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*Editor's Choice

Research Paper

Survey of Child Neurologists Highlights a Missed Opportunity for Identifying and Treating Motor Impairments in Autism

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ABSTRACT

Background: Motor impairments, such as motor delays, atypical gait, dyspraxia, and poor coordination, are highly prevalent among individuals with autism spectrum disorder (ASD). Motor impairments are detrimental to multiple aspects of development but are often underdiagnosed and undertreated in children and adolescents with ASD. Child neurologists are specialists who provide clinical care for autistic patients across the lifespan. However, little is known about how child neurologists understand, diagnose, and treat motor impairments in children with ASD.

Methods: In this preliminary study, we surveyed child neurologists (N = 100) on their knowledge of and clinical practices addressing motor impairments in pediatric patients with ASD. Our survey also sought to identify potential barriers to care and medical education efforts that may mitigate existing gaps.

Results: We found most child neurologists were not confident that motor impairments were an associated feature of ASD, do not frequently evaluate for motor impairments, lack sufficient tools for motor evaluations with autistic children, face multiple barriers to providing interventions, and do not receive adequate clinical training regarding this topic.

Conclusions: These preliminary findings suggest that substantial gaps in awareness about motor impairments in ASD persist among practicing child neurologists. Though child neurologists are trained to assess motor function, our results highlight a missed opportunity in the setting of ASD. Child neurologists would benefit from greater attention and resources to learn, evaluate, and treat motor impairments as part of holistic patient care for individuals with ASD.

Introduction

Motor impairments in autism spectrum disorder

Autism spectrum disorder (ASD) is a heterogeneous neurodevelopmental condition that impacts one in 36 children living in the United States.[1,2] The *Diagnostic and Statistical Manual of Mental Disorders* (Fifth Edition, Text Revision) (DSM) defines the core diagnostic features of ASD as persistent difficulties in social communication across multiple contexts and repetitive restricted behaviors and interests that emerge in the early developmental period.[3] Individuals with ASD commonly have co-occurring neurological conditions such as epilepsy, sleep disturbance, and motor impairment.[4-6] However, despite the high prevalence of motor impairments in ASD, there remains a

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A Note on Language: The authors acknowledge language plays an important role in self-identity for many individuals living with neurodevelopmental disabilities. We respect that there are different preferences for identify-first versus person-first language in autism. Here, we choose to use the specific terminology of "autism spectrum disorder" in the survey and article to align with the predominant terminology used among our target readership.

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paucity of research and clinical guidance on this condition compared with other co-occurring neurological conditions in ASD. Researchers have characterized a wide breadth among individuals with ASD, including gross motor delay (e.g., crawling, stepping upstairs), fine motor delay (e.g., grasping objects, picking up toys, drawing), hypotonia, gait abnormalities, poor locomotion (e.g., running, hopping), poor object control (e.g., kicking a ball), dyspraxia, poor visual-motor coordination (e.g., catching a ball), and poor postural control and balance.[7-15] Several studies revealed that motor impairments emerge as early as infancy in autistic individuals and persist over time.[16-18] Given its pervasiveness within this population, some have posited motor impairment as a cardinal feature of ASD.[7]

Current research suggests motor impairments are disruptive to multiple aspects of development in individuals with ASD. Among autistic children, numerous studies have found poor motor abilities are associated with worse social communication skills as well as expressive and receptive language delays.[19-27] In a cohort study of over 200 young children (14-49 months old), fine motor skills were predictive of adaptive social and communication skills in autistic participants.[12] Advances in motor abilities facilitate children's exploration of the physical world and their interactions with others, which open opportunities for developing language and communication. For example, the transition from crawling to walking provides greater access to objects and more sophisticated language exchange with caregivers.[28-31] It goes to follow that a toddler with ASD who has co-occurring gross motor delay or poor postural control would not fully benefit from this developmental progression.[32]

Prevalence and under-recognition of motor impairment in ASD

Motor impairment is highly prevalent among individuals with ASD but remains under-recognized.[19] Motor concerns are just as, if not more, common as verbal language deficits[33] and cognitive impairments in children with ASD.[2,34] Despite this, motor impairment has only more recently become a focus of autism research.[7,18,19,35,36] A population-based study in Australia of children with ASD ($N = 2084$, age less than or equal to six years) found that 35.4% met criteria for motor difficulties while an additional 43.7% had moderate motor impairment on a standardized measure; yet, reporting clinicians only detected motor impairment in 1.3% of cases.[37] A recent database study examining a large cohort of autistic children found 85% were at risk of motor impairment based on a validated parent questionnaire, equivalent to a 22 times greater risk compared with the general population. Yet, only 14% were formally diagnosed with developmental coordination disorder or motor impairment.[38,39] Notably, only 37.1% of the cohort received physical therapy and 15.3% recreational therapies, which were far lower rates compared with participation in occupational, speech, and behavioral therapies.[40] This finding is particularly concerning given that children with ASD are already less likely to participate in physical activity, which predisposes to worse physical health during childhood[23] and well into adulthood.[41] These health disparities will likely continue without a clear consensus defining motor impairments or standardized guidelines for screening motor impairments within ASD.[42,43]

The role of child neurologists

Child neurologists (CNs), including those subspecializing in neurodevelopmental disabilities (NDDs), play key roles in clinical care and research involving individuals with ASD. CNs/NDD physicians are trained to diagnose neurological conditions (e.g. seizures, migraines), conduct detailed neurological examinations, and manage longitudinal care for children with neurodevelopmental concerns. CNs are an important community of experts uniquely trained to detect motor impairments in children, determine if patients warrant further testing, and refer patients to appropriate therapies.[36] However, compared with other co-occurring neurological conditions, little is known about the role of CNs in assessing and managing motor impairment in ASD. The primary objective of our study was to understand CNs/NDD physicians' knowledge of motor impairments in ASD and their clinical recommendations to evaluate and treat motor impairments. We also sought to identify opportunities for advancing medical education surrounding motor function in children with ASD. We hypothesized that CNs can, and should, play a key role in assessing for and managing motor impairments in individuals with ASD given their specialized training in motor abnormalities in neurodevelopmental conditions.

Methodology

Participant recruitment

The Motor Function in Autism Spectrum Disorder Survey (survey) was approved by the Institutional Review Board at UCLA (IRB#22-000342) as part of the larger research initiative conducted under the Autism Intervention Research Network on Physical Health. Eligible study participants included attending physicians, fellow physicians, and resident physicians practicing in CN and NDDs within the United States. Survey responses were collected anonymously through an online RedCap link distributed through e-mail communications, social media (e.g., Facebook groups), and to attendees at a national neurology conference. The survey collected responses between April 4 and April 29, 2024. Participants did not receive any form of financial compensation. Participants were also given the option to include an e-mail address if interested in being contacted by the authors to contribute to consensus building in the field of autism and motor development in the future.

