Gross Motor Profile and Its Association with Socialization Skills in Children with Autism Spectrum Disorders

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Received Jun 17, 2015; received in revised form Nov 3, 2015; accepted Feb 24, 2016
Available online 2 April 2016

**Key Words**
autism spectrum disorder; gross motor skill; socialization skill; Vineland-II

**Background:** While social impairment is considered to be the core deficit in children with autism spectrum disorder (ASD), a large proportion of these children have poor gross motor ability, and gross motor deficits may influence socialization skills in children with ASD. The objectives of this study were to compare gross motor skills in children with ASD to typically developing children, to describe gross motor problems in children with ASD, and to investigate associations between gross motor and socialization skills in children with ASD.

**Methods:** This was a cross-sectional study including 40 ASD children aged from 18 months to 6 years and 40 age-matched typically developing controls. Gross motor and socialization skills were scored using the Vineland Adaptive Behavior Scales, 2nd edition (Vineland-II).

**Results:** Below average gross motor function was found in eight of 40 (20%) ASD children. The mean gross motor v-scale score in the ASD group was 15.1 (standard deviation (SD) 3.12), significantly lower than in the control group [18.7, SD 2.09, \( p = 0.0001 \); 95% confidence intervals (CI) from \(-4.725 \) to \(-2.525\)]. The differences were most prominent in ball throwing and catching, using stairs, jumping, and bicycling. The ASD children with gross motor impairments had a mean socialization domain score of 66.6 (SD 6.50) compared to 85.7 (SD 10.90) in those without gross motor impairments (\( p = 0.0001 , 95\% \) CI from \(-25.327 \) to \(-12.736\)).

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http://dx.doi.org/10.1016/j.pedneo.2016.02.004
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1. Introduction

Autism spectrum disorder (ASD) is a pervasive developmental disorder characterized by impairments in social interaction and communication skills, as well as limited and repetitive play.1 Epidemiological studies have reported varying prevalence rates in children aged 3–10 years. In New Jersey in the United States, a prevalence of four in 1000 children was reported in 2003,2 and the Centers for Disease Control and Prevention (CDC) reported a prevalence of 11.3 per 1000 children in 2008.3 In addition, the Ministry of Health of the Republic of Indonesia estimated the prevalence to be two per 1000 children in 2013.4

Impaired social interaction is considered to be the core deficit in ASD. Children with ASD have been reported to have low scores in the socialization domain of the Vineland Adaptive Behavior Scales, 2nd edition (Vineland-II).5,6 Furthermore, these children have been reported to have difficulties in initiating and maintaining social interactions with their peers due to a lack of experience and understanding of socioemotional aspects.7

Children with ASD often have motor impairments which can take the form of a gross and fine motor coordination disorder,8,9 motor stereotypy, gait disorder, postural and balance disorder,9 or dyspraxia.10 Dewey et al11 and Green et al12 reported prevalence rates of poor motor skills in ASD children of 59% and 79%, respectively. Another study reported that ASD children had a lower Vineland-II gross motor v-scale mean score than typically developing children.13 Motor impairment is a comorbidity which may affect functional capacity and socialization skills in children,13 and gross motor disorders can be detected as early 14 months of age becoming more pronounced at 24 months of age.14 Early detection is important to allow for the initiation of treatment before the child reaches school age.13

Both social dysfunction and motor impairment are crucial targets for prompt interventions in children with ASD. Previous studies15–17 have reported an association between gross motor impairments and socialization skills in children with ASD. One study using the Baby and Infant Screen for Children with Autism Traits (BISCUIT) instrument found that children with ASD and poor gross motor skills had lower socialization performance scores compared to those with normal gross motor skills [mean 17.94, standard deviation (SD) 8.57]. Another study reported that object control score on the Test of Gross Motor Development, 2nd edition can predict socialization skills in children with ASD.18 However, not all clinicians put social and motor impairment as a top priority in the management of ASD.

