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The effects of an early motor skill intervention on motor skills, levels of physical activity, and socialization in young children with autism spectrum disorder: A pilot study

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Abstract
Despite evidence suggesting one of the earliest indicators of an eventual autism spectrum disorder diagnoses is an early motor delay, there remain very few interventions targeting motor behavior as the primary outcome for young children with autism spectrum disorder. The aim of this pilot study was to measure the efficacy of an intensive motor skill intervention on motor skills (Test of Gross Motor Development-2), physical activity (accelerometers), and socialization (Playground Observation of Peer Engagement) in young children with autism spectrum disorder. A total of 20 children with autism spectrum disorder aged 4–6 years participated. The experimental group ($n = 11$) participated in an 8-week intervention consisting of motor skill instruction for 4 h/day, 5 days/week. The control group ($n = 9$) did not receive the intervention. A repeated-measures analysis of covariance revealed statistically significant differences between groups in all three motor outcomes, locomotor ($F(1, 14) = 10.07$, $p < 0.001$, partial $\eta^2 = 0.42$), object control ($F(1, 14) = 12.90$, $p < 0.001$, partial $\eta^2 = 0.48$), and gross quotient ($F(1, 14) = 15.61$, $p < 0.01$, partial $\eta^2 = 0.53$). Findings shed light on the importance of including motor programming as part of the early intervention services delivered to young children with autism spectrum disorder.

Keywords
autism spectrum disorders, dosage, interventions—psychosocial/behavioral, motor skills, physical activity, preschoolers

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 screening procedures for toddlers, the identification of ASD symptoms can be detected as early as 12 months of age (Lord et al., 2012a). To date, the majority of evidence-based treatments for young children with ASD have targeted the core deficits in the social and communication domains (Flanagan et al., 2012), as well as intervening on problem stereotypical behaviors (Vismara and Rogers, 2010). However, recent evidence suggests that children with ASD experience motor delays that emerge early in development (Bhat et al., 2012; Chawarska et al., 2007; Flanagan et al. 2012; Teitelbaum et al., 1998). Despite the distinction of motor skills as one of eight domains to be targeted in the educational curriculum for children birth through 8 years of age (National Research Council (NRC), 2001), there remain very few interventions targeting the motor skills as the primary outcome.

Qualitative differences in early movement behavior may be among the first biomarkers of ASD, as researchers have described differences in infants as early as 6 months of age (Chawarska et al., 2007; Flanagan et al., 2012; Teitelbaum et al., 1998). In retrospective video of infants (aged 6–12 months) who were later diagnosed with autism, asymmetry was evident across several early movement skill behaviors including their lying posture and pattern of crawling (Teitelbaum et al., 1998). A prospective study that measured

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infants at high risk of autism aged between 6 and 36 months found that head lag during a pull-to-sit task was significantly associated with ASD at 36 months of age (Flanagan et al., 2012). Furthermore, Landa et al. (2012) examined several developmental trajectories in infants with high risk of autism aged 6–36 months and found similar development across early ASD biomarkers at 6 months of age that later diverged into four different developmental trajectories. Two of these trajectories were characterized by early motor delays when compared to normative developmental outcomes (Landa et al., 2012). While the evaluation of early motor milestones is imperative as it may divulge insight of early indicators of ASD, it is also important to understand how these delays perseverate throughout early childhood.

In one such cross-sectional study, gross motor scores from the Mullen Scales of Early Learning (MSEL) (Mullen, 1995) were examined in toddlers and young children with ASD. The most prominent finding was motor delay that increased with age, suggesting that relative to normative data, children fall further below what would be expected given their chronological age (Lloyd et al., 2011). Longitudinal observation of a subset of 58 children substantiated this phenomenon with significantly larger delays in gross and fine motor skills observed at 36 months compared to 12 months (Lloyd et al., 2011). Similar findings have been reproduced using other robust motor assessments such as the Peabody Developmental Motor Scales-2 (PDMS-2), a standardized motor assessment (Folio and Fewell, 2000; Provost et al., 2007). In a comparison of motor skills among three groups of young children (ASD, developmental delay, and typically developing), children with ASD had significantly poorer motor quotients when compared to children who were typically developing in the gross, fine, and total (reflecting gross and fine quotients) quotients (Provost et al., 2007). Jasmin et al. (2009) revealed significant delays in both the gross and fine motor quotients (PDMS-2) in children with ASD aged 3–4 years when compared to normative data. Finally, using the Movement Assessment Battery for Children-2 (MABC-2) (Henderson et al., 1992), children with ASD aged 3–16 years exhibited lower percentile scores compared to peers with typical development, which spanned both gross and fine motor domains (Liu and Breslin, 2013). Collectively, these findings are important and highlight recent research authenticating that motor skill deficits are related to ASD symptomatology. With regard to that, MacDonald et al. (2014) found that object control skills (i.e. throwing and catching) from the Test of Gross Motor Development-2 (TGMD-2; Ulrich, 2000) were found to be a significant predictor of calibrated ASD severity in children with ASD (aged 6–15 years). These findings underscore the importance for future research to build comprehensive interventions (i.e. targeting social, communicative, and motor domains) that target changes to core symptoms of ASD, which includes motor outcomes.

