Motor skills and calibrated autism severity in young children with autism

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Author Note: Dr. Lord receives royalties for the Autism Diagnostic Observation Schedule. All royalties from clinics and projects in which she is involved are donated to charity. Drs. MacDonald & Ulrich have no disclosures.

Abstract

In addition to the core characteristics of autism motor skill deficits are present, persistent and pervasive across age. Although motor skill deficits have been indicated in young children with autism they have not been included in the primary discussion of early intervention content. Young children with autism (N= 159) between the ages of 14-33 months participated in this study. The univariate GLM tested the relationship of fine and gross motor skills on social communicative skills (using calibrated autism severity scores). Fine motor skills and gross motor skills significantly predicted calibrated autism severity ($p < 0.01$). Children with weaker motor skills have greater social communicative skill deficits. Future directions and the role of motor skills in early intervention are discussed.

Keywords: autism, motor skills, young children, calibrated severity

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Motor skills and calibrated autism severity in young children with autism spectrum disorder

Abstract

In addition to the core characteristics of autism spectrum disorder (ASD) motor skill deficits are present, persistent and pervasive across age. Although motor skill deficits have been indicated in young children with autism they have not been included in the primary discussion of early intervention content. 159 young children with a confirmed diagnosis of ASD (n= 110), PDD-NOS (n= 26) and non-ASD (n=23) between the ages of 14- 33 months participated in this study.[1] The univariate general linear model (GLM) tested the relationship of fine and gross motor skills on social communicative skills (using calibrated autism severity scores). Fine motor skills motor skills significantly predicted calibrated autism severity ($p < 0.05$). Children with weaker motor skills have greater social communicative skill deficits. Future directions and the role of motor skills in early intervention are discussed.

Keywords: autism, motor skills, young children, calibrated severity

[1] Data for this project were collected before the DSM-V was published in 2013. Thus, the authors included ASD sub-categories, as they existed in the DSM-IV R.

Autism spectrum disorder (ASD) is a pervasive developmental disorder characterized by deficits in social skills, communication and repetitive or restricted interests (APA, 2013). The most recent prevalence statistics suggest that 1 in 88 children are diagnosed with ASD (CDC, 2012) . Standardized diagnostic tools can identify children with autism as early as 1-year of age (Luyster et al., 2009). Unfortunately the continuous rise in diagnosis makes autism one of the most frequent childhood neurodevelopmental disorders and poses difficulty for service providers in adhering to the concurrent increase in service needs (Downs & Downs, 2010; Fombonne, 2009; Matson & Kozlowski, 2011; Wise, Little, Holliman, Wise, & Wang, 2010).

The most widely cited and recommended mode of treatment for the youngest children with autism is early intervention focused on improving social communicative skills (Dawson et al., 2010; Kasari et al., 2005; Kasari, Gulsrud, Wong, Kwon, & Locke, 2010; NRC, 2001; Wong & Kwan, 2010). Successful early intervention has resulted in children's improved IQ, language, adaptive behavior, play skills and autism diagnosis (ie. moving from autism, to pervasive developmental disorder-not otherwise specified [PDD-NOS]) (Dawson, et al., 2010; Kasari, et al., 2010; Lovaas, 1987). Although there is widespread agreement on the necessity of early intervention, best practice recommendations for early intervention are less well defined and there is less consistent agreement on specific program content (Kasari, et al., 2005). For example, social communicative skills may be targeted in intervention using reading circles in a group-based format, while another successful early intervention may use activities of daily living to focus on social communicative skills. One potential content area that has been underexplored is the use of motor skill development.

Children with ASD frequently have motor skill deficits that are present at a young age (Lloyd, MacDonald, & Lord, 2013; Provost, Heimerl, & Lopez, 2007; Provost, Lopez, &

Heimerl, 2007). Traditionally the motor skill discussion of children with ASD is focused on stereotypies and imitation, however empirical data has shown that motor skill deficits in children with autism range in nature and across tasks (Landa & Garrett-Mayer, 2006; Lloyd, et al., 2013; Staples & Reid, 2009; Vernazza-Martin et al., 2005). Empirical data has confirmed that early motor delays are included in initial developmental concern to parents (Landa & Garrett-Mayer, 2006; Lloyd, et al., 2013; Teittelbaum, Teittelbaum, Nye, Fryman, & Maurer, 1998). In addition to delays in motor milestones deficits exist in gait, postural control and motor planning (Esposito & Venuti, 2008; Fabbri-Destro, Cattaneo, Boria, & Rizzolatti, 2009; Lloyd, et al., 2013; Vernazza-Martin, et al., 2005). Descriptive studies have clearly demonstrated significant motor skill deficits in children with autism and even gone so far as to suggest motor skill deficits as a preliminary diagnostic marker of ASD early in development (Landa, Gross, Stuart, & Bauman, 2012; Teittelbaum, et al., 1998).

