)
		1	-5.45(2.06)*	-0.27(0.99)	-5.73(2.17)*
Stationary	36.00(4.86)	0	-2.44(1.54)	0.89(1.01)	-1.56(1.29)
		1	-1.91(1.39)	-1.64(0.91)	-3.55(1.17)*
Gross quotient	52.32(9.72)	0	-2.89(2.61)	-0.78(2.22)	-3.67(2.35)
		1	-4.82(2.36)	-5.00(2.01)	-9.82(2.13)*
PA					
Sedentary	444.75(82.03)	0	16.45(39.21)	-35.62(34.93)	-19.17(32.40)
		1	28.98(28.63)	-31.08(27.63)	-60.06(24.28)
Light	15.38(17.33)	0	11.29(13.25)	4.52(6.62)	15.81(9.39)
		1	13.40(10.93)	6.04(4.86)	19.44(8.01)
Moderate	6.82(14.82)	0	6.16(8.74)	4.52(6.62)	10.67(5.71)
		1	6.70(6.72)	5.90(4.63)	12.60(4.87)
Mod.toVig.	13.23(18.37)	0	8.62(10.62)	6.84(8.10)	15.46(7.10)
		1	5.65(8.14)	9.58(5.66)	15.22(6.05)
Vigorous	9.73(8.02)	0	6.57(5.12)	2.99(3.58)	9.57(3.97)
		1	-2.10(3.98)	7.35(2.47)	5.26(3.39)

SE=Standard error; T=time point; DV=dependent variable; PA=physical activity;
TGMD-2=Test of Gross Motor Development-2; PDMS-2=Peabody Developmental Motor Skills-2;
*p<.05; **p<.001; ***p<.0001

Table 3.3 Between group differences in pre, post, and maintenance time points using raw scores on *TGMD-2*, *PDMS-2* and physical activity (PA) mean minutes per day

DV	Control	Experimental	*p*
	Mean (Estimated Mean)		
Locomotor (t1)	16.55(2.83)	14.61(2.53)	0.63
Locomotor (t2)	20.22(2.67)	31.43(2.39)	0.009*
Locomotor (t3)	19.85(2.82)	31.16(2.50)	0.01*
Object control (t1)	15.94(2.74)	11.94(2.46)	0.32
Object control(t2)	18.49(2.51)	30.21(2.25)	0.004*
Object control(t3)	17.84(2.63)	26.84(2.32)	0.03*
Gross quotient(t1)	71.77(4.31)	67.97(3.87)	0.64
Gross quotient(t2)	76.77(4.13)	100.69(3.70)	0.001*
Gross quotient(t3)	74.43(3.98)	94.97(3.51)	0.002*
Locomotor(t1)	139.91(7.69)	147.62(6.90)	0.48
Locomotor(t2)	147.02(6.91)	152.98(6.18)	0.55
Locomotor(t3)	151.69(6.34)	160.07(5.69)	0.37
Object manip. (t1)	25.49(3.13)	28.15(2.81)	0.55
Object manip.t2)	28.82(3.14)	33.60(2.81)	0.29
Object manip.(t3)	28.60(2.89)	33.88(2.58)	0.21
Stationary(t1)	44.84(1.75)	44.22(1.56)	0.80
Stationary(t2)	47.29(2.01)	46.13(1.80)	0.69
Stationary(t3)	46.40(2.00)	47.77(1.79)	0.63
Gross quotient(t1)	75.44(3.39)	73.64(3.03)	0.72
Gross quotient(t2)	78.32(4.04)	78.46(3.62)	0.98
Gross quotient(t3)	79.10(4.00)	83.46(3.58)	0.45
Sedentary(t1)	489.97(29.31)	477.53(23.20)	0.77
Sedentary(t2)	473.52(44.74)	448.55(32.76)	0.67
Sedentary(t3)	509.13(36.71)	508.61(29.89)	0.99
Light(t1)	86.72(8.51)	75.15(6.98)	0.33
Light(t2)	75.43(9.25)	61.75(7.21)	0.28
Light(t3)	70.91(7.70)	55.72(6.27)	0.17
Moderate(t1)	61.22(6.35)	53.01(5.14)	0.36
Moderate(t2)	55.07(7.43)	46.31(5.31)	0.37
Moderate(t3)	50.55(5.97)	40.41(4.80)	0.24
Mod.toVig.(t1)	72.31(8.17)	64.89(6.64)	0.52
Mod.toVig(t2)	63.69(8.96)	59.24(6.35)	0.71
Mod.to.Vig(t3)	56.85(7.20)	49.67(5.76)	0.48
Vigorous(t1)	22.79(4.39)	23.40(3.63)	0.92
Vigorous(t2)	16.22(4.03)	25.50(2.82)	0.09
Vigorous(t3)	13.22(2.97)	18.15(2.35)	0.25

SE=Standard error; t=timepoint; DV=dependent motor or physical activity variable; PA=physical activity; TGMD-2=Test of Gross Motor Development-2; PDMS-2=Peabody Developmental Motor Skills-2; *p*=Level of significance; *p<.05; **p<.001; ***p<.0001

Table 3.4 Estimated marginal means (standard errors in parenthesis) using percent time in each Playground Observation of Peer Engagement (*POPE*) category for experimental group only

DV	Time point (Estimated Mean)					F(df)
	Baseline	T1	T2	T3	T4	
Joint Engage.	20.61(5.79)	23.03(7.75)	30.46(7.42)	23.03(7.32)	32.12(7.51)	F(4,10.1)=1.5
Solitary	49.69(6.51)	38.18(10.17)	31.97(8.63)	36.97(7.54)	18.79(6.53)	F(4,8.76)=7.94**
Proximity	1.21(1.21)	1.82(1.30)	7.67(3.57)	15.75(4.15)	11.51(4.13)	F(4,6.14)=4.40*
Parallel Aware	15.76(3.15)	17.57(3.40)	10.69(3.10)	7.86(2.51)	15.76(4.15)	F(4,9.32)=3.50*
Parallel Play	9.70(3.29)	16.98(5.71)	12.70(4.49)	10.91(4.95)	12.12(4.00)	F(4,7.18)=0.82
Onlooking	3.03(1.89)	1.21(0.81)	1.10(1.00)	3.03(1.89)	1.11(1.55)	F(4,2.37)=2.19
Games	-	-	-	-	-	-

T=time point; DV=POPE outcome variable; F=F test, df=degrees of freedom; *p**<.10***p*<.05; ****p*<.001

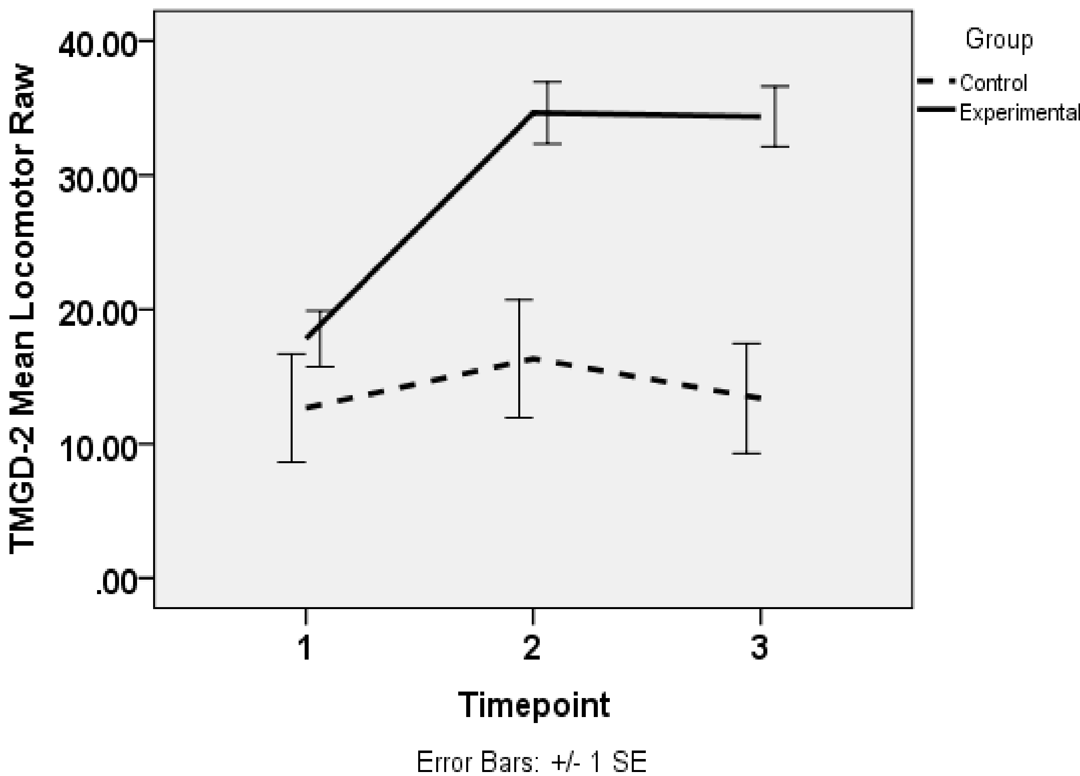


Figure 3.1 Change in *TGMD-2* Locomotor raw scores from pre to post intervention

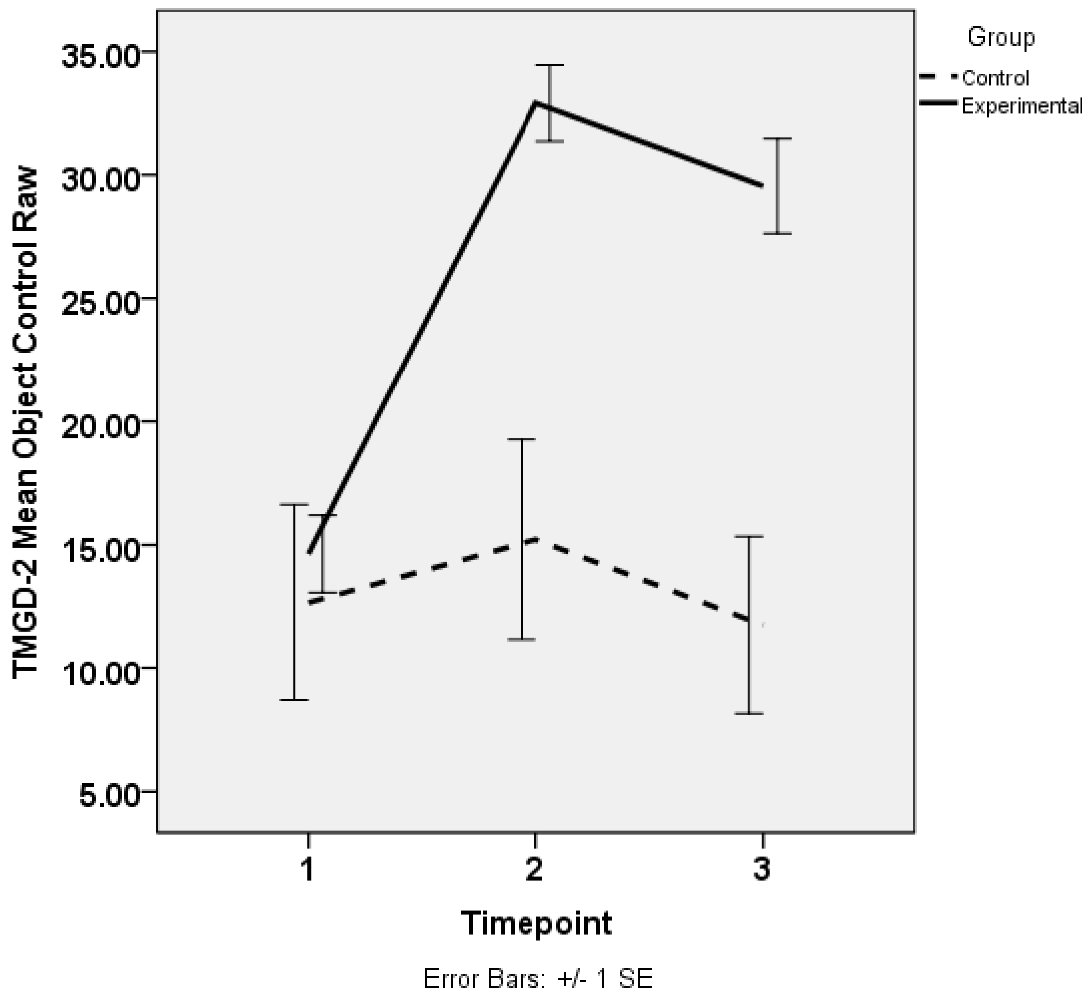


Figure 3.2 Change in *TGMD-2* Object Control raw scores from pre to post intervention

