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

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Motor skills, calibrated severity & autism

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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.

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.

Motor skills, calibrated severity & autism

Key words: Autism, motor skills, young children, calibrated severity

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11 spectrum disorders

12

1   **Abstract**

2   Motor skill deficits are pervasive and persistent in young children with autism spectrum

3   disorder (ASD). Yet the focus of intervention is on core impairments, which are part of the

4   diagnostic criteria for ASD, deficits in social communication skills. The purpose of this study is

5   to determine whether a relationship exists between the motor skills of young children with ASD

6   (14- 49 months) and adaptive behavior skills. Two hundred and thirty three children with ASD

7   between the ages of 14- 49 months participated in this study. A multiple regression analysis

8   tested the relationship of motor skills on the adaptive behavior composite, daily living, adaptive

9   social and adaptive communicative skills holding constant age, non-verbal problem solving, and

10 clinical ASD diagnosis. Fine motor skills significantly predicted all adaptive behavior skills ($p <$

11 0.01). Gross motor skills were predictive of daily living skills ($p < 0.05$). Children with weaker

12 motor skills displayed greater deficits in adaptive behavior skills.

13

1   Autism spectrum disorder (ASD) is a pervasive developmental disorder characterized by

2   deficits in social communicative skills and repetitive or restricted interests (APA, 1994, 2000,

3   2013). ASD affects 1 in 88 individuals (CDC, 2012) and a recent national survey indicated that

4   ASD affects 1 in 50 school-aged children (Blumberg et al., 2013). In addition to the hallmark

5   characteristics of ASD, social communicative deficits, children also display motor skill deficits

6   (Landa & Garrett-Mayer, 2006; Lloyd, MacDonald, & Lord, 2013; Provost, Heimerl, & Lopez,

7   2007; Provost, Lopez, & Heimerl, 2007; Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer,

8   1998; Yirmiya & Ozonoff, 2007). In fact, in some of the original clinical descriptions of what is

9   now called ASD, Asperger attached considerable weight to motor clumsiness (Frith, 1991).

10   Motor skill deficits appear early in life for many young children with ASD, and become

11   prominent around 14- 24 months of age (Chawarska et al., 2007). Delayed infant motor

12   milestones have been reported and these late milestones (especially walking) have acted as initial

13   developmental concerns to parents, who later received an ASD diagnosis for their child

14   (Chawarska et al., 2007; Flanagan, Landa, Bhat, & Bauman, 2012; Landa & Garrett-Mayer,

15   2006; Lloyd et al., 2013; Teitelbaum, et al., 1998).

16   For the most part the use of motor skill performance in an ASD diagnosis is embedded in

17   gestures, stereotypies and imitation (Lord et al., 2000; Luyster et al., 2009). However it has been

18   suggested that one of the earliest detectable signs and a cardinal feature of the disability may

19   reside in motor skill ability early in life (Flanagan et al., 2012; Fournier, Hass, Naik, Lodha, &

20   Cauraugh, 2010; Sutera, Pandey, Esser, & Rosenthal, 2007; Teittelbaum, Teittelbaum, Nye,

21   Fryman, & Maurer, 1998). When a group of children at high-risk for ASD (children who had a

22   sibling diagnosed with ASD), were studied prospectively three groups emerged for comparison,

23   children with language delay, ASD and typical development (Landa & Garrett-Mayer, 2006).

1   Deficits in fine motor skills were evident in children with ASD at 6 months of age and

2   significantly worsened fine and gross motor skills were evident at 14 and 24 months of age

3   (Landa & Garrett-Mayer, 2006). This prospective study suggested early motor skill deficits as a

4   potential diagnostic distinction between children with ASD and children with other

5   developmental delays (language delay) (Landa & Garrett-Mayer, 2006). These findings

6   corroborated previous studies suggesting motor skill delays early in development may act as

7   some of the first signs for developmental concern (Teittelbaum et al., 1998). Through video

8   analysis Teitelbaum et al. (1998) found oral motor deficits as well as delays in motor milestones

9   such as lying, righting, sitting, crawling and walking were present in young children with ASD

10   long before a diagnosis was conclusive.

