JAMA Pediatrics | Original Investigation

Prevalence of Motor Milestone Delays in Autistic Children

Olivia M. Pokoski, MPH; Sarah M. Furnier, PhD; Ronald E. Gangnon, PhD; Ellen M. Howerton, PhD; Anne V. Kirby, PhD; Tyra Protho, MS; Marin L. Schweizer, PhD; Brittany G. Travers, PhD; Maureen S. Durkin, PhD

IMPORTANCE Prior literature has explored the prevalence of motor impairments in autistic individuals, but estimates come from clinical, convenience, or small samples, limiting generalizability. Better understanding of the frequency of motor milestone delays in autistic individuals could improve early identification and subsequently lead to earlier intervention and better developmental outcomes.

OBJECTIVE To determine the prevalence of motor milestone delays in a population-based sample of 8-year-old autistic children and to evaluate if having motor milestone delays is associated with an earlier age at autism evaluation or diagnosis.

DESIGN, SETTING, AND PARTICIPANTS This cross-sectional study of autistic 8-year-old children was conducted using Autism and Developmental Disabilities Monitoring (ADDM) Network data between surveillance years 2000 and 2016. ADDM Network data are population based and are drawn from 17 sites across the US. Data were analyzed from October 2023 to August 2024.

EXPOSURE Binary indicator of motor milestone delays documented in health or educational records.

MAIN OUTCOMES AND MEASURES The primary outcome was the prevalence of motor milestone delays among autistic 8-year-old children. Associations between motor milestone delays and age at autism evaluation or diagnosis were evaluated using linear regression. Covariates included study site, surveillance year, the number of autism discriminators, intellectual disability, child sex, and child race and ethnicity.

RESULTS Among 32 850 children aged 8 years identified with autism by active surveillance, 23 481 children (71.5%) met criteria for motor milestone delays. A total of 5973 children (18.2%) were female. In linear regression models, children with motor milestone delays were evaluated for autism significantly earlier (mean age, 43.65 months; 95% CI, 43.38-43.91) than children without motor milestone delays (mean age, 51.64 months; 95% CI, 51.22-52.06). After stratifying by the co-occurrence of intellectual disability (ID), children with motor milestone delays were evaluated for autism earlier than those without motor milestone delays, regardless of ID.

CONCLUSIONS AND RELEVANCE This cross-sectional study estimates the prevalence of motor milestone delays among autistic 8-year-old children and highlights the association between these delays and an earlier autism evaluation, even in children without co-occurring ID. Early identification of autism is a public health priority, and assessing motor milestone delays, particularly in children with an increased likelihood of being autistic, may facilitate an earlier autism evaluation, leading to more timely interventions and better developmental outcomes.

Supplemental content

Author Affiliations: Author affiliations are listed at the end of this article.

Corresponding Author: Olivia M. Pokoski, MPH, Department of Population Health Sciences, University of Wisconsin-Madison, 610 Walnut St, Room 717, Madison, WI 53726 (oliviapokoski@gmail.com).

JAMA Pediatr. doi:10.1001/jamapediatrics.2025.0216
Published online April 14, 2025.

© 2025 American Medical Association. All rights reserved, including those for text and data mining, AI training, and similar technologies.

Downloaded from jamanetwork.com by University of Wisconsin -Madison user on 04/21/2025

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterized by difficulties in social communication or interaction and restricted interests or repetitive behaviors.[1] Although autism can be reliably diagnosed in children as young as 18 months,[2] the median age at autism diagnosis in the US is 49 months.[3] Understanding factors associated with early autism identification is essential, as early intervention can significantly improve outcomes for autistic individuals.[2]

Motor impairment was noted in the first clinical description of autism[4] and is currently included as an associated feature in the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM*).[1] Difficulties with motor abilities are highly heterogeneous and may include clumsiness, uncoordinated gait, impaired postural stability, difficulties with fine or gross motor movements, or dyspraxia.[5-7] Prevalence estimates of motor challenges in autistic individuals range from 35% in an Australian population-based study of children aged 6 years[8] to 50% to 88% in a 2024 meta-analysis.[9] (Please note, identity-first language is used in consideration of the majority preference of those in the autism community.)[10,11] This variation may stem from differences in study designs, motor impairment instruments, or participant age ranges. Most prevalence estimates are derived from small clinical or convenience samples, limiting their generalizability. Population-based data may lead to a more accurate understanding of the prevalence of motor difficulties and could inform targeted interventions for autistic individuals.

Delays in achieving motor milestones have emerged as potential early predictors of ASD.[12,13] Several studies have found that motor impairments become more pronounced with age,[8,14-18] suggesting that interventions targeting motor skills should be prioritized in early childhood to mitigate the progression of motor impairments. Moreover, motor skills acquired during infancy facilitate enhanced interactions with objects and people, which may have cascading effects on broader developmental outcomes.[19-22] Additionally, cognitive impairment has been linked to increased motor difficulties in autistic individuals.[23-25] This suggests that a co-occurring diagnosis of intellectual disability (ID) may either account for or exacerbate these motor challenges.

While it is generally recognized that autistic individuals experience varying degrees of motor skill difficulties, a debate exists among autism researchers about including motor impairment in diagnostic definitions of ASD. Currently, autism diagnosticians are asked to specify if individuals have autism with or without accompanying intellectual or language impairment, another neurodevelopmental disorder, or catatonia or if their ASD diagnosis is associated with another known factor.[1] Some believe that adding motor impairment to diagnostic definitions as a specifier will aid in early recognition of autism and open up pathways to therapies,[26-30] while critics argue that motor impairments are neither specific to nor universal among autistic individuals[31] and recommend focusing on therapy access rather than the semantics of the criteria.[32] Population-based prevalence estimates of motor milestone delays in autistic individuals are needed to address this debate and understand the role of motor impairments in early identification. Using a large, population-based sample of autistic children in the US, this study aimed to (1) estimate the prevalence of motor milestone delays in 8-year-old autistic children; (2) determine whether motor milestone delays predict the age at earliest autism evaluation or diagnosis; and (3) examine if ID confounds the association between motor milestone delays and the age at earliest autism evaluation or diagnosis.

