Research Article

MOTOR SKILLS PROFILE OF CHILDREN WITH AUTISM SPECTRUM DISORDER AND ITS ASSOCIATION TO SOCIALIZATION SKILLS, COMMUNICATION SKILLS AND SYMPTOM SEVERITY

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Abstract

Background: Autism Spectrum Disorder (ASD) is characterized by core impairments in socialization and communication skills, alongside restricted and repetitive behaviors. Recent studies suggest that motor skills, essential for early exploration and learning, might be intrinsically linked to these core deficits. This study aims to explore the motor skills profile of children with ASD and its association with their socialization skills, communication skills, and symptom severity.

Objectives: This study aims to profile the motor skills of children with ASD and examine their association with socialization skills, communication skills, and symptom severity.

Methods: An analytical cross-sectional study was conducted at the Child Development Center of the National Children's Hospital, targeting children diagnosed with ASD aged 1.6-5.11 years. Motor skills were assessed using the Peabody Developmental Motor Scales-2 (PDMS2), while socialization and communication skills were evaluated using the Battelle Developmental Inventory-2 Normative Update (BDI-2 NU). Symptom severity was determined using the Childhood Autism Rating Scale-2 ST (CARS-2 ST).

Results: The study found significant motor impairments (cumulative percentage of below average, poor and very poor for total motor, 85.84%) in children with ASD, with fine motor skills (79.3%) being more severely affected than gross motor skills (78.1%). There was a notable correlation between motor skills and both socialization (gross motor, r=.202, p=.002; fine motor, r=.381, p<.001) and communication skills (gross motor, r=.307, p<.001; fine motor, r=.133, p=.039), as well as with symptom severity (gross motor, poor OR=2.70, 95% CI (1.00-7.25), p=.049) and very poor (OR=5.82, 95% CI (1.57-21.59), p=.008), (fine motor, poor (OR=4.66, 95% CI (1.77-12.28), p=.002) and very poor (OR=13.60, 95% CI (6.11-30.28), p<.001). Multivariate analysis identified several significant associations with severity symptoms such as poor fine motor skills, older age, higher cognitive skills, better socialization skills and children whose fathers had a college-level education.

Conclusions: The results of this study show that motor impairments are significantly evident in children with autism spectrum disorder at the National Children's Hospital, with their fine motor skills being more severely affected than their gross motor skills. The motor skills of these children are correlated with their socialization skills, communication skills and symptom severity. The results contribute to the growing body of literature on ASD, highlighting the need for integrated therapeutic strategies that address both motor and core autism-related deficits. The implications of this research are pivotal for developing comprehensive care plans that enhance the overall development and quality of life for children with ASD.

Keywords: Autism spectrum disorder, Motor skills, Socialization skills, Communication skills, Symptom severity

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by core impairments in socialization and communication skills with the presence of restricted and repetitive behaviors and sensory integration issues. Recent epidemiological data reported that 1 in 36 children has been diagnosed with autism spectrum disorder; a finding that has been notably increasing over the years and evidently, being constantly under the radar of clinicians, therapists, educators and other concerned societies given the complexity and heterogeneity of the condition and its profound impact in the lives of these children, their families and the community at large [1]. Given this trend and still, the elusive etiology of this condition, management approaches have been understandably transitioning from being therapeutic to being preemptive in nature. Research studies, likewise, have gained a substantial momentum not only in addressing and unravelling the nature and impact of its core impairments but also in exploring other possible neurobiological and developmental phenomena that could strengthen the holistic approach in the care of these children.

Apart from integral sensory skills, motor skills have been recognized and proven to be the groundwork for exploration and learning for children in their early years of development. Likewise, the achievement of the full repertoire of these skills serves as a pivotal element in the emerging skills of socialization and communication. As the child gains motor maturity and full mobility, from being mostly in lying supine or carried positions to sitting, crawling and walking, he progressively gets wider visual access to all angles (*i.e.,* ceiling, floor, periphery) of his surroundings and the faces of his caregivers at the eye-level, paving the way for initiation and maintenance of social interactions. In the same way, the movement of the hands and its coordination with the eyes, such as when the child picks up an object or point to it, creates habitual moments of language stimulation among caregivers as they respond to it through labelling. Following this school of thought, recent literatures have been shedding light on these seemingly unrelated developmental domains, the gross and fine motor skills, with respect to the core deficits of autism spectrum disorder. The mounting interest on this matter is built on the premise that even before social-communication impairments, repetitive, and atypical behaviors become recognizable to caregivers and physicians, motor delays such as poor head control and overall muscle tone, delayed sitting and walking are already apparent during infancy. Further acquisition of fundamental motor skills in locomotion, gait patterns, postural control, balance and coordination, object manipulation, dexterity and more so, complex motor planning and execution have been reported to be inevitably delayed and impaired. Although not specific to autism alone, these deficits have been reported to be significantly related to the core impairments which are typically and robustly seen at 2 years of life and beyond and are oftentimes difficult to qualify and elicit objectively. The inadequate consolidation of these skills throughout the developmental period, if unaddressed, could negatively impact in a child's ability to play (e.g. manipulation of small parts of toys using a neat pincer grasp) and interact with others (e.g. imitation of actions, participation in ball catching and throwing), participate in self-care (e.g. buttoning clothes, tying shoe laces), assume domestic responsibility (e.g. sweeping the floor, washing plates) and facilitate learning in school (e.g. hand writing) and in the community (e.g. crossing streets). Hence, deficits must always be regarded in the whole context of the child's development and be addressed methodically, especially among children in the spectrum.

Statement of the problem

Internationally published studies have shown that motor impairments in children in autism spectrum disorder are estimated to be around 50-80% and these impairments were varied and did not change until 15 years of age. Despite this, only 31.6% of these patients receive physical therapy to solely focus on these motor impairments, apart from the conventional occupational therapy that also addresses these concerns but mostly focuses on the core impairments of autism spectrum disorder [2]. The under recognition among clinicians and therapists could about these prevailing concerns in motor deficits have probably led to these skills being under targeted despite provisions for interventions. As the impairments accumulate, the magnitude of its impact in their daily lives become more evident when the child reaches school age and adolescence, when the child is expected to perform a variety of pencil-and-paper tasks and participate in self-help skills of buttoning garments and tying shoe laces and in domestic skills such as the washing the dishes, mopping the floor and the like. Hence, explaining the numerous studies among these populations. With efforts to expand the focus of early diagnosis and holistic intervention to domains such as the motor skills, equally, its contribution and relationship to the social-communication deficits of autism and its symptom severity must be explored as early as possible as soon as they become apparent.

Objectives

General objective: To describe the motor profile of children with newly diagnosed autism spectrum disorder and determine its association with social-communication skills and symptom severity.

Specific objectives:

To determine baseline motor profile of patients with autism spectrum disorder as to their:

- Gross motor skills
- Fine motor skills

To determine the socialization (adult interaction, peer interaction, self-concept and social role) and communication (receptive and expressive language) skills of the patients diagnosed with autism spectrum disorder.
To determine the symptom severity of the patients diagnosed with autism spectrum disorder.
To determine the relationship of the gross and fine motor skills with:

- **Communication skills**: Receptive; Expressive language
- **Socialization skills:** Adult interaction; Peer interaction; Self-concept and social role
- Symptom severity of autism.

Significance of the study

The implications of this study sit well with the thrusts of providing early diagnosis and holistic intervention. The efforts on being vigilant on social and communication delays have been markedly emphasized over the years which could be due to the increasing prevalence of children being diagnosed with autism. Motor skills acquisition and impairments, being the early objective and remarkable skills of children that register among their caregivers, may also give initial cues on how they can be potentially related and impactful to other domains of development. This study will not only contribute to the existing global literatures on the motor profile of children with autism spectrum disorder but also, more importantly, will kindle local efforts to recognize and highlight the importance of motor skills early in life. This will also serve as a baseline study that will fully employ clinician-administered standardized tools, as different from most published studies that rely also on parent-questionnaire standardized scales, in the assessment of developmental domains in motor, socialization and communication. In doing so, we could minimize bias and instead, be more objective in identifying the specific motor domains that could be also targets for interventions not only by therapists but also by caregivers even when they are at home. Institutionally, this study could expand intervention modalities with the provision for physical therapy for patients with autism spectrum disorder who are also with motor impairments. Those identified with motor deficits could be referred to physical therapy to also address those impairments since occupational therapy, which is the usual therapeutic intervention recommended to patients with autism, mostly focuses on behavioral modification, activities of daily living and other skills directly affected by the core symptoms of autism (Figure 1).

Conceptual framework

Figure 1 illustrates the association of motor skills with the communication and socialization skills and symptom severity among children who are newly diagnosed with autism spectrum disorder. The potential confounding variables ware also depicted in this Figure.

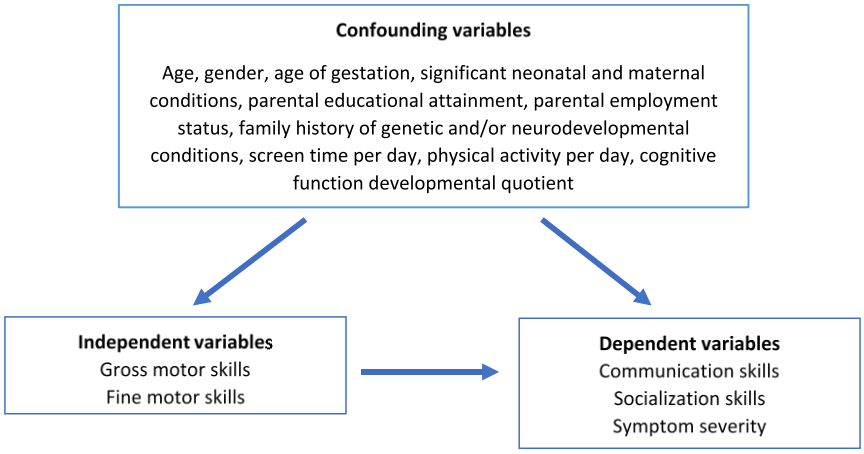

Figure 1. Conceptual framework for the association of motor skills with communication skills, socialization skills and symptom severity.

Motor skills, particularly in the early years of childhood, contribute to the subsequent development of a child's abilities to interact with and understand his caregivers and his environment and respond to them effectively as exemplified in the different transitions in mobility, strength, balance, coordination and hand use (*i.e.*, a walking child with good coordination is able to explore more his surroundings, a child whose use of index finger to point is able to establish connection and express his want to his caregiver). These possible associations and when taken these variables individually, could be impacted by the innate characteristics of the child, his

perinatal and neonatal history, the presence of neurodevelopmental disorders in his family, educational background of his parents. A child's motor skills, socialization and communication skills could also be modified by his physical activity and screen time per day by brain rewiring processes given that those with lesser physical activities and more screen time exposure may have poorer socialization and communication skills. Lastly, overall cognitive function should be accounted since motor skills become more complex and purposeful and socialization and communication skills become more meaningful and relationship-building as the child ages, which are reflection of the higher, executive functions of the brain.