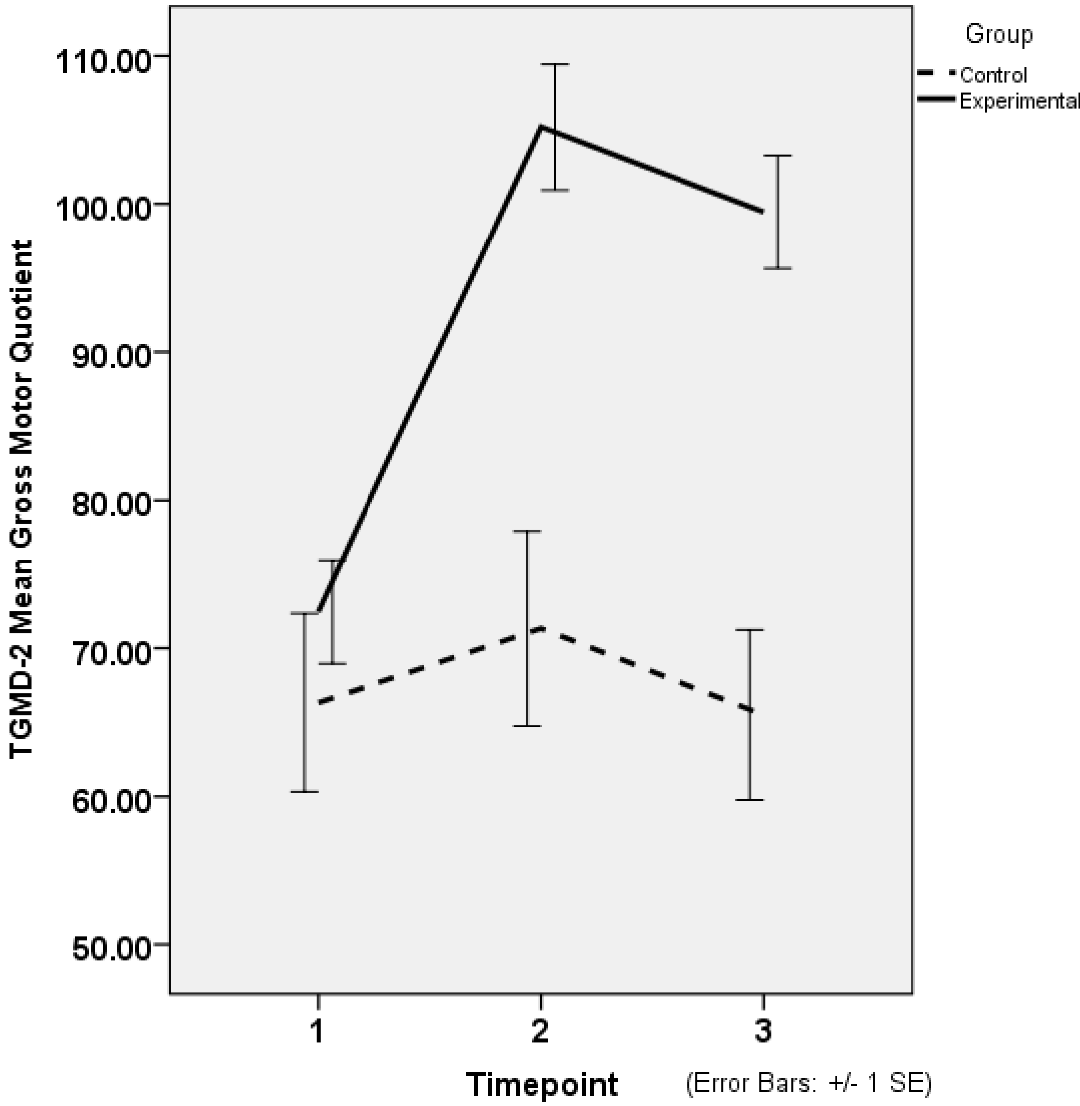


Figure 3.3 Change in *TGMD-2* Gross Motor Quotient scores from pre to post intervention

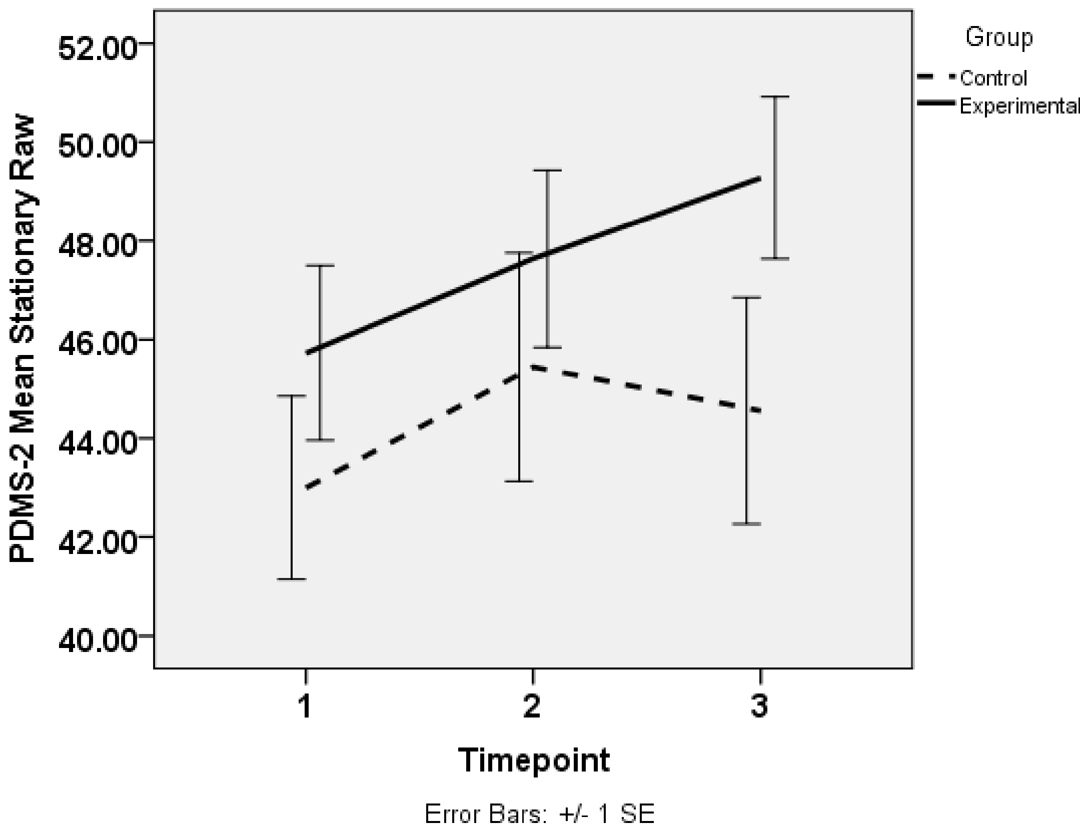


Figure 3.4 Change in *PDMS-2* Stationary raw scores from pre to post intervention

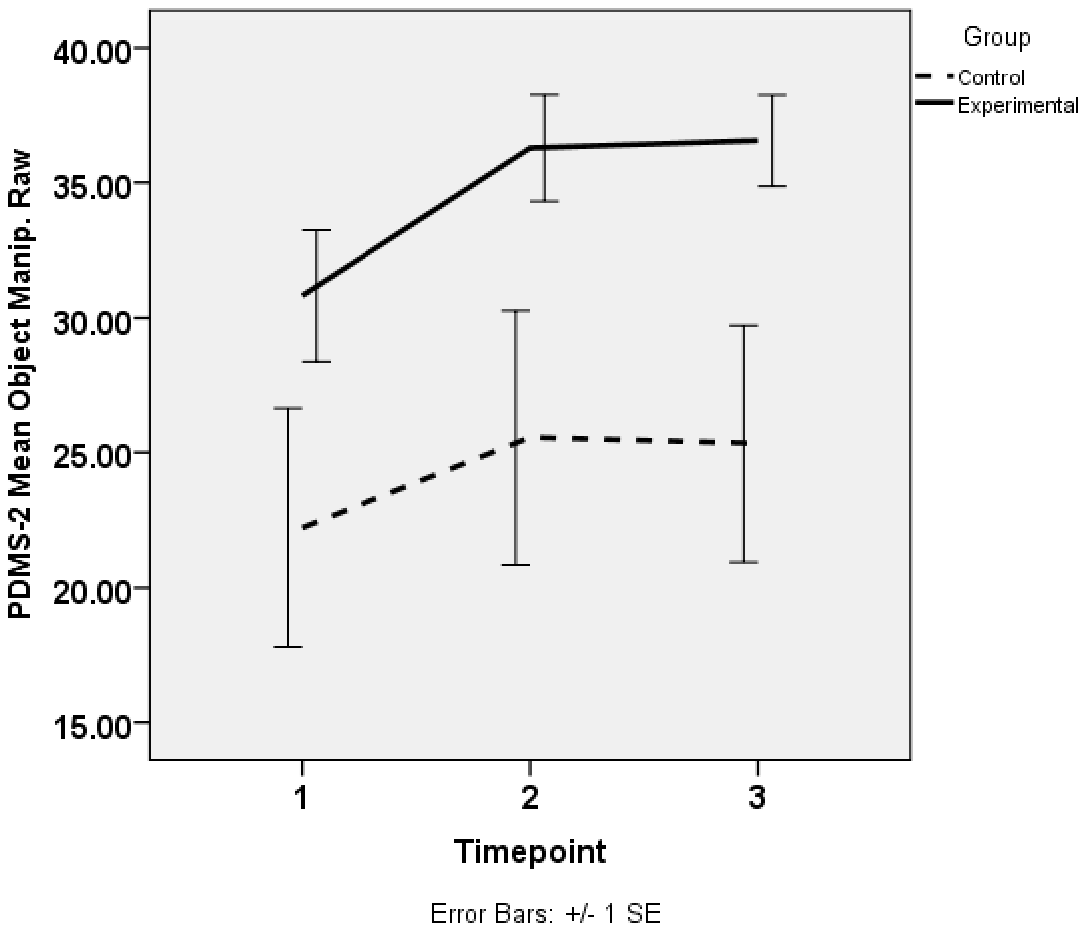


Figure 3.5 Change in *PDMS-2* Object Manipulation raw scores from pre to post intervention