While the motor domain remains a relatively underrepresented area of early intervention for young children with ASD, one recent study examined the effectiveness of a fundamental motor skill intervention on motor outcomes, adaptive behavior, and social skills in 4-year-old children with ASD (Bremer et al., 2014). Following a 12-week intervention, the experimental group achieved significant gains in gross motor skills (PDMS-2) (Bremer et al., 2014). While significant changes were not reported in either social skills or adaptive behavior, there is evidence to support that proficiency in motor skills at 2 years of age is a significant predictor of optimal outcomes at 4 years of age in children with ASD (Sutera et al., 2007). In a separate study examining similar outcomes, children with autism like characteristics (aged 3–7 years) participated in a fundamental motor skill intervention which consisted of two 6-week instructional blocks (Bremer and Lloyd, 2016). Among findings, improvement in both motor skill proficiency and social skills was reported (Bremer and Lloyd, 2016). Next, Pan (2010) conducted a 10-week water exercise intervention for children with ASD (aged 5–9 years), implementing strategies from the Treatment and Education of Autistic and Related Communication Handicapped Children (TEACCH) (Mesibov et al., 2005) along with modifications to the pool deck and environment. Findings revealed a significant improvement in both aquatic skills and a reduction in the number of antisocial behaviors exhibited (Pan, 2010). Findings from Bremer et al. (2014), Bremer and Lloyd (2016), and Pan (2010) represent the limited but important literature examining the impact of a motor behavior intervention on secondary domains.

When compared to the social and communication domains, research in the motor domain is relatively underrepresented in children and youth with ASD. However, even less well understood are the physical activity (PA) levels in children and youth with ASD. Despite physical exercise being named by the National Standards Report (NSR) as an emerging treatment for individuals with ASD (birth to 22 years), PA research in children and youth with ASD is scarce and contradictory (Randolph, 2009). Current guidelines from the United States Department of Health and Human Services (USDHHS; Physical Activities Guidelines Advisory Committee, 2008) recommend that children aged 6–17 years participate in a minimum of 60 min of moderate or vigorous physical activity (MVPA) every day. In a large cross-sectional study examining objective PA in youth with ASD, both the younger (aged 9–11 years) and the older (aged 12–18 years) groups met the current recommendations of 60 min of daily MVPA (MacDonald et al., 2011). Most interesting, however, is that the findings revealed an age-related decline in activity, where participants in the older group spent significantly more time per day in sedentary activity and significantly less time in MVPA (MacDonald et al., 2011). In a conflicting study measuring objective PA in young children with and without ASD (aged 3–11 years), only 43% of children with typical development met the minimum requirement of 60 min of daily MVPA compared to just 23% of children with ASD (Bandini et al., 2013). The measurement of PA, particularly following an intervention, may identify modifiable factors related to declining PA trajectories throughout development.

Among recommendations from the NRC (2001), effective interventions should begin early in development, adopt a low child-to-adult ratio, and include year round comprehensive instruction that includes a minimum of 25 h/week of services. Pivotal Response Treatment (PRT) (Koegel and Kern Koegel, 2006) was identified by the NSP (2009) as an effective behavioral treatment for individuals with ASD. However, a common criticism is that it is difficult to implement in educational settings (Stahmer et al., 2011). As a result, Classroom Pivotal Response Teaching (CPRT) (Stahmer et al., 2011) was researcher developed for implementation into the classroom (i.e. special education and inclusive classrooms). Briefly, CPRT (PRT for a classroom environment) is a behavioral intervention that is implemented in a naturalistic setting. Learning opportunities in CPRT can occur within the child's natural environment, and parents, peers, or service providers (occupational therapist, physical therapist, adapted physical education teacher) act as the principal intervention agent. There are eight 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, and multiple cues) and consequence strategies (direct reinforcement, contingent consequence, and reinforcement of attempts).

Therefore, the primary aim of this pilot study was to measure the efficacy of a motor skill intervention on motor skills and levels of PA, implementing CPRT as a framework for instruction in preschool-aged children with ASD. A secondary aim was to measure changes in socialization behavior in the experimental group following the motor skill intervention. This study addresses several of the recommendations from the NRC (2001) by intervening early on in development, while maintaining a low child-to-instructor ratio. Furthermore, antecedent and consequence strategies from CPRT were used as a framework for the delivery of instruction throughout the intervention, in turn meeting recommendations for intervention research from the NSP (2009).