11   In a large cross-sectional study of young children with ASD (N= 172, aged 14- 36

12   months) fine and gross motor skill deficits became significantly worse within a short

13   chronological timeframe (6- 18 months) (Lloyd et al., 2013). The same study confirmed cross-

14   sectional findings through a longitudinal analysis of children who had two motor skill

15   assessments approximately one-year apart. When the same children were studied over time, they

16   displayed significantly worse motor skill deficits as they aged (Lloyd et al., 2013).

17   Other motor deficits areas have been found in gait and postural control. Children with

18   ASD (aged 4- 6 years) demonstrated a short step length and irregular body oscillations during

19   locomotion consistent with a less stable and more variable posture compared to a control group

20   without a disability (Vernazza-Martin et al., 2005). Young children with ASD (less than 2 years)

21   displayed similar gait and postural control deficits (Esposito & Venuti, 2008). At 20 months of

22   age children with ASD showed deficits in gait parameters which included performing abnormal

23   heel-to-toe patterns, odd arm posturing and generally higher frequencies of anomalies in

1 movement including waddle walking (Esposito & Venuti, 2008). Postural sway in school-aged

2 children with ASD was significantly greater than typically developed controls in mediolateral,

3 anteroposterior and normalized sway (Fournier et al., 2010; Memari et al., 2013). Similarly,

4 postural sway in the mediolateral direction was greater in children with autism during dynamic

5 movements such as walking (Fournier, Kimberg, et al., 2010).

6   Consistent with other motor skill deficits at a young age, motor planning deficits were

7 evident when children with ASD were unable translate motor intention into a global motor action

8 (mean age 7.6 years), but rather treated each motor task involved in an overall action as an

9 independent task (Fabbri-Destro, Cattaneo, Boria, & Rizzolatti, 2009). Vernazza-Martin et al.

10 (2005) found that young children with ASD (4- 6 years) had difficulty defining the goal of the

11 motor action. Even when the task was adapted in a highly motivating fashion, children appeared

12 to understand the instruction, marked in their purposeful action of moving toward the object, but

13 the final motor goal could not be completed, indicating shortfalls in motor planning (Vernazza-

14 Martin, et al., 2005). These children were able to perform simple motor tasks but unable to chain

15 multiple motor tasks together into a more complex motor action.

16   Descriptive studies have clearly demonstrated that motor skill deficits exist in children

17 with ASD at a young age and have even gone so far as to suggest early motor skill deficits as a

18 preliminary diagnostic marker and a cardinal characteristic of the disability (Flanagan et al.,

19 2012; Fournier, Hass, et al., 2010; Matson, Mahan, Fodstad, Hess, & Neal, 2010; Teittelbaum et

20 al., 1998). These deficits in young children with autism range in nature and across tasks

21 (Berkeley, Zittel, Pitney, & Nichols, 2001; Rinehart et al., 2006; Staples & Reid, 2009; Sutera et

22 al., 2007; Teittelbaum et al., 1998; Vernazza-Martin et al., 2005).Even though evidence suggests

23 motor deficits are prominent and pervasive across time and age very little has been discussed in

1   terms of how motor skill deficits interact with the core-characteristics of autism, deficits in social

2   communication skills (Berkeley, et al., 2001; Fournier, Hass et al., 2010; Landa & Garrett-

3   Mayer, 2006; Staples & Reid, 2009). It is well known that deficits in social communicative

4   skills are core diagnostic characteristics of ASD. For young children this includes skills such as

5   imitation, joint attention, general social interactions with others, as well as functional and

6   symbolic play (Kasari et al., 2005).

7   The importance of improving social communicative skills in children with autism early in

8   life has been clearly indicated (Dawson et al., 2010; Helt et al., 2008; Kasari, et al., 2005; Kasari,

9   Gulsrud, Wong, Kwon, & Locke, 2010; Kasari, Paparella, Freeman, & Jahromi, 2008; Kelley,

10 Naigles, & Fein, 2010; Wong & Kwan, 2010). The purpose of this study is to test the

11 relationship of fine and gross motor skills on the behavior composite, daily living, adaptive

12 social and communicative skills of children with autism. It is hypothesized that children with

13 better motor skills will have better adaptive behavior skills.