Key Points

Question What is the prevalence of motor milestone delays in a population-based sample of 8-year-old autistic children in the US, and how do these delays impact the age at earliest autism evaluation?

Findings In this cross-sectional study of 32 850 autistic children, 23 481 children (71.5%) had motor milestone delays noted in their health or educational records. On average, children with motor milestone delays were evaluated for autism 8 months earlier than children without motor milestone delays, a significant difference.

Meaning Motor milestone delays are common in autistic children and identification of these delays may lead to earlier evaluation for and diagnosis of autism.

Methods

Study Sample

A cross-sectional study was conducted of 32 850 autistic 8-year-old children using Autism and Developmental Disabilities Monitoring (ADDM) Network data from 2000 to 2016. Since 2000, the ADDM Network has surveilled 8-year-old children biennially at various US sites to estimate autism prevalence, with different sites participating each surveillance year. For this analysis, children lived in catchment areas within 17 US states. The Centers for Disease Control and Prevention (CDC) developed a standardized protocol to ensure consistency across sites. Trained staff reviewed records from health, special education, and other community autism service professionals, documenting behaviors consistent with autism. Research-reliable clinician reviewers then classified children as autistic using a standard case definition of ASD based on the *DSM-IV* (2000-2014) or *DSM-5* (2016).[33,34] Additional demographic information was acquired through linkages with birth certificate data to assess variations in characteristics. These methods have been described in detail elsewhere.[35-37]

Variables

Motor Milestone Delays

The primary exposure variable for this study was motor milestone delays, a binary variable indicating the presence of fine or gross motor delays, hypotonia, or motor clumsiness recorded in any of the child's available health or educational records.

Outcomes

Age at earliest autism evaluation is the child's age in months at their earliest known autism evaluation. This continuous variable ranged from 9 to 107 months. For 6% of children, records

© 2025 American Medical Association. All rights reserved, including those for text and data mining, AI training, and similar technologies.

Downloaded from jamanetwork.com by University of Wisconsin -Madison user on 04/21/2025

suggested that age at autism diagnosis was younger than age at the first evaluation, presumably due to incomplete records. For these children, age at earliest autism evaluation was set equal to age at autism diagnosis.

Age at autism diagnosis is the child's age in months at their earliest known autism diagnosis. This continuous variable ranged from 12 to 107 months. Around one-third of children (31%) did not have an autism diagnosis but were classified as autistic based on their records by research-reliable clinicians. These children were excluded from the analyses examining the association between motor milestone delays and age at autism diagnosis.

ID

ID was measured by the child's most recent intelligence quotient (IQ) test and adaptive behavior test scores. A score of 70 (2 SDs below the mean on standard tests) is the cutoff for intellectual and adaptive behavior impairments. Both scores had to be 70 or lower for the child to qualify as having an ID.[38] ID may confound the relationship between motor milestone delays and autism diagnosis or earliest evaluation given the association between intellectual and motor delays,[24,25] and autism is diagnosed earlier in children with co-occurring ID than in children without an ID.[3,39,40]

Covariates

Sociodemographic covariates included the child's sex, race, and ethnicity, which were extracted from health, educational, and birth certificate records. This study's analytic models also adjusted for the number of autism discriminators recorded for each child as a proxy for autism symptom severity. Autism discriminators are binary indicators representing prototypically autistic symptoms and reflecting core ASD symptoms. Clinicians coded a behavior as an autism discriminator if it was significant in intensity or persistence, caused functional limitations, and characterized the child over time and across situations. A list of autism discriminators can be found in eTable 1 in Supplement 1. ADDM Network surveillance-related covariates included the surveillance year and study site.

Statistical Analysis

To account for missing data, multiple imputation was conducted using the multivariate imputation by chained equations approach, creating 50 imputed datasets with a burn-in of 20 iterations. All regression model and auxiliary variables were included in the imputation model and imputed in order of least to most missing. Auxiliary variables were included if they were correlated with any variable in the analytic model (Spearman correlation coefficient ≥0.15). Multiple imputation assumes that the data are missing at random (MAR). While we believe this assumption to be reasonable based on the data patterns and observed variables, it cannot be definitively tested statistically. The fact that the complete case analysis and the analysis using multiple imputation produced slightly differing results is consistent with the MAR assumption rather than the missing completely at random assumption. Additional details on the multiple imputation model are documented in eTable 2 in Supplement 1. Complete case analysis results are reported in eTables 3-6 in Supplement 1.

Differences in motor milestone delay frequencies across key characteristics were tested using likelihood ratio χ^2 tests for nominal variables and Mantel-Haenszel χ^2 tests for ordinal variables. The population prevalence and 95% confidence intervals of autism with and without motor milestone delays were calculated per 1000 children aged 8 years overall and by sociodemographic characteristics, surveillance site, and year. Population denominators were obtained from the National Center for Health Statistics vintage 2018 bridged race postcensal population estimates.[41] Multiply imputed Wilson intervals were used for 95% confidence intervals, which provide better coverage than Wald intervals.[42] Additionally, the prevalence ratio (PR) and 95% confidence intervals were calculated to compare autism prevalence with and without motor milestone delays. Linear regression models assessed the impact of motor milestone delays on the mean age at earliest autism evaluation and diagnosis. Adjusted models included the following covariates: surveillance site; year; child sex, race and ethnicity; number of autism discriminators; and ID status. Results were stratified by ID status to examine confounding and effect modification related to co-occurring ID. χ^2 Tests were used to compare the ages at earliest autism evaluation and diagnosis between children with and without co-occurring ID.

This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.[43] All statistical tests were 2-sided, with $P < .05$ considered statistically significant. Statistical analyses and data management were performed using SAS version 9.4 (SAS Institute).