Methods

Participants

Recruitment occurred through local Early On programs in Southeast 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., 2012b) were aged between 4 and 6 years, could participate 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. The participants in both the experimental and control groups were enrolled in a range of services including speech, occupational therapy (OT), a social skills group, and a combination of both OT and a social skills group. An exclusion criterion for both the control and experimental groups was the participation in any other gross motor or PA 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. Finally, the 4- to 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 implemented a motor skill program for children with ASD upon entry into preschool or kindergarten.

Descriptive measures and diagnostic instruments

All study participants were administered the MSEL (Mullen, 1995), which is a standardized measure of cognitive functioning appropriate for children birth through 68 months. The MSEL consists of four 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 intelligence quotients (IQs) could be calculated for every child in the study, the cognitive *t* score was used in our analysis.

The Vineland Adaptive Behavior Scale-2 (VABS-2; Sparrow et al., 2005) is a standardized parental report measure of overall adaptive behavior. 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.

The ADOS-2 (Lord et al., 2012b) 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. The ADOS-2 consists of five 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 1 through 10, where 0–3 does not meet ASD thresholds, 4–5 meets ASD classification, and 6–10 represents an autism classification (Gotham et al., 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 were 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 fifth administration (inter-rater reliability $>$80%).

Outcome variables

The 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). The TGMD-2 was selected as it represents an assessment of motor skills that is composed of skills and equipment common to children ranging from 3 to 10 years of age (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 (Ulrich, 2000). Furthermore, acquisition of the skills represented in the TGMD-2 has the potential to increase opportunities for future specialized and context-specific movements (Burton and Miller, 1998). 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). During administration of the TGMD-2, picture task cards were supplemented (as needed) along with the visual demonstration of each task requirement; this method has been previously found to produce the most accurate results on the TGMD-2 for children with ASD (Breslin and Rudisill, 2011). The TGMD-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 coded live video recordings of every administration of the TGMD-2. Percent agreement on assessments ranged from 0.85 to 1.00. Neither of the TGMD-2 testers were involved in the day-to-day delivery of the intervention.

PA was measured with an ActiGraph GT3X+ (Pensacola, FL), a small (4.6 cm $\times$ 3.3 cm $\times$ 1.5 cm) and lightweight (19 g) triaxial accelerometer (measuring activity in three planes) device. Accelerometers have been previously reported as a valid and reliable objective measure of PA in young children and preschoolers (Pate et al., 2006). The PA data were collected during the summer months, at 1-week preintervention, 1-week post-intervention, and 4-week post-intervention. This time represented a warm period in the region where participants resided. Participants were instructed to wear the monitor for 7 days 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 et al., 2009). Next, a method found to increase wear-time adherence in children with disabilities included 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 for comfort. Monitors were returned by priority mail following a 7-day wear period.

All accelerometer data were downloaded with ActiLife 6 software. This study adopted recommendations from an evidence-guided protocol for objectively measuring habitual PA in young children (Cliff et al., 2009). Therefore, participants were included in the analysis if they met a minimum of 3 days of monitoring with 3 h of wear time per day. A 15-s epoch was employed based on previous research supporting the frequent and intermittent movements which typically characterizes this age population (Cliff et al., 2009). 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 were 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; $\geqslant$3368). MVPA was calculated as the mean of the sum of MPA and VPA (MVPA).

For participants in the experimental group only, the Playground Observation of Peer Engagement (POPE; Frankel et al., 2011) was administered. The POPE includes six interactive states—solitary (participant plays alone

Table 1. Daily intervention schedule.

Session	Purpose	Skill	Time (min)	Location
4-h breakdown				
1	Free play	Choice	25	Indoor gym
2	1:1 direct instruction	LO or OC	50	Soccer field
3	1:1 direct instruction	LO or OC	50	Soccer field
Break (15 min)				
4	Small group	LO or OC	50	Soccer field
5	Small group	LO or OC	50	Soccer field

LO: locomotor skills; OC: object control skills.

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 the 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 15 min, where 1-min intervals were recorded for 15 min, with the first 40 s spent observing the state of interaction and the final 20 s designated for coding the behavior. The percent of time spent during 15 min within each of the six socially interactive states was the interval used in the analyses. Two researchers trained to assess the POPE to young children live coded participant social behavior every 2 weeks throughout the intervention.

