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The levels of physical activity and motor skills in young children with and without autism spectrum disorder, aged 2–5 years

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Abstract

Autism spectrum disorder is the fastest growing developmental disability in the United States. As such, there is an unprecedented need for research examining factors contributing to the health disparities in this population. This research suggests a relationship between the levels of physical activity and health outcomes. In fact, excessive sedentary behavior during early childhood is associated with a number of negative health outcomes. A total of 53 children participated in this study, including typically developing children (mean age = 42.5 ± 10.78 months, n = 19) and children with autism spectrum disorder (mean age = 47.42 ± 12.81 months, n = 34). The t-test results reveal that children with autism spectrum disorder spent significantly less time per day in sedentary behavior when compared to the typically developing group ($t(52) = 4.57$, $p < 0.001$). Furthermore, the results from the general linear model reveal that there is no relationship between motor skills and the levels of physical activity. The ongoing need for objective measurement of physical activity in young children with autism spectrum disorder is of critical importance as it may shed light on an often overlooked need for early community-based interventions to increase physical activity early on in development.

Keywords

autism spectrum disorders, motor skills, physical activity, preschool children

Autism spectrum disorder (ASD) is the fastest growing developmental disability in the United States (Baio, 2012). As such, there is an unprecedented need for research examining factors contributing to the health disparities in this population. This research suggests a relationship between the levels of physical activity and health outcomes (Humphreys et al., 2014). In addition, excessive sedentary behavior during early childhood is associated with a number of negative health outcomes (Van Ekris et al., 2016). Among physical activity guidelines from the Society of Health and Physical Educators (SHAPE) (2009), preschool-aged children should engage in a minimum of 60 min of structured and 60 min of unstructured physical activity each day. Furthermore, recommendations from the United States Department of Health and Human Services (USDHHS; Physical Activity Guidelines Advisory Committee, 2008) recommend that children 6–17 years of age participate in a minimum of 60 min of moderate to vigorous physical activity (MVPA) every day. Despite these recommendations, children with ASD have been found to participate in less physical activity than in children with typical development (McCoy et al., 2016).

Measuring habitual physical activity (daily/weekly physical activity) is helpful in determining whether children are meeting minimal or cumulative thresholds for recommended totals. In one such study, objective physical activity was measured in children with and without ASD (aged 3–11 years; Bandini et al., 2012). After controlling for age and sex, peers of typical development accumulated a significantly greater adjusted mean score for moderate physical activity (MPA) during the weekdays than children with ASD (Bandini et al., 2012). However, only 43% of children who were of typical development met the minimum recommendation from USDHHS (Physical Activity Guidelines Advisory Committee, 2008) achieving 60 min of daily MVPA, compared with just 23% of children with

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ASD (Bandini et al., 2012). Next, differences in objective physical activity patterns (defined periods of day) were examined in children with and without ASD (aged 7–12 years; Pan, 2008). Children with ASD were found to spend just 27.70% of recess time engaged in physical activity at a moderate intensity or higher compared to children with typical development who spent 36.15% of time at a moderate or higher intensity (Pan, 2008). In a separate study, physical activity outcomes in a group of children with and without ASD (mean age = 14 years) were evaluated during an inclusive physical education class (Pan et al., 2011). Children with ASD were found to spend a less percent of time in MPA, vigorous physical activity (VPA), and MVPA than their peers of typical development, although these findings were not significant (Pan et al., 2011). When considering mean steps per minute, children with ASD accumulated a significantly lower total score than children with typical development (Pan et al., 2011). While this research suggests that school-aged children with ASD are less physically active than their peers, the rise in physical inactivity has recently been cited as a contributor to the growing health disparity (Myers et al., 2016).