Definition of terms

Independent variables:

- **Gross motor skills:** Use of the large muscles of the body for locomotion and sustain posture and balance to do a certain task. After adding the subtest standard scores, which are from the raw scores of stationary, locomotion, and object manipulation in the peabody developmental motor scales-2, the gross motor quotient score of at least 90 will be categorized as average, 80-89 as below average, 70-79 as poor, and 69 and below as very poor.
- **Fine motor skills:** Use of the small muscles of the body and eye-hand coordination to do a certain task. After adding the subtest standard scores, which are from the raw scores of Grasping and visual-motor integration in the peabody developmental motor scales-2, the fine motor quotient score of at least 90 will be categorized as average, 80-89 as below average, 70-79 as poor, and 69 and below as very poor.

Dependent variables:

- **Communication skills:** A developmental domain that pertains to the comprehension (receptive) and production (expressive) of language modalities (*i.e.*, verbal or nonverbal). Using the developmental quotient from the converted raw score of each subdomain to its corresponding scaled score of this domain of the Battelle Developmental Inventory, 2nd Edition Normative Update (BDI-2 NU), developmental quotient of at least 90 will be categorized as average, 80-89 as low average, 70-79 as mild developmental delay, and 69 and below as significant developmental delay.
- **Receptive communication:** This is a subdomain of the communication skills that refers to a child's ability to discriminate, recognize and understand sounds and words, information received through gestures and nonverbal means and assess a child's understanding and use of conversational skills. This is reported as a scaled score and added to the scaled score of expressive communication, where in the sum will be converted to the developmental quotient of the communication domain.
- **Expressive communication:** This is a subdomain of the communication skills that assesses a child's production and use of sounds, words or gestures to relate information. It also assesses the child's ability to use simple rules of grammar to produce phrases and sentences and his ability to use language as a tool for social contact. This is reported as a scaled score and added to the scaled score of receptive communication, where in the sum will be converted to the developmental quotient of the communication domain.
- **Socialization skills:** A developmental domain that pertains to a child's abilities to develop his or her own self-concept and establish social interaction with peers and adults. Using the developmental quotient from the converted raw score of each subdomain to its corresponding scaled score of this domain of the Battelle Developmental Inventory, 2nd Edition Normative Update (BDI-2 NU), developmental quotient of at least 90 will be categorized as average, 80-89 as low average, 70-79 as mild developmental delay, and 69 and below as significant developmental delay e. Adult interaction: This is a subdomain of the socialization skills which measures the quality and frequency of a child's interactions with adults such as attachment, responding to an initiation of social contact with adults and the use of adults as resources to solve problems. This is reported as a scaled score and added to the scaled scores of peer interaction and self-concept subdomains, where in the sum will be converted to the developmental quotient of the socialization domain.
- **Peer interaction:** This is a subdomain of the socialization skills which measures the quality and frequency of a child's interactions with children of a similar age, including the ability to form friendships and personal associations and respond to and initiate social contact with peers, interactive effectively in a small group and cooperate. This is reported as a scaled score and added to the scaled scores of adult interaction and self-concept subdomains, where in the sum will be converted to the developmental quotient of the socialization domain.
- **Self-concept and social role:** This is a subdomain of the socialization skills which assesses a child's development of self-awareness, personal knowledge, self-worth and pride, moral developmental, sensitivity to

others' needs and feelings and coping skills. This is reported as a scaled score and added to the scaled scores of adult interaction and peer interaction subdomains, where in the sum will be converted to the developmental quotient of the socialization domain.

- **Symptom severity:** Using the childhood autism rating scale-2 SF, those with scores of 30-36.5 have mild-to-moderate symptoms and those with 37 and above have severe symptoms.

Confounding variables:

- **Age of the patient:** This will be categorized as, 18-24 months, 25-36 months, 37-48 months, 49-59 months.
- **Age of gestation:** This will be categorized as, preterm (<37 weeks), term (37-41 weeks), post-term (>41 weeks).
- **Mode of delivery:** This will be categorized as, vaginal delivery, cesarean section, forceps/vacuum-assisted delivery
- **Birthweight:** This will be categorized as, low (<2500 grams), normal (2500-3500 grams), high (>3500 grams)
- **Significant maternal and perinatal conditions:** This will be defined as the presence or absence of any of the following: maternal infection, maternal comorbidities during pregnancy, peripartum difficulties such as fetal bradycardia, tachycardia, prolonged or difficult labor, meconium staining
- **Maternal age:** Age of the mother in years, upon birth of the patient and will be categorized as: less than 20 years old, 20-34 years and 35 years old and above
- **Paternal age:** Age of the father in years, upon birth of the patient and will be categorized as: less than 40 years old, more than 40 years' old
- **Parental educational attainment:** Highest educational level achieved by the mother/father such as: Grade school, high school, college, postgraduate
- **Employment status:** This will be indicated as, unemployed or employed and if employed, indicate the nature of employment
- **Screen time per day:** This will be indicated in the cumulative number of hours per day in all types of media such as television, mobile phone, tablet, laptop, other gaming devices such as playstation, nintendo switch, wii, etc and will be categorized as: 0 minutes, 1-29 minutes, 30 minutes to 1 hour, 1-2 hours, >2 hours.
- **Physical activity per day:** Any sustained and active body movement such as running, jogging, dancing, or exercising or any sports involvement, measured in hours per day; categorized as less than 30 minutes in most days of the week (4/7 days in a week), 30 minutes or more in most days of the week (4/7 days in a week)
- **Family history:** This will be indicated as the presence or absence of known genetic syndromes and/or neurodevelopmental conditions such as autism spectrum disorder, attention-deficit hyperactivity disorder, language disorder, intellectual disability, global developmental delay, cerebral palsy, specific learning disorder, sensory impairments
- **Cognitive function:** A developmental domain that pertains to the child's attention, memory, reasoning, academic skills and perception and concepts. Using the developmental quotient from communication domain of the Battelle Developmental Inventory, 2nd Edition Normative Update (BDI-2 NU), developmental quotient of at least 90 will be categorized as average, 80-89 as low average, 70-79 as mild developmental delay, and 69 and below as significant developmental delay.

Materials and Methods

The body of knowledge on all facets of autism spectrum disorder has tremendously grown over the years. Not only that management is gearing towards being preemptive in the recent time, but also, more studies are unfolding the possible risk factors that are highly associated with it such as older parental ages (*i.e.*, maternal age above 35, paternal age above 40) [3,4], low socioeconomic status, low maternal education, paternal employment [5], maternal physical (such as hypertension, diabetes, congenital infections, exposure to teratogens) [6-9] and mental health [10-12]. Meanwhile, among the prenatal factors and postnatal factors identified are prematurity, low birth weight, assisted delivery, hypoxic events during delivery [13-15]. Given the multitude of risk factors, the process of developmental surveillance and screening cannot be overemphasized enough. With early recognition of socialization, communication and behavior red flags being long advocated in the light of autism, it is not surprising for the experts in the field to investigate other possible earlier biomarkers in human development such as the motor skills [16,17].

Motor impairments in autism spectrum disorder

Motor skills delays have been reported during the first year of life, such as sitting, standing and walking independently. These findings were apparent even before social and communication deficits become more recognizable to caregivers. Apart from delay, atypicality in motor patterns have been reported such as in persistence of primitive reflexes, asymmetry of limb

movements, use of objects, low muscle tone and posture control [17].

Approximately 80% of children with ASD show motor deficits [18-21]. Differences in the fine, gross and generalized motor functions between children diagnosed with ASD and typically developing children, increase with age, with the largest difference noted at 18-24 months of age [22]. Results of the study of Zhou, et al., which were conducted on 210 Chinese toddlers with ASD with ages 18-36 months, showed that the prevalence of gross and fine motor skills in this population were at 59.5% and 82.5%, respectively [20]. Using bayley scales infant development-3 for children with ASD, Lane, et al., they found out that fine and gross motor delays are present in children under 40 months, with 6 months and 8 months' delay, respectively [22]. High Risk (HR) infants (infants with an older sibling diagnosed with ASD) who were later on diagnosed to have ASD as well, spent significant more time in lying positions and slower trajectory in achieving sitting without support as compared to the low-risk counterparts and even those who are HR but did not receive a diagnosis of ASD. This creates a mechanical constraint on their view of the environment, limited only to the ceiling or floor, and that of their caregivers' faces and eyes [23]. With recognition of early motor signs among HR children for ASD, motor skills' assessment must be pursued as they initially present with them, ahead of language delays [24].

The recent study of Wang, et al., stands out among the numerous literatures about gross motor impairments among patients in ASD as it analyzed the gross motor skill type, muscle group and measurement modality as moderators of the magnitude of these deficits. They found out that the greatest deficits were in object control skills, which could be possibly explained by deficits in the perception-action coupling among patients with ASD. Difficulties of the patients in visually attending to pertinent social information relevant to the situation and the people extends to coordinating their interpersonal motor responses to such social interactions. Meanwhile, reaching skill 20 was found to be the least affected as it was regarded as, "less perceptually demanding, less sensorimotor integration, and with less complex motor planning." With respect to gross motor skill measurement modality, standardized clinical assessments, objective measures (*i.e.,* kinematic motion capture) and parent-report questionnaires, despite some inherent weaknesses such as recall bias for questionnaires or lack of blinding for standardized clinical assessments, overall, each modality was able to report significant gross motor deficits. Lastly, the difference among the muscle group recruited to do a gross motor task was noted to be significant, with the upper extremities or a combination of upper and lower extremities being more impaired than the lower extremities. In this study, age, sex and cognitive ability were seen to have no moderating effects on gross motor deficit but more researches are needed to solidify these findings. This is in support the hypothesis that gross motor deficits could be standalone core features as well for ASD, however, more studies are needed to identify which motor deficits are specific for it. Similarly, the association between gross motor and social skills is not limited to being causal in nature alone. While early gross motor skills lay the groundwork to facilitate emerging social skills, differences in social skills among children with ASD could likewise "limit their participation that would allow them practice gross motor skills." Hence, the relationship between gross and fine motor skills could be "reciprocally cascading on one another throughout development."

Neurobiology of motor impairment in autism spectrum disorder

Numerous structures and networks in the brain are implicated in the motor deficits of children with ASD. First, these processes could be pointed to cerebellar and/or basal ganglia deficits in handling sensory-motor integration as well as modulation of movements [25,26]. Automatization process, a function distinct in the cerebellar area, is reported to be faulty in children with ASD and not only in patients with Developmental Coordination Disorder (DCD). This process pertains to the ability of a person to execute a task with "little conscious attention [27]".