Intervention

The experimental group participated in the intervention, 4 h/day, 5 days a week for 8 weeks, during the summer months. See Table 1 for daily intervention schedule. The control group did not receive the intervention. The instructor-to-participant ratio was 1:1 for each session, while the principal investigator (PI) of the study facilitated the delivery of instruction. A weekly rotation between the TGMD-2 subtests (object control and locomotor) continued throughout the 8–week-long intervention, meaning that a total of 4 weeks were spent on each TGMD-2 subtests respectively.

The PI of this intervention had 10 years of combined teaching and research experience related to early motor behavior programming. All research assistants were undergraduate students who had previous work with children with disabilities and were interested in pursuing a graduate degree in pediatrics or a related field. The eight components from the CPRT manual were used as the framework for delivery of instruction throughout the intervention. Therefore, the PI followed the CPRT manual for instructional cues and examples for implementation techniques. See Table 2 for an example of how CPRT strategies were implemented. This framework was selected as CPRT can be delivered in individual and small/large group instruction. Furthermore, since CPRT strategies are meant to be delivered in a child's natural environment, they were easily adopted from the classroom to fit within a gymnasium and outdoor environment. For example, strategies can be implemented across a wide variety of learning opportunities (i.e. turn taking and new skill acquisition) and environments (i.e. social and play settings). Finally, central to CPRT is that child motivation is instrumental in facilitating learning acquisition; therefore, choices in materials (i.e. size and color of ball) were easily facilitated throughout the intervention. There were two informational sessions that were meant to provide researchers with the necessary background to encourage the use of strategies within each of the eight CPRT components. Once the intervention began, a measure of fidelity was assessed by the PI for every research assistant on a biweekly basis, with exception to the first week where all research assistants were evaluated for fidelity. To achieve fidelity, the research assistants earned a minimum of 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 *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.; DSM-IV; American Psychiatric Association (APA), 2000). All assessments were conducted over 1 day in a quiet and private laboratory with minimal distractions.

First, a parental preference sheet was administered to the parents prior to the beginning of the evaluations; researchers used this feedback to guide their method of reinforcers (if needed). Next, a questionnaire regarding summer services was administered to both the control and experimental groups. The MSEL was then administered to all study participants in order to obtain a measure of cognitive functioning. In order to support their previous

Table 2. CPRT implementation—lesson example—overhand throw.

CPRT strategy	Lesson instruction	Implementation of strategy
Antecedent strategies		
Student attention	Instructor models overhand throw while children are sitting on designated "X" on floor	Children remain at each station for a short period of time (i.e. 1 min), throughout acquisition of skill, there is a gradual increase in expectation for length of time required at each station (i.e. 3 min)
Clear and appropriate instruction	During circle time instructor asks "Can you show me how to throw?" Allow stationary practice before moving onto stations	For beginning throwers, children complete stations first without a ball, RA reinforces key words, when child is ready, stations are completed again, this time using the equipment at each station
Easy and difficult tasks	RA helps to facilitate approximately 50% maintenance of skills and 50% new acquisition of skills throughout completion of stations	At each throwing station, there are beginner and advanced options, for example, a child can stand on the designated X that is 5 or 10 feet away from the target on the wall. The RA helps child to choose appropriate option
Shared control	Instructor models turn taking by joining in activity and completing 1 or 2 of the stations	While the goal would be to complete all stations by the end of the session (modeling turn taking intermediately), RA allows child to choose the order in which the stations are completed
Multiple cues	During station demonstration, RA uses auditory and visual cues to describe learning goal and intended outcome	Each station is represented by a picture and keywords that are taped to the wall. Furthermore, a variety of different sized and shaped balls can be chosen in order to complete activity
Consequence strategies		
Direct reinforcement	Instructor makes sure that child's preferred equipment (i.e. favorite ball or color of ball) is located at each station	When the child demonstrates a correct throwing technique (i.e. by stepping forward on non-dominant leg), RA then allows child to continue to practice technique while throwing with their favorite ball
Contingent consequence	Before beginning stations, instructor shares that if everyone completes the activity, they will be rewarded	RA's encourage children to remain on task throughout the duration of the stations in order to be rewarded with their favorite "throwing and catching" game at the end of the session. If children collectively demonstrate their best effort to complete each station, the final few minutes can be spent playing a game
Reinforcement of attempts	RA reinforces broad range of attempts (i.e. attempts that demonstrate correct technique or purpose but does not necessarily achieve goal) to complete goal at each station	During a station that focuses on target practice, a child may attempt to throw a ball at a target on the wall while standing 5 feet away, if child misses target, RA would still reinforce that attempt by high five or verbal praise

RA: research assistant.

diagnoses, 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 TGMD-2 was 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. The VABS-2 was then administered by a researcher to provide a measure of overall adaptive behavior. Next, all study participants were given a PA monitor to wear 1 week prior to the beginning of the intervention.