Children and adolescents are less physically active and more sedentary today than they were 10 years ago (Bassett et al., 2015). Further complicating this trend, children with ASD experience fewer opportunities to engage in health enhancing physical activity than their peers of typical development (Obrusnikova and Cavalier, 2011). Based on the National Survey of Children's Health (2011–2012), when compared to children with typical development, adolescents with ASD are 60% less likely to engage in regular physical activity and 74% less likely to have participated in an organized sport (McCoy et al., 2016). Furthermore, based on parental report, children with ASD (aged 3–11 years) were found to spend significantly less time participating in physical activities and engaged in a smaller variety of activities than compared to children with typical development (Bandini et al., 2012). Using the Children's Assessment of Participation and Enjoyment (CAPE; King et al., 2000), the frequency and regularity of health enhancing participation activities were low among youth with ASD with declining regularity and levels of MVPA as youth aged (Pitchford et al., 2013). Regular participation averaged only one to two times per month and common activities included swimming, walking/hiking, using play equipment, and individual physical activities. Next, as parent report of ASD severity increases, the likelihood of engaging in regular physical activity significantly decreases (McCoy et al., 2016). Specifically, parents who classified their child's ASD symptoms as severe were 70% less likely to engage in physical activity when compared to their peers with typical development (McCoy et al., 2016). Therefore, this research suggests children with ASD are less active and more likely to experience sedentary behavior than their peers of typical development. One known facilitator to physical activity in children with typical development is proficiency in motor skills (Logan et al., 2015); generally those with greater motor skill competence are more physically active. However, this research suggests children with ASD experience pervasive motor skill delays (Landa and Garrett-Mayer, 2006; Lloyd et al., 2013) which persists and worsens throughout development.

Beginning as early as 6 months of age, there are qualitative and quantitative differences in the acquisition and achievement of early movement skill milestones in high-risk infants (i.e. older sibling with ASD) or children who later receive a diagnosis of ASD (Flanagan et al., 2012; Teitelbaum et al., 1998). In one such study, the gross motor development of infants at high and low risk was evaluated in the first 6 months of life (Bhat et al., 2012). Findings revealed that high-risk infants demonstrated significantly greater gross motor delay based on outcomes from the Alberta Infant Motor Scale (AIMS; Fleuren et al., 2007) precipitate by poor scores across the prone and supine sub-scales (Bhat et al., 2012). Unfortunately, this research supports that gross motor delays persists and become more pronounced with age (Lloyd et al., 2013). In a large cross-sectional study examining the gross and fine motor scores in toddlers with ASD, the Mullen Scales of Early Learning (MSEL; Mullen, 1995) was administered to a subset of children longitudinally, where gross and fine motor delays at 36 months of age were significantly larger than when compared to 12 months of age (Lloyd et al., 2013).

Descriptive research examining motor outcomes across several subgroups is helpful in determining whether children with ASD exhibit a specific trajectory of motor outcomes. In a large sample of toddlers, 17–36 months, children were grouped by disability according to *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; DSM IV) criteria, including autism, pervasive developmental disorder—not otherwise specified (PDD-NOS), and atypical development (i.e. those not meeting ASD criteria). Children were assessed using the *Battelle Developmental Inventory-2* (BDI-2; Newborg et al., 1998); findings reveal that children with autism exhibited significantly greater gross and fine motor impairments than in children with PDD-NOS or atypical development (Matson et al., 2010). These findings are further supported when children with ASD aged 3–4 years were evaluated using the Peabody Developmental Motor Scales, second edition (PDMS-2; Folio and Fewell, 2000) and were found to achieve very poor motor skills compared to what would be expected given the normative data (Jasmin et al., 2009). In a separate study, the Movement Assessment Battery for Children-2 (MABC-2) (Henderson et al., 2007) was administered to children and youth with and without ASD aged 3–16 years; findings revealed that when compared to their peers of typical development, children with ASD exhibited significantly lower gross and fine motor percentile scores. Therefore, while motor skill delays appear to be a ubiquitous feature of children with ASD, it is promising that recent research suggests that motor skill interventions can positively influence motor skill acquisition (Bremer et al., 2015; Bremer and Lloyd, 2016; Ketcheson et al., 2016). However, the contribution of poor motor skills in the facilitation of physical activity has been relatively underexplored in this population.

