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The relationship of motor skills and adaptive behavior skills in young children with autism spectrum disorders

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Abstract

Objective—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.

Design—The univariate GLM 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.

Setting—Majority of the data collected took place in an autism clinic.

Participants—A cohort of 159 young children with ASD (n=110), PDD-NOS (n=26) and non-ASD (developmental delay, n=23) between the ages of 12–33 months were recruited from early intervention studies and clinical referrals. Children with non-ASD (developmental delay) were included in this study to provide a range of scores indicted through calibrated autism severity.

Interventions—Not applicable.

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Main Outcome Measures—The primary outcome measures in this study were calibrated autism severity scores.

Results—Fine motor skills and gross motor skills significantly predicted calibrated autism severity ($p < 0.01$). Children with weaker motor skills displayed higher levels of calibrated autism severity.

Conclusions—The fine and gross motor skills are significantly related to autism symptomology. 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 and motor skills need to be a part of the discussion.

Keywords

Autism; motor skills; young children; calibrated severity

Autism spectrum disorder (ASD) is a pervasive developmental disorder characterized by deficits in social communicative skills and repetitive or restricted interests (APA, 1994, 2000, 2013). ASD affects 1 in 88 individuals (CDC, 2012) and a recent national survey indicated that ASD affects 1 in 50 school-aged children (Blumberg et al., 2013). In addition to the hallmark characteristics of ASD, social communicative deficits, children also display motor skill deficits (Landa & Garrett-Mayer, 2006; Lloyd, MacDonald, & Lord, 2013; Provost, Heimerl, & Lopez, 2007; Provost, Lopez, & Heimerl, 2007; Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998; Yirmiya & Ozonoff, 2007). In fact, in some of the original clinical descriptions of what is now called ASD, Asperger attached considerable weight to motor clumsiness (Frith, 1991).

Motor skill deficits appear early in life for many young children with ASD, and become prominent around 14–24 months of age (Chawarska et al., 2007). Delayed infant motor milestones have been reported and these late milestones (especially walking) have acted as initial developmental concerns to parents, who later received an ASD diagnosis for their child (Chawarska et al., 2007; Flanagan, Landa, Bhat, & Bauman, 2012; Landa & Garrett-Mayer, 2006; Lloyd et al., 2013; Teitelbaum, et al., 1998).

For the most part the use of motor skill performance in an ASD diagnosis is embedded in gestures, stereotypies and imitation (Lord et al., 2000; Luyster et al., 2009). However it has been suggested that one of the earliest detectable signs and a cardinal feature of the disability may reside in motor skill ability early in life (Flanagan et al., 2012; Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Sutera, Pandey, Esser, & Rosenthal, 2007; Teittelbaum, Teittelbaum, Nye, Fryman, & Maurer, 1998). When a group of children at high-risk for ASD (children who had a sibling diagnosed with ASD), were studied prospectively three groups emerged for comparison, children with language delay, ASD and typical development (Landa & Garrett-Mayer, 2006). Deficits in fine motor skills were evident in children with ASD at 6 months of age and significantly worsened fine and gross motor skills were evident at 14 and 24 months of age (Landa & Garrett-Mayer, 2006). This prospective study suggested early motor skill deficits as a potential diagnostic distinction between children with ASD and children with other developmental delays (language delay)

(Landa & Garrett-Mayer, 2006). These findings corroborated previous studies suggesting motor skill delays early in development may act as some of the first signs for developmental concern (Teittelbaum et al., 1998). Through video analysis Teitelbaum et al. (1998) found oral motor deficits as well as delays in motor milestones such as lying, righting, sitting, crawling and walking were present in young children with ASD long before a diagnosis was conclusive.

In a large cross-sectional study of young children with ASD (N= 172, aged 14–36 months) fine and gross motor skill deficits became significantly worse within a short chronological timeframe (6–18 months) (Lloyd et al., 2013). The same study confirmed cross-sectional findings through a longitudinal analysis of children who had two motor skill assessments approximately one-year apart. When the same children were studied over time, they displayed significantly worse motor skill deficits as they aged (Lloyd et al., 2013).