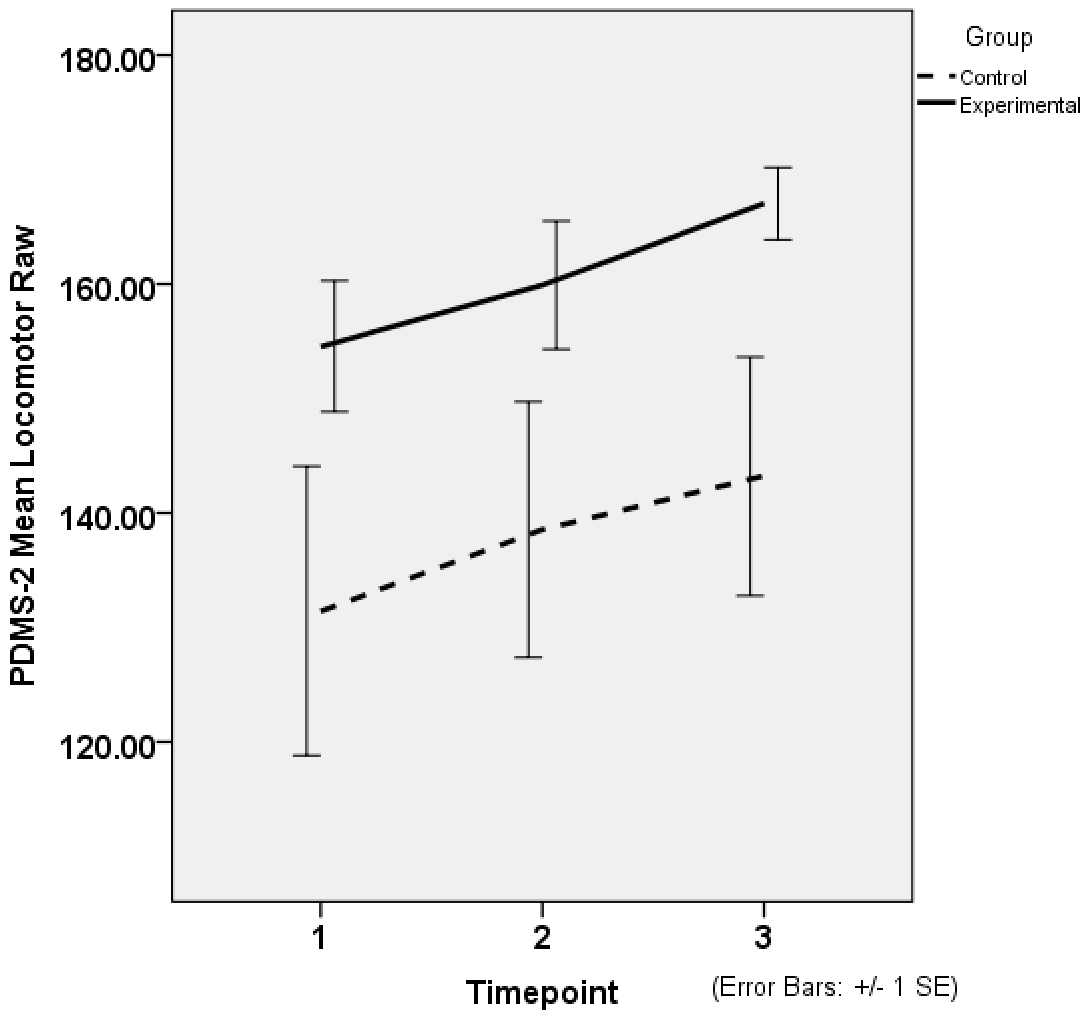


Figure 3.6 Change in *PDMS-2* Locomotor raw scores from pre to post intervention

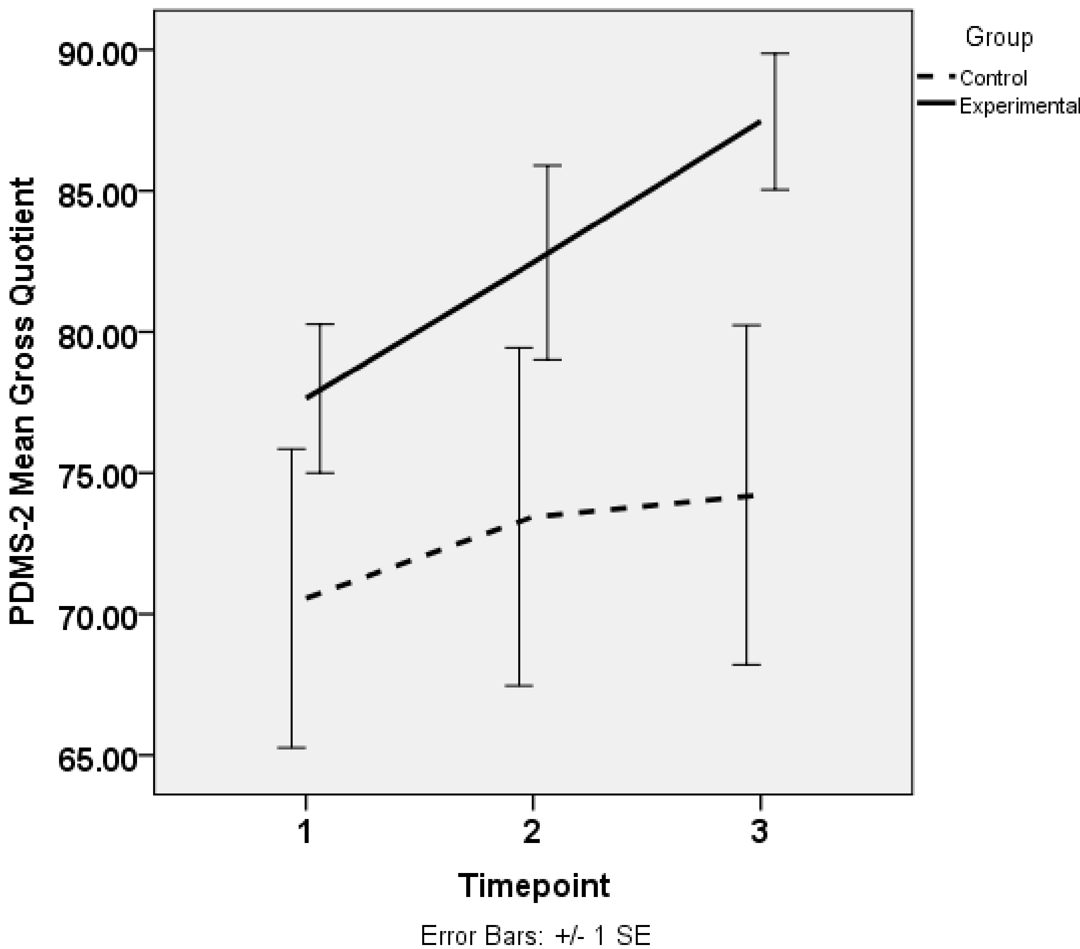


Figure 3.7 Change in *PDMS-2* Gross Quotient scores from pre to post intervention

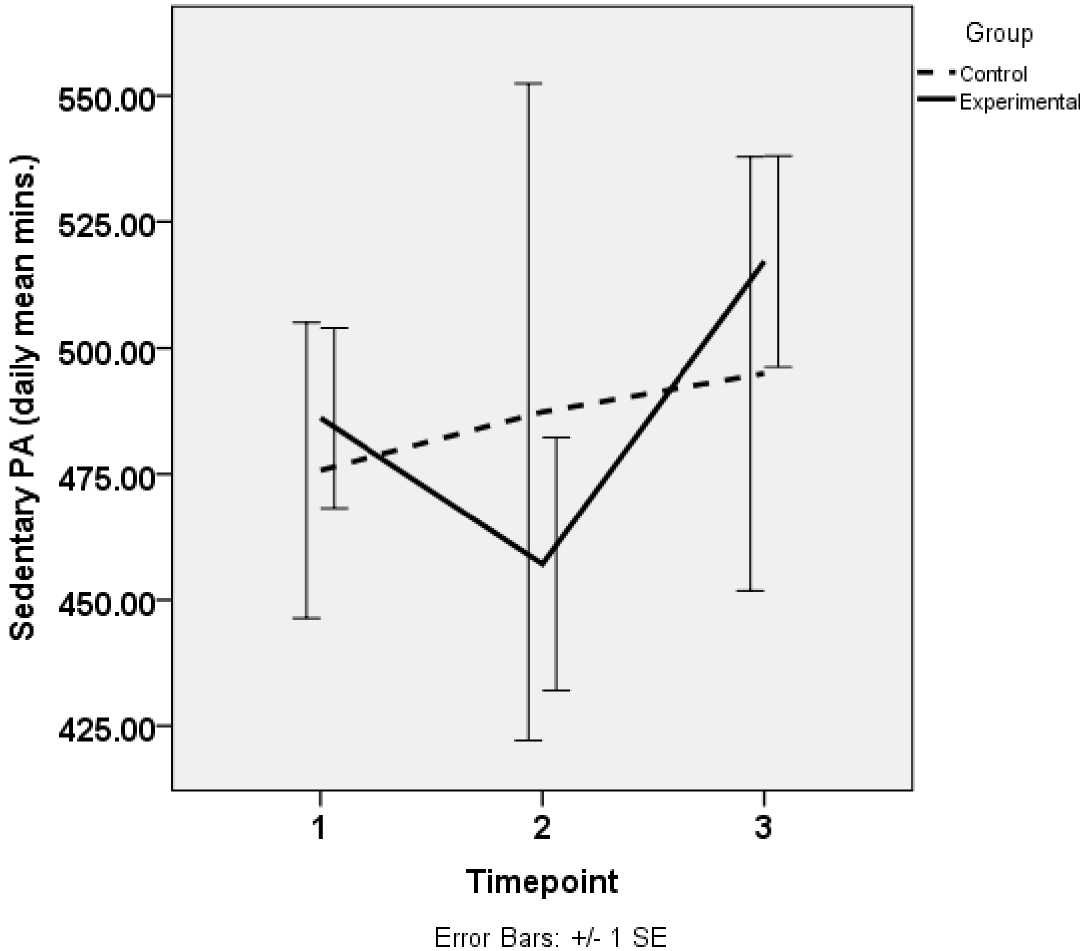


Figure 3.8 Change in sedentary physical activity mean minutes per day from pre to post intervention

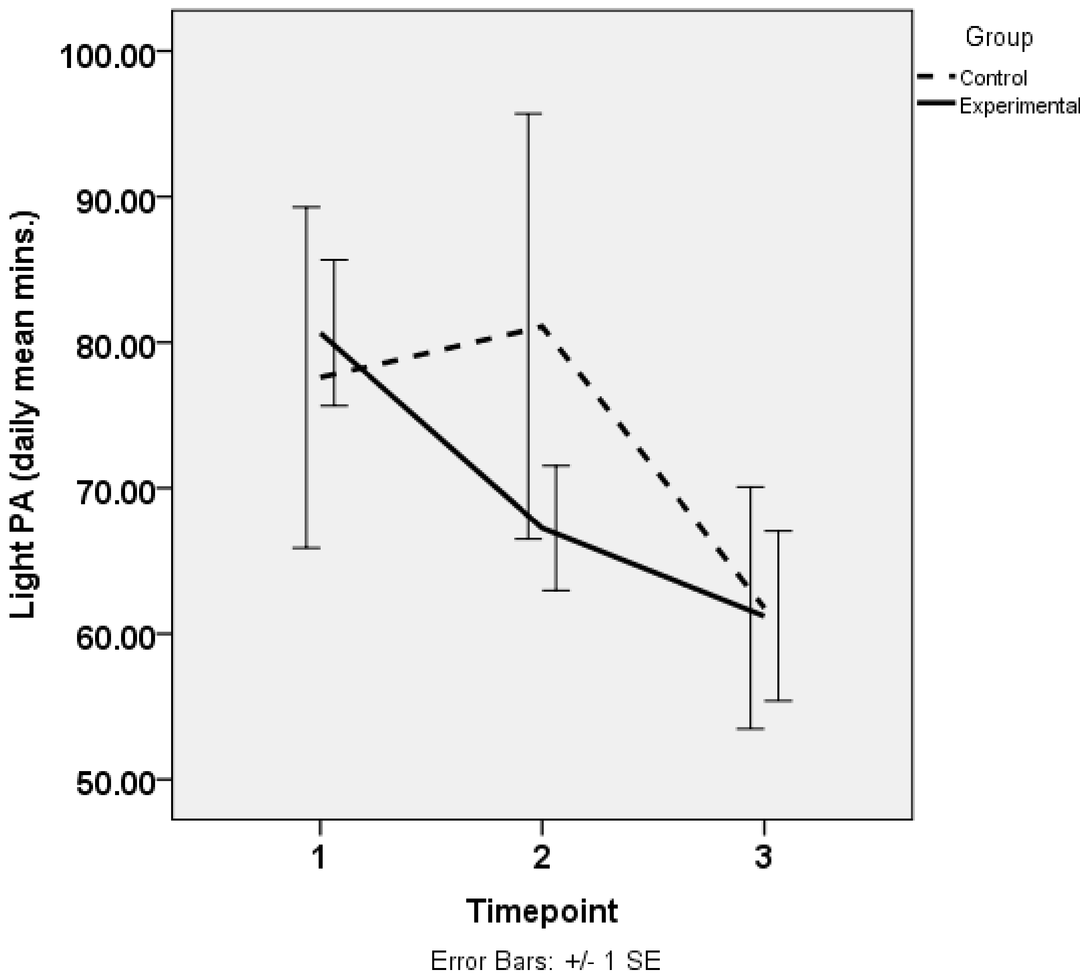


Figure 3.9 Change in light physical activity mean minutes per day from pre to post intervention