In preschool-aged children who are typically developing, the relationship between motor skills and the levels of physical activity is contradictory. In a recent systematic review of literature examining the relationship between motor skill competence and physical activity in preschoolers (aged 3–5 years), of the 11 articles which met inclusion criteria, 8 of them reported a significant relationship between motor outcomes and physical activity (Figueroa and An, 2016). However, methodological differences (self-reported physical activity vs objective measurement) were found to be one factor making it difficult to draw any conclusive statements about this relationship (Figueroa and An, 2016). While these findings are intriguing, in a separate study, motor thresholds were examined as it relates to the levels of physical activity (Williams et al., 2008). Children who were in the highest quartile of motor proficiency spent significantly more time in MVPA and VPA and significantly less time in sedentary physical activity (SPA) than children in lower quartiles (Williams et al., 2008; Wrotniak et al., 2006). Next, when fundamental motor skills (i.e. object control and locomotor skills) and objectively measured physical activity were evaluated in a group of preschool boys (aged 3–5 years), a positive association was found between motor proficiency in object control skills (i.e. strike, catch, throw) and percent of time in MPA, MVPA, and total physical activity (Cliff et al., 2009a). Next, in a large study with 2-year-old children who were typically developing, no correlation was found between fine, gross, or total movement scores and objectively measured physical activity (Johansson et al., 2015) Similarly, in a group of preschool-aged children (mean age = 4 years), total motor proficiency (i.e. stability, locomotion, and manipulative skills) was not significantly associated with directly observed physical activity (Livonen et al., 2016). Therefore, while this relationship remains somewhat inconclusive in preschool-aged children, there appears to be more consensus as children age, suggesting that the association between motor skills and physical activity albeit weak early on actually strengthens throughout development (Stodden et al., 2008). However, this relationship remains relatively underexplored in young children with ASD.

To date, much of physical activity research in ASD has prioritized school-aged children (McCoy et al., 2016; MacDonald et al., 2011; Pan et al., 2016), rendering little insight regarding the objective levels of physical activity in young children with ASD. Next, when factors including the levels of physical activity are examined as potential correlates, there is little conclusive evidence that this relationship exists early on in development. Therefore, the primary aim of this study was to objectively measure the physical activity levels of young children (aged 2–5 years) with ASD and to compare those results to children with typical development. The secondary aim of this study was to examine the relationship between objectively measured physical activity and motor skills in young children with ASD and their peers of typical development. The need for objective measurement of physical activity in young children with ASD is of critical importance as it may shed light on an often overlooked need for early community-based interventions to increase physical activity early on in development.

Methods

Participants

For recruitment, study information was shared with Early On programs in the South East Michigan region; also flyers were distributed to local ASD parent support groups. Children were recruited to participate in this study if they were between 2 and 5 years of age and met ASD criteria based on the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 1999). Additionally, children were included if they completed the motor and physical activity requirements for this study. Children with typical development ranged in age from 26 to 62 months (mean age = 42.5 ± 10.78 months), and children with ASD were between 24 and 68 months (mean age = 47.42 ± 12.81 months).

Procedures

All study procedures were approved by the Health Sciences Institutional Review Board.

First informed consent (and when appropriate, child assent) was administered to the parents and child, respectively. Next, the MSEL (Mullen, 1995) was administered for two purposes. First, the outcome from the MSEL was used to describe the IQ in the research sample. Second, outcomes in MSEL assisted researchers in determining the most appropriate module to administer in the ADOS. Following the administration of the ADOS, the PDMS-2 was evaluated in each participant as our measure of gross and fine motor skills (Folio and Fewell, 2000). Next, the protocol for physical activity measurement was described by the administration of a social story. All assessments were completed in half a day in a laboratory setting with the exception of the objective measure of physical activity which was completed over 1 week in the participants' home environment.