Results

The study included 32 850 autistic 8-year-old children, identified across 17 ADDM Network sites from 2000 to 2016. A total of 5973 children (18.2%) were female. Overall, 23 481 of 32 850 children (71.5%) (**Table 1**) met criteria for motor milestone delays in the imputed data and complete case analysis (eTable 3 in Supplement 1). The prevalence of autism with motor milestone delays was 8.59 per 1000 children aged 8 years (95% CI, 8.48-8.70), indicating a ratio of 2.50 autistic children with motor milestone delays for every autistic child without such delays (**Table 2**).

Most of the sample was male (26 877 children [81.8%]) and non-Hispanic White (18 917 children [57.6%]). The sample was composed of 164 American Indian or Alaska Native non-Hispanic children (0.5%), 1232 Asian or Pacific Islander children (3.7%), 7037 Black non-Hispanic children (21.4%), 4589 Hispanic children (14.0%), 18 917 White non-Hispanic children (57.6%), and 911 non-Hispanic children whose race was listed as other or included multiple racial groups (2.8%) (Table 1). The prevalence of autism with motor milestone delays per 1000 children aged 8 years was highest among non-Hispanic White children (9.12; 95% CI, 8.97-9.28), followed by Asian or Pacific Islander children (7.96; 95% CI, 7.43-8.53),

© 2025 American Medical Association. All rights reserved, including those for text and data mining, AI training, and similar technologies.
Downloaded from jamanetwork.com by University of Wisconsin -Madison user on 04/21/2025

American Indian or Alaskan Native children (7.48; 95% CI, 6.21-9.00), and Hispanic children (7.32; 95% CI, 7.07-7.58) and was lowest among non-Hispanic Black children (6.73; 95% CI, 6.54-6.94). Conversely, the highest prevalence of autism without motor milestone delays was found among Asian or Pacific Islander children (3.58; 95% CI, 3.22-3.98) and non-Hispanic Black children (3.45; 95% CI, 3.31-3.60) (Table 2).

Most children had an IQ greater than 70 (20 795 children [63.3%]), an adaptive behavior score of 70 or less (17 273 children [52.6%]), and did not have ID (22 960 children [69.9%]) (Table 1). Motor milestone delays were more frequent in autistic children with ID than those without ID (Table 1). Notably, the prevalence of autism with motor milestone delays and co-occurring ID was more than 2-fold that of autism with motor milestone delays without ID (Table 2). Additionally, children with motor milestone delays had more autism discriminators than those without these delays (Table 1).

Table 1. Sample Key Characteristics Overall and by Indication of Motor Milestone Delays[a]

Variable	Total, No. (%)[a]	% With motor milestone delays (95% CI) (n = 23 481)	*P* value[b]
Total sample	32 850 (100)	71.5 (71.0-72.0)	NA
Child's sex			
Female	5973 (18.2)	73.3 (72.2-74.5)	<.001
Male	26 877 (81.8)	71.1 (70.5-71.6)	
Race or ethnicity[c]			
American Indian or Alaska Native, non-Hispanic	164 (0.5)	71.9 (64.9-78.9)	<.001
Asian or Pacific Islander, non-Hispanic	1232 (3.7)	68.8 (66.1-71.4)	
Black, non-Hispanic	7037 (21.4)	65.7 (64.6-66.9)	
Hispanic	4589 (14.0)	72.1 (70.8-73.4)	
White, non-Hispanic	18 917 (57.6)	73.7 (73.0-74.3)	
Other or multiple races, non-Hispanic[d]	911 (2.8)	71.3 (68.3-74.3)	
Cognitive status, IQ score			
>70	20 795 (63.3)	69.2 (68.5-69.9)	<.001
≤70	12 055 (36.7)	75.4 (74.5-76.4)	
Adaptive behavior score			
>70	15 577 (47.4)	68.1 (67.2-69.0)	<.001
≤70	17 273 (52.6)	74.5 (73.7-75.3)	
Intellectual disability			
No	22 960 (69.9)	69.5 (68.9-70.2)	<.001
Yes	9890 (30.1)	76.0 (74.9-77.0)	
No. of autism discriminators			
Mean (SD) [range]	2.45 (1.93) [0-17]	2.59 (2.00) [0-17]	NA
Abstracted record source			
Education only	10 343 (31.5)	68.2 (67.3-69.2)	<.001
Health only	11 984 (36.5)	68.0 (67.1-68.8)	
Both	10 523 (32.0)	78.7 (77.8-79.5)	
Born in state			
Yes	24 093 (73.3)	72.1 (71.5-72.7)	<.001
No	8757 (26.7)	69.9 (68.9-70.9)	
Previous autism diagnosis			
Yes	23 006 (70.0)	72.3 (71.7-72.9)	<.001
No	9844 (30.0)	69.6 (68.6-70.5)	
Study year			
2000	1246 (3.8)	62.2 (59.5-64.9)	<.001
2002	2682 (8.2)	63.9 (61.5-66.3)	
2004	1372 (4.2)	62.8 (59.4-66.2)	
2006	2757 (8.4)	68.1 (66.4-69.8)	
2008	3818 (11.6)	73.0 (71.6-74.4)	
2010	5334 (16.2)	79.7 (78.6-80.7)	
2012	5063 (15.4)	72.2 (70.9-73.4)	
2014	5470 (16.7)	71.3 (70.1-72.5)	
2016	5108 (15.6)	71.8 (70.5-73.0)	

(continued)

© 2025 American Medical Association. All rights reserved, including those for text and data mining, AI training, and similar technologies.