For those in the experimental group, 1 week following premeasures, participants began the 8-week summer motor intervention. In order to measure change in motor skills throughout the intervention, a biweekly assessment of their motor skills was assessed using the TGMD-2 for the experimental group only. Furthermore, the POPE was administered to the experimental group every other week throughout the intervention. One week following the intervention, both the control and experimental groups returned for a post-intervention data collection to measure the changes in motor skills and PA. In order to measure the sustainability in changes to motor skills and level of PA, the experimental and control groups returned for a second follow-up measurement 4 weeks following the completion of the motor skill intervention.

Statistical procedures

Descriptive statistics were computed by group to describe central tendencies and variance for all demographic variables at baseline, and two sample *t*-tests were performed to identify any baseline differences between groups. Chi-square effect sizes were computed to interpret the magnitude of group differences in demographic variables at baseline, regardless of statistical significance.

A repeated-measures analysis of covariance (ANCOVA) was performed to identify differences in motor outcomes (locomotor, object control raw scores, and gross quotient) by time point, using cognitive *t* score (MSEL), adaptive behavior (VABS-2), and CSS (ADOS) as covariates. A second repeated-measures ANCOVA was conducted to identify differences in levels of PA (SPA, LPA, MPA, MVPA, and VPA) by time point with cognitive *t* score, adaptive behavior, CSS, and mean daily wear time (PA monitor) as covariates. Post hoc comparisons of adjusted means with Bonferroni corrections were also computed. Furthermore, bar graphs for all motor and PA data at each time point were created to visually represent unadjusted group means.

Pairwise *t*-tests were used to investigate treatment dosage, comparing biweekly observations of motor outcomes in the experimental group. Effective dose was identified as the number of weeks that elapsed since the start of the intervention where statistically significant gains in motor outcomes were no longer observed (measured in biweekly intervals). Dosage was determined separately for locomotor and object control skills.

A general linear model was used to examine the effect of time on changes in socialization, comparing biweekly observation of social skills in the experimental group. This MIXED procedure enabled any errors to be correlated over time, allowing for missing data in these variables, albeit infrequent.

All statistical procedures were performed using SPSS (version 21), and an alpha level of 0.05 was used to indicate statistical significance. All analyses presented were sufficiently powered.

Results

Descriptive statistics including age, gender, body mass index (BMI), CSS (ADOS-2), IQ (MSEL), and adaptive behavior (VABS-2) revealed no statistically significant differences between the experimental and control groups at baseline, with exception to their IQ ($p \leq 0.05$) (see Table 3). Several non-significant baseline differences (related to ASD symptomatology and PA measurement) between groups with small-to-moderate effect sizes were also noted including adaptive behavioral composite, CSS, and mean daily wear time. Therefore, along with the cognitive *t* score, these variables were used as covariates in the repeated-measures ANCOVA analysis of motor and PA outcomes.

For motor outcomes, results revealed statistically significant differences between the experimental and control groups in locomotor ($F(1, 14) = 10.07$, $p < 0.001$, partial $\eta^2 = 0.42$), object control ($F(1, 14) = 12.90$, $p < 0.001$, partial $\eta^2 = 0.48$), and gross quotient ($F(1, 14) = 15.61$ $p < 0.01$, partial $\eta^2 = 0.53$). For PA outcomes, non-significant group differences were observed for all levels of PA including SPA, LPA, MPA, MVPA, and VPA. Consistent with ANCOVA results, post hoc comparisons with Bonferroni corrections showed statistically significant differences between adjusted mean scores for locomotor, object control, and quotient from baseline to time 2 with non-significance from time 2 to 3. Post hoc comparison of PA showed non-significance for all levels of PA at all time points.

Graphical representations of motor and PA outcomes across all time points for both groups are presented as bar graphs (see Figures 1 to 3). Data represent unadjusted mean values of locomotor and object control raw scores, motor quotient, and PA at baseline (time 1), immediately following the intervention (time 2) and following a 4-week maintenance period (time 3).

Pairwise *t*-tests comparisons of intervention dosage on motor outcomes were conducted in the experimental group (see Table 4). For locomotor raw scores, statistically significant gains were observed from week 0 (baseline) to

Table 3. Descriptive data and baseline differences.