Study design

This is a descriptive study based on the survey jointly developed by a CN with clinical and research expertise on motor impairments in individuals with NDDs, a developmental psychologist who regularly collaborates with neurodiverse researchers, and a medical student with prior research experience with ASD (R.B.W., E.H., and H.K., respectively). The survey underwent multiple iterative revisions to ensure the use of clear unbiased terminology within multiple choice questions. To dissuade revision of initial answer selections, participants were restricted from revisiting prior questions while completing the survey. Unless otherwise specified, respondents were asked to only consider motor impairments in pediatric patients with ASD but *without* known neurogenetic conditions (e.g., tuberous sclerosis complex, fragile X syndrome, Rett syndrome, Dup15q syndrome) or known acquired neurological injury (e.g., hypoxic brain injury, cerebral palsy). Participants were also asked to exclude "repetitive motor behaviors" when considering motor impairment for the purposes of the survey. Given that the survey was intended as a preliminary effort to address our research question and no financial incentives were provided, the researchers prioritized expediency in data collection and ensured participants could comfortably complete the survey under 10 minutes.

Survey questions were developed based on clinical experience, available medical literature, and definitions included in the DSM. The survey included demographic questions regarding

participants' clinical training, current clinical practice setting, and experience working with pediatric patients with ASD. The remaining survey questions were designed to address four central themes. Theme 1 questions focused on participants' current knowledge of ASD and associated motor impairments, including current definitions in the DSM, prevalence of motor impairments in ASD, and how early in life these impairments emerge. Questions linked to Theme 2 used a Likert scale to gauge perceived impact of motor impairments on other domains, including educational outcomes, language and communication, emotional and behavioral health, and social engagement. Survey items in Theme 3 centered on participants' recommendations for assessment of motor function in pediatric patients with ASD, recommended interventions, and identifying systemic barriers to performing clinical care. Questions in Theme 4 focused on participants' exposure to motor impairments in ASD during graduate medical education and potential educational resources to advance awareness of this subject.

Results

Participant demographics

During the study period, 128 participants began the survey and 100 participants responded to all questions (completion rate of 78%). Only fully complete responses were included in the results presented here (Table 1). The majority of respondents were board-certified attending physicians (n = 78) of which one completed a nonaccredited NDD fellowship and 34 completed other subspecialty fellowship or postdoctoral training. Most attending physician

respondents indicated their current practice setting to be in academic medical centers and private practice with almost all indicating outpatient clinic and inpatient hospitalist service duties. The remaining survey respondents (n = 22) were active resident physicians in CN and fellow physicians with prior residency training in CN or NDDs.

Survey respondents reported seeing an average of 80 patients per month (S.D. = 83) in their clinical practice, and three fourths of participants reported seeing less than 150 patients per month (Fig 1). The majority of respondents noted that less than 40% of their patient population had an ASD diagnosis (Fig 2). Participants diagnosed ASD in their clinical practice to varying degrees, with 20% doing so very often (at least 75% of the time), 17% often (at least 50% of the time), 29% sometimes (at least 25% of the time), 26% rarely (less than 25% of the time), and 8% never. Respondents commonly refer patients to further testing when they suspect ASD, with 27% referring very often, 30% often, 21% sometimes, and the remaining 22% referring rarely.

Theme 1: Assessing knowledge about motor impairments associated with ASD

Only 38% of participants correctly identified the core diagnostic criteria for ASD defined in the DSM (Table 2). On subsequent questions, 88% of respondents correctly identified motor impairments were not part of the core diagnostic criteria and 36% indicated motor impairments as associated deficits of ASD in the DSM (Table 3). A subset of participants who correctly identified motor impairment as an associated deficit (N = 36) or who erroneously identified motor impairment as a core criterion (N = 5) then reported “fine motor delay” (80%) and “clumsiness” (66%) as the specific motor impairments in the DSM (Table 4). Fifteen respondents estimated the prevalence of motor impairments in the general ASD population to be less than 15%, 57 participants estimated prevalence between 15% and 50%, 26 participants estimated prevalence between 51% and 80%, and two participants indicated greater than 80% prevalence. Fifteen percent of physicians surveyed indicated motor impairment in individuals with ASD first present during early infancy (age less than one year), 59%

TABLE 1.
Survey Participant Demographics

Participant Current Occupation	N	Attending Physician Participants	n (%)
Resident physician in child neurology	16	Practice setting	
Resident physician in neurodevelopmental disabilities	0	Academic medical center	58 (74)
Fellow physician (completed CN or NDDs)	6	Private practice	11 (14)
Attending physician in child neurology	43	Community-based health center	7 (9)
Attending physician in neurodevelopmental disabilities (completed 6-year program)	0	Rural health center	0 (0)
Attending physician in child neurology + non-ACGME neurodevelopmental disabilities fellowship	1	Integrated managed care system	2 (3)
Attending physician in CN + additional training	34	Other	0 (0)
Total	100	Total	78 (100)
Trainee physician participants	n (%)	Year of training completion	
Current year in training		2018-2023	25 (32)
PGY-1	1 (5)	2012-2017	21 (27)
PGY-2	1 (5)	2006-2011	11 (14)
PGY-3	2 (9)	2000-2005	11 (14)
PGY-4	5 (22)	1994-1999	3 (4)
PGY-5	7 (32)	1988-1993	3 (4)
PGY-6	3 (13)	1987-1982	2 (2.5)
PGY-7+	2 (9)	1981-1976	2 (2.5)
Other (e.g., leave of absence)	1 (5)	Clinical practice types	
Total	22 (100)	Outpatient clinic (including telehealth visits)	77 (99)
		Inpatient hospitalist service	60 (77)
		Clinical and/or translational research	33 (42)
		Basic sciences research	6 (8)

Abbreviations:
ACGME = Accreditation Council for Graduate Medical Education
CN = Child neurologist
NDDs = Neurodevelopmental disabilities
PGY = Postgraduate year