Another plausible explanation resides with how the Action Observation Network (AON) in the brain operates. The Action Observation Network (AON) is a collection of neural networks responsible for sensory-motor integration and it includes the following structures: Inferior Frontal Gyrus (IFG), premotor cortex, Inferior Parietal Lobule (IPL), posterior Middle Temporal Gyrus (MTG) and Superior Temporal Gyrus (STG). To differentiate from mirror neurons, these structures are involved in action observation as opposed to the latter which are involved both in action observation and execution. However, using the MRI studies, no clear conclusion about the exact connection between the function of AON and ASD symptoms can be drawn. The aberrant findings in AON disruption could not be explained by a single mechanism. They posited that through the connection of IFG to MTG and IPL, imitation ability of ASD is intact but not the modulation part of what is being copied. Reward system is likewise linked such that actions that have perceived value are imitated more; hence in those with higher functioning ASD, social stimulus is deemed more rewarding; hence a higher level of AON activation. Imitation from familiar individuals was observed to have typical AON activation as compared to observing actions done by unfamiliar individuals. Other areas of the AON region, particularly

the visual areas and Superior Temporal Sulcus (STS) were suggested to be disrupted, which are involved in the visual-motor pathways. Visual representation and processing in these areas influence motor planning in the "parietal and premotor regions of the mirror neurons as well as motor plans in the ventral premotor cortex which change to predict action in the STS." White matter organization abnormalities in AON, as documented in diffusion weighted imaging, could also account for the functional impairments in brain activation and connections [27,28]. Lastly, the neural connectivity theory supports dysfunction in sensory-motor integration processes of the different areas in the brain such as the noted excessive short-range neuronal connectivity in the frontal, temporal, parietal and visual cortices and dysfunctional long-range connectivity in cortico-subcortical networks.

Motor skills and its association with social-communication skills

How motor skills are related to social skills remain exactly unclear but possible mechanism involves the loss of cerebellar Purkinje cells, as previously mentioned. Dysfunction the cerebellar cortex causes impairment in motor coordination and movement control as well as sensory-motor integration, which is crucial for visual feedback for intact motor execution [28]. The work of Pusponegoro, et al., is one the most cited researches in this motor-socio-communication relationship among autism. Apart from reporting gross motor impairments in children in ASD, these children were also noted to have lower socialization skills as compared to those without motor impairments. The role of mirror neuron system by which socialization and gross motor skills can be possibly related. These neurons sub-serve the imitation process of another person's actions from understanding, simulating and mapping them onto the brain's motor regions. Dysfunction in this motor neurons has also been linked to the difficulties among children with ASD to perceive and internalize other people's actions, thoughts and emotions [29].

In the study by Rios and Benson, caregivers were asked of how they view their children's social and motor skills and they regarded the latter as a strength of their children as they can do the big movements of running, jumping and climbing. Although they acknowledge that these were delayed and with note of difficulty in coordination, characterized as, "it's kind of clunky, it's not as fluid as the kids his age," "he's clumsy, he bumps into walls." Fine motor skills, however, parents agreed that are areas of concern particularly those that involve participation in activities of daily living such as brushing one's teeth, washing his hair, etc. These are activities that even at an older age, these caregivers still do it for them. Admittedly, parents reported that those who have better motor and/or social skills are more participative in group and physical activities [30]. The quasi-experimental study of Najafabadi and colleagues showed that the SPARK program, an evidenced-based physical education program designed for children and adolescents with developmental disorders, particularly ASD, showed improvement in their socialization skills such as their self-esteem, self-confidence and self-competence [31]. Furthermore, Holloway, et al., revealed that gross motor was associated with general social interaction but not with quality of the social overtures. Tasks on stability and object manipulation were related to social skills which could be related to the difficulties of children with ASD in processing visual feedback [32]. Praxis skills-"Representational or non-representational imitation and gesture production," were noted to be lower in accuracy for children with ASD compared with children with DCD when both social and motor performance deficits were controlled. In the study by Kilroy and colleagues, the "theory of mind" ability was highlighted as the cornerstone of praxis skills, highlighting the social component of motor skills. Ohara and colleagues found out that with object control such as aiming and catching skills-tasks that integrate social and motor cues, are those that are related to social skills. For fine motor skills, it was manual dexterity that was related to social skills. Between the two subdomains, however, it was the latter that was more associated with communication skills.

The work of Iverson provided a systematic review of literatures on how motor abilities can have cascading effects on other domains particularly communication. For example, sitting mechanically provides, "greater expansion of the chest cavity, permitting deeper respiration and resulting increased capacity for extended phonation," which lead for speech articulators to be in alignment with gravitational forces. This then prompts infants to explore more possibilities with their phonation and vocalization capabilities. This supports the pioneering work of Lezenbaum, which showed that syllabic vocalization was higher among sitters than non-sitters. In addition to this, reduplicative babbling was likewise delayed among nonsitters. Moreover, a child who has poor truncal tone to sit independently will spend more time in maintaining balance instead of using his hands to explore which can be language and play stimulation cues for his caregiver to respond to the object being explored.

Choi et al., conducted a prospective, longitudinal study among high-risk infants later diagnosed with ASD and low-risk infants without ASD diagnosis whom he assessed the fine motor skills at 6, 12, 18 and 24 months and the expressive language outcomes at 36 months. Notable findings that have been repeatedly cited in succeeding studies are as follows: HR infants who are later diagnosed with ASD showed slowed trajectory in fine motor skill acquisition from 6 to 24 months, differences in their fine motor skills became more

pronounced at 2 years old and that fine motor skills at 6 months were predictive of language outcomes at 3 years old. These findings were alluded to the cascading effects of early motor skills to language acquisition; therefore, can influence and target early intervention strategies to improve these set skills and maximize the sensitive period of language development [33]. Bal et al., identified the predictors of expressive language development in preschoolers with ASD and they found out that those with extremely delayed fine motor skills at age 3, remained minimally verbal, with fewer advancement in expressive language skills by the time they reached age 19 [34].

Motor skills and its association with symptom severity

When it comes to the core features of autism, they found out that gross motor skills may predict the severity of autism and social communication skills while fine motor skills may be affected by non-verbal developmental quotient and restricted and repetitive behaviors. Children with mild to moderate symptoms of autism have significantly higher average gross motor skills than those children whose symptoms are severe as obtained in their CARS-2 scores. Using Artificial Neural Networks (ANN) analysis, a computational model to simulate brain processes, this study showed that those with the most impaired motor skills were those also with the most impaired socialization and language skills and with the highest rate of repetitive and restricted behaviors [35].

A recent study conducted by Bhat in 2021 among 13,887 children with ASD showed that 88.2% was at risk for motor impairment. They also found out that compared to the general population, the relative risk for motor impairment among children with ASD is 22.2 times greater. With increasing impairments across other domains of development such as social communication, adaptive and cognitive, risk further increased up to 6.2. This trend was also reported with respect to repetitive behavior severity [36].

Theoretical frameworks

Perception-action-cognition: In their review of literature, Bhat and colleagues, highlighted the development of the "perception-action-cognition" role in a child's ability to make sense of his world.

Banking on the premise that early in a child's life, a full gamut of motor skills is essential to be able to facilitate other skills in socialization and communication. They proposed that this motor learning principle be also adopted in performing interventions for patients with autism spectrum disorder. For example, since perceptual or visual processing is challenging for these children, proprioceptive feedback, "by physically guiding the child through the action sequence" can be employed instead [37]. Whyatt and Craig further explored the perception-action-coupling theory by substantiating it findings that the motor difficulties found among patients with ASD, in terms of manual dexterity and ball skills, could be due to their difficulties in controlling temporality of actions such as internal timing and preparatory processes.

Developmental cascade

The developmental cascade theory provides a framework in understanding how motor skills in early childhood can have "far-reaching and lasting changes" in other domains of developmental such as the language and social skills. Such changes can be "direct or indirectly; multidirectional; or even span multiple timescales." She cited the early works of Gilbert Gottlieb, Esther Thelen and Joseph Campos in the conceptualization of the developmental cascade theory, with the latter two elucidating this through their work on stepping reflex, the development of reaching and the link between crawling and walking on the other domains (e.g. socioemotional) of development, respectively. Through a young child's locomotion and ability to use his hands to explore, they create an essential medium for the developing senses to be more organized and goaldirected towards people, object and environment. In the presence of motor skills delay, greater effort might be exerted in using these movements (e.g. coordinating hands and feet during crawling, maintain balance during walking) rather than establishing connection with others and communicating one's needs [38].

The work of Bradshaw et al., showed how the developmental cascades framework applies to the study of the heterogeneity of autism spectrum disorder not only in its core features but also in the cross-domain interaction among the domains of development in the hope of accounting also for the biological, behavioral and environmental contributors. It cited three examples of development cascades that can be seen in patients with ASD. First, the developmental milestone of sitting was regarded, "as a watershed moment," in an infant's life, from which eye-hand coordination and socio-communication skills can emerge and be enhanced, as also cited in previous studies. Visual attention is also implicated as an important example of skill with cascading effects given the nonsocial preference of gaze among children with ASD, even early in life. It could have an impact on the establishment of the triadic joint attention with their caregivers and later on, with problems on difficulties in attentional shifting and disengagement which can cascade to cognitive deficits since attention is one of the important components of executive function skills. This highlights the importance of joint attention in establishing interaction between the person and objects in play, which are essential for language development. Lastly, sleep, being one of the "first bio regulatory behaviors" that infants must master

to optimize other physiological processes, also has a cascading effect on behaviors in infancy. This study cited the early works on sleep as an activity that aids in the pruning of synaptic connections, a vital process in brain development which facilitates learning for higher-cognitive processes. When this process is disturbed, efficiency in the synaptic pruning rate and process also gets negatively affected. Sleep dysregulation is a common problem in patients with ASD which leads to under arousal and more challenging behavior in one's daily activities. These developmental and biological processes happen at a multilevel and cross-domain manner and not necessarily, causal in nature [39].

Neural-connectivity theory

The "multisystemic nature" of ASD which could be also explained by the "neural connectivity theory." This theory was based on studies which reported "reduced longrange connectivity between cortices (e.g., reduced fronto-temporal or frontoparietal connectivity) as well as excessive/reduced short-range connectivity within the frontal, parietal, temporal, and visual cortices." Dysfunction in cortico-subcortical, interhemispheric and callosal connectivity have been also implicated in the correlation between the motor and socio-communication deficits observed in patients with ASD. Lastly, this study highlighted again the transdiagnostic utility of motor symptoms and suggested that "motor impairment could be an indicator of how severe the original neuropathology is."

Gap bridged by the study

Clinical implications of motor deficits and motor interventions in autism spectrum disorder : Given the earlier onset of motor delays among children ASD than that of the language delays and repetitive and atypical behaviors, Posar and Visconti suggested the possible need for an assessment of motor development such as the Peabody.