Nevertheless, even though significant motor skill deficits are present in young children with ASD the primary focus of early intervention is typically based on improving social communication skills, a phenotypic characteristic of ASD. In 2001, a report from the NRC indicated that motor skill development should be emphasized in specialized early intervention curriculum for young children with ASD. Yet, more than a decade later early intervention has not specifically targeted motor skill development (NRC, 2001). Consequently, very little has been discussed in terms of how motor skill deficits relate to the core characteristics of the disability in young children with autism, children young enough to qualify for early intervention services. One recent study identified a relationship between the motor skills of young children with ASD and their respective adaptive behavior skills (MacDonald, Lord, & Ulrich, 2013a). Another study reported that motor skill deficits in school-aged children with autism were related

to calibrated autism severity scores, thus confirming that a relationship exists between motor skill deficits and autism symptomology (MacDonald, Lord, & Ulrich, 2013b). However, how this relationship, of motor skills calibrated autism severity, exists in much younger children with ASD has not been explored.

The purpose of this study is to determine the relationship of motor skills and the core behaviors of young children with autism, social affective skills and repetitive behaviors, as indicated through the calibrated autism severity scores (Gotham, Pickles, & Lord, 2009). It is hypothesized that children with better motor skills will have better calibrated autism severity scores.

Method

Participants

The Institutional Review Board approved all methods and procedures for this study and parents of the children consented to participation. Young children with ASD, PDD-NOS and non-ASD (developmental delay) between the ages of 12- 33 months were recruited from early intervention studies and clinical referrals (n=159). Generally, children were recruited through autism support groups, study flyers, referrals from pediatricians and teachers, and others were informed of the research study when visiting the autism clinic. Children with non-ASD (developmental delay) were included in this study to provide a range of scores indicted through calibrated autism severity. All participants in this study had a confirmatory diagnosis of ASD (n=110), PDD-NOS (n=26) or non-ASD (n=23). Diagnosis was determined by standardized algorithms established from the Autism Diagnostic Observation Schedule (ADOS) (Gotham, Risi, Pickles, & Lord, 2007; Lord et al., 2000).

Measurements

Developmental Level. The Mullen Scales of Early Learning (MSEL) was used to assess cognitive development (Mullen, 1995). This test of development provides reliable and valid information for children from birth to 68 months of age. The subscales of the MSEL are organized into 5 domains: gross motor, fine motor, visual reception (nonverbal problem solving), receptive language, and expressive language. All items are administered, observed and scored by the assessor. Majority of items are scored as either 1 (present) or 0 (not present/ completed). A standardized early learning composite score is derived from the fine motor, visual reception, receptive language and expressive language scales.

Motor Skill Measurement. The gross motor scale of the MSEL was used to assess gross motor skills and the fine motor scale of the MSEL was used to assess fine motor skills (Mullen, 1995). This scale was administered in a clinical setting with other developmental and diagnostic assessments at baseline. A gross motor and fine motor standard score was used in analysis. Unfortunately, standardized scores do not provide sub-scores below 20, therefore age equivalent scores were also described.

Child Diagnostic Measures. All participants were administered the The Autism Diagnosis Observation Schedule (ADOS) (Lord, et al., 2000; Luyster, et al., 2009) in order to acquire diagnostic information through direct observation by a trained research reliable clinician. Each member of the research clinical team established inter-rater reliability exceeding 80% exact agreement (kappa>0.60) on codes for the ADOS for three consecutive administrations before the study began. Reliability was maintained over time through consensus coding, this occurred approximately every sixth administration with a second rater who was blind to referral status. This method of inter-rater reliability has been used previously (Gotham, et al., 2009; Gotham, et al., 2007; Lord, 2000; Lord, et al., 2000).