	Experimental ($n=11$)	Control ($n=9$)	p	ES
	Mean ± SD (range)	Mean ± SD (range)		
Demographic variables				
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)	0.29	0.48
Mean weekly time in external therapies	51.81 ± 35.09 (0–120)	58.33 ± 33.07 (0–120)	0.68	0.19
Physical activity—wear time				
Mean daily time 1 (min)	648.86 ± 73.86 (513.71–750.50)	627.79 ± 130.66 (393.00–853.00)	0.69	0.20
Mean weekly time 1 (days)	5.81 ± 0.87 5–7	5.5 ± 0.53 5–6	0.10	0.43
Mean daily time 2 (min)	601.87 ± 90.55 (447.96–739.95)	637.45 ± 153.90 (393.00–809.33)	0.65	0.28
Mean weekly time 2 (days)	6.91 ± 1.87 4–6	6.0 ± 0.71 5–7	0.02*	0.64
Mean daily time 3 (min)	642.64 ± 87.52 (529.50–838.61)	610.92 ± 136.49 (387.31–806.11)	0.57	0.28
Mean weekly time 3 (days)	7.45 ± 0.93 6–9	7.62 ± 0.74 7–9	0.51	0.20

SD: standard deviation; 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; BMI: body mass index; MSEL: Mullen Scales of Early Learning; VABS-2: Vineland Adaptive Behavior Scales-2; ES: effect size; p: level of significance.
*$p < 0.05$.

week 2 ($t(1, 10)=3.54$, $p \leqslant 0.05$). Statistically significant dosage response persisted through 8 weeks (weeks 0–4, 0–6, 0–8) of intervention when compared to baseline ($p < 0.001$). Statistically significant gains in locomotor raw scores continued from 2 to 4 weeks ($t(1, 10)=2.48$, $p < 0.001$), again with subsequent gains continuing through 8 weeks (weeks 2–6, 2–8; $p \leqslant 0.05$). Locomotor raw scores plateaued thereafter (from weeks 4 to 6 and beyond). For object control raw scores, statistically significant gains were observed from week 0 (baseline) to week 2 ($t(1, 10)=3.59$, $p \leqslant 0.05$). Statistically significant dosage response persisted through 8 weeks (weeks 0–4, 0–6, 0–8) of intervention when compared to baseline ($p \leqslant 0.05$). Gains in object control raw scores approached significance from 2 to 4 weeks ($t(1, 10)=2.16$, $p=0.056$), with statistically significant gains present through 8 weeks (weeks 2–6, 2–8; $p \leqslant 0.05$) when compared to week 2. Thereafter, statistically significant object control raw score gains were observed between weeks 4 and 8 ($t(1, 10)=2.42$, $p \leqslant 0.05$), but not from 4 to 6 weeks or 6 to 8 weeks.

For socialization outcomes measured in the experimental group, results revealed a statistically significant effect of time (for decreasing minutes) in solitary ($F(4, 8.76)=7.94$, $p < 0.01$) (Table 5). No significant effects of time (for increasing or decreasing minutes) were found in the remaining POPE-dependent variables including joint engagement, parallel play, or onlooking. Time effects approached significance for proximity ($F(4, 6.14)=4.40$, $p=0.052$) and parallel aware ($F(4, 9.32)=3.50$, $p=0.054$). Regarding games, too few minutes were accumulated throughout the intervention, and therefore an analysis was not performed.

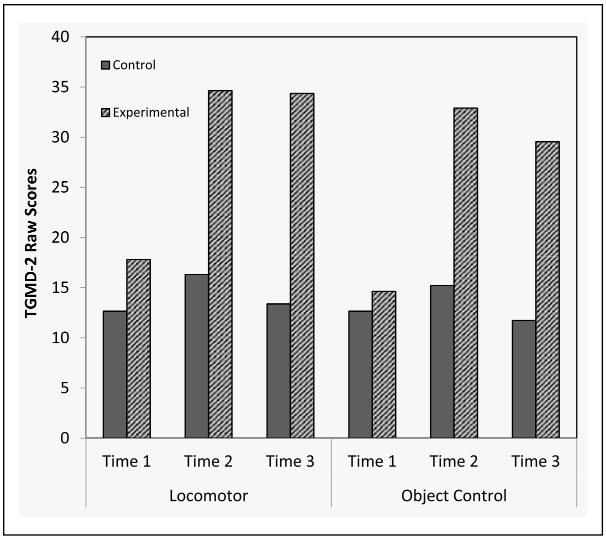

Figure 1. Between-group change in TGMD-2 locomotor and object control raw scores.

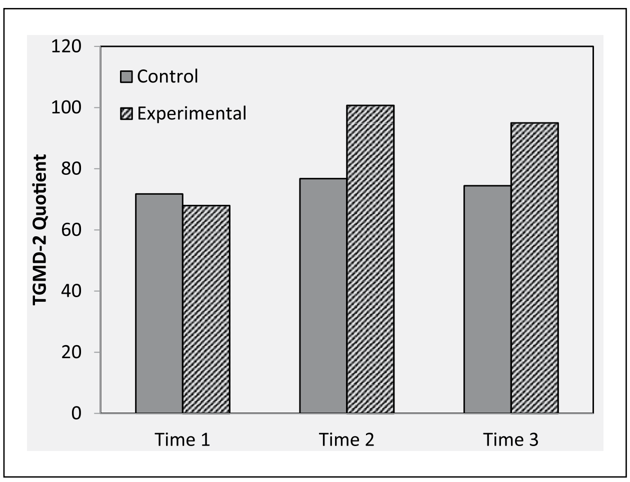

Figure 2. Between-group change in TGMD-2 gross quotient.