Development Motor Scales (PDMS), which has good utility for the said population. This also calls for a fundamental motor skill intervention given the high prevalence of impairment and its consequence in other domains of development such as adaptive skills [40]. Among children with ASD ages 7-12 years old, Bremer and Cairney reported that better motor coordination, especially manual dexterity, was positively correlated to better adaptive function. Columna and colleagues conducted a randomized feasibility trial of fundamental motor skill parent-mediated intervention for children with ASD. In this study, fundamental motor skills were referred to as those that need object control (e.g. ball skills such as throwing, catching) and locomotor skills (e.g. sliding, hopping, running)-skills that require, "additional time and practice" for mastery to take place. Findings from this study showed positive and promising possibilities for a parent-mediated program to improve fundamental motor skills. The caregivers perceived the intervention, "feasible and acceptable." Further research is being suggested on adhering to structured programs to be taught to parents and be implemented and sustained at home address the motor impairments of children with ASD [41]. Valeria and Bruno reported improvements in the stereotyped behaviors, inhibitory control and socio-communication skills of children with autism when provided with specific physical interventions with specific duration per session over a span of time. Apart from that, they emphasized the benefits of these motor-based interventions to their metabolism, sleep quality and duration, adaptive functioning and overall quality of life.

Study design and setting

This was an analytical cross-sectional study that was conducted in the Child Development Center of the National Children's Hospital. The target population was children diagnosed with autism spectrum disorder using the DSM-5 TR criteria (see Appendix), with ages 1.6-5.11 years old, that were seen *via* face-to-face consultation in the outpatient clinic of the Child Development Center. The basis for the said age range is that it corresponds to the sensitive period of brain development which encompasses the toddlerhood and preschool years, wherein the aim of early intervention is centered on so that later skills such as those needed in the school could be more effectively learned.

Sources of data

Sampling design: The study used a non-probability, purposive sampling method given the said target population of patients in the center.

Sample size/sample size computation: The clinic census from January to December 2023 recorded a total of 1295 diagnosed cases of autism spectrum disorder. 600 of them, which is almost half of this figure, were newly diagnosed patients in the institution and belonged to the age range of 1.6-5.11 years old. Since this number reflected the actual number of patients diagnosed with autism belonging to the said age range, this was the basis of the computation of the sample size. A minimum sample size of 242 subjects was required for this study, based on a conservative estimate of the association between exposure and outcome (odds ratio equal to 2.0), an 80% power to detect an effect size of 0.224 at 0.05 α-level of significance.

Inclusion criteria:

The following were the inclusion criteria:

- 1.6-5.11 years old, seen for the first time in the outpatient Child Development Center of the

National Children's Hospital for a developmental assessment
- Diagnosed with autism spectrum disorder using the diagnostic statistical manual 5-text revision criteria
- Has not received any therapeutic intervention (occupational, speech and physical therapy, applied behavioral analysis therapy)

Exclusion criteria:

The following were the exclusion criteria:

- Patients who have medical conditions or neurodevelopmental conditions with physical impairments affecting motor function such as: Cerebral palsy, neuromuscular dystrophies, intracranial pathologies, down syndrome, sensory impairment such as vision (*i.e.,* irregular pupil size, lack of visual fixation and tracking, absent visual threat, impaired primary, secondary and tertiary gaze, diagnosed case of cortical blindness) and hearing (*i.e.,* does not alert to environmental sounds, does not turn to localize sound upon presentation of bell on each ear, diagnosed case of hearing loss both conductive and sensorineural loss, regardless of severity), which were elicited as part of routine neurological examination.

Withdrawal criteria:

Noncompletion of any of the developmental and/or motor assessment was the basis for the withdrawal from the study.

Suitability of site

Housed in a development center providing assessment and intervention for children with autism spectrum disorder, the study site was apt to meet the demands of the proposed study as to the following measures:

- Target population and sample size.
- Well-lit and well-ventilated, isolated rooms for the conduct of the developmental assessment .
- Availability and completeness of the developmental tools that were used (*i.e.,* battelle developmental inventory 2nd Edition-normative update, peabody developmental motor scales, 2nd Edition, childhood autism rating scale 2nd Edition)
- Provision for spacious areas to adequately perform motor tasks (*i.e.,* ball throwing, jumping, staircase use, hopping, etc.).

Duration of the study

The duration of the study was 3 months which factored in the sample size needed during data collection period.

Procedure (conduct of the study):

- Recruitment of participants

Scheduled patients underwent developmental assessment and counselling by the fellows-in-training of the section developmental and behavioral pediatrics. Each developmental assessment (which includes socialization skills, communication skills and symptom severity determination through the aforementioned developmental tools) and counselling took about 1½-2 hours. Those who were eligible as stipulated by the eligibility criteria were recruited. The BAER technologist, who is some personnel from the child development center and not directly involved in the management of the patients, was oriented well on the inclusion and exclusion criteria of the study, screened eligible patients and secured the informed consent from the parent or guardian. The child was assigned a research code to maintain his/her anonymity in the collection data form. The parents were given a referral form to the physical therapist, with 7 years of clinical experience in handling children with special needs, for the conduct of the motor skills assessment using the peabody developmental motor scales-2 in their outpatient clinic, with no additional cost. The motor skills assessment took about 20-30 minutes. An hour of break in between assessments (developmental and motor) was provided. The parent was advised on the result of the motor assessment and was given recommendations by the physical therapist on how to address the motor deficits, should there be any (Figure 2).

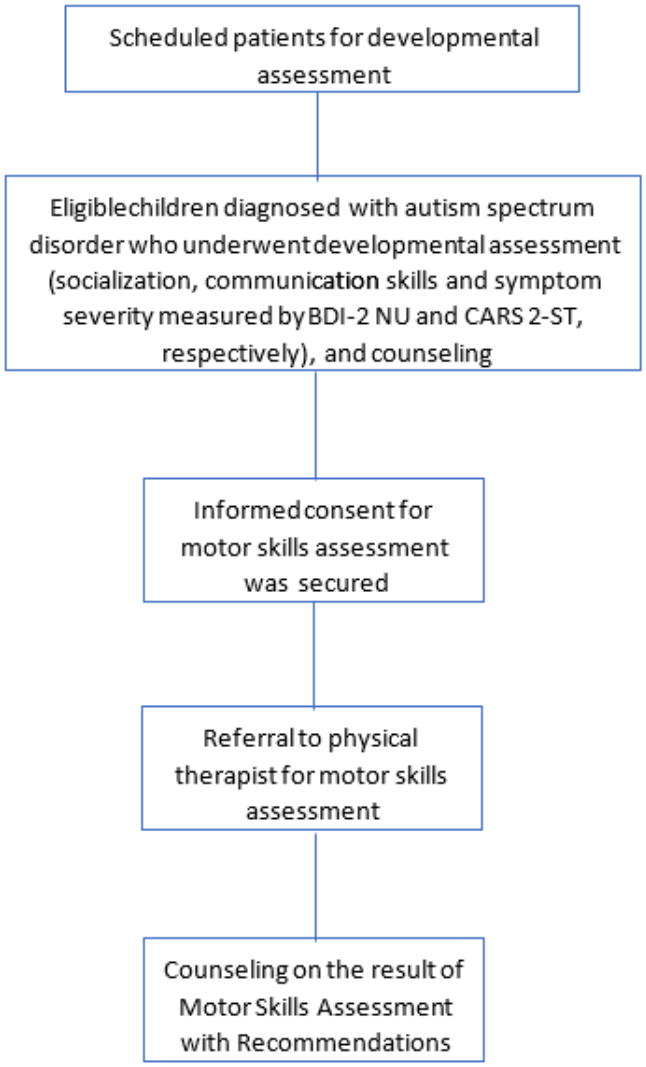

Figure 2. Procedure of participants for recruitment.

Data collection and method

Data collection employed primary data from the medical records of the patients as obtained by the primary investigator. The following data were obtained: Demographic data (age, gender), gestational and neonatal history (age of gestation, mode of delivery, birth weight, significant neonatal and maternal illness), personal-social history (maternal and paternal education level, maternal and paternal ages at the time of birth, marital status, educational attainment, employment status, screen time per day, physical activity per day) and family history (presence of genetic, neurodevelopmental conditions up to 2nd degree on maternal and/or paternal side). The Battelle Developmental Inventory-2 Normative Update (BDI-2 NU) record form was used for developmental assessment of socialization and communication skills, while symptom severity of ASD was assessed using Childhood Autism Rating Scale, 2nd Edition (CARS 2-ST). The motor assessment of the patients was obtained from the Peabody Developmental Motor Scales (PDMS-2) record form. Patients' data was protected using coding and electronic storage mechanism in order to guarantee confidentiality of patients' identity. A final data collection form was constructed so that the data collection procedure was systematic and accurate.

Instruments

Battelle Developmental Inventory-2nd Edition, Normative Update (BDI-2 NU)

Battelle developmental inventory, 2nd Edition normative update is a standardized assessment tool, used to quantitatively and qualitatively measure a child's developmental abilities from 0-7.11 years, in 5 different domains: Adaptive, personal-social, communication,

motor and cognitive skills. Each domain will yield a Developmental Quotient (DQ) which has a corresponding qualitative descriptor (e.g. DQ 90 and above-average, DQ 80-89 low average, DQ 70-79 mild developmental delay, DQ 69 and below significant developmental delay). The internal-consistency of BDI-2 NU is high, with coefficient alpha for all subdomains ranging from 0.85-0.95 and domain DQ scores ranging from 0.89-0.96. The utility of BDI-2 in special groups such as in autism spectrum disorder was also demonstrated and it showed that all the domain DQ scores were below 72, with the most significant lowest ones in the personal-social and communication domains (DQ scores 62.53, 65.27). When compared to typically developing counterparts, the largest differences using effect sizes were noted in the personal social scores and total DQ score; hence, BDI-2 NU scores can discriminate children with autism from their typical age-matched counterparts.

Childhood autism rating scale, 2nd Edition (CARS 2-ST)

Childhood autism rating scale, 2nd Edition is a 15-item observer-rating scale that is used to aid in the diagnosis of autism spectrum disorder in children 6 years old and below. Each item is scored on a 7-point Likert scale which would yield a total score which then would correspond to the level of severity of the symptoms such as those with scores of 15-29.5 have minimal-to-no symptoms, 30-36.5 have mild to-moderate symptoms and those with 37 and above have severe symptoms. Reported inter-rater reliability and internal consistency of CARS were good at 0.796 and 0.896, respectively. Its diagnostic agreement with DSM-5 was at 0.84.

Peabody developmental motor scales, 2nd Edition (PDMS-2)

Peabody developmental motor scales, 2nd Edition is a standardized tool used for the assessment of gross and fine motor skills in children from birth to 5 years old. It has six subtests namely: Reflexes, stationary, locomotion, object manipulation, grasping and visual-motor integration. Each subtest will give a raw score which will be converted to standard scores that will have corresponding qualitative descriptors (e.g. 8 and above average, 6-7 below average, 4-5 poor, 1-3 very poor). There are three composite scores generated: Gross motor quotient, fine motor quotient and total motor quotient, which have corresponding qualitative descriptors as well. The internal consistency coefficient alphas of PDMS-2 subtests were from 0.89-0.96 while those for the composites were higher ranging from 0.91-0.98. Testretest reliability for the subtests ranged from 0.82-0.94 while 0.89-0.93 for the composites. Interscorer reliability were also from 0.96-0.98. Content and construct validity for PDMS-2 were also good.