Autism symptomology. Calibrated autism severity scores were used to assess autism symptomology. The ADOS is widely accepted as the criterion standard in autism diagnosis (Lord, et al., 2000; Luyster, et al., 2009; Matson & Sipes, 2010). The ADOS is a standardized assessment of social interaction, communication, play, and the imaginative use of materials. The ADOS generates diagnostic algorithms with thresholds set for autism and the broader autism phenotype (Lord, et al., 2000). Revised algorithms for the ADOS modules 1, 2 and 3 have been published with stronger specificity and sensitivity (Gotham, et al., 2007). Standardized scores of calibrated severity are available using raw scores from the revised algorithms of the ADOS (Gotham, et al., 2009). Calibrated autism severity scores have been indicated optimal for comparisons of assessments across time (and age), and to identify different trajectories of autism severity independent of verbal IQ (Gotham, et al., 2009).

Procedures

Assessments were typically administered in the order presented above. Developmental level was assessed first in order to assist the administrator in choosing the appropriate ADOS module (ADOS modules are based on the child's language level).

Data Reduction

All examiners strictly adhered to the standardized procedures outlined in each respective test manual. As indicated in the measurement description of instruments, research reliability and inter-rater reliability was established for the ADOS. The MSEL was also administered to all participants, and each administration strictly adhered to manualized protocols (Mullen, 1995). Descriptive scores from the MSEL included an age difference score. The age difference score was calculated by subtracting the gross motor and fine motor age equivalents score from the chronological age of the participant. Standardized scores for the fine and gross motor scales of

the Mullen are standardized for children birth to 33 months. Standardized scores were used for analysis in this study as the sample consisted of children 33 months and younger. A diagnosis of autism, PDD-NOS or non-autism was obtained and reported based on the participant's standard ADOS score (Lord, et al., 2000; Luyster, et al., 2009); standard developmental levels are reported based on the measures of the MSEL (Mullen, 1995). Additionally a ratio verbal IQ and non-verbal IQ was calculated. Ratio verbal IQ was calculated by taking the mean age equivalent of the expressive and receptive language subtests, dividing by chronological age, and multiplying by 100. Ratio non-verbal IQ was calculated in the same manner using the age equivalents from the fine motor and visual reception subtests, this method has been used in other studies (Lloyd, et al., 2013).

Data Analysis

Data analysis tested the relationship of gross and fine motor skills measured by the gross motor scale and the fine motor scale of the MSEL with autism symptomology as measured by calibrated autism severity scores (Gotham, et al., 2009; Gotham, et al., 2007). Data analysis was conducted in Statistical Package for the Social Sciences (SPSS) version 16.0. The univariate GLM (Garson, 2012) was used to test the relationship of motor skills and autism symptomology. The univariate GLM was chosen based on its ability to analyze fixed factors and covariates as predictors (Garson, 2012). Age, non-verbal problem solving (as based on the visual receptive organization subscale of the MSEL), gender, ethnicity and autism diagnosis were also included in the model.

Results

A total of 159 children with a confirmed diagnosis of ASD (n= 110), PDD-NOS (n= 26) and non-ASD (n=23) between the ages of 14- 33 months were included in this study (mean age=

27.6 months (±4.6 months). A frequency analysis revealed a high proportion of the sample scored within the basal norm range (a standard score of 20). Fifty percent (50.7%) of the sample scored the basal norm of the gross motor scale and twenty-four percent (24.5%) of the sample scored within the basal norm range of the fine motor scale. Based on skewed gross and fine motor skill distributions, a visual binning analysis was conducted for the gross motor scale and the fine motor scale respectively. The visual binning analysis created three distinct categorical variables, low, medium and high, based on motor skill standard score distribution. This visual binning analysis used SPSS 16.0 automatic options.

Average age equivalent scores are reported for all scales of the MSEL along with descriptive characteristics of the sample (Table 1). For descriptive purposes a gross and fine motor difference variable was calculated. The variable quantifies the amount of motor delay in months regardless of chronological age. Based on the age difference calculation, children were performing 6.4 months behind the norm-referenced gross motor skills and 9.5 months behind the norm-referenced fine motor skills of typically developed children.