It has also been shown in separate studies that both socioemotional skills in children with ASD and gross motor development are socioculturally influenced. In a study comparing the motor development of infants in Ghana, China, and infants of African-American ethnicity in the United States, it was found that gross motor scores were significantly higher in the Ghanaian infants than in their Chinese and African-American counterparts.19 In addition, native African children in Ghana were shown to attain motor milestones earlier than those in Norway, India, Oman, and the United States, and most markedly in sitting without support, in the World Health Organization’s Multicentre Growth Reference Study.19 In Ghana, it is common practice for parents and caretakers to “train” infants in order to accelerate their motor development, such as propping infants up to sit in various positions from an early age. Norwegians believe in relying on a child’s spontaneous development rather than pushing children to perform.18,19 By contrast, East Asian parents tend to engage in more protective child care practices, allowing for less gross motor explorative play.18 In typically developing children, differences in the attainment of motor abilities become less marked in tasks requiring more complex coordination, such as crawling on hands and knees.18,19

Differences across cultures in the socioemotional skills of children with ASD were demonstrated in a study by Sotgiu et al.20 Their study compared Italian to Cuban children aged 4–11 years with ASD in the ability to recognize their own and others’ emotions and the ability to attribute mental states to others (i.e., theory of mind). The Italian children were found to be superior to the Cuban children both in emotion comprehension and theory of mind tests. The Italian children were also found to have quantitatively larger social networks compared to the Cuban children, however, these networks were largely made up of the technical and professional figures involved in the management of their ASD (e.g., therapists, pediatricians), while the Cuban children’s smaller social networks consisted more of family and close relatives with multifunctional roles in the care of the child.20

To the best of our knowledge, differences across cultures in the gross motor ability of children with ASD and the relationship to socialization skills have not previously been described. Therefore, we believe that studying the gross motor profile of Indonesian children with ASD, as well as the association with socialization skills, will be a valuable contribution to this cross-cultural discussion.

The Vineland-II instrument has been shown to be a reliable tool for measuring gross motor ability and social-personal skills, and it has been used in individuals aged...
0–90 years with disabilities, including children with ASD. In Vineland-II, parents are considered to be the most appropriate resource to assess a child’s best ability, so that the child’s performance at the time of testing is not the sole determinant of their highest attainable score.6

This study aimed to compare gross motor skills in children with ASD to those of typically developing children, to describe gross motor problems in ASD, and to identify associations between gross motor and socialization skills in children with ASD.

### 2. Methods

This was a cross-sectional study including children aged from 18 months to 6 years. We consecutively recruited 40 children with ASD and 40 age-matched (± 3 months) controls. All participants had to be able to sit and walk without support. Children in the ASD group met the diagnostic criteria for ASD based on The Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5) and were recruited from Klinik Anakku Kelapa Gading and Klinik Anakku Check My Child Kayu Putih, Jakarta, Indonesia. The clinical diagnosis of ASD was established by an experienced clinician (H.D.P.). Children who had received sensory integration therapy for > 3 months within the past 6 months and children whose parents refused to participate were excluded from the study. The control group consisted of children without ASD from Adik Irma Kindergarten, Jakarta, Indonesia and Cipto Mangunkusumo Hospital, Jakarta, Indonesia. Children with speech delay, hearing impairment, and children whose parents refused to participate were excluded. The minimum required sample size in each group was 34, calculated based on an α of 0.05, a power of 80%, a standard deviation of the Vineland-II domain score of 15, an expected clinical difference of 12, and a prevalence of gross motor impairments in the children with ASD of 59%.11

Gross motor and socialization skills were measured using Vineland-II, which was administered in the form of a structured interview by a trained interviewer (P.E.) to minimize recall bias. Of the four domains in Vineland-II (communication, daily living skills, socialization, and motor skills), we measured only the gross motor subdomain and the socialization domain. In the gross motor subdomain, Vineland-II measures 13 clusters including sitting, beginning mobility, beginning to stand and walk, throwing a ball, climbing, running, using stairs, jumping/hopping/skipping, walking places, catching a ball, riding a tricycle or bicycle, lifting and carrying, and stamina. All parents were interviewed by the same interviewer and were asked to assign a score of 4 (almost always), 3 (often), 2 (sometimes), 1 (seldom), or 0 (never) to questions asking whether the child was able to do a specified action without assistance or reminder.6