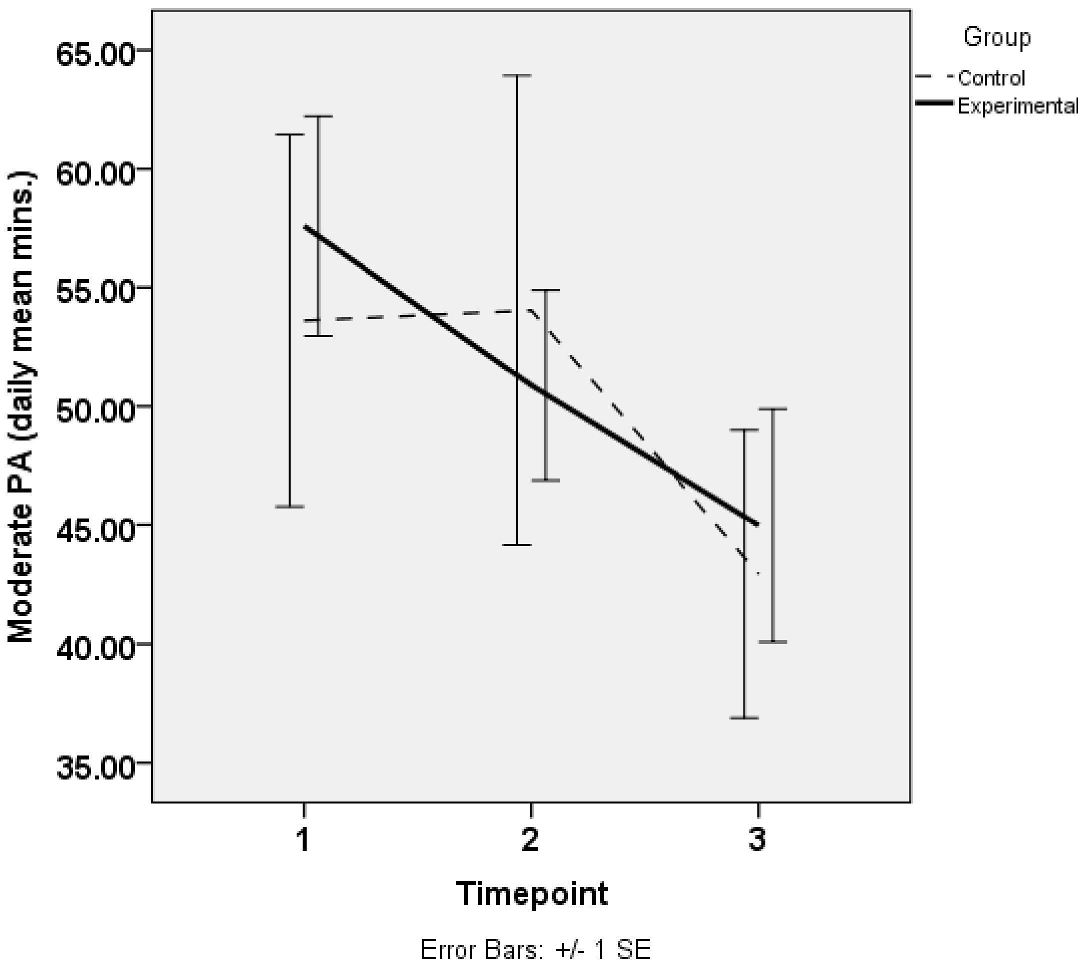


Figure 3.10 Change in moderate physical activity mean minutes per day from pre to post intervention

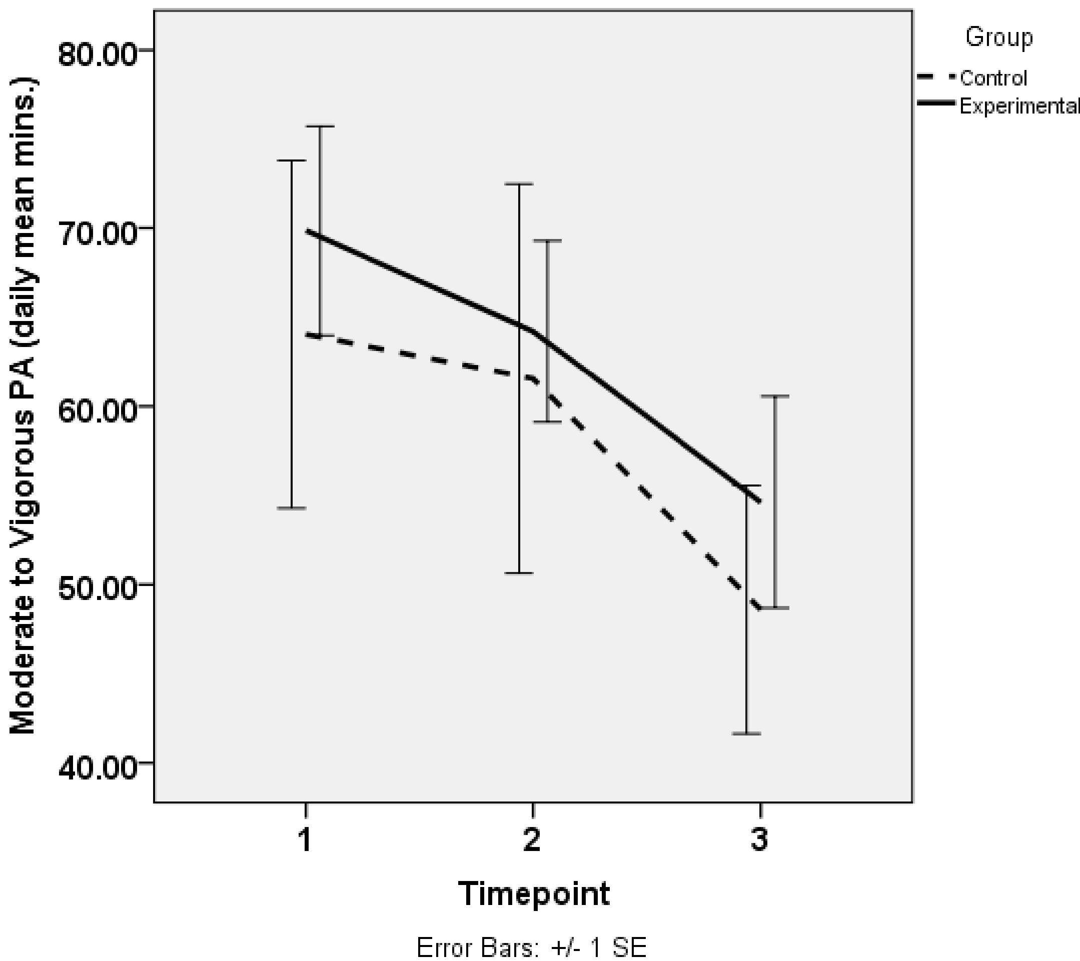


Figure 3.11 Change in moderate to vigorous physical activity mean minutes per day from pre to post intervention

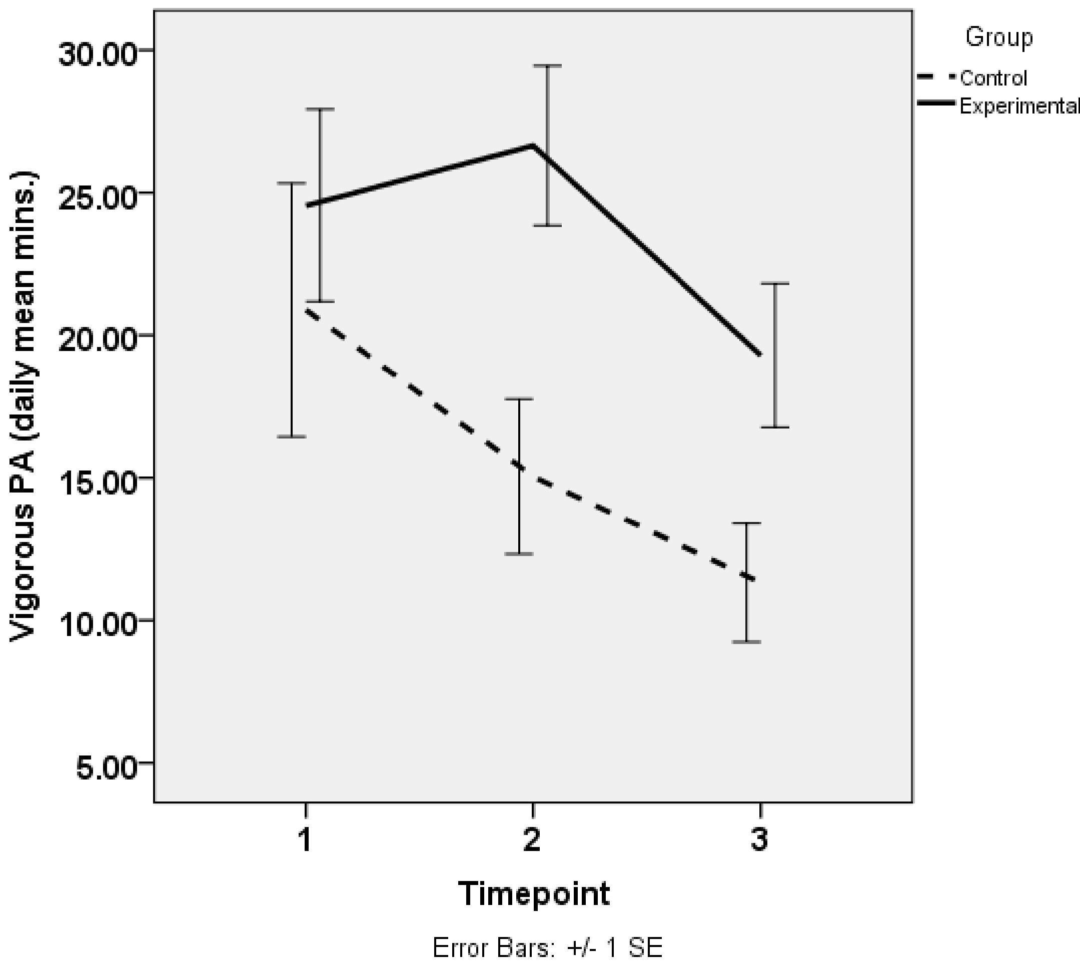


Figure 3.12 Change in vigorous physical activity mean minutes per day from pre to post intervention

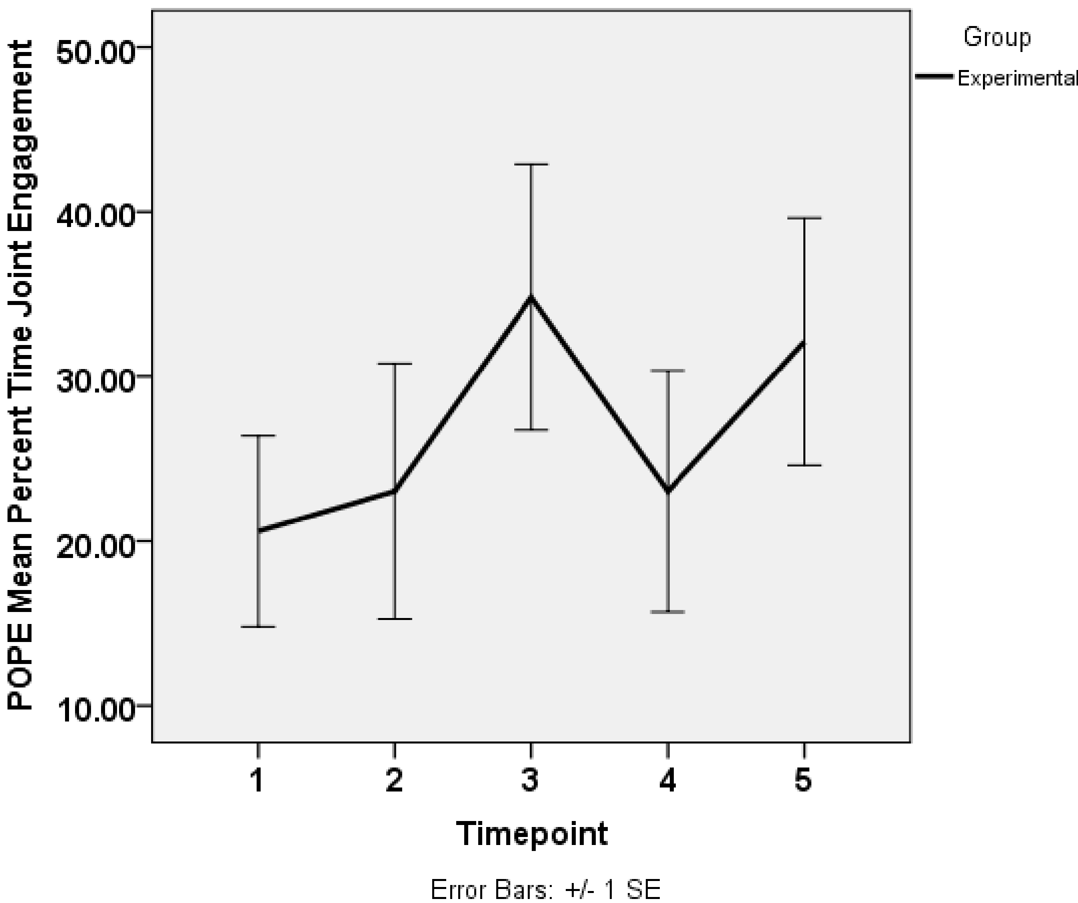


Figure 3.13 Change in percent time spent in joint engagement from baseline to week 8 (measured biweekly)