Downloaded from jamanetwork.com by University of Wisconsin -Madison user on 04/21/2025

Table 1. Sample Key Characteristics Overall and by Indication of Motor Milestone Delays[a] (continued)

Variable	Total, No. (%)[a]	% With motor milestone delays (95% CI) (n = 23 481)	*P* value[b]
Study site			
Alabama	678 (2.1)	69.8 (66.3-73.4)	<.001
Arizona	3373 (10.3)	77.1 (75.6-78.5)	
Arkansas	2206 (6.7)	87.5 (86.1-89.0)	
Colorado	2138 (6.5)	84.7 (83.2-86.2)	
Florida	327 (1.0)	67.9 (62.7-72.7)	
Georgia	4944 (15.1)	67.6 (66.2-69.0)	
Maryland	2243 (6.8)	67.3 (65.2-69.4)	
Minnesota	546 (1.7)	73.9 (70.3-77.6)	
Missouri	2329 (7.1)	63.0 (60.9-65.1)	
New Jersey	4250 (12.9)	73.2 (71.8-74.5)	
North Carolina	3392 (10.3)	78.3 (76.9-79.7)	
Pennsylvania	506 (1.5)	67.0 (62.7-71.4)	
South Carolina	1175 (3.6)	62.6 (59.8-65.4)	
Tennessee	792 (2.4)	48.1 (44.6-51.6)	
Utah	1114 (3.4)	60.2 (57.2-63.2)	
West Virginia	257 (0.8)	40.5 (34.7-46.6)	
Wisconsin	2580 (7.9)	66.9 (65.0-68.7)	

Abbreviation: NA, not applicable.

[a] Percentages may not add up to 100% due to rounding the mean proportion in each group for the 50 imputed datasets.

[b] *P* values were calculated using likelihood ratio χ^2 tests for nominal variables and Mantel-Haenszel χ^2 tests for ordinal variables, comparing the percentages of children with motor milestone delays across sociodemographic characteristics.

[c] Race and ethnicity were extracted from health, educational, and birth certificate records.

[d] Health and educational records received from data sources described children as either other race or being of ≥2 races.

Children whose records were abstracted from both education and health sources had a significantly higher frequency of motor milestone delays than children whose records were only from 1 source (Table 1). Furthermore, motor milestone delays were more prevalent among children who had a previous autism diagnosis than among those who did not (PR, 2.43; 95% CI, 1.99-2.96) (Table 2). Overall, autism prevalence generally increased with each study year, regardless of the presence of motor milestone delays (Table 2). Additionally, the prevalence of autism with motor milestone delays varied significantly by site, ranging from 2.34 (95% CI, 1.93-2.83) per 1000 children in West Virginia to 17.18 (95% CI, 15.60-18.93) per 1000 children in Minnesota (Table 2).

Among children with motor milestone delays, the mean age at earliest autism evaluation was 43.65 months (95% CI, 43.38-43.91) compared to 51.64 months (95% CI, 51.22-52.06) in children without motor milestone delays (mean difference, −7.99; 95% CI, −8.50 to −7.49). On average, children with motor milestone delays were diagnosed with autism 2.97 months earlier (95% CI, −3.64 to −2.30) than those without such delays. These mean differences slightly attenuated after adjusting for covariates (**Table 3**). Both the mean age at earliest autism evaluation and at diagnosis remained relatively constant across the study years (eFigures 1-2 in Supplement 1).

In analyses stratified by ID, children with ID were evaluated and diagnosed with autism earlier than children without ID, regardless of motor milestone delays (**Table 4**). On average, individuals with both ID and motor milestone delays were the youngest to be evaluated for autism (38.35 months; 95% CI, 37.89-38.81). However, among children with ID, the age at autism diagnosis was similar for those with and without motor milestone delays (mean difference, −0.82; 95% CI, −2.11 to 0.47). In contrast, children without ID with motor milestone delays were diagnosed slightly earlier than those without such delays (mean difference, −3.23; 95% CI, −4.07 to −2.40). After adjusting for surveillance site, year, child sex, race, ethnicity, and number of autism discriminators, the mean difference in the mean age at diagnosis decreased in each model.

Discussion

To our knowledge, this is the largest population-based study documenting the prevalence of motor milestone delays in autistic children. Among 32 850 autistic children, over 71% met criteria for motor milestone delays. The prevalence of autism with motor milestone delays was 2.5-fold higher than that of autism without motor milestone delays per 1000 children aged 8 years in the US. Motor milestone delays were associated with earlier autism evaluation and diagnosis, even after stratifying by co-occurrence of ID. These findings highlight the importance of motor development in early autism identification.

Published estimates of motor difficulties in autistic children vary widely. This study's findings align with the average estimate reported by a recent systematic review and meta-analysis, although it excluded studies involving children with ID.[9] One study estimated that 88% of autistic children had significant motor impairments based on a subset of children whose parents completed the Developmental

© 2025 American Medical Association. All rights reserved, including those for text and data mining, AI training, and similar technologies.
Downloaded from jamanetwork.com by University of Wisconsin -Madison user on 04/21/2025

Coordination Disorder Questionnaire. This estimate may be biased due to an overrepresentation of parents concerned about their child's motor skills.[21] In contrast, an Australian population-based study estimated that 35.4% of autistic children younger than 6 years old had motor difficulties as measured by the Vineland Adaptive Behavior Scales, a percentage half of that found in this study.[8] This discrepancy could stem from differences in measurement methods or the younger age of their sample. Since the magnitude of motor differences tends to increase with age, detecting significant motor difficulties may be more challenging in the younger sample. Overall, motor difficulties in autistic individuals are highly prevalent and may be as common (if not more so) than ID or language impairment.[3,44] This highlights the need

Table 2. Prevalence of Autism (per 1000 Children) With and Without Motor Milestone Delays Among Children Aged 8 Years