The raw score of each subdomain was converted to a subdomain v-scale score (mean 15, SD 3) and domain standard score (mean 100, SD 15). Socialization domain standard scores were categorized into low (< 70), moderately low (71–85), adequate (86–114), moderately high (115–129), and high (> 130). Gross motor subdomain v-scale scores were categorized into low (< 9), moderately low (10–12), adequate (13–17), moderately high (18–20), and high (> 21). For purposes of analysis in this study, gross motor v-scale scores were further differentiated into two subgroups: below average a score ≤ 12 and average or above average for a score > 12. We used this classification to compare socialization skills in the ASD children with and without gross motor impairments.5

All parents of the eligible children were informed of the objectives, benefits, and procedures of the study, and we obtained written consent from those who agreed to participate. Baseline data regarding sex, age at diagnosis of ASD, and type of ASD based on DSM-IV TR21 were obtained through interviews with the parents. We directly measured the child’s body weight, height, and body mass index, and determined nutritional status based on the WHO 2005 Child Growth Standards for children ≤ 5 years old and the CDC 2000 growth curve for children > 5 years old.

Data analysis was done using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA). A p value < 0.05 was considered to be statistically significant. Ethical approval for this study was obtained from the Medical Research Ethics Committee of Universitas Indonesia Medical School, Jakarta, Indonesia.

### 3. Results

The study was conducted from August 2013 to September 2013, and included 40 children with ASD and 40 age-matched controls. The median age of the participants was 2.9 years (range, 1.5–6.4 years). There was a predominance of male individuals (80%) in the ASD group. One participant in the control group was born at 36 weeks of gestation, whereas all participants in the ASD group were born at term. Table 1 shows the participants’ baseline characteristics.

Using the DSM-IV TR subtypes of ASD, Pervasive Developmental Disorder—Not Otherwise Specified (PDD-NOS) was the most common diagnosis (65%), followed by autistic disorder (12%) and Asperger’s syndrome (5%). Overall, 77.5% of the participants were diagnosed at < 3 years of age.

Gross motor impairments were found in eight of 40 (20%) children with ASD. Two children aged 3.7 years and 6 years with autistic disorder had low gross motor v-scale scores, and two children with autistic disorder and four children with PDD-NOS had moderately low scores; all of these children were younger than 3 years. Nine of 40 (22.5%) stated that they were able to do a specified action without assistance or reminder.

<table>
<thead>
<tr>
<th>Table 1 Participant characteristics.</th>
<th>ASD group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 40</td>
<td>n = 40</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>32 (80)</td>
<td>20 (50)</td>
</tr>
<tr>
<td>Female</td>
<td>8 (20)</td>
<td>20 (50)</td>
</tr>
<tr>
<td><strong>Median age (y) (range)</strong></td>
<td>2.8 (1.5–6.1)</td>
<td>2.9 (1.6–6.4)</td>
</tr>
<tr>
<td><strong>Nutritional status</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undernourished</td>
<td>1 (2.5)</td>
<td>1 (2.5)</td>
</tr>
<tr>
<td>Good nutritional status</td>
<td>32 (80)</td>
<td>36 (90)</td>
</tr>
<tr>
<td>Overweight or obese</td>
<td>7 (17.5)</td>
<td>3 (7.5)</td>
</tr>
</tbody>
</table>

Data are presented as n (%). ASD = autism spectrum disorder.
children with ASD had moderately high gross motor ability. In the control group, most children had adequate (32.5%) or moderately high (52.5%) gross motor ability, and no individual showed a below-average gross motor score.