Descriptive measures and diagnostic instruments

The MSEL is a standardized assessment of cognitive functioning for young children (aged 0–68 months). Four scales (non-verbal problem solving, fine motor, and receptive and expressive language) were combined to determine a measure of cognition. If a child's score fell within basal norms (*t*-scores of at least 20 on each sub-scale), full-scale IQs were calculated using both verbal and non-verbal sub-test age equivalents. If it was not possible to calculate IQ scores (*t*-scores fell below 20 on each sub-scale), then ratio IQs were calculated. The non-verbal ratio IQs were calculated by taking the mean of non-verbal sub-tests' age equivalents. Once the mean of the non-verbal sub-tests was 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 IQs have been previously cited as a method to describe IQ for children with ASD (Lloyd et al., 2013; Richler et al., 2007).

All children with ASD who were enrolled into the study had previously received an ASD diagnoses from a practitioner. A verbal confirmation of this diagnosis was provided to the research team. However, in order to confirm this diagnosis of ASD, an ADOS was administered for research purposes. This assessment evaluates characteristics of ASD through a standardized protocol which elicits a measure of imagination, social interaction, play, and communication. Participants in this study were administered either a Module 1 (for children who use little or no phrase speech) or Module 2 (for children who use phrase speech but not yet fluent). In order to obtain a measure of severity of ASD symptoms, calibrated severity scores (CSSs) were calculated by raw scores on a revised algorithm (Gotham et al., 2009). Participants could score in one of three classifications, on a scale ranging from 0 to 10. The ADOS was conducted by an experienced, research reliable assessor.

Outcome variables

The PDMS-2 is a valid and reliable standardized assessment developed to measure gross and fine motor skills in children birth through 71 months of age (Folio and Fewell, 2000). The *PDMS-2* is comprised of six sub-tests, 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 and Fewell, 2000). The reflex sub-test was not used in this study because all of the children in this study were >24 months of age (Folio and Fewell, 2000). The reflex sub-test was not used in this study because all the children in this study were >24 months of age. For the purpose of this study, motor quotients were used in the analyses. Motor quotients are computed by summing the sub-test standard scores from the gross, fine, and total motor skills, which are then converted into a quotient. The Gross Motor Quotient (GMQ) includes stationary, locomotion, and object manipulation sub-tests while the Fine Motor Quotient (FMQ) includes grasping and visual motor integration. The Total Motor Quotient (TMQ) summarizes 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 30% of the administered PDMS-2. Percent agreement on assessments ranged from 0.96 to 1.00.

Physical activity was evaluated with Actigraph GT3X+ accelerometers (Pensacola, FL, USA), which are small and lightweight devices designed to measure acceleration in three planes of movement. All physical activity data were collected during the spring months which represented a cold to moderate period in the region where participants resided. Study participants were told to wear the monitor around their waist above their right iliac crest for 7 continuous days. Placement around the waist was selected as it represents best practices in objective physical activity in preschool-aged children (Cliff et al., 2009b). A log was provided to each family in order to record periods of non-wear time, not including sleep time. For example, when the monitor was removed for swim or bath time. All accelerometers were returned after 7 days by priority mail.

Accelerometer data were downloaded using Actilife 6 software. Based on best practices for physical activity measurement in young children, participants were included in the analysis if they wore the monitor for a minimum of 10 h per day for 5 days including a weekend day (Trost et al., 2000). Furthermore, families were instructed to remove the accelerometer during nap time and evening hours. Next, previous research supports the use of a 15-s epoch in preschool-aged children (Cliff et al., 2009b), and therefore it was applied to evaluate all physical activity data. Cut points were selected based on a review of literature examining methodological considerations in the evaluation of physical activity in children 0–5 years of age (Cliff et al., 2009b). Physical activity data were cleaned, reduced, and categorized into one of five physical activity levels. Cut points included SPA (counts of <799), light physical activity (LPA; 800–1679), and MPA (1680–3367); MVPA was calculated as the mean of the sum of MPA and VPA (⩾3368; Pate et al., 2006).