Data/statistical analysis

Descriptive statistics were used to summarize the general and clinical characteristics of the participants. Frequency and proportion were used for categorical variables (nominal/ordinal), mean and standard deviation for normally distributed interval/ratio variables, and median and range for non-normally distributed interval/ratio variables (Table 1).

Table 1. List of continuous and categorical variables for descriptive statistics.

Continuous variables	**Categorical variables**
Mean ± SD; Median (IQR)	**Frequency (%)**
Maternal age at child's time of birth	Age group
Paternal age at child's time of birth	Sex
Screen time per day (hours)	Age of gestation
Physical activity per day (hours)	Mode of delivery
PDMS-2 domains	Birthweight
BDI-2-NU domains	Significant neonatal and maternal
CARS-2 ST	• Illness • Maternal educational attainment • Paternal educational attainment • Type of indwelling • Employment status • Family history (genetic and neurodevelopmental conditions)
	• PDMS-2 domains • BDI-2-NU domains • CARS-2 ST

Spearman's rank correlation was used to evaluate the monotonic relationship between motor skills and social-communication skills. Crude and adjusted odds ratios and 95% CI from binary logistic regression were used to determine the association between motor skills and outcomes (socialization, communication, and ASD symptom severity). Analysis of association of motor skills with outcomes was adjusted for identified confounding variables and estimates were presented as adjusted odds ratios and 95% CI. Backward elimination method was used for variable selection to build the final model that retains only the predictor variables that contribute significantly to explaining the variation in the outcome (ASD symptom severity). Firth's logistic regression was planned to mitigate biased estimates if with small number of events observed in the social-communication skills outcomes. Missing variables were neither replaced nor estimated. Null hypothesis was rejected at 0.05 α-level of significance. Stata 15.0 was used for data analysis.

Ethical considerations

The final manuscript was submitted, underwent review and given approval by the Institutional Review Board of the National Children's Hospital. Informed consent was secured from the parents prior to the motor skills assessment part of the study. The patient's anonymity was guaranteed by assigning research code in the patient data form and was assured that no patient's photo or video was used without the consent of the parent, outside the dictates of this study. The parents who refused photo- or video-taking of the patient, were honored by the investigators but did not mean exclusion from the study and disclosure of results to them. No compensation monetary or in kind was given to participants. The author had no potential conflict of interest to the study proposed.

Results

Sociodemographic profile of patients

The study included 242 pediatric patients, 4.1-4.11 years old (32.23%) and 5.1-5.11 years old (34.71%) age groups. The majority of patients were male (81.4%). Most children were born term (90.91%), with vaginal delivery being the most common mode of delivery (74.79%). Normal birth weight was observed in 83.47% of the cohort. Significant maternal infections such as urinary tract infection and upper respiratory tract infection were reported in 10.33% of cases. The most frequent comorbidities were gestational hypertension (4.13%) and gestational diabetes (3.31%). Maternal age at the child's birth predominantly fell within the 21-34 years range (65.7%), while most fathers were younger than 40 years (80.58%). High school was the highest educational attainment for majority of mothers (60.74%) and fathers (61.98%). For employment status, more fathers were employed at 95.87% compared to mothers at 38.02%. Screen time exceeding 120 minutes per day was reported by 53.72% of children, and 64.05% of children engaged in physical activity for less than 30 minutes on most days of the week. Neurodevelopmental conditions in first-degree relatives were present in 3.72% of families. Using BDI-2 NU, the cognitive skills of 89.67% of the children were significantly delayed (*i.e.*, DQ<69) (Table 2).

Table 2. Sociodemographic profile of patients (n=242).

	Frequency (%)
Age (months)	
18-24	4 (1.65)
25-36	28 (11.57)
37-48	48 (19.83)
49-59	78 (32.23)
60-71	84 (34.71)
Sex	
Male	197 (81.4)
Female	45 (18.6)
Age of gestation	
Preterm (<37 weeks)	22 (9.09)
Term (37-41 weeks)	220 (90.91)
Mode of delivery	
Normal spontaneous delivery	181 (74.79)
Cesarean section	61 (24.38)

Birthweight	
Low birthweight (<2500 grams)	25 (10.33)
Normal (2500-3500 grams)	202 (83.47)
High birthweight (>3500 grams)	15 (6.2)
Significant neonatal and maternal illness	
Maternal infection	25 (10.33)
Comorbidities	
Gestational hypertension	10 (4.13)
Gestational diabetes	8 (3.31)
Oligohydramnios	7 (2.89)
Pre-eclampsia	3 (1.24)
Asthma	1 (0.41)
Polyhydramnios	1 (0.41)
Peripartum difficulties	
Fetal bradycardia	10 (4.13)
Tachycardia	0
Prolonged labor	0
Meconium staining	9 (3.72)
Personal-social history	
Maternal age at child's time of birth (years)	
≤ 20	11 (4.55)
21-34	159 (65.7)
≥ 35	72 (29.75)
Paternal age at child's time of birth(years)	
<40	195 (80.58)
≥ 40	47 (19.42)
Maternal educational attainment	
Grade school	0
High school	147 (60.74)
College	95 (39.26)
Paternal educational attainment	
Grade school	2 (0.83)
High school	150 (61.98)
College	90 (37.19)
Employment status of mother	
Employed	92 (38.02)
Unemployed	150 (61.98)
Employment status of father	
Employed	232 (95.87)
Unemployed	10 (4.13)
Screen time per day (minutes)	
0	14 (5.79)
1-29	8 (3.31)
30-60	52 (21.49)
60-120	38 (15.7)

>120	130 (53.72)
Physical activity per day less than 30 minutes for most days of the week (4/7)	155 (64.05)
more than 30 minutes for most days of the week (4/7)	87 (35.95)
Family history	
Genetic conditions None	242 (100)
First degree	0
Second degree	0
Neurodevelopmental conditions None	232 (95.87)
First degree	9 (3.72)
Second degree	1 (0.41)
Cognitive skills developmental quotient (BDI-2 NU)	
≥ 90	0
80-89	16 (6.61)
70-79	9 (3.72)
≤ 69	217 (89.67)

Motor skills profile of patients

In the assessment of motor skills using the PDMS-2, 42.15% of children scored below average on the gross motor quotient, while 16.53% fell into the very poor category. For fine motor skills, 58.26% of children were classified as very poor, and only 0.83% achieved a superior rating. When evaluating the total motor quotient, 35.12% of children were categorized as very poor, and 26.45% were classified as poor. Only a small fraction of the cohort scored above average or higher across gross (5.37%), fine (3.72%), and total motor skills (0.82%). The majority of children fell into the below average, poor, and very poor categories across all motor skill assessments (Table 3).

Table 3. Performance on motor skills.

	Frequency (%)
Peabody developmental motor Scales-2	
Gross motor quotient very superior	1 (0.41)
Superior	5 (2.07)
Above average	7 (2.89)
Average	40 (16.53)
Below average	102 (42.15)
Poor	47 (19.42)
Very poor	40 (16.53)
Fine motor quotient very superior	1 (0.41)
Superior	2 (0.83)
Above average	6 (2.48)
Average	41 (16.94)
Below average	16 (6.61)
Poor	35 (14.46)
Very poor	141 (58.26)
Total motor quotient Very superior	1 (0.41)

Superior	0
Above average	1 (0.41)
Average	33 (13.64)
Below average	58 (23.97)
Poor	64 (26.45)
Very poor	85 (35.12)

Table 4 shows that for the gross motor subscales, majority of patients were at the above average and below average categories. The reverse was observed for the fine motor subscales wherein most of the patients were at the poor and very poor categories. Overall, when those with subpar performance were categorically placed together, majority of patients were still with impairments for each subscale, with the most significant ones in the grasp (*i.e.*, above average at 78.52% *vs.* below average, poor and very poor 78.52%) and visual motor integration (*i.e.*, above average at 17.7% *vs.* below average, poor and very poor 82.3%) (Table 4).

Table 4. Performance on motor skills subscales.

Frequency (%)			
Peabody developmental motor scales-2		**Gross motor subscales**	
Scaled score	**Stationary**	**Locomotion**	**Object manipulation**
Above average	104 (42.97%)	100 (41.32%)	97 (40.08%)
Below average	87 (35.95%)	90 (37.19%)	64 (26.44%)
Poor	34 (14.04%)	40 (16.52%)	18 (7.43%)
Very poor	17 (7.02%)	12 (4.95%)	63 (26.03%)
Fine motor subscales			
Scaled score	**Grasp**		**Visual-motor integration**
Above average	52 (21.48%)		43 (17.7%)
Below average	39 (16.11%)		34 (14.04%)
Poor	74 (30.57%)		89 (36.77%)
Very poor	77 (31.81%)		76 (31.4%)

Socialization skills, communication skills and symptom severity of patients

The evaluation of socialization and communication skills using the BDI-2 NU indicated that 99.17% of children had a personal-social developmental quotient of ≤ 69, with only 0.83% scoring between 70-79. Communication skills were similarly significantly impaired, with 98.76% of children scoring ≤ 69, and 0.41% each scoring in the 70-79, 80-89, and ≥ 90 ranges. The CARS-2 ST indicated that 75.62% of children exhibited severe symptoms, while 24.38% had mild to moderate symptoms (Table 5).

Table 5. Socialization and communication skills, and symptom severity.

Median (IQR); Frequency (%)	
Battelle developmental inventory-2 NU	
Personal-social (developmental quotient)	55 (55-57)
≥ 90	0
80-89	0
70-79	2 (0.83)
≤ 69	240 (99.17)
Personal-social sub-domains	
Adult interaction	26 (20-37)

Median (IQR); Frequency (%)	
Peer interaction	2 (1-14)
Self-concept	18 (13-31)
Communication (developmental quotient)	55 (55-57)
≥ 90	1 (0.41)
80-89	1 (0.41)
70-79	1 (0.41)
≤ 69	239 (98.76)
Communication sub-domains receptive language	25 (18-28)
Expressive language	24 (17-28)
Childhood autism rating scale-2 ST mild to moderate symptoms	59 (24.38)
Severe symptoms	183 (75.62)

Analysis of association between motor skills and socialization skills and communication skills

The study had insufficient evidence to demonstrate an association between motor skills and socialization, as demonstrated by wide 95% confidence intervals (Table 6).

Table 6. Analysis of association between motor skills and socialization skills.

Variable	**Crude odds ratio (95% CI)**	**p-value**
Gross motor quotient		
Average to very superior	**Reference**	**-**
Below average	0.52 (0.01-26.67)	0.89
Poor	1.13 (0.02-57.88)	0.953
Very poor	1.32 (0.03-68.00)	0.89
Fine motor quotient		
Average to very superior	**Reference**	**-**
Below average	3.06 (0.06-160.41)	0.58
Poor	1.42 (0.03-73.39)	0.861
Very poor	0.36 (0.01-18.22)	0.608

The analysis of the association between motor skills and communication skills did not reveal significant relationships. Results were likewise inconclusive of any association between motor and communication skills, as demonstrated by wide 95% confidence intervals, indicating high levels of uncertainty and low precision (Table 7).