The mean v-scale score was 13.7 (SD 3.82) in the children with autistic disorder, 14.5 (SD 0.71) in the children with Asperger’s disorder, and 15.8 (SD 2.73) in the children with PDD-NOS. The overall mean v-scale score was 15.1 (SD 3.12) in the ASD group and 18.7 (SD 2.09) in the control group (p = 0.0001; 95% confidence interval from −4.725 to −2.525).

With regards to age, the controls had higher mean v-scale scores than their ASD counterparts in all age groups (Table 2). The smallest mean difference in v-scale scores was found at 1–2 years of age (2.6 points), and the largest difference was found at 6 years of age (8 points). The mean v-scale score was significantly lower in the ASD group than in the control group at 1–2 years of age (16.8 vs. 19.4; p = 0.0001) and 3 years (13.4 vs 18.2; p = 0.014).

Table 2 shows an overview of the raw scores of the ASD and control groups in each cluster of the gross motor subdomain. There were marked differences in clusters D (throwing a ball), G (using stairs), H (jumping/hopping/skipping), J (catching a ball), and K (riding a tricycle or bicycle) between the two groups.

Compared to the controls, the children with ASD showed a delayed ability in object manipulation. Almost all of the children aged 1–3 years in the control group were able to roll a ball while sitting on the floor or ground, throw a ball, and kick a ball, whereas in the ASD group only 19 of 33 children were able to roll a ball while sitting on the floor, 20/33 were able to throw a ball, and 17 of 33 children were able to kick a ball. In addition, the children in the ASD group tended to have difficulties in using stairs. All children aged 3–6 years in the control group were able to walk up and down stairs using alternating feet, while in the ASD group, at the same age only 14 of 16 children were able to walk up stairs and only eight of 16 children were able to walk down stairs using alternating feet. There was also a difference in the ability to hop upward and forward on one foot, with only five of 40 (12.5%) children with ASD being able to hop on one foot without falling over. Standing on one foot was also a problem in the ASD group, with only six children (15%) being able to stand on one foot. A delay in the ability to hop upward and forward on one foot was also observed in the ASD group, with only six children (15%) able to hop on one foot without falling over.

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**Table 2**: Comparison of mean gross motor v-scale scores in the autism spectrum disorder (ASD) and control groups.

<table>
<thead>
<tr>
<th>Gross motor sub-domain v-scale score</th>
<th>1–2 y (n = 48)</th>
<th>3 y (n = 18)</th>
<th>4 y (n = 6)</th>
<th>5 y (n = 4)</th>
<th>6 y (n = 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD group</td>
<td>16.8 (1.98)</td>
<td>13.4 (2.92)</td>
<td>12.0 (2.00)</td>
<td>13.0 (2.83)</td>
<td>9.0 (1.41)</td>
</tr>
<tr>
<td>Control group</td>
<td>19.4 (1.97)</td>
<td>18.2 (2.22)</td>
<td>17.7 (1.53)</td>
<td>16.5 (2.12)</td>
<td>17 (0.00)</td>
</tr>
<tr>
<td>p (paired t test)</td>
<td>0.0001</td>
<td>0.014</td>
<td>0.093</td>
<td>0.295</td>
<td>0.205</td>
</tr>
<tr>
<td>95% CI</td>
<td>−3.731 to −1.436</td>
<td>−8.317 to −1.239</td>
<td>−13.652 to 2.319</td>
<td>−29.41 to 21.41</td>
<td>−39.27 to 24.27</td>
</tr>
</tbody>
</table>

Data are presented as mean (standard deviation). ASD = autism spectrum disorder; CI = confidence intervals.

4. Discussion

This study is the first in Indonesia to compare gross motor skills in children with ASD to those in typically developing children using Vineland-II. We enrolled children younger than 6 years of age as the study cohort to represent the period in life during which gross motor impairment should be identified to enable timely interventions. Our results showed poor gross motor skills in children with Asperger’s disorder, as listed in DSM-IV TR,21 and also in those with autistic disorder and PDD-NOS. The lack of direct observations of the individuals’ gross motor ability is a potential limitation of this study, since the accuracy of Vineland-II is highly dependent on the honesty and objectivity of the parents.