Characteristic	Overall		Motor milestone delays		No motor milestone delays	
	Prevalence (95% CI)	Prevalence ratio (95% CI)	Prevalence (95% CI)	Prevalence ratio (95% CI)	Prevalence (95% CI)	Prevalence ratio (95% CI)
Overall	12.02 (11.89-12.15)	NA	8.59 (8.48-8.70)	NA	3.43 (3.36-3.50)	NA
Sex						
Female	4.28 (4.17-4.40)	1 [Ref]	3.14 (3.05-3.24)	1 [Ref]	1.14 (1.09-1.20)	1 [Ref]
Male	20.09 (19.85-20.32)	4.69 (4.56-4.82)	14.28 (14.07-14.48)	4.55 (4.40-4.70)	5.81 (5.68-5.94)	5.08 (4.82-5.36)
Race and ethnicity[a]						
American Indian or Alaska Native	10.20 (8.70-11.95)	0.83 (0.71-0.97)	7.48 (6.21-9.00)	0.82 (0.68-0.99)	2.72 (2.00-3.71)	0.85 (0.63-1.16)
Asian or Pacific Islander	11.54 (10.91-12.22)	0.94 (0.88-0.99)	7.96 (7.43-8.53)	0.87 (0.81-0.94)	3.58 (3.22-3.98)	1.12 (1.01-1.24)
Black, non-Hispanic	10.18 (9.94-10.43)	0.83 (0.80-0.85)	6.73 (6.54-6.94)	0.74 (0.71-0.76)	3.45 (3.31-3.60)	1.08 (1.03-1.13)
Hispanic	10.14 (9.84-10.44)	0.82 (0.80-0.85)	7.32 (7.07-7.58)	0.80 (0.77-0.83)	2.81 (2.66-2.98)	0.88 (0.83-0.94)
White, non-Hispanic	12.32 (12.14-12.50)	1 [Ref]	9.12 (8.97-9.28)	1 [Ref]	3.20 (3.10-3.29)	1 [Ref]
Cognitive status, IQ score						
≤70	4.41 (4.31-4.51)	0.58 (0.57-0.59)	3.33 (3.25-3.41)	0.63 (0.62-0.65)	1.08 (1.03-1.14)	0.46 (0.44-0.48)
>70	7.61 (7.49-7.73)	1 [Ref]	5.27 (5.17-5.36)	1 [Ref]	2.34 (2.28-2.41)	1 [Ref]
Adaptive behavior score						
≤70	6.32 (6.20-6.44)	1.11 (1.09-1.13)	4.71 (4.62-4.81)	1.21 (1.18-1.24)	1.61 (1.55-1.67)	0.89 (0.85-0.92)
>70	5.70 (5.59-5.81)	1 [Ref]	3.88 (3.79-3.97)	1 [Ref]	1.82 (1.75-1.88)	1 [Ref]
ID						
Yes	3.62 (3.52-3.72)	0.43 (0.42-0.44)	2.75 (2.67-2.83)	0.47 (0.46-0.48)	0.87 (0.82-0.92)	0.34 (0.32-0.36)
No	8.40 (8.27-8.53)	1 [Ref]	5.84 (5.74-5.95)	1 [Ref]	2.56 (2.49-2.63)	1 [Ref]
Previous ASD diagnosis						
Yes	8.42 (8.31-8.53)	2.34 (1.98-2.76)	6.08 (5.99-6.18)	2.43 (1.99-2.96)	2.33 (2.27-2.39)	2.13 (1.57-2.89)
No	3.60 (3.53-3.67)	1 [Ref]	2.51 (2.45-2.57)	1 [Ref]	1.10 (1.06-1.14)	1 [Ref]
Born in state						
Yes	8.82 (8.71-8.93)	2.75 (2.68-2.82)	6.35 (6.26-6.45)	2.84 (2.76-2.92)	2.46 (2.40-2.53)	2.55 (2.44-2.67)
No	3.20 (3.14-3.27)	1 [Ref]	2.24 (2.18-2.30)	1 [Ref]	0.96 (0.93-1.00)	1 [Ref]
Abstraction type						
Education only	3.78 (3.71-3.86)	0.98 (0.96-1.01)	2.58 (2.52-2.64)	0.85 (0.83-0.88)	1.20 (1.16-1.24)	1.46 (1.39-1.54)
Health only	4.39 (4.31-4.46)	1.14 (1.11-1.17)	2.98 (2.92-3.05)	0.98 (0.95-1.01)	1.40 (1.36-1.45)	1.71 (1.62-1.80)
Both	3.85 (3.78-3.92)	1 [Ref]	3.03 (2.96-3.10)	1 [Ref]	0.82 (0.79-0.86)	1 [Ref]
Study year						
2000	6.62 (6.27-7.00)	1 [Ref]	4.12 (3.84-4.42)	1 [Ref]	2.50 (2.28-2.74)	1 [Ref]
2002	6.46 (6.22-6.70)	0.98 (0.91-1.04)	4.12 (3.91-4.35)	1.00 (0.92-1.09)	2.33 (2.16-2.52)	0.93 (0.84-1.04)
2004	7.96 (7.55-8.39)	1.20 (1.11-1.30)	5.00 (4.64-5.39)	1.21 (1.10-1.34)	2.96 (2.67-3.29)	1.18 (1.05-1.34)
2006	8.95 (8.62-9.29)	1.35 (1.26-1.44)	6.10 (5.83-6.38)	1.48 (1.36-1.61)	2.85 (2.67-3.05)	1.14 (1.02-1.28)
2008	11.33 (10.97-11.69)	1.71 (1.60-1.82)	8.27 (7.97-8.58)	2.01 (1.85-2.17)	3.06 (2.88-3.25)	1.22 (1.10-1.36)
2010	14.66 (14.28-15.06)	2.21 (2.08-2.35)	11.68 (11.34-12.04)	2.84 (2.63-3.06)	2.98 (2.81-3.17)	1.19 (1.07-1.33)
2012	14.59 (14.20-15.00)	2.20 (2.07-2.34)	10.53 (10.20-10.88)	2.56 (2.37-2.76)	4.06 (3.85-4.28)	1.62 (1.46-1.80)
2014	16.81 (16.37-17.25)	2.54 (2.39-2.70)	11.98 (11.61-12.36)	2.91 (2.69-3.14)	4.83 (4.60-5.07)	1.93 (1.74-2.14)
2016	18.55 (18.05-19.06)	2.80 (2.63-2.98)	13.31 (12.89-13.74)	3.23 (2.99-3.49)	5.24 (4.98-5.52)	2.09 (1.89-2.32)

(continued)

© 2025 American Medical Association. All rights reserved, including those for text and data mining, AI training, and similar technologies.