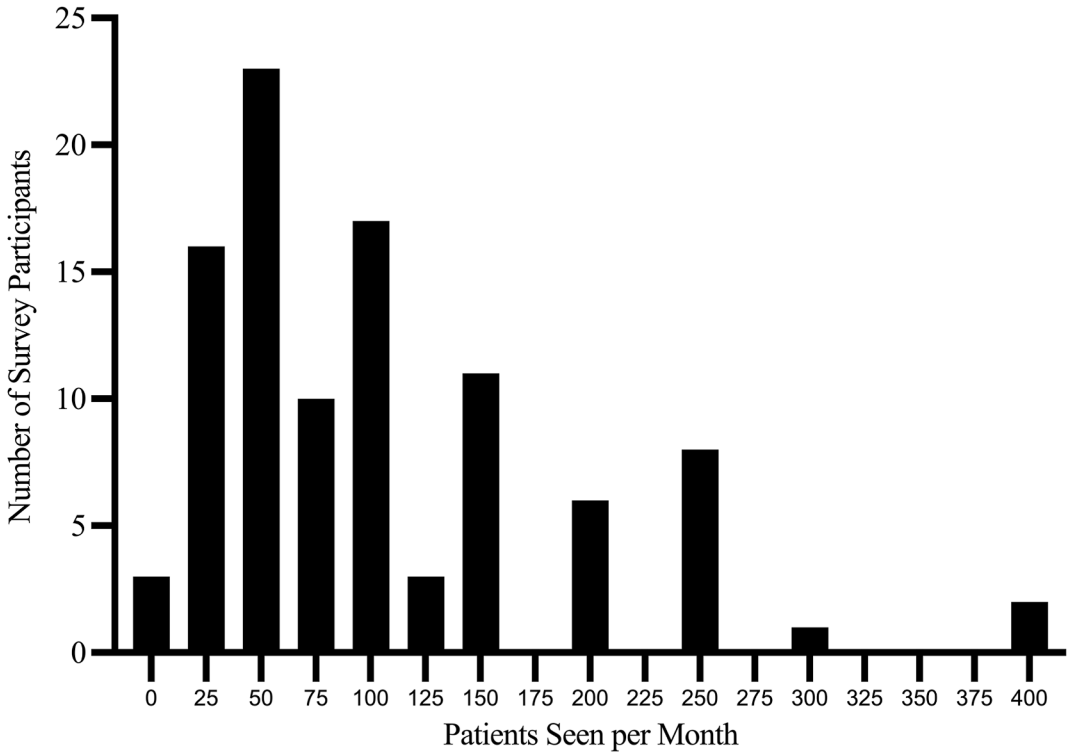

FIGURE 1. Number of patients seen by survey respondents in their clinical practice per month.

indicated toddlerhood (one to two years), 23% indicated preschool/kindergarten age (3-5 years), and 3% indicated school-going age (greater than six years); no participants selected adolescence (>12 years).

Theme 2: Perceived impact of motor impairments on other developmental domains

A similar distribution of Likert scores was obtained across the four different developmental domains. For each domain, the preponderance of scores were 3's (39%-51%) and 4's (31%-39%), which indicated a moderate to moderately significant impact on daily life, respectively (Fig 3). The Likert scale end points were defined as a score of 1 equivalent to "no impact on daily life" and a score of 5 equivalent to "significant impact on daily life."

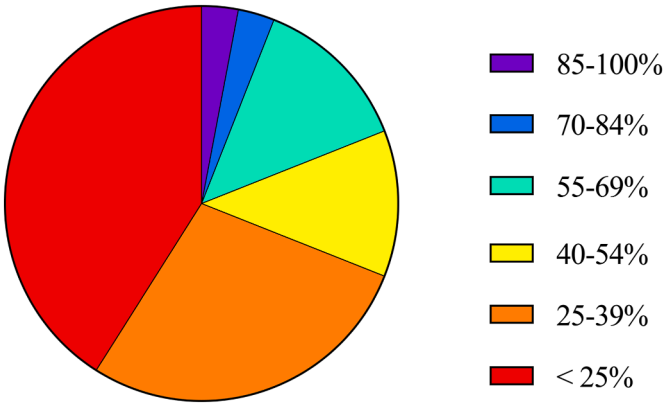

FIGURE 2. Reported percentage of patients with ASD in clinical practice. Surveyed physicians were asked to select the basic estimate among the percentage ranges. The color version of this figure is available in the online edition.

Theme 3: Recommendations for evaluation, intervention, and barriers to care

Only 58 surveyed participants reported performing motor evaluations in patients with ASD at least half the time during clinical practice (Table 5). Among the 78 participants who conducted motor evaluations at least "sometimes," fine motor deficits were more frequently observed than gross motor deficits in children with ASD (Fig 4). For assessing motor functioning for pediatric patients in ASD, clinicians largely utilize developmental history (88%)

and neurological examination (94%) as tools, whereas only 5% reported using various standardized assessments in clinical practice (Table 6). Additionally, four participants indicated involvement in research related to motor function in ASD and specified the following assessments used in their research settings: Mullen Scales of Early Learning,[44] Vineland Adaptive Behavioral Scales,[45]

TABLE 2.
Clinician Responses to Identifying Core Criteria for ASD Diagnosis in the DSM

Diagnostic Criterion*	%
Social communication impairments	97
Repetitive behaviors and restricted interests	88
Motor impairments	8
Verbal language impairment	53
I do not know	1
Participants who correctly identified core DSM criteria for ASD†	38
Participants who did not correctly identify core DSM criteria for ASD	62

Abbreviations:
ASD = Autism spectrum disorder
DSM = *Diagnostic and statistical manual of mental disorders* (fifth edition, text revision)
* Participants were asked to select all that apply.
† Correct response defined as selecting "social communication impairments" and "repetitive behaviors and restricted interests" only.

TABLE 3.
Clinician Awareness of Motor Impairments as Diagnostic Criteria Versus Associated Deficits of ASD

Participant Responses to Whether Motor Deficits Are Part of the Core Diagnostic Criteria for ASD in the DSM	
	%
Yes	5
No	88
I do not know	7
Subsequent Participant Responses to Whether Motor Deficits Are Associated Deficits of ASD in the DSM*	
	N (%)
Yes	36 (38)
No	38 (40)
I do not know	21 (22)

Abbreviations:
ASD = Autism spectrum disorder
DSM = *Diagnostic and statistical manual of mental disorders* (fifth edition, text revision)
* Only participants who selected "No" or "I do not know" to the initial question about criteria were then asked whether motor impairments were associated deficits of ASD ($N = 95$).

Bayley Scales of Infant and Toddler Development,[46] Bruininks-Oseretsky Test of Motor Proficiency,[47] Hypertonia Assessment Tool,[48] Gross Motor Function Classification System,[49] Manual Ability Classification System,[50] and review of patient videos.