The study cohort included 40 children with ASD and 40 controls with a male-to-female ratio of 4:1 and 1:1 in the ASD group and in the control group, respectively. This composition reflects that found in the United States National Health and Nutrition Examination Survey, in which among 3–17-year-old children with ASD, 79% were male and 21% were female,22 as well as ratios found in other studies, which vary from 3:1 to 6:1.23,24

The diagnosis of ASD in this study was made based on the DSM-5 criteria through history taking and clinical evaluation by one of the investigators who was a clinician experienced in ASD. The reliability of the clinical diagnosis of ASD based on the DSM-IV has been reported, with all children diagnosed with ASD at 20 months of age retaining the diagnosis at 42 months.25 After consolidating Asperger’s disorder and
PDD-NOS into one ASD category, another study reported that 80% retained their diagnosis.26 We chose to use a clinical diagnosis instead of formal tools such as the Autism Diagnostic Observation Schedule or the Autism Diagnostic Interview-Revised because their concordance with DSM-5 has not been studied, and Indonesian translations have not been validated.

Prematurity has been identified to be a risk factor for a delay in motor skills in children with ASD. Movsas and Paneth27 reported that out of 4188 ASD children, 66.3% and 55% of those born at <34 weeks’ and 34—36 weeks’ gestation, respectively, had a delay in motor skills compared to only 44.2% of children born at term. In the present study, only one individual in the control group had a history of prematurity. Therefore, premature birth was not a confounding factor for gross motor skill score in our participants.

In the present study, the children with ASD had subpar gross motor skills compared to the controls. This finding is consistent with a previous study by Perry et al,5 who used the Vineland instrument in 290 Canadian children with ASD aged 22—71 months. They reported a mean motor skills domain standard score of 62.6, which was categorized as low ability.

Twenty percent of our participants in the ASD group had below-average gross motor skills, which is lower than that in previous studies by Dewey et al11 (59%) and Green et al12 (79%). Several factors may have contributed to the lower incidence of gross motor impairments in the present study. Our participants were in the toddler to preschool age range, while the aforementioned studies included school-age to adolescent children.11,12 Gross motor impairments become increasingly prominent with age, which explains the greater prevalence in older age groups. A similar trend was observed in the present study (Table 2). The difference in v-scale scores between the ASD and control groups was most marked at 6 years of age (8 points), with the smallest difference at 18 months to 2 years of age (2.6 points). All individuals with below-average gross motor skills (8 in the ASD group) were >3 years old. Other studies by Perry et al5 and Kanne et al21 also reported a negative correlation between age and Vineland standard scores. In children with ASD, the rate of motor development is slower than the increase in age, such that the difference between the child’s actual score and the age-specific expected score widens with time. This is especially true given the practice-dependent nature of the acquisition of gross motor skills, particularly in object control (e.g., throwing or kicking a ball).28 Children with gross motor deficits tend to be reluctant to practice these skills.

Another factor which may contribute to the difference in the prevalence of gross motor impairments between studies is the instrument used to measure gross motor ability. Dewey et al11 used the Bruininks-Oseretsky Test of

Table 3 Raw scores in each cluster of the gross motor subdomain.