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 22). In children with ASD, preliminary analysis revealed that physical activity was not significantly related to autism severity (CSS) or IQ, nor was there a relation with age or gender in either group. For this reason, age and gender were combined for subsequent analyses.

The primary aim of this study was to describe and compare the levels of physical activity in young children with ASD and a group of peers who were typically developing. In order to compare whether the two groups differed significantly from one another based on percentage of time spent in each of the five physical activity levels (SPA, LPA, MPA, MVPA, and VPA), *t*-tests were performed.

The secondary aim of this study was to examine the relationship of motor quotients as measured on the PDMS-2 with the levels of physical activity (in each of the five physical activity categories) in young children with ASD and a group of typically developing children. First, *t*-tests were computed to examine 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. Second, an analysis of variance (ANOVA) was used to compare the two groups in terms of the relationship of physical activity outcomes with motor skill competence. Finally, a general linear model (GLM) was used to determine whether the levels of physical activity differed between groups after controlling for differences in motor quotients wear time and IQ.

Results

Descriptive statistics are presented in Table 1. Differences in physical activity by group were examined using *t*-tests. Children with ASD spent significantly less time per day in the mean SPA category when compared to the group with typical development ($t(52)=4.57$, $p<0.001$). 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 group with typical development ($t(52)=-5.25$, $p<0.001$). Next, the results from the daily mean MPA category revealed that children with ASD spent significantly more time in MPA than the group with typical development ($t(52)=-4.02$, $p<0.001$). Similarly, the results from the daily mean MVPA category reveal that the ASD group spent significantly more time in this category compared to the group with typical development ($t(52)=-3.81$, $p<0.001$). Finally, the ASD group spent significantly more time in VPA than the group with typical development ($t(52)=-2.56$, $p<0.05$; see Figure 1).

Next, motor quotient scores were analyzed by group (see Figure 2). The group with typical development achieved a significantly greater gross ($t(52)=5.72$, $p<0.001$), fine ($t(52)=4.12$, $p<0.001$), and total ($t(52)=5.83$, $p<0.001$) motor quotient when compared to the ASD group, regardless of autism severity (CSS).

For the relationship between the levels of physical activity and motor skills, the ANOVA results reveal that there are no significant relationships between motor quotients and any of the physical activity categories within groups. Next, the direction and significance of differences in the levels of physical activity between groups persisted after controlling for motor quotients, IQ, and wear time in a GLM (see Table 2). Specifically, there was a significant difference in SPA after controlling for the gross ($F(1, 52)=8.47$, $p=0.006$), fine ($F(1, 52)=6.31$, $p=0.015$), and total motor ($F(1, 52)=8.12$, $p=0.006$) quotients. For LPA, there was a significant difference after controlling for the gross ($F(1, 52)=13.75$, $p=0.001$), fine ($F(1, 52)=11.59$, $p=0.001$), and total motor ($F(1, 52)=12.68$, $p=0.001$) quotients. For MPA, there was a significant difference between groups after controlling for gross ($F(1, 52)=5.02$, $p=0.030$), fine ($F(1, 52)=3.66$, $p=0.062$), and total motor ($F(1, 52)=4.80$, $p=0.034$) quotients. For MVPA, there was a significant difference after controlling for the gross ($F(1, 52)=4.77$, $p<0.034$), fine ($F(1, 52)=3.29$, $p=0.076$), and total motor ($F(1, 52)=4.64$, $p=0.036$) quotients. Finally, for VPA there are significant differences after controlling for the gross ($F(1, 52)=2.67$, $p=0.109$), fine ($F(1, 52)=1.52$, $p=0.223$), and total motor ($F(1, 52)=2.70$, $p=0.107$) quotients.