In terms of systemic barriers preventing clinicians from conducting motor evaluations, 73% selected difficulties due to other co-occurring impairments, 68% selected inadequate time during patient visits, and 66% selected lack of knowledge (Table 7). Five participants specified "Other" barriers, including lack of knowledge among clinician-educators (particularly in general neurology practices), variability across programs on which specialty manages or diagnoses autism, and emphasis on social and language deficits (over motor concerns). Almost all surveyed physicians would recommend placing referrals to physical therapy (92%) and occupational therapy (93%) as interventions for improving motor skills in pediatric patients with ASD. Over half of participants would recommend referrals to applied behavioral analysis therapy (56%) and organized physical activity programs (64%), whereas a minority would recommend referral to speech therapy (37%). Two participants specified additional recommendations for music therapy, hippotherapy, and aquatic therapy. In terms of systemic barriers preventing clinicians from providing motor interventions to patients, a notable 83% cited a lack of available service providers, while lack of insurance coverage and challenges with school systems were similarly common concerns (Table 8).

Theme 4: Medical training and graduate medical education

During postgraduate medical training, 69% respondents had almost no exposure or minimal exposure to the topic of motor function in patients with ASD *without* neurogenetic conditions (Fig 5). Fifty-eight participants reported almost no or minimal exposure to motor impairment in patients with ASD *with* neurogenetic conditions (e.g., tuberous sclerosis complex, Rett syndrome) (Fig 5). Participants indicated the following resources as being most helpful for furthering medical education around motor function in ASD: didactic sessions (68%), case series/studies (55%), interactive learning modules (66%), webinars (45%), and patient/family histories (39%). Six participants shared "Other" recommendations, including live presentations (conferences/grand rounds), screening tools for resident clinic, integrating clinical exposure with teaching, videos of motor assessments, and more dedicated time to pediatric-specific training during residency.

TABLE 4.
Clinician Identification of DSM-Listed Motor Impairments in ASD*

Type of Motor Impairment	n (%)
Delayed onset of walking	15 (37)
Odd gait	24 (59)
Fine motor delay	33 (80)
Clumsiness	27 (66)
Other abnormal motor signs	18 (44)

Abbreviations:
ASD = Autism spectrum disorder
DSM = *Diagnostic and statistical manual of mental disorders* (fifth edition, text revision)
* Only includes participants who previously identified motor impairments as a core feature or associated deficit of ASD in the DSM ($N = 41$).

Discussion

This is the first published survey of CNs focused on motor impairments associated with ASD in the United States. Although current literature has established that motor impairments are highly prevalent among children with ASD and are detrimental to their development, significant gaps in screening, diagnosis, and intervention persist. However, there is limited understanding of whether CNs possess specific awareness of the motor impairments in ASD and the tools needed to mitigate these gaps. To begin addressing these questions, our survey studied how CNs/NDD physicians understand, identify, and treat motor impairments in pediatric patients with ASD. The survey captured 100 complete responses during our study period in April 2024. Our results corroborate the need for greater education around motor impairments in this patient population, aligning with prior calls to action.[36,40]

Theme 1: Child neurologists lack accurate knowledge regarding associated motor impairments in ASD

Only a minority of participants (36 of 100) correctly identified motor deficit as an associated feature of ASD explicitly stated in the DSM, which has been included since 2013.[3] Additionally, 53 of 100 of our respondents incorrectly indicated verbal language impairment as a diagnostic criterion of ASD. These results may reflect the relatively greater emphasis placed on language deficits in medical practice and parents' initial complaints most commonly centered on communication deficits in autistic children.[51] It is also plausible that although CNs play an integral role in the clinical care of autistic children, other medical providers (e.g., psychiatrists, developmental-behavioral pediatricians) are often providing ASD diagnoses to their patients.[52] CNs are likely more involved in autistic children's care when they present with new or chronic neurological conditions (e.g., seizures, migraines). Although these reasons may account for knowledge gaps regarding the core diagnostic ASD criteria, it remains important to ensure CNs maintain up-to-date clinical knowledge.

Our survey results also found gaps in CNs' awareness of the prevalence and onset of motor impairments in children with ASD. When asked to select the prevalence of motor impairments in the general ASD population, over half of the respondents selected the "15%-50%" range. This finding indicated that the surveyed CNs underestimate its true prevalence. In fact, recent large-scale studies have noted rates as high as 87%.[39,53] It is likely that participants based their answers on impressions from clinical practice rather than awareness of current literature on motor impairments.

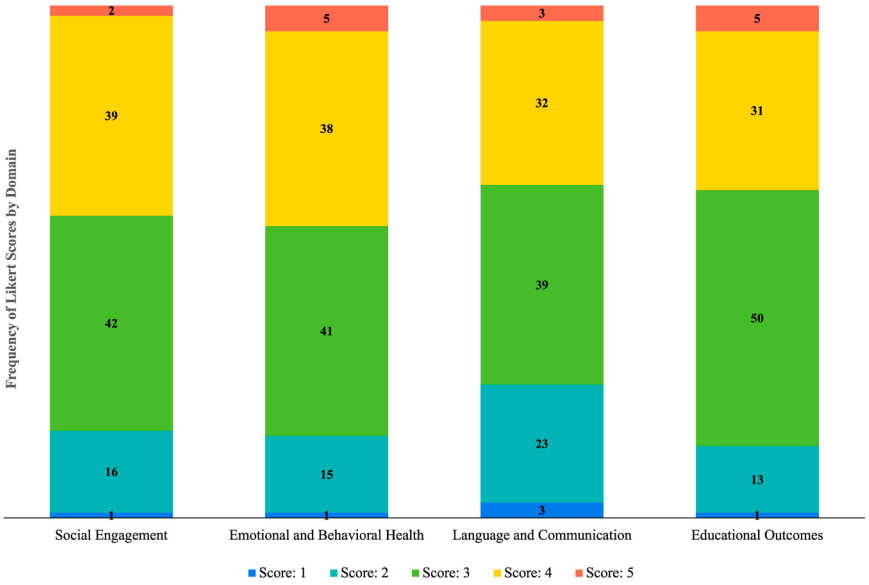

FIGURE 3. Distribution of Likert scores rated by clinicians based on perceived impact of motor impairments on educational outcomes, language and communication, emotional and behavioral health, and social engagement. For each developmental domain, survey respondents indicated an integer score of 1-5, with a minimum score of 1 defined as "no impact on daily life" and maximum score of 5 defined as "significant impact on daily life." The color version of this figure is available in the online edition.