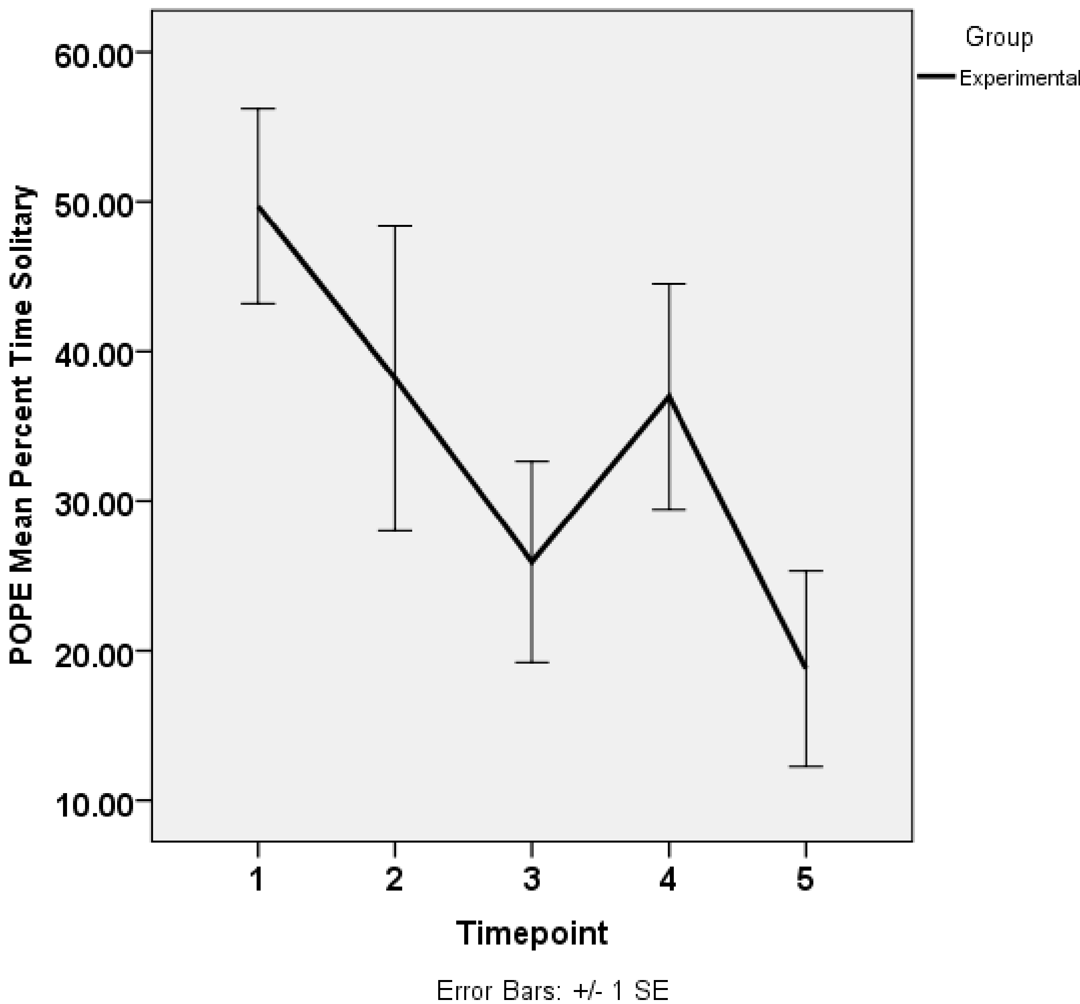


Figure 3.14 Change in percent time spent in solitary from baseline to week 8 (measured biweekly)

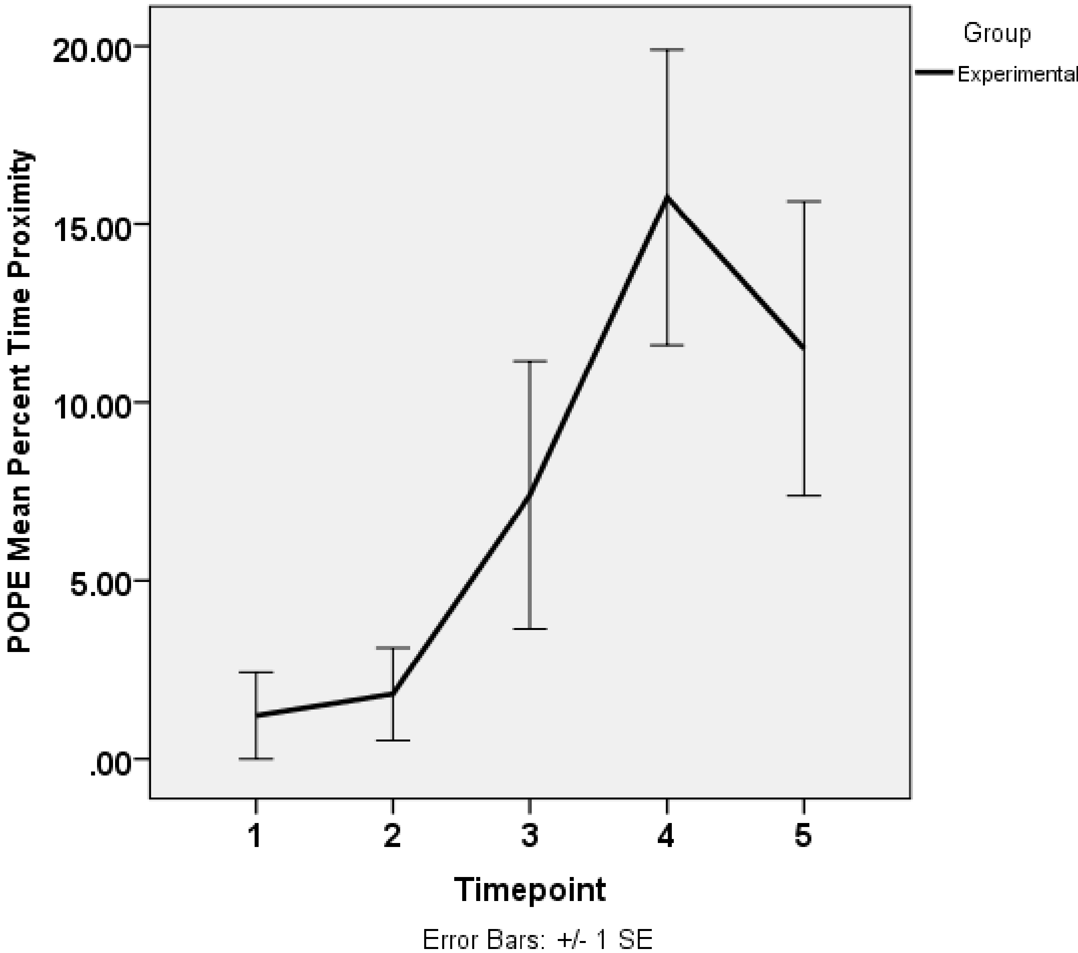


Figure 3.15 Change in percent time spent in proximity from baseline to week 8 (measured biweekly)

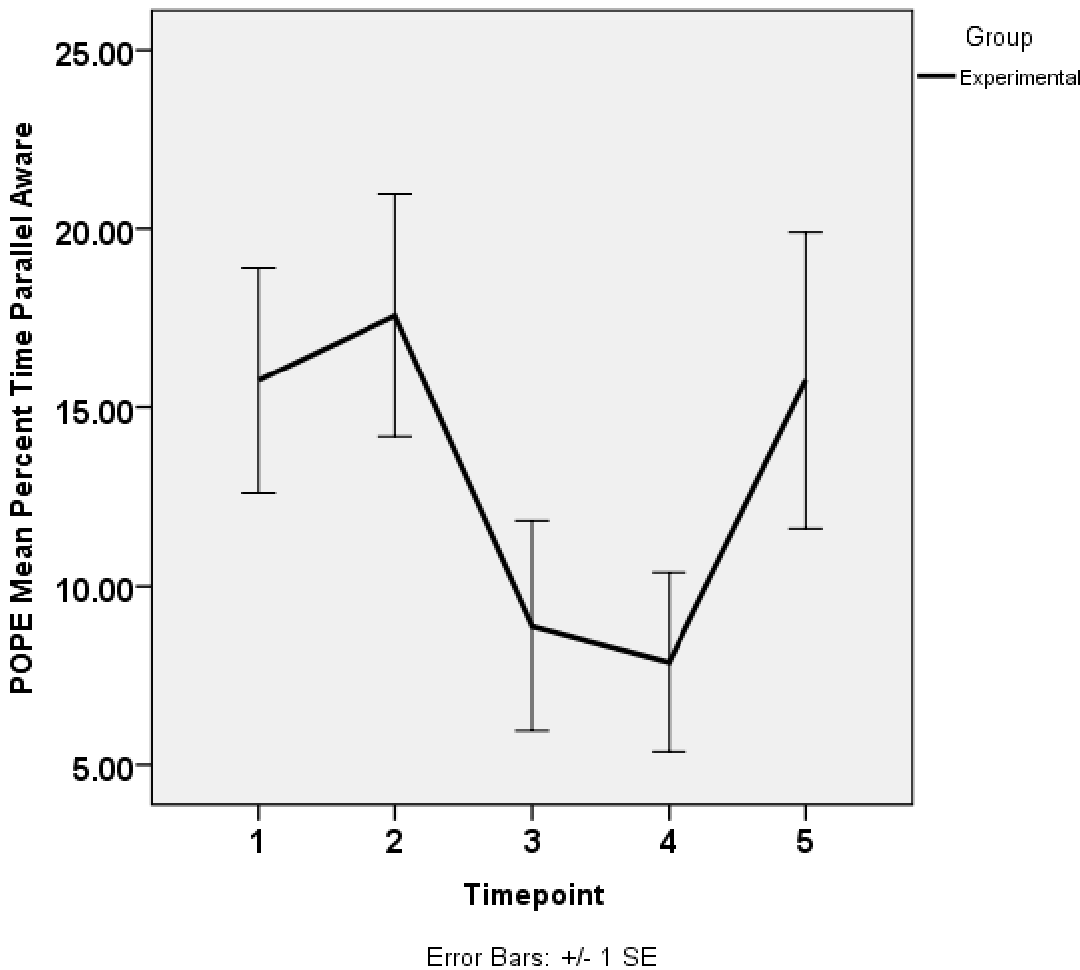


Figure 3.16 Change in percent time spent parallel aware from baseline to week 8 (measured biweekly)