Discussion

The National Standards Project (NSP) named physical exercise as 1 of 22 emerging treatments for children and young adults with autism (National Autism Center, 2009). Despite these recommendations, to date, very little is known regarding the levels of physical activity in young children with ASD. This study adds to the growing but limited data on the physical activity levels in young children with ASD. The current findings extend outcomes from Bandini et al. (2012) by exploring the relationship between physical activity and motor skills. Despite both groups meeting or exceeding minimum MVPA recommended guidelines, it is important to note that the majority of their time was spent engaging in sedentary activity. This is concerning since low levels of physical activity early in life have been cited as a factor contributing to the obesity epidemic (Nemet, 2016). Additionally, physical inactivity is associated with a number of negative health outcomes (Kohl et al., 2012).

Although study findings would suggest that young children with ASD are more physically active than their peers of typical development, it is still unknown how their physical activity trajectory may change throughout development. A cross-sectional study measuring the physical activity levels in adolescents with ASD found that there appears to be an age-related decline in activity throughout development (MacDonald et al., 2011). Participants in the older group spent a significantly more amount of time per day in SPA

Table 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	–	–
Race	A = 4, B = 2, H = 1, W = 23, O = 4	A = 2, B = 4, H = 2, W = 11	–	–
SES	HS = 5, SC = 7, ASC = 7, B = 9, PB = 6	HS = 1, B = 10, PB = 8	–	
Age (months)	47.42 ± 12.81	42.50 ± 10.78	0.149	0.26
	(24–68)	(26–62)		
CSS (range 0–10)	6.6 ± 1.2	–	–	–
	(4–10)	–	–	–
Full-scale IQ	35.09 ± 16.80	105.50 ± 21.81	<0.001**	0.86
	(4.44–67.10)	(75.69–162.03)	–	–
NVRatioIQ	43.16 ± 18.14	–	–	–
	(6.66–78.21)	–	–	–
VRatioIQ	27.97 ± 17.51	–	–	–
	(1.78–71.05)	–	–	–
% SPA	73.61 ± 5.96	80.89 ± 4.55	<0.001**	0.57
	(62–85)	(72–87)	–	–
% LPA	13.16 ± 2.17	10.11 ± 1.59	<0.001**	0.62
	(10–18)	(8–13)	–	–
% MPA	9.56 ± 2.46)	6.87 ± 2.08	<0.001**	0.51
	(5–15)	(5–11)	–	–
% MVPA	13.22 ± 4.52	9.00 ± 3.20	<0.001**	0.47
	(6–24)	(5–16)	–	–
% VPA	3.66 ± 2.44	2.13 ± 1.16	0.014	0.37
	(1–12)	(1–5)	–	–
Wear time (min)	784.81 ± 70.41	822.15 ± 152.75	<0.05*	0.16
	(661.19–924.42)	(662.07–1050.43)	–	–
PA monitored (days)	6.03 ± 1.00	6.47 ± 0.72	0.100	0.24

ASD: autism spectrum disorder; TD: typical development; SD: standard deviation; ES: effect size; M: male; F: female; A: Asian; B: Black; H: Hispanic; W: White; O: Other; SES: socioeconomic status; HS: high school; SC: some college; B: bachelor degree; PB: post bachelor degree; ASC: associates; 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; PA: physical activity.
$^{*}p < 0.05$; $^{**}p < 0.001$.