When asked to indicate when motor impairments first present in the general ASD population, 59% of surveyed CNs indicated toddlerhood (age one to two years). Similarly, participants likely based their selection on clinical encounters with patients that largely take place after children receive ASD diagnoses, which occurs on average at age four years.[2] Motor impairments have been described as the earliest signs of atypical neurodevelopment in retrospective studies of infants who are later diagnosed with ASD as well as in longitudinal prospective studies in infants at high familial likelihood of ASD.[17,54,55] Providing education based on current ASD research may improve CNs' awareness that motor impairments may emerge in early infancy and, when identified with other early signs of ASD, likely warrant greater developmental surveillance or referral for evaluation. Ongoing research efforts are focused on determining which motor differences are specific to ASD.[26,54-56]

Theme 2: Child neurologists perceive motor impairments moderately impact children with ASD across other developmental domains

Given CNs are trained to provide long-term care for children with neurodevelopmental conditions and are uniquely trained to assess motor function, they are well situated to monitor the impact of motor impairments on broader development over time. Our survey made an initial effort to examine this by asking about educational outcomes, language and communication, emotional and behavioral health, and social engagement. Notably, surveyed CNs did feel that motor impairments have a moderate to moderately high functional impact across all four listed domains. The deleterious impacts of motor impairments on these developmental domains have been supported by numerous studies of individuals with ASD.[12,17,18,20,25,38,57] Our findings suggest that CNs have indeed recognized motor impairments as having noticeable impact on daily and adaptive function of autistic individuals. Providing educational opportunities for CNs to learn more about the broader developmental impacts of motor impairments could leverage their existing clinical expertise and motivate greater motor screening, diagnosis, and therapy referrals for patients with ASD.

TABLE 5.
Participant-Reported Frequencies of Conducting Motor Evaluation in Autistic Children During Clinical Practice

Frequency	%
Very often (at least 75% of the time)	36
Often (at least 50% of the time)	22
Sometimes (at least 25% of the time)	20
Rarely (less than 25% of the time)	18
Never	4

Theme 3: Child neurologists do not evaluate for motor impairments in pediatric patients with ASD due to inadequate knowledge and encounter multiple barriers to providing interventions

Our results suggest CNs do not frequently evaluate motor function in pediatric patients with ASD (Table 5), which is consistent with prior literature.[37,53] Among CNs who did evaluate motor function in at least 25% of visits with autistic patients, fine motor deficits were more frequently observed than gross motor deficits. These results seem to reflect the mixed evidence on whether children with ASD present overt motor milestone delays, such as delayed onset of walking.[32] However, studies have shown that even with normal age of walking onset, individuals with ASD often have abnormal quality of gait that could be routinely assessed by CNs.[32,58,59] Additionally, of the 41 participants who selected motor deficits are stated in the DSM (either incorrectly as part of diagnostic criteria or correctly as an associated feature), 59% specified "odd gait," while 81% specified "fine motor delay," which could speak to the current vague language used in the DSM.[3]

CNs face serious barriers to assessing motor function in autistic patients, including challenging comorbidities, lack of specific knowledge, and insufficient time to implement standardized tools. Only 5% of participants reported using standardized assessments to evaluate motor function in the clinical setting. It is likely that CNs are not readily equipped or do not have the clinical bandwidth to screen for motor impairments in children with ASD beyond

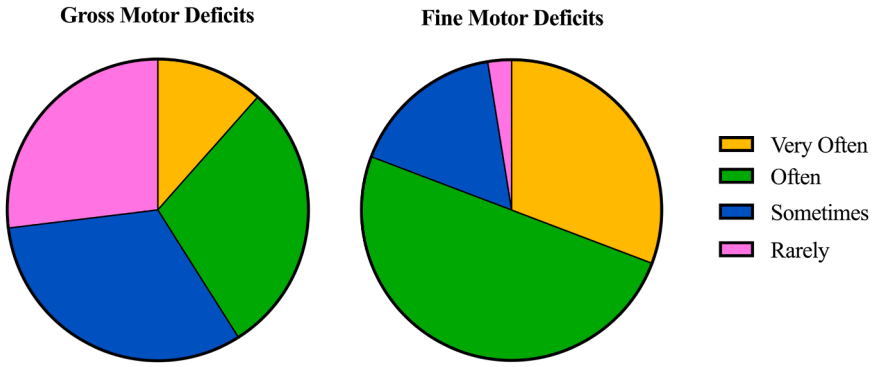

FIGURE 4. Clinician-reported frequencies of gross motor and fine motor deficits observed in children with ASD. Only survey respondents who indicated that they performed motor evaluations in at least 25% of clinical visits were included ($N = 78$). *The color version of this figure is available in the online edition.*

routine physical examination. CNs often encounter multiple comorbidities that take priority in the patient's immediate care (e.g., addressing new-onset epilepsy or self-injurious behaviors) and may make it more challenging to conduct detailed neurological motor examinations. Further training is needed to educate CNs about atypical motor findings presenting in autistic individuals, which may be unique or more subtle than in other neurological conditions. Standardized motor assessments have limitations to identifying motor differences across the heterogeneous ASD population,[43] and no clear guidelines exist to determine which standardized assessments are most appropriate for autistic individuals.[42] Administering standardized motor assessments requires trained personnel and is time intensive. Outside of comprehensive clinical and psychological evaluations, it is unlikely that a CN could employ such measures routinely. Freely available caregiver reports of motor skills, such as the Developmental Coordination Disorder Questionnaire, may be beneficial to assess children with ASD in a routine CN clinical visit.[14,60,61] Simultaneously, there are active efforts to create quantitative methods that could be scalable to the clinical setting.[32,35,55]

Although CNs would recommend physical therapy and occupational therapy as appropriate interventions for motor impairment, they report numerous systemic barriers to accessing these services. Barriers to intervention featured in our survey (e.g., insurance policies, scarcity of service providers) are shaped by complex political, economic, and geographic forces that CNs cannot control on an individual basis (Table 8). However, data from this survey and greater education on motor impairments could empower CNs to advocate for increasing access to these services and to improve developmental trajectories of children with ASD. Thus far, a nascent research literature has shown that autistic individuals can improve motor skills through structured physical interventions; however, more research is necessary to conclude which interventions are best suited for specific motor impairments and whether improved motor skills translate to better social communication.[62-65]

TABLE 6.
Frequency of Clinical Tools Used to Assess Motor Function in Children With ASD by Clinicians

Tool	%
Developmental history	88
Neurological examination	94
Standardized assessments*	5
Other†	1

Abbreviations:
ASD = Autism spectrum disorder
DSM = *Diagnostic and statistical manual of mental disorders* (fifth edition, text revision)
OT/PT = Occupational therapy/Physical therapy
* Participants specified the following: Denver Developmental Screening Test (one), Developmental Coordination Disorder Questionnaire (one), OT/PT Assessments (one), Gesell Figures (one), and Luria Sequence (one).
† Go through DSM criteria as part of history.