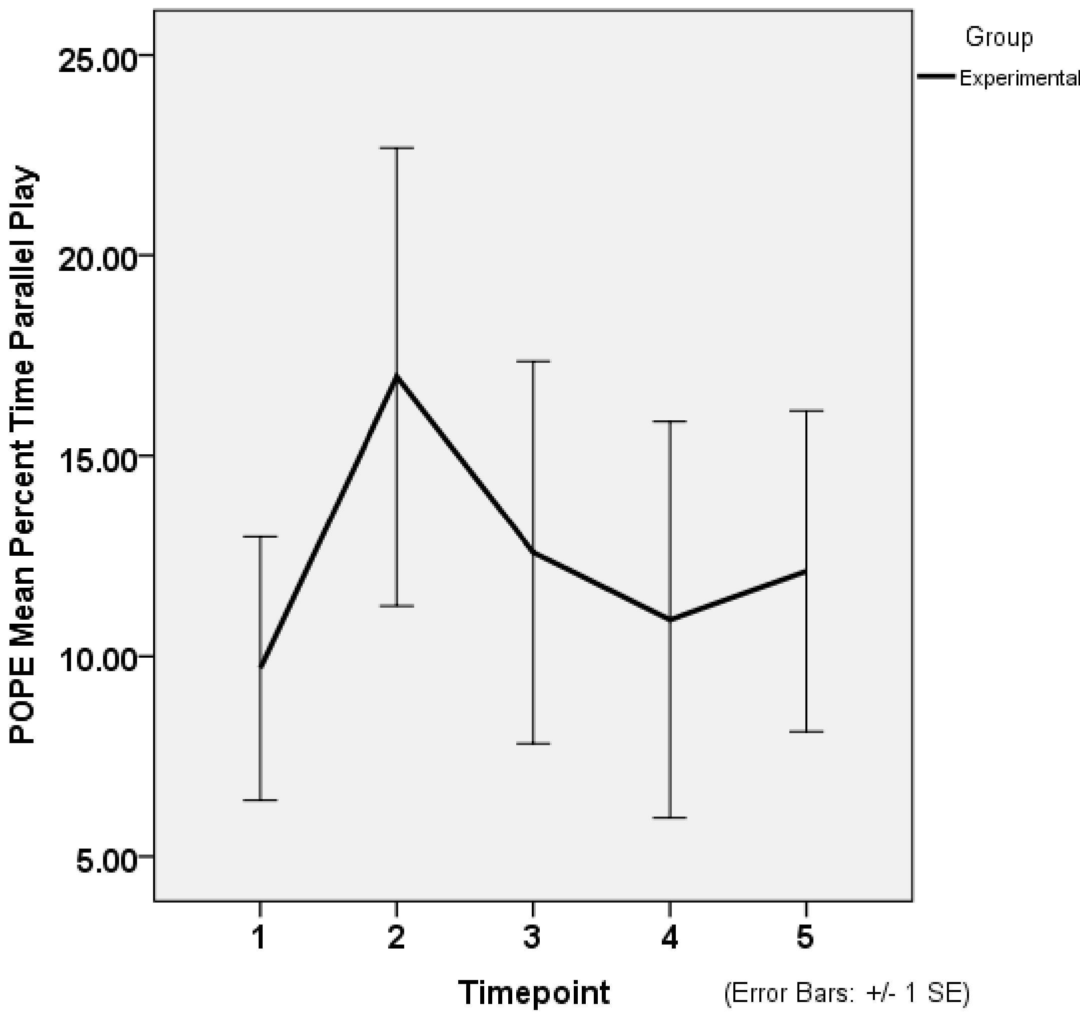


Figure 3.17 Change in percent time spent in parallel play from baseline to week 8 (measured biweekly)

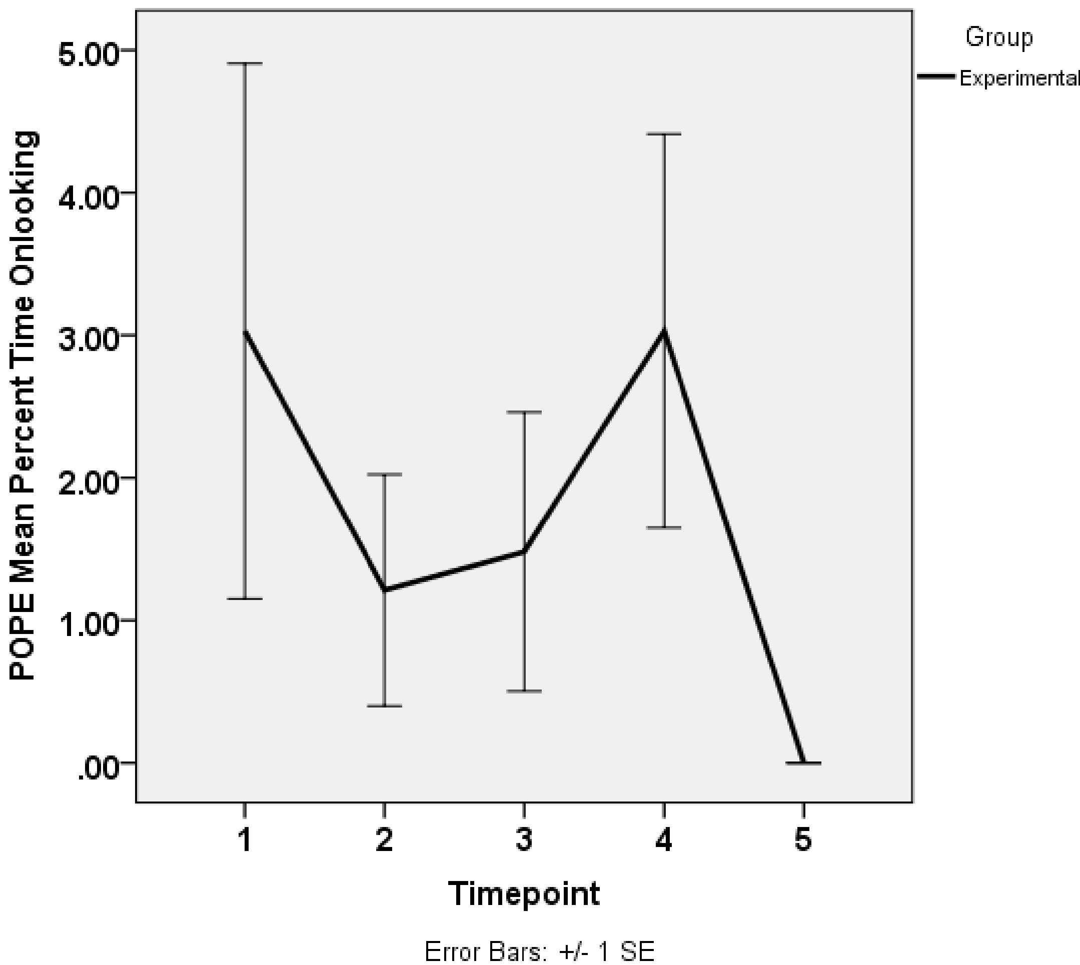


Figure 3.18 Change in percent time spent in onlooking from baseline to week 8 (measured biweekly)

APPENDIX

Appendix 1.1 Group differences in physical activity categories after controlling for *MSEL* cognitive scores

	F (df)
SPA	F(1,52)=4.94*
LPA	F(1, 52) =6.05*
MPA	F(1,52)=1.98
MVPA	F(1,52)=2.23
VPA	F(1,52)=1.92

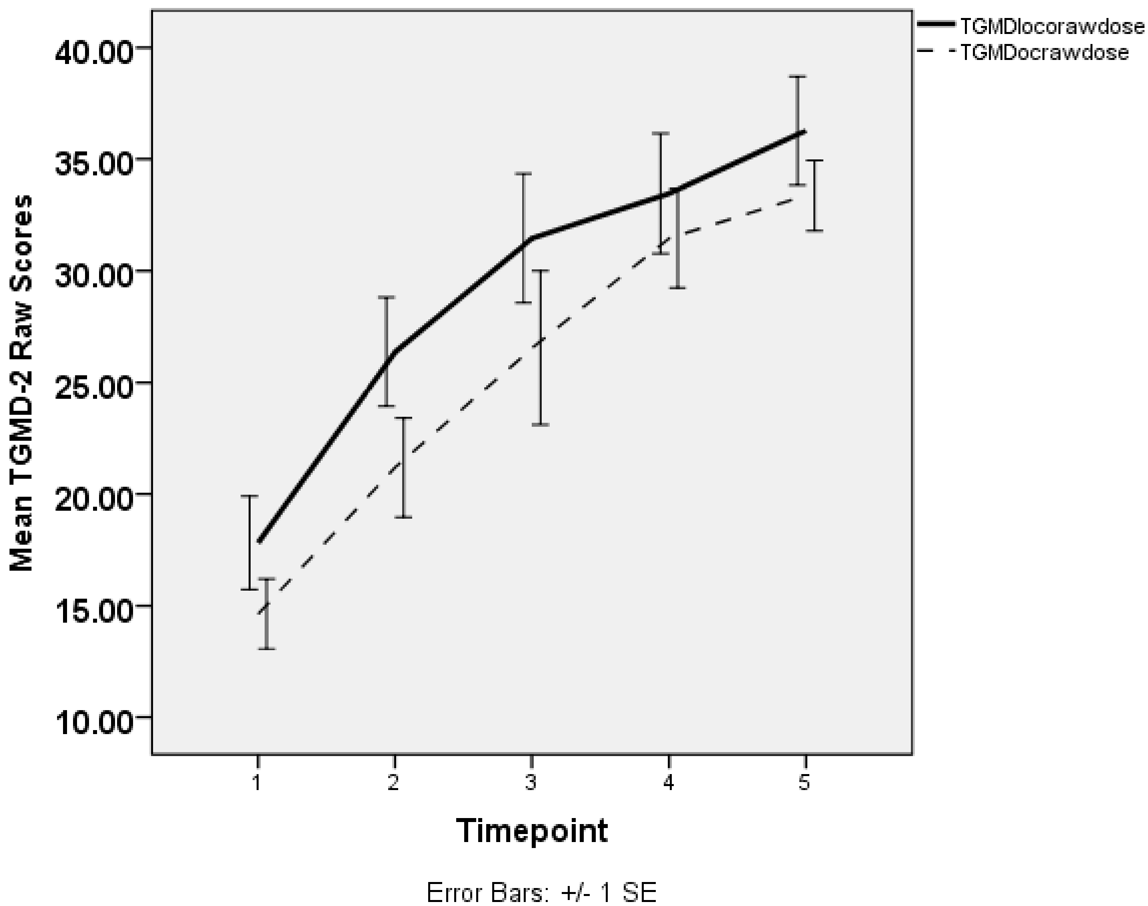
MSEL=Mullen scales of early learning; SPA=Sedentary physical activity; LPA=Light physical activity; MPA=moderate physical activity; MVPA=Moderate to vigorous physical activity; VPA=Vigorous physical activity; DF=degrees of freedom; F=F test; *$p < 0.05$; ** $p < 0.01$; *** $p \leq 0.001$

Appendix 2.1 Pairwise comparison for *TGMD-2* locomotor raw scores, object control raw scores and gross quotient between time points for experimental group only