14   **Method**

15 **Participants**

16   The Institutional Review Board approved all methods and procedures for this study.

17 Young children with ASD, pervasive developmental disorder- not otherwise specified (PDD-

18 NOS) and non-ASD (developmental delay) between the ages of 12- 60 months were recruited

19 from early intervention studies and clinical referrals to university-based clinics. Generally,

20 children were recruited through autism support groups, study flyers and clinical referrals from

21 pediatricians and teachers were informed of the study during clinical visits.

1   All participants (N=233) in this study were children between the ages of 14- 49 months

2   (mean age= 30.36 months) with a confirmatory diagnosis of ASD, PDD-NOS or non-ASD (non-

3   ASD developmentally delayed children) based on the DSM-IV(see Table 1).

4   **Measurements**

5   **Child diagnostic measures.** All participants were administered the Autism Diagnostic

6   Observation Schedule (ADOS) (Lord, et al., 2000; Lord, Rutter, DiLavore, & Risi, 1999) or its

7   precursor, the Pre-Linguistic Autism Diagnostic Observation Schedule (DiLavore, Lord, &

8   Rutter, 1995), in order to acquire diagnostic information through direct observation of the

9   children by a trained clinician. The participants at one university-based center were administered

10   the Toddler module of the ADOS (Luyster, et al., 2009). Diagnosis was determined by

11   standardized algorithms established for the Autism Diagnostic Observation Schedule (Gotham,

12   Pickles, & Lord, 2009; Lord, et al., 2000). A clinical psychologist or a trainee who completed

13   research training and met standard requirements for research reliability administered the ADOS

14   (Lord, et al., 1999).

15   Revised algorithms for the ADOS modules 1, 2 and 3 have been published with stronger

16   specificity and sensitivity (Gotham, Risi, Pickles, & Lord, 2007). Standardized scores of

17   calibrated severity are available using raw scores from the revised algorithms of the ADOS

18   (Gotham, et al., 2009). Calibrated autism severity scores have been indicated optimal for

19   comparisons of assessments across time (and age), and to identify different trajectories of autism

20   severity independent of verbal IQ (Gotham, et al., 2009).

21   Each member of the research team, at all centers, established inter-rater reliability

22   exceeding 90% exact agreement (kappa>0.70) for all items on the ADI-R and 80% exact

23   agreement (kappa>0.60) on codes for the PL-ADOS, ADOS, and Toddler module for three

1 consecutive administrations before the study began. Reliability was maintained over time

2 through consensus coding of approximately every sixth administration with a second rater who

3 was blind to referral status.

4   **Developmental level measurement.** The Mullen Scales of Early Learning (MSEL)

5 (Mullen, 1995) was used to assess cognitive development. This test of development provides

6 reliable and valid information for children from birth to 68 months of age. The subscales on the

7 MSEL are organized into 5 domains: gross motor, fine motor, visual reception (nonverbal

8 problem solving), receptive language, and expressive language. An early learning composite

9 score is derived from the fine motor, visual reception, receptive language and expressive

10 language scales.

11   **Adaptive skills.** The Vineland Adaptive Behavior Scales, 2nd Ed. (VABS) (Sparrow,

12 Cicchetti, & Balla, 2005) were used to assess adaptive skills. The VABS is a standardized

13 parent-report measure of everyday adaptive functioning and yields domain scores in the areas of

14 communication, daily living skills, social skills, and motor development (fine motor and gross

15 motor). A standardized behavior composite score is derived from all domains. This assessment

16 was administered by interview or over the phone, to the parent or primary caregiver of the

17 participant.

18   **Motor skill measurement**. The gross motor and fine motor scales of the MSEL were

19 used to assess motor skills (Mullen, 1995). A gross motor and fine motor age equivalent score

20 was used for analysis as standardized T-scores are not provided for children beyond 33 months

21 of age on the gross motor scale, even though most children with ASD did not meet the ceiling

22 requirements for this scale.