Other motor deficits areas have been found in gait and postural control. Children with ASD (aged 4–6 years) demonstrated a short step length and irregular body oscillations during locomotion consistent with a less stable and more variable posture compared to a control group without a disability (Vernazza-Martin et al., 2005). Young children with ASD (less than 2 years) displayed similar gait and postural control deficits (Esposito & Venuti, 2008). At 20 months of age children with ASD showed deficits in gait parameters which included performing abnormal heel-to-toe patterns, odd arm posturing and generally higher frequencies of anomalies in movement including waddle walking (Esposito & Venuti, 2008). Postural sway in school-aged children with ASD was significantly greater than typically developed controls in mediolateral, anteroposterior and normalized sway (Fournier et al., 2010; Memari et al., 2013). Similarly, postural sway in the mediolateral direction was greater in children with autism during dynamic movements such as walking (Fournier, Kimberg, et al., 2010).

Consistent with other motor skill deficits at a young age, motor planning deficits were evident when children with ASD were unable translate motor intention into a global motor action (mean age 7.6 years), but rather treated each motor task involved in an overall action as an independent task (Fabbri-Destro, Cattaneo, Boria, & Rizzolatti, 2009). Vernazza-Martin et al. (2005) found that young children with ASD (4–6 years) had difficulty defining the goal of the motor action. Even when the task was adapted in a highly motivating fashion, children appeared to understand the instruction, marked in their purposeful action of moving toward the object, but the final motor goal could not be completed, indicating shortfalls in motor planning (Vernazza-Martin, et al., 2005). These children were able to perform simple motor tasks but unable to chain multiple motor tasks together into a more complex motor action.

Descriptive studies have clearly demonstrated that motor skill deficits exist in children with ASD at a young age and have even gone so far as to suggest early motor skill deficits as a preliminary diagnostic marker and a cardinal characteristic of the disability (Flanagan et al., 2012; Fournier, Hass, et al., 2010; Matson, Mahan, Fodstad, Hess, & Neal, 2010; Teittelbaum et al., 1998). These deficits in young children with autism range in nature and across tasks (Berkeley, Zittel, Pitney, & Nichols, 2001; Rinehart et al., 2006; Staples &

Reid, 2009; Sutera et al., 2007; Teittelbaum et al., 1998; Vernazza-Martin et al., 2005).Even though evidence suggests motor deficits are prominent and pervasive across time and age very little has been discussed in terms of how motor skill deficits interact with the core-characteristics of autism, deficits in social communication skills (Berkeley, et al., 2001; Fournier, Hass et al., 2010; Landa & Garrett-Mayer, 2006; Staples & Reid, 2009). It is well known that deficits in social communicative skills are core diagnostic characteristics of ASD. For young children this includes skills such as imitation, joint attention, general social interactions with others, as well as functional and symbolic play (Kasari et al., 2005).

The importance of improving social communicative skills in children with autism early in life has been clearly indicated (Dawson et al., 2010; Helt et al., 2008; Kasari, et al., 2005; Kasari, Gulsrud, Wong, Kwon, & Locke, 2010; Kasari, Paparella, Freeman, & Jahromi, 2008; Kelley, Naigles, & Fein, 2010; Wong & Kwan, 2010). The purpose of this study is to test the relationship of fine and gross motor skills on the behavior composite, daily living, adaptive social and communicative skills of children with autism. It is hypothesized that children with better motor skills will have better adaptive behavior skills.

Method

Participants

The Institutional Review Board approved all methods and procedures for this study. Young children with ASD, pervasive developmental disorder- not otherwise specified (PDD-NOS) and non-ASD (developmental delay) between the ages of 12–60 months were recruited from early intervention studies and clinical referrals to university-based clinics. Generally, children were recruited through autism support groups, study flyers and clinical referrals from pediatricians and teachers were informed of the study during clinical visits.

All participants (N=233) in this study were children between the ages of 14–49 months (mean age= 30.36 months) with a confirmatory diagnosis of ASD, PDD-NOS or non-ASD (non-ASD developmentally delayed children) based on the DSM-IV(see Table 1).