Table 7. Analysis of association between motor skills and communication skills.

Variable	**Crude odds ratio (95% CI)**	**p-value**
Gross motor quotient		
Average to very superior	**Reference**	**-**
Below average	0.52 (0.01-26.67)	0.746
Poor	1.13 (0.02-57.88)	0.953
Very poor	1.32 (0.03-68.00)	0.89
Fine motor quotient		
Average to very superior	**Reference**	**-**
Below average	3.06 (0.06-160.41)	0.608
Poor	1.42 (0.03-73.39)	0.861

Very poor	0.36 (0.01-18.22)	0.608

Table 6 presents the relationship between motor skills and personal-social and communication skills. The analysis investigated correlations using the continuous motor skills and social-communication quotients due to the non-informative findings resulting from extremely uneven distribution of categories in the BDI-2 NU domains, which were predominantly centered around the 'below average' category.

The gross motor quotient showed a weak but significant positive correlation with personal-social skills (r=.202, p=.002) and a moderate positive correlation with communication skills (r=.307, p<.001). The fine motor quotient demonstrated moderate to strong positive correlations with personal-social skills (r=.381, p<.001), adult interaction (r=.409, p<.001), peer interaction (r=.333, p<.001), self-concept (r=.428, p<.001), communication skills (r=.133, p=.039), receptive language (r=.428, p<.001), and expressive language (r=.419, p<.001) (Table 8).

Table 8. Relationship between motor skills and socialization skills and communication skills.

	Gross motor quotient		**Fine motor quotient**	
	Correlation coefficient, r	**P value**	**Correlation coefficient, r**	**P value**
Personal-social	0.202	0.002	0.381	<.001
Adult interaction	0.059	0.36	0.409	<.001
Peer interaction	-0.026	0.683	0.333	<.001
Self-concept	0.094	0.144	0.428	<.001
Communication	0.307	<.001	0.133	0.039
Receptive language	0.137	0.033	0.428	<.001
Expressive language	0.168	0.009	0.419	<.001
Statistical test used: Spearman's correlation				

Analysis of association between motor skills and symptom severity

Table 7 presents significant associations between motor skills and the severity of Autism Spectrum Disorder (ASD) symptoms, particularly concerning the fine motor quotient. Children with poor (OR=2.70, 95% CI (1.00-7.25), p=.049) and very poor (OR=5.82, 95% CI (1.57-21.59), p=.008) gross motor skills were significantly more likely to exhibit severe ASD symptoms compared to those with at least average gross motor skills, showing a near threefold and nearly six fold increase in risk, respectively.

Even more pronounced were the findings for fine motor skills. Children with poor (OR=4.66, 95% CI (1.77-12.28), p=.002) and very poor (OR=13.60, 95% CI (6.11-30.28), p<.001) fine motor skills had significantly higher odds of severe ASD symptoms compared to their peers with at least average fine motor skills, indicating more than a fourfold and thirteen fold increase in risk, respectively.

Furthermore, the observed trend or gradient, where the odds of severe ASD symptoms rose progressively with worsening motor skills, strengthens the association between poor motor skills and ASD severity (Table 9).

Table 9. Analysis of association between motor skills and symptom severity.

Variable	**Crude odds ratio (95% CI)**	**p-value**
Gross motor quotient		
Average to very superior	**Reference**	**-**
Below average	1.03 (0.51-2.11)	0.929
Poor	2.70 (1.00-7.25)	0.049
Very poor	5.82 (1.57-21.59)	0.008
Fine motor quotient		
Average to very superior	**Reference**	**-**
Below average	1.07 (0.35-3.35)	0.902

Poor	4.66 (1.77-12.28)	0.002
Very poor	13.60 (6.11-30.28)	<.001

Multivariable analysis of association between patient characteristics and severity of ASD symptoms (disaggregated motor skills)

The multivariable analysis identified several significant associations with the severity (ASD) symptoms. After adjusting for other variables, children with poor fine motor skills were found to be 5.45 times more likely to have severe ASD symptoms compared to those with average to very superior fine motor skills (OR=5.45, 95% CI (1.34, 22.21), p=.018). Additionally, children with very poor fine motor skills were 13.88 times more likely to exhibit severe ASD symptoms (OR=13.88, 95% CI (4.05, 47.52), p<.001). This suggests a strong association between lower fine motor skills and increased severity of ASD symptoms, with a clear gradient that strengthens the association.

Other significant findings included an inverse relationship between age and symptom severity, with older children being 5% less likely to have severe symptoms for each additional year (AOR=0.95, 95% CI (0.91, 0.99), p=.011). Cognitive skills also showed a protective effect, with higher cognitive scores associated with a 11% reduced likelihood of severe symptoms (AOR=0.89, 95% CI (0.83, 0.95), p<.001). Personal-social skills were similarly protective, with better skills reducing the likelihood of severe symptoms by 33% (AOR=0.67, 95% CI (0.57, 0.79), p<.001) (Figure 3). Additionally, children whose fathers had a college-level education were 73% less likely to have severe ASD symptoms compared to those whose fathers had at most a high school education (AOR=0.27, 95% CI (0.10, 0.75), p=.011) (Table 10).

Table 10. Multivariable analysis of association between patient characteristics and severity of ASD symptoms.

Variable	**Adjusted odds ratio (95% CI)**	**p-value**
Below average to very poor fine motor skills (reference category: Average to very superior)	6.22 (2.30-16.81)	<.001
Age	0.94 (0.91-0.98)	0.005
Cognitive skills	0.89 (0.84-0.95)	<.001
College level paternal education (reference category: At most high school)	0.35 (0.14-0.88)	0.026
Personal-social skills	0.66 (0.56-0.77)	<.001
Pseudo-R^2=0.3574; p-value<.001		

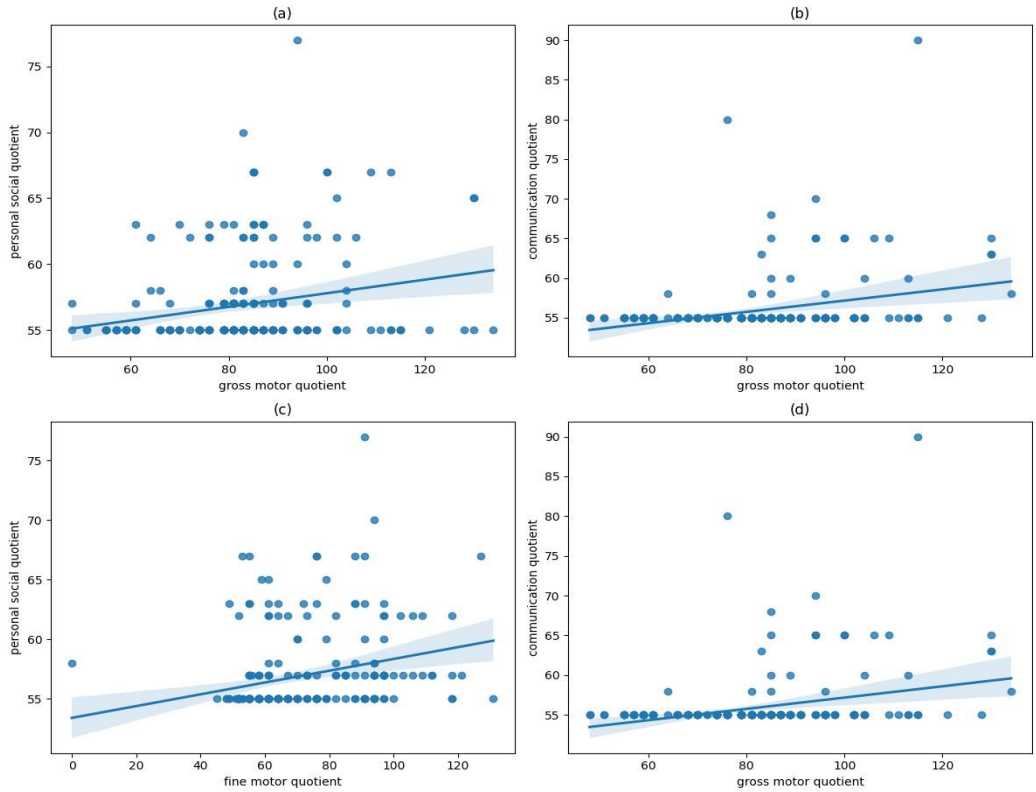

Figure 3. Scatterplot depicting the relationship between PDMS-2 motor skills and BDI-2 NU domains. a) gross motor quotient *vs.* personal-social quotient; b) gross motor quotient *vs.* communication quotient; c) fine motor quotient *vs.* personal-social quotient; and d) fine motor quotient *vs.* communication quotient.

Discussion

We analyzed 242 pediatric patients with Autism Spectrum Disorder (ASD), primarily aged 49-71 months and predominantly male (81.4%). Most children were born at term (90.91%) *via* normal spontaneous delivery (74.79%) and had a normal birth weight (83.47%). Maternal infections were reported in 10.33% of cases, with gestational hypertension (4.13%) and gestational diabetes (3.31%) as the most frequent comorbidities. Socioeconomic data revealed that the majority of parents had high school education, and there was a notable difference in employment status between mothers (38.02% employed) and fathers (95.87% employed).

Motor skills assessments indicated widespread challenges. Using PDMS-2, the percentage of gross, fine and total motor impairments (*i.e.*, cumulative percentage of below average, poor and very poor), registered at 78.1%, 79.3% and 85.84%. Majority of children with gross motor impairments were categorized as below average at 42.1% while those with fine motor impairments were at the very poor at 58.26% category. With respect to gross motor impairments, under the object manipulation subscale of the PDMS-2, a substantial portion of patients scored very poor at 26.03% versus that of stationary subscale at 7.02% and locomotion subscale at 4.95%. Faulty object control (e.g, throwing and/or catching a ball) which equates to poor praxis skills is the most reported finding in the gross motor component of patients with autism spectrum disorder [25,26,29,33,42]. The ability to conceptualize, plan, organize and finally execute a motor response or task is governed by the intactness of the perception of the action which corresponds to the social component of motor skills [20]. Meanwhile, for both PDMS-2 subscales of the fine motor, *i.e.*, grasping and visual-motor integration, the distribution of patients was majority in the poor and very poor categories. This was in alignment to the finding of manual dexterity being the affected fine motor subcomponent as noted in various literatures [26.27,29]. In addition to the previously mentioned reason, such difficulties in those subcomponents could be explained by their difficulties in controlling the timing of their actions as well as their preparatory processes. Neurobiologically, motor impairments in children with autism spectrum disorder are reportedly due to alteration and/or impairments in the brain structures particularly in the Purkinje cells of the cerebellar cortex and basal ganglia, activation observation network, mirror neurons [23.28,30]; connectivity (*i.e.*, excessive short-range neuronal connectivity in the frontal, temporal, parietal and visual cortices and dysfunctional long-range connectivity in

cortico-subcortical networks) and processes (*i.e.*, perception-action coupling and developmental cascade) [26,38,39,40] that correspond to sensory-motor integration, specifically visual feedback, movement coordination and control.