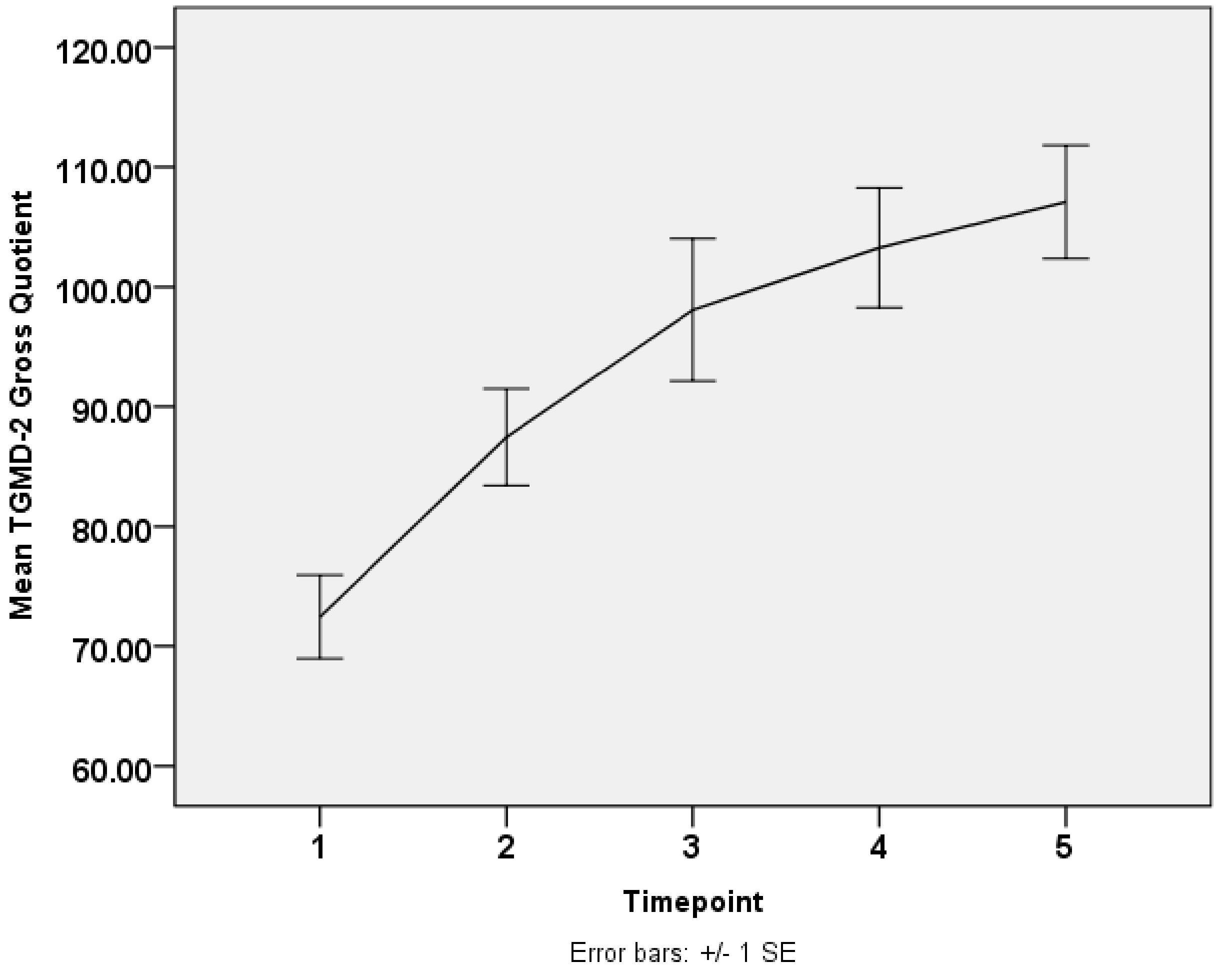
	Locomotor		Object control		Gross quotient	
Weeks compared to baseline						
	M(SD)	T(df)	M(SD)	T(df)	M(SD)	T(df)
0	17.81(6.91)	-	14.63(5.20)	-	72.45(11.60)	-
0-2	26.36(8.11)	-3.54 (1,10)*	21.18(7.35)	-3.59(1,10)*	87.45(13.40)	-3.55(1,10)*
0-4	31.46(9.58)	-7.68 (1,10)***	26.55(11.46)	-3.61(1,10)*	98.09(19.73)	-4.49(1,10)*
0-6	33.45(8.91)	-8.36 (1,10)***	31.45(7.35)	-6.65(1,10)***	103.27(16.57)	-5.62(1,10)***
0-8	36.27(8.10)	-8.63 (1,10)***	33.36(5.22)	-11.57(1,10)***	107.09(15.66)	-6.52(1,10)***
Weeks compared to 2						
2	26.36(8.11)	-	21.18(7.35)	-	87.45(13.40)	-
2-4	31.46(9.58)	-2.48(1,10)*	26.55(11.46)	-2.16(1,10)*	98.09(19.73)	-3.33(1,10)*
2-6	33.45 (8.91)	-3.37(1,10)*	31.45(7.35)	-4.14(1,10)*	103.27(16.57)	-4.74(1,10)*
2-8	36.27 (8.10)	-5.46(1,10)***	33.36(5.22)	-6.68(1,10)***	107.09(15.66)	-6.20(1,10)***
Weeks compared to 4						
4	31.46(9.58)	-	26.55(11.46)	-	98.09(19.73)	-
4-6	33.45(8.91)	-1.26(1,10)	31.35(7.35)	-1.79(1,10)	103.27(16.57)	-1.41(1,10)
4-8	36.27(9.59)	-3.41 (1,10)*	33.36(5.22)	-2.64(1,10)	107.09(15.66)	-2.87(1,10)*
Weeks compared to 6						
6	33.45(8.91)	-	31.35(7.35)	-	103.27(16.57)	-
6-8	36.27(8.10)	2.82(1,10)*	33.36(5.22)	-1.09(1,10)	107.09(15.66)	-1.22(1,10)

M=Mean; SD=Standard deviation; TGMD-2=Test of Gross Motor Development-2; df=Degrees of freedom; *p<.05, **p<.001, ***p<.0001

Appendix 2.2 Change in experimental group mean raw scores on *TGMD-2* locomotor and object control by time point



Appendix 2.3 Change in experimental group *TGMD-2* gross quotient scores by time point

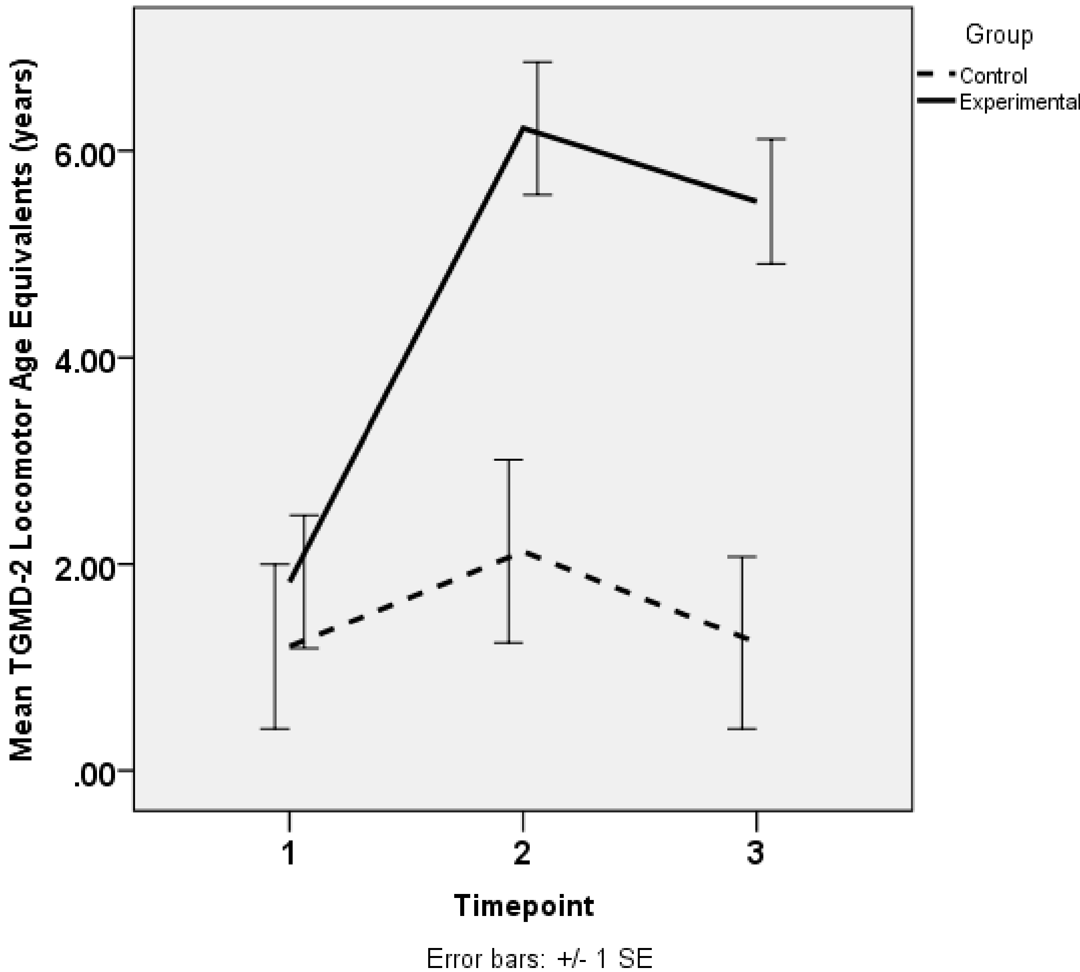


Appendix 3.1 Within group differences in pre, post and maintenance time points in age equivalents (years) on *TGMD-2*

Timepoint	Pre (1)	Post (2)	Maintenance (3)
Control	1.03	1.60	1.23
Experimental	1.82	6.21*	5.50

**p*<.05, ***p*<.001, ****p*<.0001; Note: Object control could not run due to gender distribution

Appendix 3.2 Change in *TGMD-2* locomotor age equivalents (years) by time point

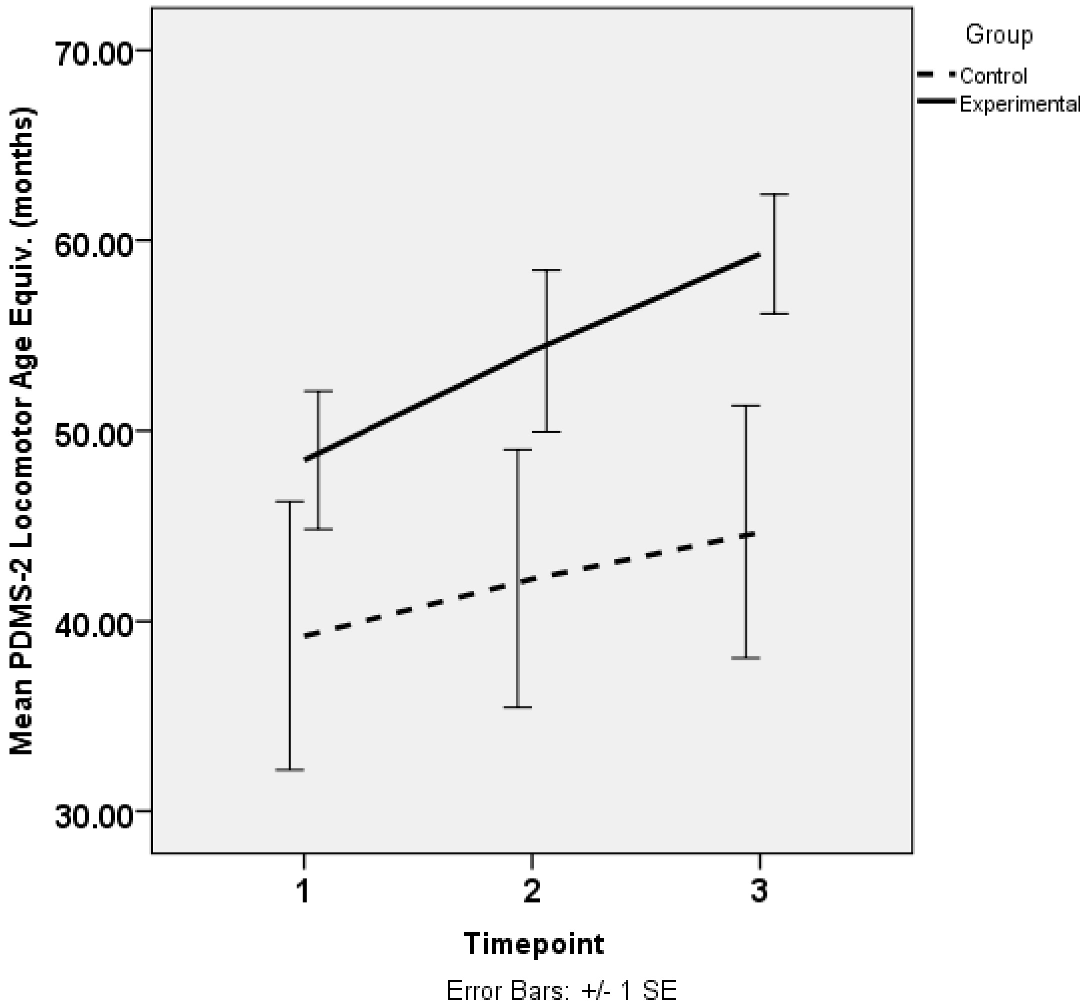


Appendix 4.1 Within group differences in pre to post time points in age equivalents (months) on *PDMS-2*