Measurements

Child diagnostic measures—All participants were administered the Autism Diagnostic Observation Schedule (ADOS) (Lord, et al., 2000; Lord, Rutter, DiLavore, & Risi, 1999) or its precursor, the Pre-Linguistic Autism Diagnostic Observation Schedule (DiLavore, Lord, & Rutter, 1995), in order to acquire diagnostic information through direct observation of the children by a trained clinician. The participants at one university-based center were administered the Toddler module of the ADOS (Luyster, et al., 2009). Diagnosis was determined by standardized algorithms established for the Autism Diagnostic Observation Schedule (Gotham, Pickles, & Lord, 2009; Lord, et al., 2000). A clinical psychologist or a trainee who completed research training and met standard requirements for research reliability administered the ADOS (Lord, et al., 1999).

Revised algorithms for the ADOS modules 1, 2 and 3 have been published with stronger specificity and sensitivity (Gotham, Risi, Pickles, & Lord, 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).

Each member of the research team, at all centers, established inter-rater reliability exceeding 90% exact agreement (kappa>0.70) for all items on the ADI-R and 80% exact agreement (kappa>0.60) on codes for the PL-ADOS, ADOS, and Toddler module for three consecutive administrations before the study began. Reliability was maintained over time through consensus coding of approximately every sixth administration with a second rater who was blind to referral status.

Developmental level measurement—The Mullen Scales of Early Learning (MSEL) (Mullen, 1995) was used to assess cognitive development. This test of development provides reliable and valid information for children from birth to 68 months of age. The subscales on the MSEL are organized into 5 domains: gross motor, fine motor, visual reception (nonverbal problem solving), receptive language, and expressive language. An early learning composite score is derived from the fine motor, visual reception, receptive language and expressive language scales.

Adaptive skills—The Vineland Adaptive Behavior Scales, 2nd Ed. (VABS) (Sparrow, Cicchetti, & Balla, 2005) were used to assess adaptive skills. The VABS is a standardized parent-report measure of everyday adaptive functioning and yields domain scores in the areas of communication, daily living skills, social skills, and motor development (fine motor and gross motor). A standardized behavior composite score is derived from all domains. This assessment was administered by interview or over the phone, to the parent or primary caregiver of the participant.

Motor skill measurement—The gross motor and fine motor scales of the MSEL were used to assess motor skills (Mullen, 1995). A gross motor and fine motor age equivalent score was used for analysis as standardized T-scores are not provided for children beyond 33 months of age on the gross motor scale, even though most children with ASD did not meet the ceiling requirements for this scale.

Data reduction—All examiners strictly adhered to the standardized procedures outlined in each respective test manual. As indicated in the measurement description, research reliability and inter-rater reliability was established for the ADOS. Autism cut-off was based on standardized algorithms (Gotham, et al., 2007; Lord, et al., 2000). These algorithms included scores based on social communication, repetitive and restricted interests and stereotyped behaviors. Experienced administrators familiar in working with young children with autism conducted all assessments. Included in the descriptive characteristics of the sample is an age difference score- the age difference score was calculated based on the chronological age of the participant and the child's motor skill age based on MSEL norms (Mullen, 1995) (see Table 2).

Data analysis

Data analysis tested the relationship of fine and gross motor skills on the adaptive behavior composite, adaptive social, adaptive communicative and daily living skills of children with ASD, non-ASD and PDD-NOS. Adaptive behavior, adaptive social, adaptive communicative and daily living skills were indicated through the standardized scales of the Vineland Adaptive Behavior Scales (VABS) (Sparrow, et al., 2005). A multiple regression analysis was conducted on for each respective dependent variable.

Results

A total of 233 children with a confirmatory diagnosis of ASD (*n*= 172), PDD-NOS (*n*= 22) and non-ASD (*n*= 39) were included in this study (mean age= 30.36 months). Descriptive characteristics of the sample can be found in Table 1.

An initial multiple regression analysis was conducted on the adaptive behavior composite score, which is comprised of all subscales. Separate multiple regression analyses were conducted for each subscale of interest, this included the standard daily living, adaptive social behavior and adaptive communicative behavior. For each dependent variable the multiple regression analysis included non-verbal problem solving, ethnicity and calibrated autism severity scores. Age was not included as a predictor as age and non-verbal problem solving were collinear. There were no interactions.