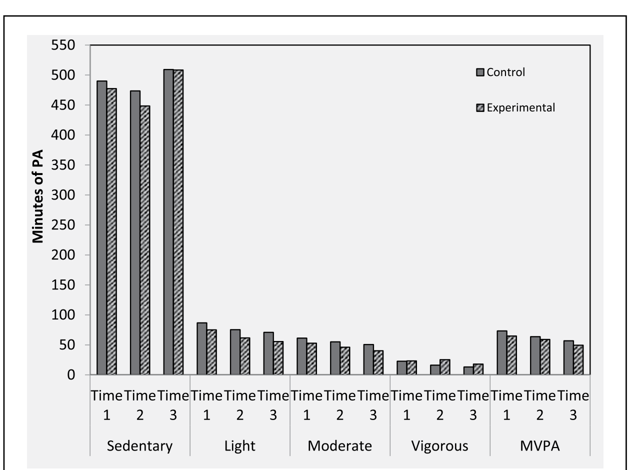

Figure 3. Between-group change in PA levels.

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. However, recommendations from the NSP (2009) suggest that evidence-based practices are now considered the gold standard for treatments of individuals' birth to 22 years of age (Randolph, 2009).

This study builds upon early motor skill intervention results from Bremer et al. (2014), by implementing research-supported strategies from within each of the eight CPRT components to deliver a motor skill instruction to young children with ASD. Next, this study adds to what is known about the PA levels of children with ASD by providing an objective measurement of activity for this population.

Statistically significant differences were found between groups on all three motor outcomes including locomotor, object control raw scores, and the total gross quotient ($p \leqslant 0.01$). The increase in motor proficiency achieved in the experimental group is promising and underscores the importance for the ongoing need for interventions targeting the motor domain. MacDonald et al. (2013) found that object control skills based on the TGMD-2 significantly predicted ASD symptom severity. Authors cite the importance of creating environments (i.e. playground), where children can practice their social skills with an opportunity to explore their environment. While the evaluation of motor trajectories was beyond the scope of this intervention, an important next would be to evaluate how the acquisition of motor skills impacts play and social opportunities throughout development.

Regarding the dosage results in the experimental group only, it is not surprising that given the high dosage (i.e. 20 h/week) significant improvements were made throughout the intervention when compared to premeasure results. When considering locomotor outcomes, dosage results suggest that children may have reached a plateau in skills following 4 weeks of intervention, where non-significant gains were made between weeks 4 and 8. In object control outcomes, non-significant improvements were made between weeks 2 and 4, 4 and 6, and 6 and 8, with a significant gain in skills between weeks 4 and 8. It is difficult to know whether or not the differences in length of time to achieve significant improvements are attributed to the initial delay in motor skill or related to the demands of the task (i.e. complexity of object control skill demands). There is an ongoing need for more information regarding intensity and dosage. Furthermore, future research should consider a measurement of skills administered to both the control and experimental groups in order to determine if motor skill changes are truly a direct result of the motor intervention.

Next, CPRT seeks to target pivotal "core areas," which can include any developmental domain that upon intervention results in immediate changes and has a cascading

Table 4. Biweekly assessment of intervention dosage for locomotor and object control skills for experimental group only.

	Locomotor		Object control	
	M (SD)	*T* (df)	*M* (SD)	*T* (df)
Weeks compared to baseline				
0	17.81 (6.91)	–	14.63 (5.20)	–
0–2	26.36 (8.12)	3.54 (1, 10)*	21.18 (7.36)	3.59 (1, 10)*
0–4	31.46 (9.59)	7.68 (1, 10)***	26.55 (11.46)	3.61 (1, 10)*
0–6	33.45 (8.91)	8.36 (1,10)***	31.45 (7.35)	6.65 (1, 10)***
0–8	34.63 (7.66)	9.33 (1, 10)***	32.91 (5.17)	10.24 (1, 10)***
Weeks compared to 2				
2	26.36 (8.11)	–	21.18 (7.36)	–
2–4	31.46 (9.58)	2.48 (1, 10)*	26.55 (11.46)	2.16 (1, 10)
2–6	33.45 (8.91)	3.37 (1, 10)*	31.45 (7.35)	4.14 (1, 10)*
2–8	34.63 (7.66)	4.15 (1, 10)*	32.91 (5.17)	6.31 (1, 10)***
Weeks compared to 4				
4	31.46 (9.58)	–	26.55 (11.46)	–
4–6	33.45 (8.91)	1.25 (1, 10)	31.45 (7.35)	1.79 (1, 10)
4–8	34.63 (7.66)	1.79 (1, 10)	32.91 (5.17)	2.42 (1, 10)*
Weeks compared to 6				
6	33.45 (8.91)	–	31.45 (7.35)	–
6–8	34.63 (7.66)	0.92 (1, 10)	32.91 (5.17)	0.76 (1, 10)