<table>
<thead>
<tr>
<th>Clusters in gross motor subdomain</th>
<th>ASD group</th>
<th>Control group</th>
<th>p (Wilcoxon signed rank test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Sitting</td>
<td>20 (20—20)</td>
<td>20 (20—20)</td>
<td>1.000</td>
</tr>
<tr>
<td>B. Beginning mobility</td>
<td>16 (12—16)</td>
<td>16 (16—16)</td>
<td>0.059</td>
</tr>
<tr>
<td>C. Beginning to stand &amp; walk</td>
<td>28 (23—28)</td>
<td>28 (28—28)</td>
<td>0.180</td>
</tr>
<tr>
<td>D. Throwing a ball</td>
<td>10 (0—16)</td>
<td>16 (10—16)</td>
<td>0.000</td>
</tr>
<tr>
<td>E. Climbing</td>
<td>12 (6—12)</td>
<td>12 (6—12)</td>
<td>0.111</td>
</tr>
<tr>
<td>F. Running</td>
<td>12 (0—12)</td>
<td>12 (7—12)</td>
<td>0.073</td>
</tr>
<tr>
<td>G. Using stairs</td>
<td>26 (1—28)</td>
<td>28 (18—28)</td>
<td>0.007</td>
</tr>
<tr>
<td>H. Jumping/hopping/skipping</td>
<td>7 (0—23)</td>
<td>17 (1—24)</td>
<td>0.000</td>
</tr>
<tr>
<td>I. Walking places</td>
<td>7 (0—12)</td>
<td>10.5 (2—12)</td>
<td>0.077</td>
</tr>
<tr>
<td>J. Catching a ball</td>
<td>1.5 (0—9)</td>
<td>7 (0—12)</td>
<td>0.000</td>
</tr>
<tr>
<td>K. Riding tricycle or bicycle</td>
<td>0 (0—12)</td>
<td>9 (0—16)</td>
<td>0.000</td>
</tr>
<tr>
<td>L. Lifting &amp; carrying</td>
<td>4 (0—18)</td>
<td>4 (0—14)</td>
<td>0.781</td>
</tr>
<tr>
<td>M. Stamina</td>
<td>5.5 (0—10)</td>
<td>5.5 (0—12)</td>
<td>0.872</td>
</tr>
</tbody>
</table>

Data are presented as median (range).

Table 4 Association between gross motor and socialization skills in children with autism spectrum disorder (ASD).

<table>
<thead>
<tr>
<th>Socialization skills domain standard score</th>
<th>Gross motor skills</th>
<th>95% CI for mean difference</th>
<th>p (unpaired t test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below average</td>
<td>66.6 (6.50)</td>
<td>85.7 (10.90)</td>
<td>−25.327 to −12.736</td>
</tr>
<tr>
<td>Average or above average</td>
<td>6.1 (1.46)</td>
<td>9.9 (2.40)</td>
<td>−5.185 to −2.378</td>
</tr>
<tr>
<td>Play &amp; leisure time subdomain v-scale score</td>
<td>8.4 (2.13)</td>
<td>11.9 (3.05)</td>
<td>−5.856 to −1.207</td>
</tr>
<tr>
<td>Coping skills subdomain v-scale score*</td>
<td>12.0 (1.07)</td>
<td>15.2 (1.61)</td>
<td>−4.376 to −1.937</td>
</tr>
</tbody>
</table>

Data are presented as mean (standard deviation). CI = confidence intervals.
Motor Proficiency (BOT), while Green et al.\textsuperscript{12} used the Movement Assessment Battery for Children (MABC). Since the BOT and MABC require that the children understand the instructions, the studies by Dewey et al.\textsuperscript{11} and Green et al.\textsuperscript{12} found that gross motor deficits in children with ASD were evident in verbally-instructed tasks and imitation. In another study, Scattone et al.\textsuperscript{29} observed that the gross motor scores of ASD children were higher when measured using Vineland-II than Bayley-III, an instrument requiring instruction and direct observation of the child. Due to their poor comprehension of instructions, children with ASD tend to perform below their actual ability when assessed using instruction-based instruments. We consider this to be a strength of the Vineland-II instrument.

Each developmental instrument has its own scoring focus. Vineland-II divides gross motor skills into several clusters: sitting, beginning mobility, beginning to stand and walk, throwing a ball, climbing, running, using stairs, jumping/hopping/skipping, walking places, catching a ball, riding a tricycle or bicycle, lifting and carrying, and stamina. If the same participants in the current study were measured using instruments such as the BOT or MABC, we would likely have found a higher prevalence of gross motor impairments because the Vineland-II clusters most affected in ASD children are given greater weight in the scoring of both the BOT and MABC. In our ASD group, low scores in throwing and catching a ball, jumping, using stairs, and riding a tricycle or bicycle were partially compensated by average or high scores in other clusters including walking places, lifting and carrying, and stamina.