1   **Data reduction.** All examiners strictly adhered to the standardized procedures outlined in

2   each respective test manual. As indicated in the measurement description, research reliability and

3   inter-rater reliability was established for the ADOS. Autism cut-off was based on standardized

4   algorithms (Gotham, et al., 2007; Lord, et al., 2000). These algorithms included scores based on

5   social communication, repetitive and restricted interests and stereotyped behaviors. Experienced

6   administrators familiar in working with young children with autism conducted all assessments.

7   Included in the descriptive characteristics of the sample is an age difference score- the age

8   difference score was calculated based on the chronological age of the participant and the child's

9   motor skill age based on MSEL norms (Mullen, 1995) (see Table 2).

10   **Data analysis**

11   Data analysis tested the relationship of fine and gross motor skills on the adaptive

12   behavior composite, adaptive social, adaptive communicative and daily living skills of children

13   with ASD, non-ASD and PDD-NOS. Adaptive behavior, adaptive social, adaptive

14   communicative and daily living skills were indicated through the standardized scales of the

15   Vineland Adaptive Behavior Scales (VABS) (Sparrow, et al., 2005). A multiple regression

16   analysis was conducted on for each respective dependent variable.

17   **Results**

18   A total of 233 children with a confirmatory diagnosis of ASD (*n*= 172), PDD-NOS (*n*=

19   22) and non-ASD (*n*= 39) were included in this study (mean age= 30.36 months). Descriptive

20   characteristics of the sample can be found in Table 1.

21   << Insert Tables 1 about here >>

22   An initial multiple regression analysis was conducted on the adaptive behavior

23   composite score, which is comprised of all subscales. Separate multiple regression analyses

1   were conducted for each subscale of interest, this included the standard daily living, adaptive

2   social behavior and adaptive communicative behavior. For each dependent variable the multiple

3   regression analysis included non-verbal problem solving, ethnicity and calibrated autism severity

4   scores. Age was not included as a predictor as age and non-verbal problem solving were

5   collinear. There were no interactions.

6   **Fine motor skills and adaptive behavior composite, daily living, adaptive social**

7   **behavior & adaptive communicative behavior.** A multiple regression analysis tested the

8   relationship of fine motor skills, visual receptive organization (non-verbal problem solving),

9   calibrated autism severity and ethnicity on the adaptive behavior composite, daily living skills,

10   adaptive social behavior and adaptive communicative behavior of young children with autism.

11   For each dependent variable the multiple regression analysis included fine motor skills, non-

12   verbal problem solving, ethnicity and calibrated autism severity. There were no interactions.

13   Fine motor skills and calibrated autism severity were significant predictors of adapted behavior

14   composite ($p < .001$), daily living skills ($p < .001$), adaptive social skills ($p < .05$) and adaptive

15   communicative skills ($p < .001$) (Table 2).

16   **Gross motor skills and adaptive behavior composite, daily living, adaptive social**

17   **behavior & adaptive communicative behavior.** A multiple regression analysis tested the

18   relationship of gross motor skills, visual receptive organization (non-verbal problem solving),

19   calibrated autism severity and ethnicity on the adaptive behavior composite, daily living skills,

20   adaptive social behavior and adaptive communicative behavior of young children with autism.

21   There were no interactions.

1   **G**ross motor skills and calibrated autism severity were predictors of daily living skills (p

2   < .001). Calibrated autism severity and non-verbal problem solving were predictors of the

3   adaptive behavior composite, adaptive social communicative skills (p < .001) (Table 3).