Influence of Gross Motor Skills on Calibrated Autism Severity

The univariate GLM tested the relationship of categorical gross motor skills (grouped into categories of low, medium and high) on calibrated autism severity. Non-verbal problem solving, age, gender, ethnicity and diagnosis were included in the model. There were no interactions. Results indicated that gross motor skills were related to calibrated autism severity ($p < 0.05$, $\eta^2 = 0.02$). This model also indicated that diagnosis ($p < 0.001$, $\eta^2 = 0.71$), age ($p < 0.001$, $\eta^2 = 0.03$) and non-verbal problem solving ($p < 0.01$, $\eta^2 = 0.01$) were predictors of calibrated autism severity. The final model indicated that children with lower gross motor skills had a higher calibrated autism severity.

Influence of Fine Motor Skills on Calibrated Autism Severity

The univaritae GLM tested the relationship of categorical fine motor skills (grouped into categories of low, medium and high based on a visual binning analysis) on calibrated autism severity. Non-verbal problem solving, age, gender, ethnicity and diagnosis were included in the model. Fine motor skills were significant predictor of calibrated autism severity ($p \leq 0.01$, $\eta^2=0.02$), there were no interactions. This model also indicated that diagnosis was a predictor in calibrated autism severity ($p < 0.001$, $\eta^2=0.74$). This final model indicated that children with lower fine motor skills had a higher calibrated autism severity.

Discussion

The fine and gross motor skills of young children with autism (12- 33 months) were related to calibrated autism severity. Children with lower fine and gross motor skills had higher calibrated autism severity scores indicating more behaviors specific to autism symptomology. Given the young age-range of the participants in this study motor skill deficits are substantial. Fine motor skill deficits were 9.5 months behind chronological age and gross motor skill deficits were 6.4 months behind chronological age. The relationship of motor skills and calibrated autism severity held constant non-verbal problem solving. In other words, this relationship is not driven entirely by intellectual ability. Motor skills were an independent predictor of calibrated autism severity. Although effect sizes were small for both fine and gross motor skills (both at $\eta^2=0.02$), majority of the variance was explained by diagnosis (based on DSM-IV-R criteria), however this would be expected as indicated in the creation of the calibrated autism severity scores (Gotham, et al., 2009). Thus, even a small relationship provides new insight into potential content mechanisms for early intervention.

In a similar study, the motor skills of school-aged children with autism were predictive of calibrated autism severity (MacDonald, et al., 2013b). MacDonald et al., found object control skills (motor skills), as measured by the Test of Gross Motor Development- 2nd Edition (Ulrich, 2000) were related to calibrated autism severity, as indicated through standardized algorithms (Gotham, et al., 2009). School-aged children with better object-control skills, such as overhand throwing, striking, kicking, underhand rolling, dribbling and catching, had better calibrated autism severity scores.

To our knowledge this study is the first to show a direct relationship between motor skills and calibrated autism severity scores, in young children with autism. It has been suggested that better motor skills early in life could provide a solid foundation for the components of early intervention, social communicative skills, to manifest positively (Lloyd, et al., 2013; MacDonald, et al., 2013a; Sutera, Pandey, Esser, & Rosenthal, 2007). In other words better motor skills early in life could provide children with the foundational skills needed to move towards an optimal outcome, yet this theory has not been studied directly. Both cognitive and motor skill performance have been recognized as indicators of positive prognosis (Helt et al., 2008; Landa, et al., 2012; Sutera, et al., 2007), yet rehabilitation focused on improving motor skills has been relatively limited. There is a need for well controlled motor skill-based early interventions for young children with ASD.

Although the modality of early intervention varies, the basis of early intervention focuses on teaching social communicative skills through active play (Dawson, et al., 2010; Kasari, Paparella, Freeman, & Jahromi, 2008; Rogers, Hall, Osaki, Reaven, & Herbison, 2000). Early intervention is focused on “active play”, and motor skills are influential in the functional performance of play (Dawson, et al., 2010; Lloyd, et al., 2013; Makrygianni & Reed, 2010).

Early motor skill deficits have been acknowledged as indicators of early diagnosis (Teittelbaum, et al., 1998), positive prognosis (outcome) (Sutera, et al., 2007) and often, motor skills are used as inclusion criteria for early intervention programs (ie., children need to be walking). Beyond acknowledging occupational and physical therapy, movement-based early interventions or rehabilitation programs focused on improving motor skills for these young children are underexplored (Lloyd, et al., 2013; MacDonald, et al., 2013a; Provost, Heimerl, et al., 2007; Provost, Lopez, et al., 2007).