Fine motor skills and adaptive behavior composite, daily living, adaptive social behavior & adaptive communicative behavior

A multiple regression analysis tested the relationship of fine motor skills, visual receptive organization (non-verbal problem solving), calibrated autism severity and ethnicity on the adaptive behavior composite, daily living skills, adaptive social behavior and adaptive communicative behavior of young children with autism. For each dependent variable the multiple regression analysis included fine motor skills, nonverbal problem solving, ethnicity and calibrated autism severity. There were no interactions. Fine motor skills and calibrated autism severity were significant predictors of adapted behavior composite ($p < .001$), daily living skills ($p < .001$), adaptive social skills ($p < .05$) and adaptive communicative skills ($p < .001$) (Table 2).

Gross motor skills and adaptive behavior composite, daily living, adaptive social behavior & adaptive communicative behavior

A multiple regression analysis tested the relationship of gross motor skills, visual receptive organization (non-verbal problem solving), calibrated autism severity and ethnicity on the adaptive behavior composite, daily living skills, adaptive social behavior and adaptive communicative behavior of young children with autism. There were no interactions.

Gross motor skills and calibrated autism severity were predictors of daily living skills ($p < .001$). Calibrated autism severity and non-verbal problem solving were predictors of the adaptive behavior composite, adaptive social communicative skills ($p < .001$) (Table 3).

Discussion

The motor skills of young children with ASD are related to their adaptive behavior, daily living skills and adaptive social and communicative skills. The fine motor skills of young children with autism were predictive of all of the adaptive scales used in these analyses while gross motor skills were predictive of daily living skills based on the Vineland Adaptive Behavior Scales (2nd edition) (Sparrow, et al., 2005). Motor skill deficits have been indicated in young children with ASD through retrospective and prospective research (Chawarska, et al., 2007; Landa & Garrett-Mayer, 2006; Lloyd, et al., 2013; Ozonoff et al., 2008; Teittelbaum, et al., 1998). Yet, the relationship of motor skills to other developmental characteristics of ASD has not been studied extensively. It is possible that motor skill deficits are in fact hindering improvements in social communication skills for children with ASD (MacDonald, Jaszewski, Esposito, & Ulrich, 2011; MacDonald, Lord, & Ulrich, 2013; Sutera, et al., 2007).

Early intervention, focused on social communicative improvement, is a necessity for young children with ASD (Dawson, et al., 2010; Kasari, et al., 2005; Kelley, et al., 2010; National Research Council (NRC), 2001). This includes content focused on skills such as imitation, joint attention and play (functional and symbolic play skills) (Kasari, et al., 2005). Randomized control trials have undoubtedly displayed that intensive early intervention significantly improves behavior in the social communicative domain as well as other aspects of ASD symptomology (Dawson, et al., 2010; Kasari, et al., 2010; Wong & Kwan, 2010). These improvements have included IQ, language, play skills, adaptive behavior and ASD diagnosis (ie. moving from ASD, to PDD-NOS) (Dawson, et al., 2010; Kasari, Freeman, & Paparella, 2006; Kasari, et al., 2008). Although there is widespread agreement on the necessity of early intervention, there is less consistent agreement on early intervention content (Kasari, et al., 2005). A report from the National Research Council (NRC; 2001) indicated that motor skills should be emphasized in specialized early intervention for young children with ASD. Yet, more than a decade later, motor skill content does not appear to be a priority in early intervention models.

In a group of school-aged children with ASD fundamental motor skills were significantly related to social communicative skills (MacDonald, et al., 2013). The authors concluded that motor skills needed to be included in the discussion of content for social skills-based programs for school-aged children. It has been previously acknowledged that a potential relationship exists between the motor domain and the social communicative domains, however a direct relationship between these domains has not been planned in young children with ASD (Landa & Garrett-Mayer, 2006; Ozonoff, et al., 2008; Sutera, et al., 2007). In the present study a direct relationship was found between fine motor skills and adaptive social and adaptive communication skills of young children with ASD, while holding other important variables constant including calibrated autism severity and non-verbal problem solving. Motor skills may be a missing component of current early intervention programs and an additive piece to further improve motor skills and possibly social communicative skills in young children with ASD (MacDonald, et al., 2013; Rosenbaum, 2005). In this study gross motor skills were less predictive of the adaptive social and adaptive communicative skills of these young children. However, they were predicted of daily living skills. Although the MSEL is a standardized measure of motor skills, it is typically used for developmental assessments, a more sensitive measure of motor skills, such as the Peabody Motor Development Scales- 2nd Edition (Folio & Fewell, 2000), may have been more informative. For an extensive review of motor skill assessments for children with ASD please see (Staples, MacDonald, & Zimmer, 2012).