4   << Insert Tables 2 & 3 about here >>

5

6

7   **Discussion**

8   The motor skills of young children with ASD are related to their adaptive behavior, daily

9   living skills and adaptive social and communicative skills. The fine motor skills of young

10   children with autism were predictive of all of the adaptive scales used in these analyses while

11   gross motor skills were predictive of daily living skills based on the Vineland Adaptive Behavior

12   Scales (2nd edition) (Sparrow, et al., 2005). Motor skill deficits have been indicated in young

13   children with ASD through retrospective and prospective research (Chawarska, et al., 2007;

14   Landa & Garrett-Mayer, 2006; Lloyd, et al., 2013; Ozonoff et al., 2008; Teittelbaum, et al.,

15   1998). Yet, the relationship of motor skills to other developmental characteristics of ASD has

16   not been studied extensively. It is possible that motor skill deficits are in fact hindering

17   improvements in social communication skills for children with ASD (MacDonald, Jaszewski,

18   Esposito, & Ulrich, 2011; MacDonald, Lord, & Ulrich, 2013; Sutera, et al., 2007).

19   Early intervention, focused on social communicative improvement, is a necessity for

20   young children with ASD (Dawson, et al., 2010; Kasari, et al., 2005; Kelley, et al., 2010;

21   National Research Council (NRC), 2001). This includes content focused on skills such as

22   imitation, joint attention and play (functional and symbolic play skills) (Kasari, et al., 2005).

23   Randomized control trials have undoubtedly displayed that intensive early intervention

1   significantly improves behavior in the social communicative domain as well as other aspects of

2   ASD symptomology (Dawson, et al., 2010; Kasari, et al., 2010; Wong & Kwan, 2010). These

3   improvements have included IQ, language, play skills, adaptive behavior and ASD diagnosis (ie.

4   moving from ASD, to PDD-NOS) (Dawson, et al., 2010; Kasari, Freeman, & Paparella, 2006;

5   Kasari, et al., 2008). Although there is widespread agreement on the necessity of early

6   intervention, there is less consistent agreement on early intervention content (Kasari, et al.,

7   2005). A report from the National Research Council (NRC; 2001) indicated that motor skills

8   should be emphasized in specialized early intervention for young children with ASD. Yet, more

9   than a decade later, motor skill content does not appear to be a priority in early intervention

10   models.

11   In a group of school-aged children with ASD fundamental motor skills were

12   significantly related to social communicative skills (MacDonald, et al., 2013). The authors

13   concluded that motor skills needed to be included in the discussion of content for social skills-

14   based programs for school-aged children. It has been previously acknowledged that a potential

15   relationship exists between the motor domain and the social communicative domains, however a

16   direct relationship between these domains has not been planned in young children with ASD

17   (Landa & Garrett-Mayer, 2006; Ozonoff, et al., 2008; Sutera, et al., 2007). In the present study a

18   direct relationship was found between fine motor skills and adaptive social and adaptive

19   communication skills of young children with ASD, while holding other important variables

20   constant including calibrated autism severity and non-verbal problem solving. Motor skills may

21   be a missing component of current early intervention programs and an additive piece to further

22   improve motor skills and possibly social communicative skills in young children with ASD

23   (MacDonald, et al., 2013; Rosenbaum, 2005). In this study gross motor skills were less

1   predictive of the adaptive social and adaptive communicative skills of these young children.

2   However, they were predicted of daily living skills. Although the MSEL is a standardized

3   measure of motor skills, it is typically used for developmental assessments, a more sensitive

4   measure of motor skills, such as the Peabody Motor Development Scales- 2nd Edition (Folio &

5   Fewell, 2000), may have been more informative. For an extensive review of motor skill

6   assessments for children with ASD please see (Staples, MacDonald, & Zimmer, 2012).

7   With the best content for early intervention under investigation, and with early

8   intervention on the forefront of ASD research, the importance of motor skills should also be

9   considered (Dawson, et al., 2010; Kasari, et al., 2005; Matson & Kozlowski, 2011; Sutera, et al.,

10   2007). The Denver model, an early intervention for young children with ASD, might be the

11   closest early intervention that successfully intertwines motor skills, social communicative skills

12   and social success; however how proficient motor skills impacts social success has not been

13   measured (Rogers, 2000). In fact, many early intervention models imply the use of games or

14   activities to facilitate social learning and some of the activities require relatively proficient motor

15   skills for success. For instance games like "chase", songs that require actions, climbing activities

16   (like sliding or playing on equipment), as well as activities that include coloring or drawing are

17   often important components of early intervention programs. Arguably, these activities may be

18   more successful if the participants have more proficient motor skills. Unmistakably, the

19   emphasis of early intervention programs is social communicative, but it is possible that these two

20   domains, motor and social communicative, are already working together. In short, teaching age-

21   appropriate motor skills might add to a practitioner's repertoire of intervention strategies aimed

22   at improving social success (Lloyd, et al., 2013; Sutera, et al., 2007; Swiezy, 2008).