It is not surprising that early intervention is focused on social communicative skills given the phenotypic characteristics of autism, however it is possible that motor skill deficits are hindering success (Sutera, et al., 2007). In this study, a large diagnostic sample of young children with autism and non-autism indicate strong relationships between motor skills and autism symptomology, based on the predictive validity of gross and fine motor skills on calibrated severity. These findings provide a solid foundation to further explore how this relationship manifests and ultimately how motor skill rehabilitation can be further integrated into early interventions for young children with autism.

Motor deficits are gaining recognition as a phenotypic characteristic of autism, potential diagnostic marker and influential in autism prognosis (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Sutera, et al., 2007; Teittelbaum, et al., 1998). Behavior-driven research has suggested relationships between motor skills and autism symptomology, speculating that motor skills could hinder success in early intervention (Lloyd, et al., 2013; Sutera, et al., 2007). Future studies need to address this relationship further. Although calibrated severity is relatively stable (Gotham, et al., 2009), we see positive developmental trajectories in very young children with autism spectrum disorder (Dawson, et al., 2010; Ozonoff et al., 2010; Ozonoff et al., 2008; Yirmiya &

Ozonoff, 2007). Implementing successful interventions targeted at improving basic motor skills may further assist children towards improved autism symptomology. In addition, early intervention focused on motor skill development may help to establish functional play skills necessary for age-related "play-based" activities. Better motor skills, may help young children to obtain the participation opportunities to play skill-based games and activities as well as social communicative practice.

Limitations

A limitation of this study is the use of the MSEL to measure motor skills. A more sensitive motor skill measure may have provided better motor skill data. However, the MSEL is commonly used in clinical assessments and is a valid and reliable measure of gross and fine motor skills.

Conclusion

Establishing effective strategies to improve symptomology in young children with autism is a priority in autism research (Kasari, et al., 2005; Yirmiya & Ozonoff, 2007). Dawson et al. (2010) were the first group to conduct a well controlled randomized control trial of early intervention for toddlers with autism spectrum disorder. Dawsone et al. (2010) provided clear evidence that early intervention improves IQ, language, adaptive behavior and autism diagnosis. The results of the present study suggest that there is more to focus on and new avenues to explore in the realm of discovering how to implement early intervention and rehabilitation for young children with autism. Our study demonstrates a direct relationship between motor skill deficits and autism symptomology as indicated through calibrated autism severity. In such a young group of children motor skill deficits are equivalent to a major proportion of the children's lifespan (ie. a 9 month deficits in a young children of 24 months of age, is proportionately more

than a 9 month deficit in an older children with autism). This is an area of concern and unfortunately an area of neglect (Rosenbaum, 2005). In this descriptive study, motor skills are predictive of severity, yet at a young age autism severity has an opportunity to improve, albeit with the appropriate intervention techniques.

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Table 1.

Descriptive characteristics of the participants

Variable	Mean/ Frequency	N= 159
Age (months)	27.63 (4.6)*	
Gender	125M, 34F	
Race/ Ethnicity	108 Caucasian, 48 African American, 1 Native American, 1 Biracial, 1 Unspecified	
Maternal Education	23 Graduate/ Professional, 42 College, 44 Some College, 28 High School Diploma, 2 Some High School, 20 Unspecified	
Autism Diagnostic Classification	110 ASD, 26 PDD-NOS, 23 Non-ASD	
Age Equivalent Gross Motor Subtest	21.23 (6.1)	
Age Equivalent Fine Motor Subtest	18.11 (5.7)	
Age Equivalent Visual Reception Subtest	19.12 (6.4)	

Age Equivalent Receptive Language Subtest	9.67 (7.0)
Age Equivalent Expressive Language Subtest	10.35 (5.8)
Ratio Verbal IQ	37.2 (22.6)
Ratio Non-Verbal IQ	68.7 (21.4)

*Mean (standard deviation)

Table 2.

Univariate GLM analysis of categorical fine & gross motor scores on calibrated autism severity scores

Motor Skills	p	partial ETA squared
Fine Motor (standard score)	≤0.001	0.075
Gross Motor (standard score)	<0.01	0.025