Nine of our ASD group had moderately high gross motor skills. This may be due to a tendency of the parents to overestimate their child’s ability or due to the individuals’ motor skills not being higher per se, but different from their peers. A child with ASD may be able to run fast with excellent stamina but unable to throw or kick a ball well, resulting in a compensatory effect as described above, such that their total gross motor subdomain score remains adequate or even moderately high.\textsuperscript{29} Developmental disorders can manifest as delays or deviance/deficits, both of which may be seen in children with ASD.\textsuperscript{28}

Poorer gross motor skills were observed in the ASD group compared to the control group, particularly in throwing a ball, using stairs, jumping/hopping/skipping, catching a ball, and riding a tricycle or bicycle. This finding is in accordance with studies in ASD children by Staples and Reid,\textsuperscript{28} Downey and Rapport,\textsuperscript{30} and Miyahara.\textsuperscript{31} Children with ASD usually have trouble with movements which need postural control, bilateral coordination, or upper-lower body coordination, such as jumping forward and controlling speed and direction when throwing or kicking a ball.

Although we found low socialization scores in the children with ASD who had poor gross motor skills, we did not find an independent association between gross motor impairments and socialization skills. However, a previous study by MacDonald\textsuperscript{17} using the same instrument showed that gross motor skills were associated with socioadaptive skills. Another study by the same author showed that among the gross motor subscales, object control was closely related to socialization skills.\textsuperscript{16} In both studies, confounding factors were controlled in the statistical analysis, with male gender being a risk factor for lower socialization skills. In the present study, we did not account for several potential confounding factors such as gender, cognitive level, and severity of ASD.

Both socialization skills and learning gross motor skills are facilitated by the mirror neuron system, a group of neurons located in the prefrontal gyrus and inferior parietal lobes activated during observation of the actions of another individual and when imitating that action. This system also aids in understanding the thoughts, intentions, and emotions between the observed action or behavior, by creating an internal simulation and mapping it to the observer’s own motor representations in the corresponding brain region. Failure in the activation of the mirror neuron system has been demonstrated in children with ASD, and the severity of mirror neuron system dysfunction has been shown to be correlated with the severity of autism symptoms.\textsuperscript{32} This may explain the association between gross motor ability and socialization skills in children with ASD, as these children have difficulty understanding emotions and intentions behind the behavior of others, keeping them in internal memory and imitating them in real actions.\textsuperscript{33} Imitation of movements and emotions are thought to be the key elements of affective, social, and communication development in children.\textsuperscript{34} We suggest that the presence of gross motor deficits may reduce the variety of play activities in which the child engages and contributes to a low self-esteem, which then adversely affects opportunities for socialization.

The present study does not conclusively demonstrate that motor impairment can predict socialization skills in children with ASD, but supports the view that the pathology of ASD includes extensive brain dysfunction.\textsuperscript{34} Compared to the diagnostic criteria in DSM-IV TR, the ASD criteria in DSM-5 include sensory problems as a part of the behavioral problems in children with ASD.\textsuperscript{1,21} We also found that impaired motor skills may be a part of the restricted behavioral patterns found in children with ASD. Based on our results, we suggest the addition of gross motor ability as a domain which should be evaluated in the initial assessment of children with (suspected) ASD.

5. Conclusion

Children with ASD have subpar gross motor skills compared to typically developing children. Twenty percent of children with ASD have gross motor impairments, primarily affecting skills requiring complex coordination. There is a trend toward lower socialization skills among children with ASD who have gross motor impairments.

Further research is needed to investigate whether there is an independent association between gross motor and socialization skills in children with ASD taking into account potential confounding factors such as gender, cognitive function, and severity of ASD. Gross motor ability should be assessed in children with ASD before they start treatment programs, so that the program can be tailored to and geared at improving their motor skills.

Conflicts of interest

The authors declare no conflicts of interest.
References