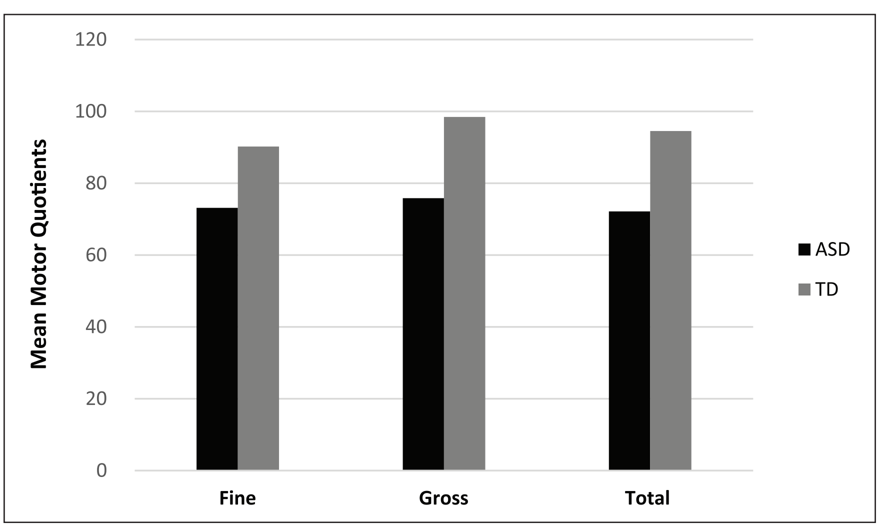

Figure 1. Motor quotient scores by group.

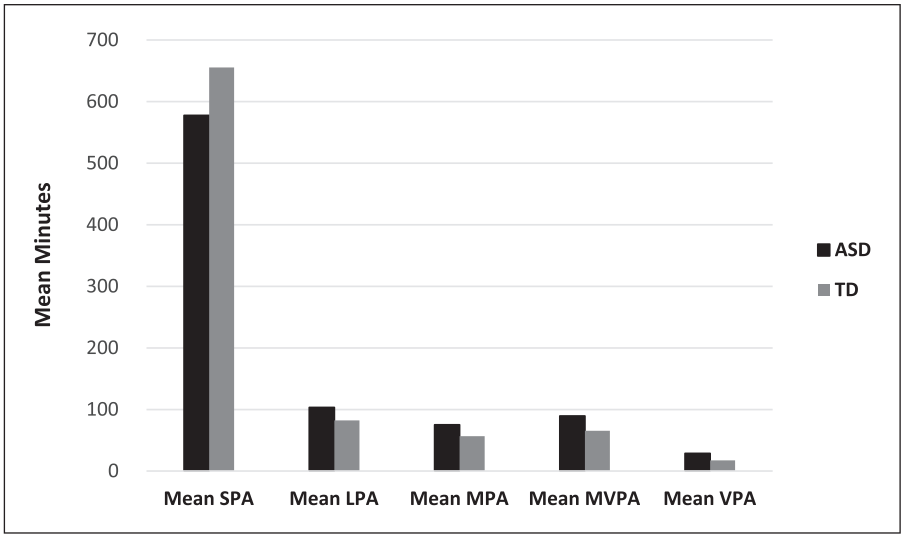

Figure 2. Levels of physical activity by group.

and significantly less time in MVPA (MacDonald et al., 2011). In a separate study, the objective measurement of physical activity patterns was compared in youth with ASD (aged 10–19 years). Participants were divided into three groups for cross-sectional analysis (Pan and Frey, 2006). Total weekly physical activity revealed that younger children spent significantly more time in MVPA than older children (Pan and Frey, 2006). Collectively, these findings are important as they demonstrate that activity levels decline as children age. In this study, the sample of children with ASD were 5 months older than children with typical development; therefore, while longitudinal analysis is outside the scope of this study, perhaps this represents a sensitive time in development where physical activity trajectories begin to change. Future studies should consider longitudinal examination of trajectories throughout development.

A recent review of behavioral outcomes following exercise interventions in children with ASD concluded that a reduction in stereotypic behaviors was among one of the positive outcomes (Bremer et al., 2016). Previous reports of physical activity 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). It is important to note that in this study, the IQ scores for the participants with ASD were significantly lower than anticipated. While GLM results determined IQ was not impacted by physical activity, this raises a few questions regarding the way in which children with ASD were accumulating their PA. Therefore, more comprehensive measurement into how young children with ASD are accumulating their physical activity is needed. For example, future studies should include an observational period while stereotypic behavior is coded. This may assist researchers in determining whether or not the accumulation of physical activity was due to stereotypy, a hallmark characteristic of ASD, or if it was due to movement through space that was purposeful. Therefore, while this study results suggest that children with ASD were more physically active than their peers with typical development, the contribution of co-morbids, such as ADHD and anxiety, could also be contributing to the number of minutes accumulated in light to vigorous activity levels. More research is needed to determine the impact of co-morbids on the levels of physical activity early on in development.