Downloaded from jamanetwork.com by University of Wisconsin -Madison user on 04/21/2025

Table 2. Prevalence of Autism (per 1000 Children) With and Without Motor Milestone Delays Among Children Aged 8 Years (continued)

Characteristic	Overall		Motor milestone delays		No motor milestone delays	
	Prevalence (95% CI)	Prevalence ratio (95% CI)	Prevalence (95% CI)	Prevalence ratio (95% CI)	Prevalence (95% CI)	Prevalence ratio (95% CI)
Study site						
Alabama	4.82 (4.47-5.20)	0.39 (0.36-0.43)	3.36 (3.07-3.68)	0.41 (0.37-0.45)	1.46 (1.27-1.67)	0.37 (0.32-0.42)
Arkansas	12.62 (12.11-13.16)	1.03 (0.98-1.08)	11.05 (10.57-11.55)	1.33 (1.26-1.41)	1.57 (1.39-1.78)	0.40 (0.35-0.45)
Arizona	11.74 (11.35-12.14)	0.96 (0.92-1.00)	9.05 (8.71-9.40)	1.09 (1.04-1.15)	2.69 (2.51-2.89)	0.68 (0.62-0.74)
Colorado	11.42 (10.95-11.91)	0.93 (0.89-0.98)	9.67 (9.24-10.12)	1.17 (1.10-1.24)	1.75 (1.57-1.95)	0.44 (0.39-0.50)
Florida	5.74 (5.15-6.39)	0.47 (0.42-0.52)	3.90 (3.42-4.44)	0.47 (0.41-0.54)	1.84 (1.52-2.23)	0.46 (0.38-0.57)
Georgia	12.25 (11.91-12.59)	1 [Ref]	8.28 (8.00-8.57)	1 [Ref]	3.97 (3.77-4.18)	1 [Ref]
Maryland	11.16 (10.71-11.63)	0.91 (0.87-0.96)	7.51 (7.13-7.91)	0.91 (0.85-0.96)	3.65 (3.38-3.93)	0.92 (0.84-1.00)
Minnesota	23.24 (21.39-25.24)	1.90 (1.74-2.07)	17.18 (15.60-18.93)	2.08 (1.87-2.30)	6.05 (5.14-7.13)	1.52 (1.29-1.81)
Missouri	11.24 (10.79-11.70)	0.92 (0.87-0.96)	7.08 (6.72-7.46)	0.86 (0.80-0.91)	4.16 (3.88-4.46)	1.05 (0.96-1.14)
New Jersey	21.55 (20.92-22.20)	1.76 (1.69-1.83)	15.77 (15.23-16.33)	1.91 (1.81-2.00)	5.78 (5.45-6.13)	1.46 (1.35-1.57)
North Carolina	14.99 (14.50-15.50)	1.22 (1.17-1.28)	11.74 (11.31-12.19)	1.42 (1.35-1.49)	3.25 (3.02-3.49)	0.82 (0.75-0.89)
Pennsylvania	8.82 (8.08-9.62)	0.72 (0.66-0.79)	5.91 (5.30-6.58)	0.71 (0.64-0.80)	2.91 (2.48-3.40)	0.73 (0.62-0.86)
South Carolina	8.34 (7.88-8.83)	0.68 (0.64-0.73)	5.22 (4.86-5.61)	0.63 (0.58-0.68)	3.11 (2.84-3.42)	0.78 (0.71-0.87)
Tennessee	15.60 (14.56-16.71)	1.27 (1.18-1.37)	7.50 (6.79-8.29)	0.91 (0.82-1.01)	8.09 (7.35-8.91)	2.04 (1.83-2.27)
Utah	14.48 (13.66-15.35)	1.18 (1.11-1.26)	8.72 (8.07-9.41)	1.05 (0.97-1.14)	5.76 (5.24-6.34)	1.45 (1.31-1.61)
West Virginia	5.77 (5.11-6.52)	0.47 (0.42-0.53)	2.34 (1.93-2.83)	0.28 (0.23-0.34)	3.44 (2.93-4.02)	0.87 (0.73-1.02)
Wisconsin	10.07 (9.69-10.46)	0.82 (0.78-0.86)	6.73 (6.42-7.06)	0.81 (0.77-0.86)	3.34 (3.12-3.57)	0.84 (0.77-0.91)

Abbreviations: ASD, autism spectrum disorder; ID, intellectual disability; NA, not applicable; Ref, reference.

[a] Race and ethnicity were extracted from health, educational, and birth certificate records. Race and ethnicity prevalence was calculated using 2002-2016 data. Those documented as multiple races or other race were not included in this analysis.

Table 3. Linear Regression Models for the Mean Earliest Age at Autism Evaluation and Diagnosis in Children With and Without Motor Milestone Delays

Age category	Mean (95% CI), mo		Mean difference (95% CI)	Adjusted mean difference (95% CI)[a]
	Motor milestone delays	No motor milestone delays		
Age at earliest autism evaluation	43.65 (43.38 to 43.91)	51.64 (51.22 to 52.06)	−7.99 (−8.50 to −7.49)	−6.31 (−6.82 to −5.81)
Age at autism diagnosis	54.38 (54.04 to 54.72)	57.36 (56.79 to 57.92)	−2.97 (−3.64 to −2.30)	−1.27 (−1.94 to −0.60)

[a] Models adjusted for site, surveillance year, child sex, child race and ethnicity, the sum of autism discriminators, and intellectual disability.

for greater attention to motor evaluations and interventions in autism.

Variations in the prevalence of motor milestone delays by race and ethnicity may reflect disparities in their identification within the community by health and education professionals. We found motor milestone delays were significantly less likely to be documented in records of non-Hispanic Black children compared to non-Hispanic White children (PR, 0.74; 95% CI, 0.71-0.76). This is similar to existing literature using data up until 2016, which indicated children of racial and ethnic minoritized groups were less likely than non-Hispanic White children to receive autism diagnoses, have associated features documented, and have relevant records from health sources compared to education-only sources.[36,45,46] These findings underscore the need for equitable access to developmental evaluations and interventions, as underascertainment of motor milestone delays may delay autism diagnoses and critical early supports for children in underserved communities.