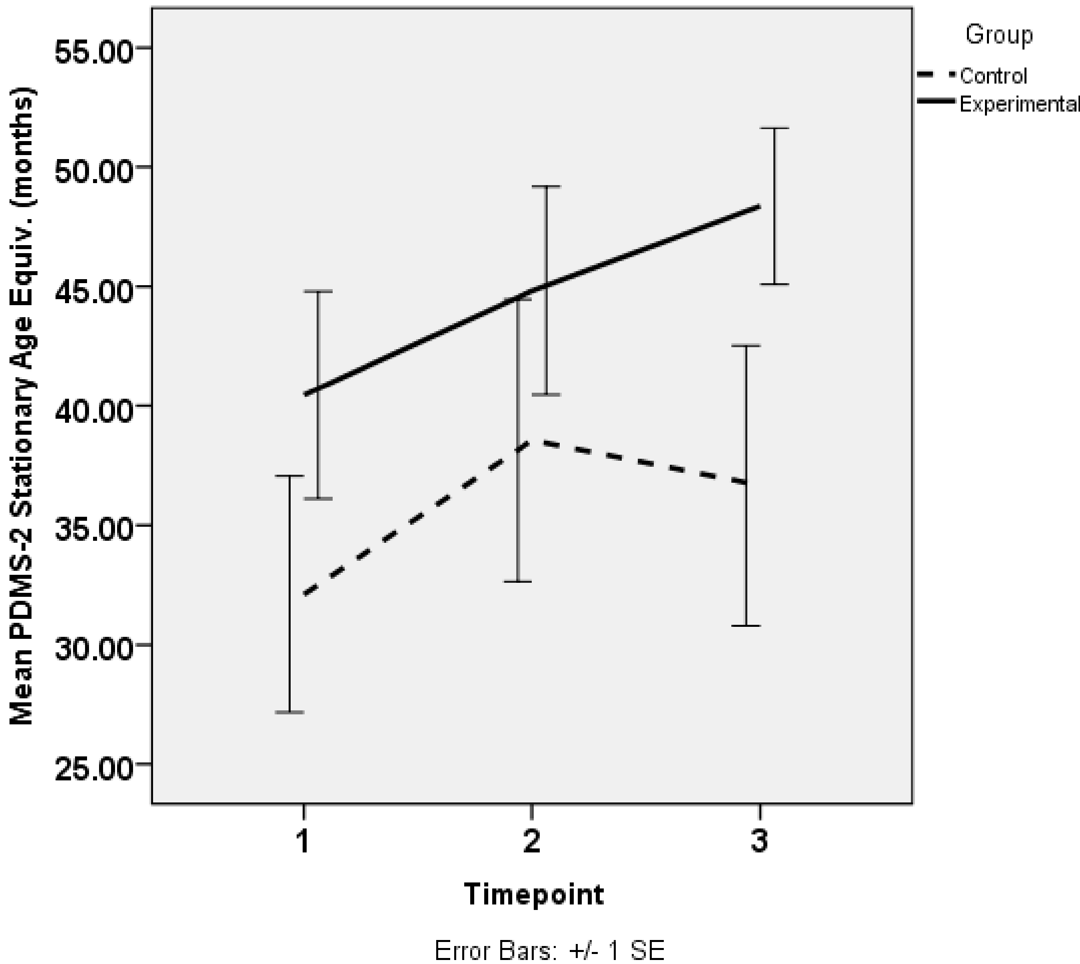
	PDMS-2 Stationary			*PDMS-2* Object manip.			*PDMS-2* Locomotor		
Timepoint	Pre (1)	Post (2)	Main. (3)	Pre (1)	Post (2)	Main. (3)	Pre (1)	Post (2)	Main. (3)
Experimental	42.99	48.71	53.81	33.88	40.33	41.51	36.58	40.94	44.49
Control	45.91	48.91	51.35	33.82	37.88	37.15	36.85	43.29	41.41

PDMS-2=Peabody Developmental Motor Scales – 2; *P<.05, **p<.001, ***p<.0001

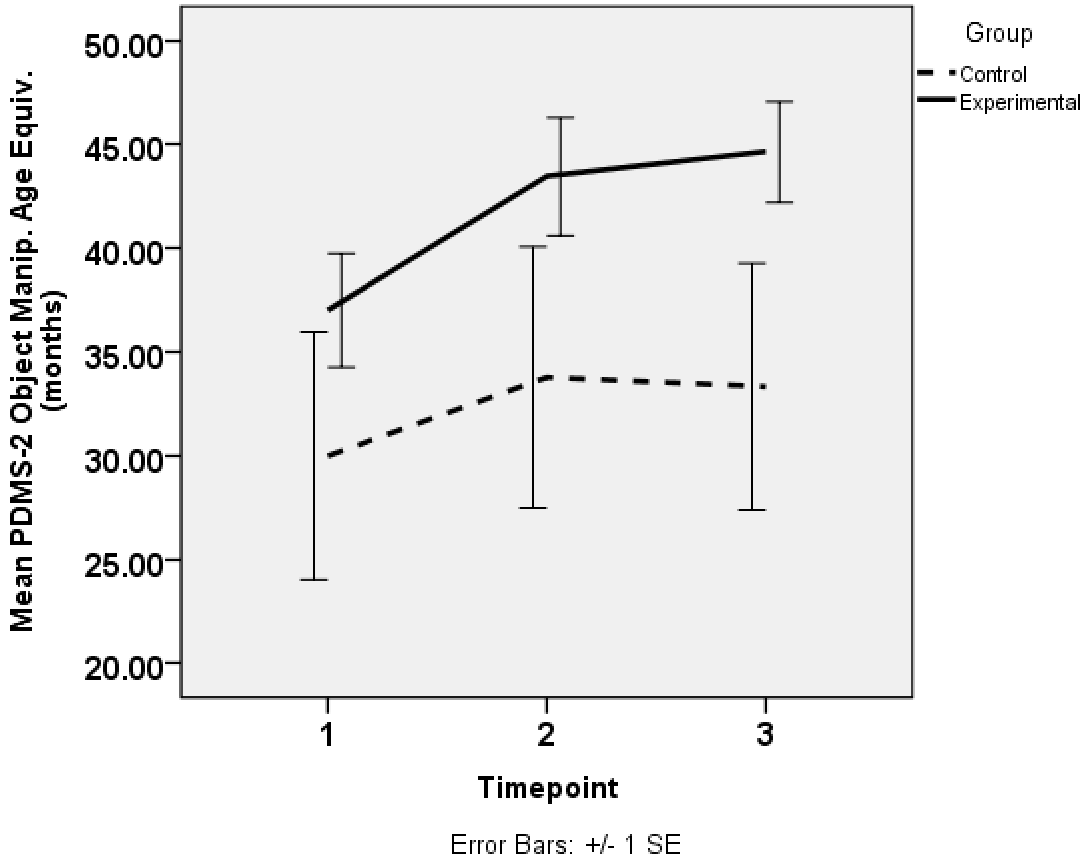
Appendix 4.2 Change in *PDMS-2* locomotor age equivalents (months) by time point



Appendix 4.3 Change in *PDMS-2* stationary age equivalents (months) by time point



Appendix 4.4 Change in *PDMS-2* object manipulation age equivalents (months) by time point



Appendix 5.1 Policy Statement

The alarming rise in Autism Spectrum Disorders (ASD) diagnosis should be considered an important health concern as individuals with ASD exhibit delays and deficits that can persist and worsen through their lifespan. Early intervention that is evidence based has been repeatedly shown to reduce disparities and lead to a higher quality of life for individuals with ASD. The research to date examining the motor skills in young children ASD suggests that significant motor delays are evident when comparisons are made to typically developing peers or normative data. Furthermore, the physical activity (PA) levels in youth with ASD have been shown to decrease with age.

Since best practices in early intervention recommend implementing evidence-based programs, strategies from Classroom Pivotal Response Teaching (CPRT) were implemented as the framework for instruction during an 8 week long early and intensive motor skill intervention for young children with ASD (aged 4 – 6).

Nineteen children participated in this study, findings revealed that participants in the experimental group significantly improved their overall gross motor skills including both locomotor (i.e.: running, hopping, galloping) and object control skills (i.e. kicking, striking, rolling). Findings also revealed an increase in socialization throughout the intervention, with an increase in social states resulting in more peer interaction and a decrease in a social state that results in isolation. Although the levels of PA did not change following the intervention, the frequent repetitive behaviors may have contributed to these findings.

Results from this intervention should be used to inform policy makers to include motor skill programming as part of the comprehensive early intervention services delivered to young children with ASD.

Appendix 5.2 Next Steps – Research Agenda

The majority of evidence based treatments for young children with autism spectrum disorders (ASD) have focused on interventions targeting core deficits in the social and communication domain as well as intervening on problem stereotypical behaviors. This is despite recent evidence to suggest that children with ASD have motor delays early in development and more advanced motor behaviors help facilitate social and communication opportunities during play. There are very few evidence based treatments targeting the motor behavior in children with ASD. Therefore the aim of this study is twofold: to examine motor and physical activity (PA) trajectories throughout preschool development, and to test short and long term effects of an intense 8 week motor skill intervention for 4-5 year old children with ASD.

Previous research would support that there is an age related decline in physical activity levels in individuals with ASD, however it is unknown when PA patterns are established and how they change in young children with ASD. Furthermore, previous research has demonstrated that the motor skills in middle school and high schooled age children with ASD are significantly behind their chronologically age matched peers in , however this has been relatively underexplored in young children with ASD. **Specific Aim 1:** To examine the motor and physical activity (PA) trajectories of young children with ASD from age 2 through 5 years. **Hypothesis 1:** The motor delays (as measured by the Test of Gross Motor Development -2 (TGMD-2) will increase over time relative to normative data. **Hypothesis 2:** The trajectory of objectively measured PA (using accelerometers and validated PA cut points) will reveal lower levels of PA with each successive developmental year. **Hypothesis 3:** Children with more proficient motor skills will have higher levels of PA; similarly, children with less proficient motor skills will have lower levels of PA.

Despite research that suggests motor delays are among the first indicators of an ASD diagnoses, to date there are no evidence based motor interventions for young children with ASD. **Specific Aim 2:** To examine the short and long term effects of an 8 week motor skill intervention employing Classroom Pivotal Response Treatment (CPRT) embedded into the intensive motor skill instruction. The proposed motor intervention will randomized children into the experimental group (those who receive the intervention) and control group (those who do not receive the intervention). This type of intervention will be early and intensive meaning it will be conducted daily, for 25 hours per week and will have a 1:1 ratio (researcher: participant) enabling a constant dyad of instruction. Furthermore, the intervention will be delivered in a naturalistic setting paralleling a youth sport camp environment. **Hypothesis 1:** There will be a short term increase in motor skills from one week pre intervention to one week post intervention. **Hypothesis 2:** There will be a long term increase in motor skills from one week pre intervention to 3 months post intervention. Next, recent findings have revealed that children with disabilities are failing to meet the recommended physical activity (PA) guidelines. These findings are concerning since low activity levels of PA early in development have been linked to an increased risk of obesity, cardiovascular disease, type 2 diabetes, and negative psychosocial well being.

Since motor skills are often considered building blocks for the advanced movement patterns required for participation later on life, examining the proficiency in movement skills early in development may shed light on factors contributing to the trends of physical inactivity. **Specific Aim 3:** To determine if motor skills are related to physical activity levels in children with ASD, at 1 week pre intervention and 1 week and 3 months post intervention**. Hypothesis 1**: Children with more proficient motor skills will have higher levels of physical activity at 1 week pre intervention. **Hypotheses 2:** Children who make significant improvement in their motor skills during the intervention will demonstrate a short term increase in their levels of physical activity measured one week post intervention. **Hypothesis 3:** Children who make significant improvement in their motor skill proficiency during the intervention will demonstrate a long term increase in their levels of PA measured 3 months post intervention.