Theme 4: Child neurologists receive insufficient exposure to motor impairments associated with ASD during postgraduate medical training, which warrants greater educational and leadership efforts

Our results suggest that child neurology education requires greater emphasis on motor function in pediatric patients with ASD. Less than 15% of respondents felt that motor function in genetic and nongenetic causes of ASD was "well integrated" into their clinical training (Fig 5). This is particularly concerning given over two thirds of our respondents were currently in training or completed training within the last 12 years (Table 1). Ensuring child neurology trainees conduct motor examinations with autistic patients in the clinic to understand abnormal motor findings in this population would improve detection of this common co-occurring neurological condition in ASD.

For CNs no longer in training, it would be important to provide educational opportunities through professional organizations—including the Child Neurology Society and American Academy of Neurology—that can deploy resources to organize forums for sharing clinical expertise, develop interactive learning modules, foster collaborations toward building consensus guidelines, and provide continuing medical education focused on motor concerns in ASD. This survey will lay the foundations for further investigations (i.e., focus groups, semistructured interviews) that will yield detailed data from clinicians, and consequently, help

TABLE 7.
Frequency of Reported Systemic Barriers to Evaluation of Motor Function in Children With ASD

Barrier	%
Lack of knowledge of what features to assess for	66
Lack of tools to assess motor function	55
Difficulties evaluating these domains due to other impairments (e.g., sensory sensitivities, nonverbal)	73
Inadequate time during clinical patient visits	68
No motor-specific concerns expressed by caregiver/guardians	44
Other	5

Abbreviation:
ASD = Autism spectrum disorder

TABLE 8.
Frequency of Reported Systemic Barriers to Providing Motor Interventions for Children With ASD

Barrier	%
Administrative burden (e.g., insufficient time for required paperwork)	46
Insurance/lack of coverage for services	58
Lack of follow-up visits	28
Lack of available service providers in geographic area (e.g., long wait list)	83
Challenges working with local school system	59
Other	1

Abbreviation:
ASD = Autism spectrum disorder

better guide educational efforts focused on motor impairments in ASD.

Considerations for clinical motor function assessment of autistic children in a child neurology clinical visit

We propose the following considerations for CNs when assessing motor function in autistic individuals in the clinic setting. These considerations are based on the literature of motor impairments in this population, expertise of the senior author, and the findings of the current study.

(1) Clinical history should include assessment of motor milestones and discussion with caregivers of any current motor difficulties. If the child is receiving physical or occupational therapy, the provider should ask and document what the therapies are specifically targeting/the priority goals of these therapies. Thorough neurological examination during clinical encounters should be prioritized. This will best elicit areas of muscle strength, tone, cerebellar function, and gait among other domains that are pertinent for motor function. Evaluation of both casual self-paced gait and gait during running/fast speed would improve the observation of any motor impairments/differences that arise during different locomotive demands. Families should be counseled about the common motor impairments and challenges seen in autistic individuals and observation of motor abilities in different environments should be encouraged.
(2) Observation of fine and gross motor abilities and visual-motor coordination through various accessible activities would improve identification of motor impairments that may not present on neurological examination or when confrontational testing may be difficult. For fine motor skills, the examiner may consider utilizing a set of blocks to evaluate stacking and pattern making (e.g., let us build a bridge with the blocks). Similarly, the availability of a thick thread/rope material and beads can allow for observation of fine motor control. Toys that include buttons for pulling, pushing, and twisting can assess fine motor control and strength. When age appropriate, evaluation of handwriting can yield information on school-aged fine motor activities. For gross motor assessment, the evaluation of locomotion (e.g., crawling, ambulation) is pertinent. Observation of how a child walks and whether gait differences (e.g., difficulty with running, wider based, falls) emerge during running is pertinent to evaluate gross motor difficulties. Examination of the ability to jump off the ground using two feet and of the ability to jump forward and maintain control is important to assess strength and stability. Balance on one leg can improve assessment of stability and postural control. Evaluation of catching a ball and throwing a ball from 3 and 10 feet away can assess visual motor coordination.
(3) When appropriate, referrals should be provided to physical therapy and occupational therapy. These therapies may be reduced in the school setting when a child safely accesses the environment. Thus a child may benefit from additional referrals to support difficulties in motor function when school-based therapies are no longer provided. When available, information should be provided for adaptive organized movement programs or families should be encouraged to look for these programs. Adaptive organized movement programs such as swimming, dancing, soccer, tennis, and martial arts can support multiple motor domains. These programs also include social aspects that may be beneficial for the individual and family. Motor impairments may persist beyond early childhood and may present differently across the lifespan in autistic individuals. Re-evaluation of the patient's access and need to these therapies is important.

Limitations

There are several limitations to this study. Our data represented attendings (54 of 100) or clinical trainees (22 of 100) largely in academic medical centers (54 of 100). The survey did not ask about the frequency of patient visits or age range, which may vary across practice settings. However, despite these limitations, our findings provide compelling preliminary evidence that motor impairments remain an under-recognized, underevaluated, and undertreated aspect of care for pediatric patients with ASD seen by CNs.

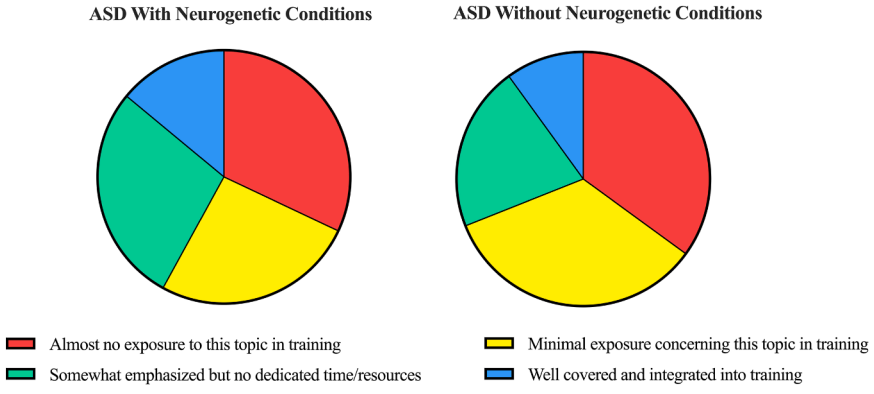

FIGURE 5. Clinician-reported degree of exposure to motor function in autistic patients with neurogenetic conditions (left) and without neurogenetic conditions (right) during postgraduate training (*N = 100*). The color version of this figure is available in the online edition.