With the best content for early intervention under investigation, and with early intervention on the forefront of ASD research, the importance of motor skills should also be considered (Dawson, et al., 2010; Kasari, et al., 2005; Matson & Kozlowski, 2011; Sutera, et al., 2007). The Denver model, an early intervention for young children with ASD, might be the closest early intervention that successfully intertwines motor skills, social communicative skills and social success; however how proficient motor skills impacts social success has not been measured (Rogers, 2000). In fact, many early intervention models imply the use of games or activities to facilitate social learning and some of the activities require relatively proficient motor skills for success. For instance games like “chase”, songs that require actions, climbing activities (like sliding or playing on equipment), as well as activities that include coloring or drawing are often important components of early intervention programs. Arguably, these activities may be more successful if the participants have more proficient motor skills. Unmistakably, the emphasis of early intervention programs is social communicative, but it is possible that these two domains, motor and social communicative, are already working together. In short, teaching age-appropriate motor skills might add to a practitioner’s repertoire of intervention strategies aimed at improving social success (Lloyd, et al., 2013; Sutera, et al., 2007; Swiezy, 2008).

The prevalence and pervasiveness of motor skill deficits in young children with ASD has been clearly indicated across tasks (Chawarska, et al., 2007; Matson, et al., 2010; Ozonoff, et al., 2008; Teittelbaum, et al., 1998; Vernazza-Martin, et al., 2005). Even at a young age, the motor skill deficits of children with ASD widen as the children become older (age range 14–36 months) (Lloyd, et al., 2013). Teaching motor skills to children with ASD, through adapted physical activity, has been successful (MacDonald et al., 2012). How to best implement motor skill improvements for young children with ASA and how to combine early intervention to include motor skill development is an area of future research. However, programs such as those implemented in pre-school adapted physical education settings and which include the use of adapted equipment and adapted instruction with a focus on motor skill improvement would be a good starting point (Goodway & Branta, 2003). Children with ASD have unique characteristics, which will be important to consider in motor skill-based programming. Given the relationship between motor skills and adaptive social communicative skills found in this study, including motor skill development in early intervention might be a significant additive piece for young children diagnosed with ASD in addition to more traditional early intervention programs.

Future directions

The necessity of early intervention for young children with ASD has clearly been indicated. However, a more concerning feature is agreement on program content (Kasari, et al., 2005). Retrospective comparisons of early intervention programs are difficult given the use of various outcome measures (Lord et al., 2005; Matson & Sipes, 2010). Clearly, motor skills deficits have been indicated, and this study shows direct relationships between fine and gross motor skills and adaptive behavioral skills in young children with ASD. A critical next step includes better understanding how motor skills interact with other types of social communicative skills. Given the motor skill deficits in this group of children, group-based programs to improve these skills are imperative and a consideration for future studies. If motor skill interventions are successful, how motor skill interventions improve social communicative success may also provide important information.

Limitations

Limitations to this study include the retrospective nature of the work and secondary data analysis. Age equivalent motor scores were used in order to standardize scores across age (as standard scores were only available up to 33 months). More sensitive motor skill assessments need to be implemented to better understand this relationship, such as the Peabody Motor Developmental Scales- 2nd Edition (Folio & Fewell, 2000; Staples, et al., 2012). Another limitation to this study included the use of motor skills in the adaptive behavior composite score derived from the Vineland Adaptive Behavior Scales. Although the specific motor scales of the Vineland were not assessed, motor scales are embedded in the adaptive behavior composite score. Another limitation to this study included the administration of the Vineland Adaptive Behavior Scales. It appears that the Vineland was implemented using two different methods, face-to-face interview and over-the-phone administration. Although similar, the reliability of these methods has not been tested, to our knowledge.