M: mean; SD: standard deviation; df: degrees of freedom.
*$p < 0.05$, ***$p < 0.0001$.

influence on secondary developmental domains. This type of intervention has the potential to simultaneously enhance both motor skill acquisitions 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. Therefore, this study findings would support previous research by Pan (2010) and Bremer and Lloyd (2016), where changes in the motor domain appeared to positively affect the social domain. Within this study, the social domain was evaluated using the POPE. Results revealed a significant trend for decreasing minutes in solitary throughout the intervention (i.e. participants spent fewer minutes playing alone) ($p < 0.05$). These findings are promising as it sheds light on the interaction between domains throughout an intervention targeting motor skills. Future motor behavior researchers should also consider the generalization of skills into a free-play, unstructured activity as this type of environment is where most of these skills are likely to emerge.

Next, although describing PA levels was not a primary aim of this article, it is interesting to note that both the control and experimental groups met or exceeded USDHHS (Physical Activities Guidelines Advisory Committee, 2008) recommendations for 60 min of MVPA per day at time 1 and time 2. However, perhaps, a more important observation may be regarding the amount of time spent in SPA, with both groups spending the majority of their day (i.e. 8 h) in sedentary activity at all three time points (Figure 3).

Another consideration regarding the PA results from this study, while it is possible that improving motor skills in this context does not result in an increase in PA. Future research should consider a measurement of PA throughout the duration of an intervention as it may capture the more sensitive changes that are occurring during the intervention over time. It is possible that study participants were more physically active during each of the five intervention sessions, but translation of this into habitual PA (post-intervention) was not captured.

Limitations

This study is not without limitations. The lack of random assignment to the control and experimental groups makes generalizations difficult to make. Furthermore, the small sample size limited our statistical power in the PA analysis. Next, as noted earlier, the TGMD-2 was used as our standardized assessment to evaluate motor skill changes. Each of the 12 skills on the TGMD-2 was targeted in the daily programming throughout the duration of the intervention. Two limitations regarding our choice of the TGMD-2 and motor skill instruction should be discussed. The TGMD-2 was selected because it comprises skills common to children within the age range of this study. However, owing to the motor skill delays present in many young children with ASD, a more appropriate assessment selection may have been an assessment with norms for children younger than 3 years of

Table 5. 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 engagement	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.
$^{*}p < 0.01$.

age, for example, the PDMS-2. Furthermore, targeting the specific skills on the TGMD-2 meant that children were receiving instruction on a daily basis pertaining to those particular skills, thereby essentially teaching to the TGMD-2. Future research should focus on teaching a wide variety of fundamental skills and promote the generalization of skills across different environments (i.e. school playground or community setting). Next, it is possible that the increase in motor skills observed in the control group was attributable to test/tester familiarly, and it is important to note this as a limitation to this study. Furthermore, given the pilot nature of the study, biweekly assessment of the POPE and TGMD-2 to both the experimental and control groups was beyond the scope of this research; therefore, it is difficult to understand if the improvements are actually from the intervention or from familiarity with the test or children in the program.

While an exclusion criterion for participation in the intervention was enrollment in another gross motor program, children in both the control and experimental groups did participate in OT throughout the duration of the intervention. No information on what was covered during their OT sessions was collected; so it is plausible that gross motor skills were addressed at some point throughout the course of their scheduled therapy.

Finally, it is important to note that because this intervention was conducted over the summer months, the first monitoring period preintervention was during a week that the participants were still in school and therefore assuming typical PA behavior. The second and third monitoring periods were following the intervention, where many families in the experimental group took the opportunity to vacation. Therefore, this study results may have been impacted by atypical PA behavior during vacations that are associated with increased sedentary behavior due to traveling constraints.

Conclusion

This study would suggest that when children with ASD receive direct and intensive instructions on targeted motor skills delivered within an evidence-based framework, the results are positive. Future research should consider recommendations from both the NRC (2001) and NSP (2009) for the successful planning, implementation, and generalizations of motor skills in children with ASD.

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