Conclusions

We found that most CNs surveyed were not confident that motor deficits were a DSM-listed associated feature of ASD, do not frequently evaluate for motor impairments in their patients, may lack sufficient tools for motor evaluations, face barriers to providing interventions, and often do not receive adequate training on this topic. Ensuring integration of motor-focused evaluation and treatment for individuals with ASD in clinical training should be considered a priority for CNs. These findings validate that substantial gaps in awareness about motor impairments in ASD persist among practicing CNs in the United States, highlighting a missed opportunity to support this patient population. We provide initial recommendations for assessment of motor function in the clinical setting. There is strong need for greater focus and resources for CNs to learn, evaluate, and treat motor impairments as part of enriching their patients' holistic development; this would empower CNs to employ their medical expertise toward increasing identification and advancing treatment of motor impairments, which would improve outcomes for individuals with ASD.

CRediT authorship contribution statement

Emily Hotez: Writing – review & editing, Supervision, Project administration. **Rujuta B. Wilson:** Writing – review & editing, Supervision, Resources, Project administration, Conceptualization.

Declaration of competing interest

The authors Harika Kottakota, Emily Hotez, and Rujuta B. Wilson all have no conflicts of interest to disclose.

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References

1. Zablotsky B, Ng AE, Black LI, Blumberg SJ. Diagnosed developmental disabilities in children aged 3-17 years: United States, 2019-2021. Available at: https://www.cdc.gov/nchs/products/databriefs/db473.htm; 2023. Accessed June 4, 2025.
2. Maenner MJ, Shaw KA, Baio J, et al. Prevalence of autism spectrum disorder among children aged 8 years-autism and developmental disabilities monitoring network, 11 sites, United States. Available at: https://www.cdc.gov/mmwr/volumes/69/ss/ss6904a1.htm; 2016. Accessed June 4, 2025.
3. American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 5th ed. 2013. https://doi.org/10.1176/appi.books.9780890425596.
4. Levy SE, Giarelli E, Lee LC, et al. Autism spectrum disorder and Co-occurring developmental, psychiatric, and medical conditions among children in multiple populations of the United States. J Dev Behav Pediatr. 2010;31:267–275.
5. Mannion A, Leader G. Comorbidity in autism spectrum disorder: a literature review. Res Autism Spectr Disord. 2013;7:1595–1616.
6. Lai MC, Lombardo MV, Baron-Cohen S. Autism. Lancet. 2014;383:896–910.
7. Fournier KA, Hass CJ, Naik SK, Lodha N, Cauraugh JH. Motor coordination in autism spectrum disorders: a synthesis and meta-analysis. J Autism Dev Disord. 2010;40:1227–1240.
8. Ming X, Brimacombe M, Wagner GC. Prevalence of motor impairment in autism spectrum disorders. Brain Dev. 2007;29:565–570.
9. Ament K, Mejia A, Buhlman R, et al. Evidence for specificity of motor impairments in catching and balance in children with autism. J Autism Dev Disord. 2015;45:742–751.
10. Jansiewicz EM, Goldberg MC, Newschaffer CJ, Denckla MB, Landa R, Mostofsky SH. Motor signs distinguish children with high functioning autism and Asperger's syndrome from controls. J Autism Dev Disord. 2006;36:613–621.
11. Staples KL, Reid G. Fundamental movement skills and autism spectrum disorders. J Autism Dev Disord. 2010;40:209–217.
12. Macdonald M, Lord C, Ulrich D. The relationship of motor skills and adaptive behavior skills in young children with autism spectrum disorders. Res Autism Spectr Disord. 2013;7:1383–1390.
13. MacDonald M, Lord C, Ulrich DA. The relationship of motor skills and social communicative skills in school-aged children with autism spectrum disorder. Adapt Phys Activ Q. 2013;30:271–282.
14. Green D, Charman T, Pickles A, et al. Impairment in movement skills of children with autistic spectrum disorders. Dev Med Child Neurol. 2009;51:311–316.
15. Travers BG, Powell PS, Klinger LG, Klinger MR. Motor difficulties in autism spectrum disorder: linking symptom severity and postural stability. J Autism Dev Disord. 2013;43:1568–1583.
16. West KL. Infant motor development in autism spectrum disorder: a synthesis and meta-analysis. Child Dev. 2019;90:2053–2070.
17. Lim YH, Licari M, Spittle AJ, et al. Early motor function of children with autism spectrum disorder: a systematic review. Pediatrics. 2021;147:1–21.
18. Kangarani-Farahani M, Malik MA, Zwicker JG. Motor impairments in children with autism spectrum disorder: a systematic review and meta-analysis. J Autism Dev Disord. 2023;54:1977–1997.
19. Zampella CJ, Wang LAL, Haley M, Hutchinson AG, de Marchena A. Motor skill differences in autism spectrum disorder: a clinically focused review. Curr Psychiatry Rep. 2021;23:64.
20. Dziuk MA, Larson JCG, Apostu A, Mahone EM, Denckla MB, Mostofsky SH. Dyspraxia in autism: association with motor, social, and communicative deficits. Dev Med Child Neurol. 2007;49:734–739.
21. Sutera S, Pandey J, Esser EL, et al. Predictors of optimal outcome in toddlers diagnosed with autism spectrum disorders. J Autism Dev Disord. 2007;37:98–107.
22. Lidstone DE, Mostofsky SH. Moving toward understanding autism: visual-motor integration, imitation, and social skill development. Pediatr Neurol. 2021;122:98–105.
23. Gehricke JG, Chan J, Farmer JG, et al. Physical activity rates in children and adolescents with autism spectrum disorder compared to the general population. Res Autism Spectr Disord. 2020;70:101490.
24. Bhat AN, Boulton AJ, Tulsky DS. A further study of relations between motor impairment and social communication, cognitive, language, functional impairments, and repetitive behavior severity in children with ASD using the SPARK study dataset. Autism Res. 2022;15:1156–1178.
25. Bedford R, Pickles A, Lord C. Early gross motor skills predict the subsequent development of language in children with autism spectrum disorder. Autism Res. 2016;9:993–1001.
26. LeBarton ES, Landa RJ. Infant motor skill predicts later expressive language and autism spectrum disorder diagnosis. Infant Behav Dev. 2019;54:37–47.
27. Simarro Gonzalez M, Ni G, Lam V, Demopoulos C. Beyond words: an investigation of fine motor skills and the verbal communication spectrum in autism. Front Psychiatry. 2024;15:1379307.
28. Iverson JM. Developmental variability and developmental cascades: lessons from motor and language development in infancy. Curr Dir Psychol Sci. 2021;30:228–235.
29. West KL, Iverson JM. Communication changes when infants begin to walk. Dev Sci. 2021;24:e13102.
30. Schneider JL, Iverson JM. Cascades in action: how the transition to walking shapes caregiver communication during everyday interactions. Dev Psychol. 2022;58:1–16.
31. Calabretta BT, Schneider JL, Iverson JM. Bidding on the go: links between walking, social actions, and caregiver responses in infant siblings of children with autism spectrum disorder. Autism Res. 2022;15:2324–2335.
32. Wilson RB, Burdekin ED, Jackson NJ, et al. Slower pace in early walking onset is related to communication, motor skills, and adaptive function in autistic toddlers. Autism Res. 2024;17:27–36.
33. Tager-Flusberg H, Kasari C. Minimally verbal school-aged children with autism spectrum disorder: the neglected end of the spectrum. Autism Res. 2013;6:468–478.
34. Christensen DL, Bilder DA, Zahorodny W, et al. Prevalence and characteristics of autism spectrum disorder among 4-year-old children in the autism and developmental disabilities monitoring Network. J Dev Behav Pediatr. 2016;37:1–8.
35. Wilson RB, Enticott PG, Rinehart NJ. Motor development and delay: Advances in assessment of motor skills in autism spectrum disorders. Curr Opin Neurol. 2018;31:134–139.
36. Wilson RB. Improving awareness, identification, and treatment of motor impairments in autism. Pediatrics. 2022;149:e2020049437K.
37. Licari MK, Alvares GA, Varcin K, et al. Prevalence of motor difficulties in autism spectrum disorder: analysis of a population-based cohort. Autism Res. 2020;13:298–306.
38. 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;14:202–219.
39. 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;14:804–816.
40. Bhat AN. Fewer children with autism spectrum disorder with motor challenges receive physical and recreational therapies compared to standard therapies: a SPARK data set analysis. Autism. 2024;28:1161–1174.
41. Croen LA, Zerbo O, Qian Y, et al. The health status of adults on the autism spectrum. Autism. 2015;19:814–823.
42. Kaur M, Gochyyev P, Tiwari D. Use of standardized motor assessments in children with autism spectrum disorder: a meta-analysis and systematic review. Res Autism Spectr Disord. 2024;110:102298.
43. Wilson RB, McCracken JT, Rinehart NJ, Jeste SS. What's missing in autism spectrum disorder motor assessments? J Neurodev Disord. 2018;10:33.