Conclusion

The findings of this study acknowledge that a relationship exists between motor skills and the core characteristics of ASD, deficits in the social and communicative domain. Motor skills need to be considered and included in early intervention programming.

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Highlights

- We examine the relationship of motor skill and adaptive skills in young children with autism
- Fine motor skills are related to adaptive behavior in young children with autism
- Gross motor skills are related to the adaptive behavior composite and daily living skills of young children with autism
- Motor skills should be considered in early intervention

Table 1

Descriptive characteristics of the participants

Variable	ASD (*n=172)*	PDD-NOS *(n=22)*	Non-ASD *(n=39)*
Age (months)	30.3 (5.7)	31.1 (7.6)	30.0 (5.9)
Gender	M=141, F=31	M=16, F=6	M=27, F=12
Race/Ethnicity	Caucasian=113, Other=59	Caucasian=14, Other=8	Caucasian=27, Other=9
Maternal Education	Grad/professional=30	Grad/professional=3	Grad/professional=6
	College degree=46	College degree=5	College degree=6
	Some college=51	Some college=4	Some college=11
	High school=26	High school=5	High school=11
	Some high school=3	Some high school=0	Some high school=1
	Unknown=5	Unknown=5	Unknown=4
Gross Motor Age Equivalent	21.7 (6.2)	20.9 (7.9)	25.3 (7.4)
Fine Motor Age Equivalent	18.4 (6.1)	21.1 (7.2)	23.5 (7.0)
Gross motor difference variable (months)	8.8(7.6)*	7.6(7.5)	6.5(7.6)
Fine motor difference variable (months)	12.0(7.2)	8.6(6.4)	8.4(8.0)
Visual Reception Age Equivalent	19.2 (6.4)	22.4 (7.7)	25.9 (7.4)
Receptive Language Age Equivalent	8.5 (6.0)	16.5 (6.7)	23.3 (9.1)
Expressive Language Age Equivalent	10.5 (5.8)	13.4 (7.1)	20.7 (10.3)
Vineland Fine Motor Age Equivalent	18.1 (4.9)	19.6 (6.9)	20.9 (6.6)
Vineland Gross Motor Age Equivalent	20.6 (5.6)	21.5 (11.1)	21.6 (7.8)
Vineland Overall Motor Age Equivalent	19.5 (5.1)	20.7 (7.9)	21.0 (7.1)
Vineland Standard Motor Score	73.2 (12.6)	75.3 (19.2)	78.0 (16.1)
Ratio Verbal IQ	31.5 (18.2)	48.8 (17.0)	73.4 (26.6)
Ratio Non-Verbal IQ	63.2 (19.9)	72.2 (24.6)	83.2 (18.4)

*Mean (standard deviation)

Table 2

Multiple regression analysis testing fine motor skill on the adaptive behavior composite, daily living skills adaptive social and adaptive communicative skills.

	Adaptive Behavior Composite			**Daily Living Skills**		
Variable	***B***	***SE B***	***β***	***B***	***SE B***	***β***
Fine motor skills	.497	0.08	.352*	1.92	0.34	.34
Calibrated severity	−.956	0.19	−.304*	−4.282	0.76	−.33
R^2	.19			.29		
F	46.7*			46.7		
	Adaptive Social Skills			Adaptive Communicative Skills		
Variable	*B*	*SE B*	*β*	*B*	*SE B*	*β*
Fine motor skills	.196	0.09	.124**	.358	0.087	.231
Calibrated severity	−1.9	0.20	−.537*	−1.70	0.194	−.49
R^2	.35			.37		
F	59.0*			65.1		

* $p < .001$

** $p < .05$.

Table 3

Multiple regression analysis testing gross motor skill on the adaptive behavior composite, daily living skills adaptive social and adaptive communicative skills.

	Daily Living Skills		
Variable	***B***	***SE B***	***β***
Gross motor skills	1.6	.32	.29*
Calibrated severity	−5.63	0.768	−.439*
R^2	.27		
F	42.5*		

*$p < .001$