1   The prevalence and pervasiveness of motor skill deficits in young children with ASD has

2   been clearly indicated across tasks (Chawarska, et al., 2007; Matson, et al., 2010; Ozonoff, et al.,

3   2008; Teittelbaum, et al., 1998; Vernazza-Martin, et al., 2005). Even at a young age, the motor

4   skill deficits of children with ASD widen as the children become older (age range 14- 36

5   months) (Lloyd, et al., 2013). Teaching motor skills to children with ASD, through adapted

6   physical activity, has been successful (MacDonald et al., 2012). How to best implement motor

7   skill improvements for young children with ASA and how to combine early intervention to

8   include motor skill development is an area of future research. However, programs such as those

9   implemented in pre-school adapted physical education settings and which include the use of

10   adapted equipment and adapted instruction with a focus on motor skill improvement would be a

11   good starting point (Goodway & Branta, 2003). Children with ASD have unique characteristics,

12   which will be important to consider in motor skill-based programming. Given the relationship

13   between motor skills and adaptive social communicative skills found in this study, including

14   motor skill development in early intervention might be a significant additive piece for young

15   children diagnosed with ASD in addition to more traditional early intervention programs.

16   **Future directions**

17   The necessity of early intervention for young children with ASD has clearly been

18   indicated. However, a more concerning feature is agreement on program content (Kasari, et al.,

19   2005). Retrospective comparisons of early intervention programs are difficult given the use of

20   various outcome measures (Lord et al., 2005; Matson & Sipes, 2010). Clearly, motor skills

21   deficits have been indicated, and this study shows direct relationships between fine and gross

22   motor skills and adaptive behavioral skills in young children with ASD. A critical next step

23   includes better understanding how motor skills interact with other types of social

1 communicative skills. Given the motor skill deficits in this group of children, group-based

2 programs to improve these skills are imperative and a consideration for future studies. If motor

3 skill interventions are successful, how motor skill interventions improve social communicative

4 success may also provide important information.

5 **Limitations**

6   Limitations to this study include the retrospective nature of the work and secondary data

7 analysis. Age equivalent motor scores were used in order to standardize scores across age (as

8 standard scores were only available up to 33 months). More sensitive motor skill assessments

9 need to be implemented to better understand this relationship, such as the Peabody Motor

10 Developmental Scales- 2nd Edition (Folio & Fewell, 2000; Staples, et al., 2012). Another

11 limitation to this study included the use of motor skills in the adaptive behavior composite score

12 derived from the Vineland Adaptive Behavior Scales. Although the specific motor scales of the

13 Vineland were not assessed, motor scales are embedded in the adaptive behavior composite

14 score. Another limitation to this study included the administration of the Vineland Adaptive

15 Behavior Scales. It appears that the Vineland was implemented using two different methods,

16 face-to-face interview and over-the-phone administration. Although similar, the reliability of

17 these methods has not been tested, to our knowledge.

18 **Conclusion**

19   The findings of this study acknowledge that a relationship exists between motor skills

20 and the core characteristics of ASD, deficits in the social and communicative domain. Motor

21 skills need to be considered and included in early intervention programming.

22

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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 College degree=46 Some college=51 High school=26 Some high school= 3 Unknown=5	Grad/professional=3 College degree=5 Some college=4 High school=5 Some high school=0 Unknown=5	Grad/professional=6 College degree=6 Some college=11 High school=11 Some high school=1 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.

Variable	Adaptive Behavior Composite			Daily Living Skills		
	B	*SE B*	*ß*	*B*	*SE B*	*ß*
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		

*p < .001 **p < .05.

	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		

Table 3.

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

Variable	Daily Living Skills		
	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