44. Mullen EM. Mullen scales of early learning: AGS edition. Circle Pines, MN: American Guidance Service Inc; 1995:58–64. Published online.
45. Sparrow S, Cicchetti D, Saulnier C. Vineland Adaptive Behavior Scales, third edition (Vineland-3). Bloomington, MN: Pearson; 2016. Published online.
46. Bayley N. Bayley Scales of Infant and Toddler Development. In: Screening Test Manual. 3rd Edition. San Antonio, TX: Harcourt Assessment, Inc; 2006.
47. Bruininks RH, Bruininks BD. Bruininks-oseretsky test of motor proficiency, second edition. Minneapolis, MN: NCS Pearson; 2005. Published online.
48. Jethwa A, Mink J, Macarthur C, Knights S, Fehlings T, Fehlings D. Development of the Hypertonia Assessment Tool (HAT): a discriminative tool for hypertonia in children. Dev Med Child Neurol. 2010;52:83–87.
49. Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Dev Med Child Neurol. 1997;39:214–223.
50. Eliasson AC, Krumlinde-Sundholm L, Rösblad B, et al. The Manual Ability Classification System (MACS) for children with cerebral palsy: scale development and evidence of validity and reliability. Dev Med Child Neurol. 2006;48:549.
51. Kozlowski AM, Matson JL, Horovitz M, Worley JA, Neal D. Parents' first concerns of their child's development in toddlers with autism spectrum disorders. Dev Neurorehabil. 2011;14:72–78.
52. Hodges H, Fealko C, Soares N. Autism spectrum disorder: definition, epidemiology, causes, and clinical evaluation. Transl Pediatr. 2020;9:S55–S65.
53. Bhat AN. Is motor impairment in autism spectrum disorder distinct from developmental coordination disorder? A report from the SPARK study. Phys Ther. 2020;100:633–644.
54. Iverson JM, Shic F, Wall CA, et al. Early motor abilities in infants at heightened versus low risk for ASD: a Baby Siblings Research Consortium (BSRC) study. J Abnorm Psychol. 2019;128:69–80.
55. Wilson RB, Vangala S, Reetzke R, Piergies A, Ozonoff S, Miller M. Objective measurement of movement variability using wearable sensors predicts ASD outcomes in infants at high likelihood for ASD and ADHD. Autism Res. 2024;17:1094–1105.
56. Landa RJ, Gross AL, Stuart EA, Bauman M. Latent class analysis of early developmental trajectory in baby siblings of children with autism. J Child Psychol Psychiatry. 2012;53:986–996.
57. Nebel MB, Eloyan A, Nettles CA, et al. Intrinsic visual-motor synchrony correlates with social deficits in autism. Biol Psychiatry. 2016;79:633–641.
58. Li Y, Koldenhoven RM, Liu T, Venuti CE. Age-related gait development in children with autism spectrum disorder. Gait Posture. 2021;84:260–266.
59. Dufek JS, Eggleston JD, Harry JR, Hickman RA. A comparative evaluation of gait between children with autism and typically developing matched controls. Med Sci (Basel). 2017;5:1.
60. Wilson BN, Crawford SG, Green D, Roberts G, Aylott A, Kaplan BJ. Psychometric properties of the revised developmental coordination disorder questionnaire. Phys Occup Ther Pediatr. 2009;29:182–202.
61. Ip A, Mickelson ECR, Zwicker JG. Assessment, diagnosis, and management of developmental coordination disorder. Paediatr Child Health. 2021;26:375–378.
62. Ruggeri A, Dancel A, Johnson R, Sargent B. The effect of motor and physical activity intervention on motor outcomes of children with autism spectrum disorder: a systematic review. Autism. 2020;24:544–568.
63. Oligbo M, Mische Lawson L, Vaduvathiriyan P. Motor interventions for children with autism spectrum disorder: a scoping review. Ther Recreation J. 2023;57.
64. Ceccarelli SB, Ferrante C, Gazzola E, et al. Fundamental motor skills intervention for children with autism spectrum disorder: a 10-year narrative review. Children. 2020;7:250.
65. Shahane V, Kilyk A, Srinivasan SM. Effects of physical activity and exercise-based interventions in young adults with autism spectrum disorder: a systematic review. Autism. 2024;28:276–300.