Socialization and communication skills were similarly impaired, with 99.17% of children scoring ≤ 69 on the personal-social developmental quotient and 98.76% scoring ≤ 69 in communication skills. The childhood autism rating scale-2 ST showed that 75.62% of children had severe ASD symptoms.

The analysis found no significant categorical associations between motor skills and socialization or communication skills, with wide confidence intervals and p-values >0.05. However, correlational analysis revealed positive relationships, particularly for fine motor skills, which showed moderate to strong correlations with personal-social skills (r=.381) and various sub-domains of communication skills, including receptive (r=.428) and expressive language (r=.419). These findings suggest that while categorical associations were non-significant, there are important continuous relationships between motor skills and social-communication abilities. The correlation tests evaluated per unit increases, offering more granularity than the categorical odds ratios, which were affected by the imbalanced data distribution skewed towards more severe categories. This imbalance contributed to the significant correlations and nonsignificant associations. Additionally, a caveat is that correlation pertains to linear relationships, so weaker correlations might indicate less linearity rather than weaker associations per se.

The gross motor skills of the patients showed weak but positive correlation socialization skills while moderate for communication skills. Gross motor skills lay the groundwork for the establishment of socialization skills later on as the child becomes more mobile and adept in using his hands use to be able to initiate and respond to social interactions, participate during play and daily activities and utilize both nonverbal and verbal means to connect with other people [18,24,39,40]. With this premise, children with poorer gross motor skills could be deficient in their repertoire of posture control, movement, balance and coordination, motor planning abilities to anticipate the actions of others while catching or throwing a ball or the reappearance of the person playing with him during hide-and-seek game. Instead of being socially engaged during the activity, children with ASD tend to focus their abilities in maintaining finding stability, coordinating and executing their movement and that even though they may seemingly participative, the quality of the social interaction is not guaranteed. Motor challenges not only limit their participation in social activities but also impact their self-concept and self-esteem. In the study conducted by Najafabadi and colleagues in 2018, their designed evidenced-based physical education program showed improvement in selfesteem, self-confidence and competence. Nevertheless, the differences in the social skills of children with ASD, could still "limit their participation that would allow them to practice their gross motor skill," implying that the relationship of motor skills with social skills could be "reciprocally cascading on one another." In this study, gross motor skills were likewise reported to be significantly correlated to the communication domain in children with ASD. Studies have demonstrated that early motor skills at 6 months and 24 months of age were predictive of language development at 36 months old, which corresponds to the sensitive period of the said domain. Furthermore, the scoping review of Hwang and Lee was able to document how early motor skills could be predictors of the rate of both receptive and expressive language especially in the early childhood [41,42]. Their study was also in agreement to previous studies that between the two motor subdomains, however, it was fine motor that predicted expressive language abilities better than gross motor skills. Intact visuospatial perception and motor exploration remain to be the mechanism for receptive language development and later on be translated to expressive language skills. Fine motor imitation skills were associated with be use of co-speech gestures (*i.e.*, hand or body movements that accompany speech) such as pointing which could further facilitate language acquisition and expansion into vocabulary building and grammatical forms [43]. Practically-speaking, a child who points, manipulates objects or makes physical gestures may ignite and enhance the communicative intent of caregivers to label, describe and engage with them in social interaction. These sociocognitive underpinnings between motor skills and language skills are transformational in the management of patients to be more targeted. In this regard, motor-based intervention programs are being piloted in order to target these deficient domains in ASD; however, results are still variable despite the establishment of association between motor skills and socio-communication skills [44].

Multivariable analysis demonstrated that poor fine motor skills significantly increased the likelihood of severe ASD symptoms, with a gradient effect showing higher odds for very poor skills (OR=13.88). Additionally, older age, higher cognitive skills, better personal-social skills, and higher paternal education levels were protective factors, reducing the likelihood of severe symptoms. These findings support the importance of comprehensive interventions that address motor skill development, cognitive and social skills, and supportive socioeconomic factors to manage and potentially mitigate ASD severity.

This study showed parallel results with previous researches in which motor skills were significantly associated to symptom severity. Numerous studies have

expounded on the nature of this relationship by accounting for several factors contributing to symptom severity and how performance in motor skills could contribute or be related to it. The pioneering study of Green and his colleagues demonstrated that motor impairments in children with ASD were more likely to be found in those with IQ of less than 70, which implicates neurodevelopmental vulnerability [45]. Recent large-scale studies have challenged this idea and have reported that the effect of motor skills on symptom severity are independent of intellectual capacity and even of other variables such as age and sex [46]. Nonetheless, the extent and mechanism as to which cognitive function creates a moderating effect could be different for gross and fine motor skills as exemplified in the work of Zhou, et. al., wherein gross motor skills could independently predict symptom severity while fine motor skills are influenced by restricted and repetitive behaviors and by nonverbal developmental quotients as in visuospatial tasks. Similarly, Taverna, et. al. was able to report that motor imitation skills are significant predictors of ASD symptomatology when controlling for nonverbal intelligence quotient. Executive functioning skills such as working memory and inhibitory control were studied in relation to the motor skill of children with ASD. Working memory, which requires more continuous and complex function of visuomotor integration, was found to be more correlated to fine motor skills which in turn, require greater functioning of the frontoparietal network of the brain. On the other hand, gross motor skills were observed to be a function of inhibitory control [47]. This also sheds light on how cognitive skills becomes an evident protective factor in symptom severity. Children with ASD who were able to demonstrate better attention and memory, reasoning, academic skills and perceptual concept were more like to be seen with less severe symptoms as they could communicate and engage more effectively and with fewer restricted and repetitive behaviors. Similarly, children with ASD who show less severe socialization deficits such as being able to engage with peers, adults and exhibit stronger self-concept, are regarded with less severe ASD symptoms.

With regards to age of the patients, the said range of 1.8-5.11 years was selected for the purpose of documenting motor impairments early in their development in the hope of providing targeted interventions that will impact their activities of daily living and school performance. Majority of the patients were at 4-5 years old, a time when most of their parents send them already to daycare or kindergarten class, thus, paving the way for more avenues for social interaction, language acquisition and even, behavior modification. Aside from this, a recent study in UC Davis Mind Institute has reported that at the age of 6 years old, symptom severity has decreased by 30%, with intelligence quotient being the strongest predictor once again [48]. This could therefore explain as to why older children are less likely to have severe symptoms. Despite this, improvement in the severity of symptoms is still best achieved through consistent provision of interventions and support at home.

In the recent years, low maternal educational attainment has been documented to be strongly associated with more severe symptoms of autism. This study demonstrated a different finding in which children whose fathers had a college-level education was less likely to have severe symptoms. Such is a novel finding which could highlight the more positive roles of fathers and their attributes in the dynamics of their child's condition. It could be surmised that high paternal education would mean better opportunities for employment and providing for the family and lesser stress for the household, especially for the mothers who are culturally and frequently left in the care of the child, as shown also in the demographics of this study. High paternal education also equates to better resilience and lesser distress. A study conducted by Cabrera and colleagues, showed that fathers' low level of distress is correlated to a child's social competence [49]. In children with autism whose socialization skills are significantly challenged and which understandably affect the severity of their symptoms, paternal level could contribute in lessening these deficits although more studies must be conducted to explore this possible relationship.

A number of limitations were identified in this study which could benefit future researches in the said topic. First, with respect to the sample size and its composition, the relatively small number and the imbalance in the distribution of patient attributes in terms of their socialization and communication skills have affected the analysis on association and correlation. As the institution caters mostly to children in the lower socioeconomic status, the developmental profile of patients could be different to those belonging in the mid and upper counterparts assessment tools which are targeted only for socialization and communication skills could benefit the yield of the study in measuring these domains. Another limitation of the study was the use of nonpurposive, convenience sampling which could limit the generalizability of the findings to a broader population as compared to a randomized sample. In addition to this, despite the power of the study at 80% it still relatively limited the study to detect true effects especially smaller or more nuanced relationships in the data.

Lastly, cognitive skills were not corrected for to identify and differentiate its verbal and nonverbal quotients. The items measuring separately for these quotients are scattered into its three subdomains namely attention and memory, reasoning and academic skills, perception and concepts in the BDI-2 NU. As such, limited data can be interpreted on how cognitive function moderate its effect on the severity of symptom for this study.

Despite the limitations of this study, its strength primarily lies in the use of standardized tools in the assessment of the independent and dependent variables in contrast to other studies which employed parent-administered questionnaires which could lead to either over or underestimation of skills. This is in addition to the notable psychometric properties of PDMS-2 in the assessment of motor skills of patients with autism and the clinical experience of the physical therapist administrating the test. Lastly, the results of this could contribute not only in the repository of resources of the relationship between motor skills and social communication skills and severity symptoms of children in autism but more so, in the holistic care of these children and their families.

Conclusion

The results of this study show that motor impairments are significantly evident in children with autism spectrum disorder at the National Children's Hospital, with their fine motor skills being more severely affected than their gross motor skills. The motor skills of these children are correlated with their socialization skills, communication skills and symptom severity.

Multicenter studies, including those in the private institutions could be considered in the future. Prospective studies can focus also those in school-age and adolescent age groups given that motor skills could improve as a function of brain maturation and as the child continues to hone them through self-help and domestic routines. The cognitive skills of these patients should be accounted for by identifying their verbal and nonverbal IQ through standardized tools for this specific domain. They also can give more insight into the degree of change in socialization and communication skills and symptom severity as a function of motor skills by considering the inclusion of those patients who have already undergone therapeutic intervention.

With the variety of techniques employed by different therapists or therapy centers as potential confounders, this could be mitigated by conducting the said study in one center such as in our institution where therapists could employ the same set of strategies for a specific time frame. Another suggestion would be the conduct of a study which would compare the effectivity of a motor-based program intervention versus that of a conventional occupational therapy and/or a combination of both.

Locally, practitioners in the field have been attentive to the struggles of caregivers as they seek placements for interventions for their children in various therapy centers as well as practical home strategies in improving their deficits. Interventional strategies have been emphasized to be provided consistently but more importantly, to be engaging and empowering. As the results of this study corroborate with and enhance the existing ones, clinically, eliciting developmental history and conduct of developmental assessment for motor domains should not be overlooked, regardless of the presenting concern of the caregiver. This study is keen on recognizing the utility of motor skills in the diagnosis of children with autism spectrum disorder; however, a specific motor deficit must be identified, whether for gross and/or fine motor, in order to serve this purpose. Recommendation for physical therapy must be considered if motor deficits are identified and its impact are apparent enough in other domains of development such as activities of daily living and school-related skills. Recommendations should remain inclusive of sensorimotor integration and development and must not be limited to the conventional ones of behavior modification, language and cognitive stimulation, and adaptive skills participation, especially in the younger age group wherein motor difficulties may be subtly elicited. The results of this study could motivate efforts to design interventions that focus mainly on fundamental and complex motor skills to address these deficits with measurable outcomes such as those identified in this study. Institutionally, the section could collaborate with the rehabilitation medicine section and its physical therapists in the construction and implementation of that intervention with the end goal of clinical application to patients especially those who are in-the-waiting for occupational and speech therapies. The said intervention could be center-based and/or home-based with more emphasis in the later to capitalize on the caregivers' efforts to be empowered and confident in addressing and supporting their children's skills.