The American Academy of Pediatrics (AAP) recommends autism screening at 18 and 24 months of age,[2] yet this study's findings show evaluations starting much later—43.65 months for those with motor milestone delays and 51.64 months for those without. This aligns with other studies that found average ages of autism evaluation and diagnosis beyond the AAP's guidelines, underscoring the need for initiatives like the Healthy People 2030 objective, which aims to increase the proportion of children younger than 36 months who are screened for ASD and other developmental disabilities.[3,39,47] Our findings also highlight the potential role of motor skills in early autism identification. Specifically, it was found that children with motor milestone delays were evaluated for autism 8 months earlier than children without such delays. These results contribute to the ongoing debate among autism researchers regarding the inclusion of motor impairments as potential diagnostic features of ASD. In particular, our findings suggest that motor milestone delays could serve as an important early marker for autism, potentially facilitating earlier diagnosis and intervention.

Our finding that children with co-occurring ID more commonly had motor milestone delays compared to children without ID aligns with prior literature.[8,23] In this study, children with

© 2025 American Medical Association. All rights reserved, including those for text and data mining, AI training, and similar technologies.
Downloaded from jamanetwork.com by University of Wisconsin -Madison user on 04/21/2025

Table 4. Linear Regression Models for the Mean Earliest Age at Autism Evaluation and Diagnosis in Children With and Without Delayed Motor Milestones, Stratified by Intellectual Disability (ID)

Model	Mean (95% CI), mo		Mean difference (95% CI)		*P* value	
	Motor milestone delay	No motor milestone delays	Unadjusted	Adjusted[a]	ASD + ID compared to ASD, no ID	Adjusted ASD + ID compared to ASD, no ID[a]
Age at earliest autism evaluation						
Autism + ID (n = 9379)	38.35 (37.89 to 38.81)	44.67 (43.79 to 45.54)	−6.32 (−7.31 to −5.33)	−5.12 (−6.13 to −4.12)	.01	.01
Autism, no ID (n = 23 471)	46.14 (45.80 to 46.48)	54.01 (53.48 to 54.54)	−7.87 (−8.50 to −7.24)	−6.78 (−7.41 to −6.14)		
Age at autism diagnosis						
Autism + ID (n = 7198)	49.77 (49.19 to 50.36)	50.59 (49.48 to 51.71)	−0.82 (−2.11 to 0.47)	1.05 (−0.26 to 2.36)	.003	<.001
Autism, no ID (n = 15 808)	56.83 (56.39 to 57.27)	60.06 (59.35 to 60.77)	−3.23 (−4.07 to −2.40)	−2.32 (−3.16 to −1.48)		

Abbreviation: ASD, autism spectrum disorder.

[a] Models adjusted for site, surveillance year, child sex, child race and ethnicity, and the sum of autism discriminators.

ID were evaluated and diagnosed with autism earlier than those without ID, and the association between motor milestone delays and earlier evaluation persisted regardless of ID status. This suggests that the impact of motor milestone delays on earlier autism identification is not solely mediated by ID status. Autistic children, regardless of co-occurring ID, could benefit from therapies targeting motor skills to address potential delays. Beyond identification, motor delays may have broader developmental implications, impacting adaptive behavior, social interactions, and opportunities to learn.[18,21,22] These delays can create cascading effects on a child's overall development, since motor skills often build upon one another. Consequently, early delays can become compounded over time, reinforcing the need for timely interventions.[14,16,22] Early interventions targeting motor skills could mitigate these challenges, underscoring the importance of incorporating motor assessments into autism screening and intervention programs.

Limitations

This study has some limitations. One limitation is the potential for measurement error, as some children may have experienced motor delays not recorded in their records. This error could be influenced by the quality or availability of records, varying by child characteristics, such as race, ethnicity, socioeconomic status, or having an autism diagnosis. However, the high prevalence of motor milestone delays observed in our sample is consistent with other studies and does not suggest underascertainment.[9,23] Another limitation is that motor milestone delays were measured as a binary variable based on clinician review of records rather than through a validated tool, which did not distinguish between fine and gross motor delays. Despite this, our study design allowed for a large, population-based assessment of motor difficulties. Future studies should explore whether more granular assessments of motor skills would yield similar results and provide insights into types of motor delays prevalent among autistic children.

Conclusions

In summary, this study found that a significant proportion of autistic children had a history of motor milestone delays, which were associated with an earlier age at autism evaluation and diagnosis. Although motor delays are not exclusive to autism, their presence could serve as an important indicator to prompt clinicians to screen for autism, potentially facilitating timely diagnosis and interventions to improve developmental outcomes. Future research is needed to understand the role of motor skills in early autism identification and the potential implications of including motor assessments in diagnostic protocols for ASD.

ARTICLE INFORMATION

Accepted for Publication: February 1, 2025.

Published Online: April 14, 2025. doi:10.1001/jamapediatrics.2025.0216

Author Affiliations: Department of Population Health Sciences, School of Medicine and Public Health, University of Wisconsin-Madison (Pokoski, Furnier, Gangnon, Durkin); Waisman Center, University of Wisconsin-Madison (Pokoski, Furnier, Travers, Durkin); Department of Biostatistics and Medical Informatics, School of Medicine and Public Health, University of Wisconsin-Madison (Gangnon); Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland (Howerton); Department of Occupational and Recreational Therapies, University of Utah, Salt Lake City (Kirby); College of Health Solutions, Arizona State University, Phoenix (Protho); Department of Medicine, School of Medicine and Public Health, University of Wisconsin-Madison (Schweizer); Occupational Therapy Program, Department of Kinesiology, University of Wisconsin-Madison (Travers).