Children with ASD have known motor skill delays which may inhibit their opportunity to engage in physical activity programming (i.e. organized sports). While there is some, albeit scarce, research to support motor proficiency in preschool-aged children is related to higher levels of physical activity (Williams et al., 2008; Wrotniak et al., 2006), this study results suggest that this relationship does not yet exist in either group and in any of the five levels of physical activity. It is important to note that the children enrolled in this study were younger than previous research in this area, and therefore perhaps the entry into preschool marks a sensitive period where this relationship emerges. More research is needed to understand whether or not this relationship exists in children with ASD as it has the potential to lend valuable programming information to early interventionists.

One important note regarding the physical activity measurement in this study is that all participants met or exceeded minimum wear time recommendations. This outcome is contradictory to much of the physical activity research implementing accelerometers in this age group. This study adopted recently published methodology found to increase physical activity monitoring adherence (Hauck et al., 2016). Evidence-based recommendations that were implemented included verbal directions to the

Table 2. General linear model results controlling for motor skills, wear time, and IQ in the five physical activity categories.

	Typically developing	Autism spectrum disorder	F (df)
	($n = 19$)	($n = 34$)	
Mean time SPA	655.59	577.57	8.12**
Mean time LPA	82.41	103.35	12.68***
Mean time MPA	56.74	75.16	4.70*
Mean time MVPA	65.45	89.52	4.64*
Mean time VPA	17.40	28.70	2.70

df: degrees of freedom; SPA: sedentary physical activity; LPA: light physical activity; MPA: moderate physical activity; MVPA: moderate to vigorous physical activity; VPA: vigorous physical activity.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

participant and parents, in-person training about how to administer the elastic belt on each child, a social story provided to all families to take home, an elastic belt concealing soft cover, an incentive provided to families upon receipt of the device, and a pre-addressed paid postage for families to return the device (Hauck et al., 2016). We believe that these strategies significantly contributed to the adherence of our wear time parameters and are a feasible way to increase adherence in this population of children.

Another important consideration regarding mean physical activity wear time is that children with typical development wore their accelerometer on average longer than the children with ASD. This may have further impacted the physical activity results of this study, suggesting that perhaps children with typical development had more time to accumulate minutes within each physical activity level.

Limitations

One important limitation in our study is the lack of anthropometric measures including height and weight. This inhibits our ability to examine associations of physical activity levels related to body composition. However, this study does fill a significant gap in the literature by providing an objective measurement of physical activity in young children with ASD and examining its relationship with motor skills. Another limitation is that accelerometers and their corresponding cut-offs for levels of physical activity have not been validated for children with ASD aged 2–5 years. Therefore, the amount of time spent in each category should be interpreted carefully, as comparison to the currently validated cut-off scores is targeted for children outside of the age range of this study. A final limitation in this study is that 36% of our sample with ASD were female; this is a high ratio and may have impacted the results of this study. More research is needed to discover whether there are gender differences in physical activity in children with ASD early on in development. This information could assist researchers in creating specific interventions that address any gender disparities before they emerge.

Conclusion

Although findings from this study would suggest that children are meeting recommended physical activity guidelines, perhaps the more important finding is how much time each group spent in sedentary activity. Interventions to reduce this behavior early on in development may curb the trajectory of the declining levels of physical activity throughout development while simultaneously addressing weight status. Unstructured play-based interventions have previously been cited as a type of intervention young children with ASD would enjoy and benefit from (Lloyd et al., 2013). Therefore, future research should consider this type of program to increase motor proficiency and physical activity during early intervention programming for young children with ASD.

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