At the household level, activities that allow movement, practice stability as well as eyehand coordination must be also emphasized to the caregivers as these strategies cascade to other domains of development, especially in the younger age group. Caregivers could be guided on practical activities that could be done as drills at homes such as throwing and catching a ball to improve locomotion and object manipulation, stringing beads and use of tongs for transferring objects to enhance grasp and eyehand coordination. These activities could be integrated in their play or even in their participation in household activities. Although physical activity and screentime were not reported to be significant with symptom severity, such factors must be always be explored and discussed with caregivers as children nowadays are observed to have a disproportion in their exposure to these activities and could negatively affect the different developmental domains.

The growing body of knowledge of the motor impairments in autism spectrum disorder has substantially geared and contributed in the understanding of these children's functioning in their daily lives. While there are still much to navigate in the dynamic nature of their motor skills, with these current findings, assessment

becomes more comprehensive and interventions evolve into being more multidisciplinary and targeted.

References

1. Centers for Disease Control and Prevention. Data and Statistics on Autism Spectrum Disorder. MMWR Surveill Summ. 2025;74(2):1-20.
2. Bhat AN. Is motor impairment in autism spectrum disorder distinct from developmental coordination disorder? A report from the SPARK study. Phys Ther. 2020;100(4):633-644.
3. Larsson HJ, Eaton WW, Madsen KM, Vestergaard M, Olesen AV, et al. Risk factors for autism: Perinatal factors, parental psychiatric history, and socioeconomic status. Am J Epidemiol. 2005;161(10):916-925
4. Sasanfar R, Haddad SA, Tolouei A, Ghadami M, Yu D, et al. Paternal age increases the risk for autism in an Iranian population sample. Mol Autism. 2010;1(1):2.
5. Lee LC, Harrington RA, Louie BB, Newschaffer CJ. Children with autism: Quality of life and parental concerns. J Autism Dev Disord. 2008;38(6):1147-1160.
6. Gardener H, Spiegelman D, Buka SL. Prenatal risk factors for autism: A comprehensive meta-analysis. Br J Psychiatry. 2009;195(1):7-14.
7. Krakowiak P, Walker CK, Bremer AA, Baker AS, Ozonoff S, et al. Maternal metabolic conditions and risk for autism and other neurodevelopmental disorders. Pediatrics. 2012;129(5):1121-1128.
8. Libbey JE, Sweeten TL, McMahon WM, Fujinami RS. Autistic disorder and viral infections. J Neurovirol. 2005;11(1):1-10.
9. London EA. The environment as an etiologic factor in autism: A new direction for research. Environ Health Perspect. 2000;108(3):401-404.
10. Zhang X, Lv CC, Tian J, Miao RJ, Xi W, et al. Prenatal and perinatal risk factors for autism in China. J Autism Dev Disord. 2010;40(11):1311-1321.
11. Bolte S, Knecht S, Poustka F. A case-control study of personality style and psychopathology in parents of subjects with autism. J Autism Dev Disord. 2007;37(2):243-250.
12. Daniels JL, Forssen U, Hultman CM, Cnattingius S, Savitz DA, et al. Parental psychiatric disorders associated with autism spectrum disorders in the offspring. Pediatrics. 2008;121(5):1357-1362.
13. Hvidtjorn D, Grove J, Schendel D, Schieve LA, Sverke C, et al. Risk of autism spectrum disorders in children born after assisted conception: A population-based follow-up study. J Epidemiol Community Health. 2011;65(6):497-502.
14. Buchmayer S, Johansson S, Johansson A, Hultman CM, Sparen P, et al. Can association between preterm birth and autism be explained by maternal or neonatal morbidity?. Pediatrics. 2009;124(5):817-825.
15. Maimburg RD, Vaeth M. Perinatal risk factors and infantile autism. Acta Psychiatr Scand. 2006;114(4):257-264.
16. Minissi ME, Gomez-Zaragoza L, Marin-Morales J, Mantovani F, Sirera M, et al. The whole-body motor skills of children with autism spectrum disorder taking goal-directed actions in virtual reality. Front Psychol. 2023;14:1140731.
17. Posar A, Visconti P. Early motor signs in autism spectrum disorder. Children. 2022;9(2):294.
18. Flori V, Angeli B. Motor intervention and autism: One way, several domains of effectiveness. J Adv Health Care. 2021;3(2):52-61.
19. Kilroy E, Ring P, Hossain A, Nalbach A, Butera C, et al. Motor performance, praxis, and social skills in autism spectrum disorder and developmental coordination disorder. Autism Res. 2022;15(9):1649-1664.
20. Zhou B, Xu Q, Li H, Zhang Y, Li D, et al. Motor impairments in Chinese toddlers with autism spectrum disorder and its relationship with social communicative skills. Front Psychiatry. 2022;13:938047.
21. Lim YH, Licari M, Spittle AJ, Watkins R, Zwicker JG, et al. Early motor function of children with autism spectrum disorder: A systematic review. Pediatrics. 2021;147(2):e2020011270.
22. Lane A, Harpster K, Heathcock J. Motor characteristics of young children referred for possible autism spectrum disorder. Pediatr Phys Ther. 2012;24(1):21-29.
23. Iverson JM. Early motor and communicative development in infants with an older sibling with autism spectrum disorder. J Speech Lang Hear Res. 2018;61(11):2673-2684.
24. Wang LAL, Petrulla V, Zampella CJ, Waller R, Schultz RT. Gross motor impairment and its relation to social skills in autism spectrum disorder: A systematic review and two meta-analyses. Psychol Bull. 2022;148(3):273-300.
25. Whyatt C, Craig C. Sensory-motor problems in autism. Front Integr Neurosci. 2013;7:51.
26. Bremer E, Cairney J. The interrelationship between motor coordination and adaptive behavior in children with autism spectrum disorder. Front Psychol. 2018;9:2350.
27. Kilroy E, Cermak SA, Aziz-Zadeh L. A review of functional and structural neurobiology of the action observation network in autism spectrum disorder and developmental coordination disorder. Brain Sci. 2019;9(4):75.
28. Ohara R, Kanejima Y, Kitamura M, Izawa KP. Association between social skills and motor skills in individuals with autism spectrum disorder: A systematic review. Eur J Investig Health Psychol Educ. 2020;10(1):276-296.

29. Pusponegoro HD, Efar P, Soedjatmiko, Soebadi A, Firmansyah A, et al. Gross motor profile and its association with socialization skills in children with autism spectrum disorders. Pediatr Neonatol. 2016;57(6):501-507.
30. Rios PC, Scharoun Benson SM. Exploring caregiver perspectives of social and motor skills in children with autism spectrum disorder and the impact on participation. Front Psychol. 2020;11:1260.
31. Najafabadi MG, Sheikh M, Hemayattalab R, Memari AH, Aderyani MR, et al. The effect of SPARK on social and motor skills of children with autism. Pediatr Neonatol. 2018;59(5):481-487.
32. Holloway JM, Long TM, Biasini FJ. Relationships between gross motor skills and social function in young boys with autism spectrum disorder. Pediatr Phys Ther. 2018;30(3):184-190.
33. Choi B, Leech KA, Tager-Flusberg H, Nelson CA. Development of fine motor skills is associated with expressive language outcomes in infants at high and low risk for autism spectrum disorder. J Neurodev Disord. 2018;10(1):14.
34. Bal VH, Fok M, Lord C, Smith IM, Mirenda P, et al. Predictors of longer-term development of expressive language in two independent longitudinal cohorts of language-delayed preschoolers with autism spectrum disorder. J Child Psychol Psychiatry. 2020;61(7):826-835.
35. Fulceri F, Grossi E, Contaldo A, Narzisi A, Apicella F, et al. Motor skills as moderators of core symptoms in autism spectrum disorders: Preliminary data from an exploratory analysis with artificial neural networks. Front Psychol. 2019;9:2683.
36. Bhat AN. Motor impairment increases in children with autism spectrum disorder as a function of social communication, cognitive and functional impairment, repetitive behavior severity, and comorbid diagnoses: A SPARK study report. Autism Res. 2021;14(1):202-219.
37. Bhat AN, Landa RJ, Galloway JC. Current perspectives on motor functioning in infants, children, and adults with autism spectrum disorders. Phys Ther. 2011;91(7):1116-1129.
38. Iverson JM. Developmental variability and developmental cascades: Lessons from motor and language development in infancy. Curr Dir Psychol Sci. 2021;30(3):228-235.
39. Bradshaw J, Schwichtenberg AJ, Iverson JM. Capturing the complexity of autism: Applying a developmental cascades framework. Child Dev Perspect. 2022;16(1):18-26.
40. Posar A, Visconti P. Early motor impairment in children with autism spectrum disorder. Turk Arch Pediatr. 2021;56(6):646-647.
41. Columna L, Prieto LA, Beach P, Russo N, Foley JT. A randomized feasibility trial of a fundamental motor skill parent-mediated intervention for children with autism spectrum disorders. Int J Environ Res Public Health. 2021;18(23):12398.
42. Hwang BH, Lee D. Association between motor and language skills development in children with autism spectrum disorder: A scoping review. Int J Disabil Dev Educ. 2022;71(2):135-149.
43. Taverna EC, Huedo-Medina TB, Fein DA, Eigsti IM. The interaction of fine motor, gesture, and structural language skills: The case of autism spectrum disorder. Res Autism Spectr Disord. 2021;86:101824.
44. Ketcheson LR, Felzer-Kim IT, Hauck JL. Promoting adapted physical activity regardless of language ability in young children with autism spectrum disorder. Res Q Exerc Sport. 2021;92(4):813-823.
45. Green D, Charman T, Pickles A, Chandler S, Loucas T, et al. Impairment in movement skills of children with autistic spectrum disorders. Dev Med Child Neurol. 2009;51(4):311-316.
46. Ketcheson LR, Pitchford EA, Wentz CF. The relationship between developmental coordination disorder and concurrent deficits in social communication and repetitive behaviors among children with autism spectrum disorder. Autism Res. 2021;14(4):804-816.
47. Sung M-C, McClelland MM, Massey W, Logan SW, MacDonald M. Association between motor skills and executive function of children with autism spectrum disorder in Taiwan and the United States. Front Public Health. 2024;11:1292695.
48. Waizbard-Bartov E, Ferrer E, Young GS, Heath B, Rogers S, et al. Trajectories of autism symptom severity change during early childhood. J Autism Dev Disord. 2021;51(1):227-242.
49. Cabrera NJ, Hennigar A, Alonso A, McDorman SA, Reich SM. The protective effects of maternal and paternal factors on children's social development. Adv Res Sci. 2021;2(2):85-98

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