Author Contributions: Ms Pokoski had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Pokoski, Kirby, Schweizer, Durkin.
Acquisition, analysis, or interpretation of data: Pokoski, Furnier, Gangnon, Howerton, Kirby, Protho, Schweizer, Travers, Durkin.
Drafting of the manuscript: Pokoski.
Critical review of the manuscript for important intellectual content: Pokoski, Furnier, Gangnon, Howerton, Kirby, Protho, Schweizer, Travers, Durkin.
Statistical analysis: Pokoski, Furnier, Gangnon.
Obtained funding: Durkin.
Administrative, technical, or material support: Protho, Travers, Durkin.
Supervision: Durkin.

Conflict of Interest Disclosures: Ms Pokoski, Dr Furnier, and Dr Durkin reported grants from the US Centers for Disease Control and Prevention (CDC) Foundation and the Eunice Kennedy Shriver National Institute of Child Health and Human Development during the conduct of the study. Dr Gangnon reported grants from US National

© 2025 American Medical Association. All rights reserved, including those for text and data mining, AI training, and similar technologies.

Downloaded from jamanetwork.com by University of Wisconsin -Madison user on 04/21/2025

Institutes of Health during the conduct of the study. Dr Kirby reported grants from the CDC during the conduct of the study. Dr Schweizer reported personal fees from 3M outside the submitted work. No other disclosures were reported.

Funding/Support: This study was supported in part by a grant from the US Centers for Disease Control and Prevention (1NUR3DD000106-01-00). It was also supported in part by a core grant to the Waisman Center from the National Institute of Child Health and Human Development (P50HD105353).

Role of the Funder/Sponsor: The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Data Sharing Statement: See Supplement 2.

REFERENCES

1. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. Fifth Edition, Text Revision. American Psychiatric Association; 2022.

2. Hyman SL, Levy SE, Myers SM; COUNCIL ON CHILDREN WITH DISABILITIES, SECTION ON DEVELOPMENTAL AND BEHAVIORAL PEDIATRICS. Identification, evaluation, and management of children with autism spectrum disorder. *Pediatrics*. 2020;145(1):e20193447. doi:10.1542/peds.2019-3447

3. Maenner MJ, Warren Z, Williams AR, et al. Prevalence and characteristics of autism spectrum disorder among children aged 8 years - Autism and Developmental Disabilities Monitoring Network, 11 sites, United States, 2020. *MMWR Surveill Summ*. 2023;72(2):1-14. doi:10.15585/mmwr.ss7202a1

4. Kanner L. Autistic disturbances of affective contact. *Nerv Child*. 1943;2:217-250.

5. 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(10):1227-1240. doi:10.1007/s10803-010-0981-3

6. 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(7):1568-1583. doi:10.1007/s10803-012-1702-x

7. Dziuk MA, Gidley Larson JC, Apostu A, Mahone EM, Denckla MB, Mostofsky SH. Dyspraxia in autism: association with motor, social, and communicative deficits. *Dev Med Child Neurol*. 2007;49(10):734-739. doi:10.1111/j.1469-8749.2007.00734.x

8. 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(2):298-306. doi:10.1002/aur.2230

9. 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*. 2024;54(5):1977-1997. doi:10.1007/s10803-023-05948-1

10. Bottema-Beutel K, Kapp SK, Lester JN, Sasson NJ, Hand BN. Avoiding ableist language: suggestions for autism researchers. *Autism Adulthood*. 2021;3(1):18-29. doi:10.1089/aut.2020.0014

11. Kenny L, Hattersley C, Molins B, Buckley C, Povey C, Pellicano E. Which terms should be used to describe autism? perspectives from the UK autism community. *Autism*. 2016;20(4):442-462. doi:10.1177/1362361315588200

12. Harris SR. Early motor delays as diagnostic clues in autism spectrum disorder. *Eur J Pediatr*. 2017;176(9):1259-1262. doi:10.1007/s00431-017-2951-7

13. Reynolds JE, Whitehouse AJO, Alvares GA, Waddington H, Macaskill E, Licari MK. Characterising the early presentation of motor difficulties in autistic children. *J Autism Dev Disord*. 2022;52(11):4739-4749. doi:10.1007/s10803-021-05333-w

14. West KL. Infant motor development in autism spectrum disorder: a synthesis and meta-analysis. *Child Dev*. 2019;90(6):2053-2070. doi:10.1111/cdev.13086

15. Mohd Nordin A, Ismail J, Kamal Nor N. Motor development in children with autism spectrum disorder. *Front Pediatr*. 2021;9:598276. doi:10.3389/fped.2021.598276

16. Lim YH, Licari M, Spittle AJ, et al. Early motor function of children with autism spectrum disorder: a systematic review. *Pediatrics*. 2021;147(2):e2020011270. doi:10.1542/peds.2020-011270

17. Lloyd M, MacDonald M, Lord C. Motor skills of toddlers with autism spectrum disorders. *Autism*. 2013;17(2):133-146. doi:10.1177/1362361311402230

18. Travers BG, Bigler ED, Duffield TC, et al. Longitudinal development of manual motor ability in autism spectrum disorder from childhood to mid-adulthood relates to adaptive daily living skills. *Dev Sci*. 2017;20(4):e12401. doi:10.1111/desc.12401

19. 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(1):69-80. doi:10.1037/abn0000390

20. 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*. 2019;10(1):276-296. doi:10.3390/ejihpe10010022

21. 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. doi:10.1002/aur.2453

22. Posar A, Visconti P. Early motor signs in autism spectrum disorder. *Children (Basel)*. 2022;9(2):294. doi:10.3390/children9020294

23. Green D, Charman T, Pickles A, et al. Impairment in movement skills of children with autistic spectrum disorders. *Dev Med Child Neurol*. 2009;51(4):311-316. doi:10.1111/j.1469-8749.2008.03242.x

24. Surgent OJ, Walczak M, Zarzycki O, Ausderau K, Travers BG. IQ and sensory symptom severity best predict motor ability in children with and without autism spectrum disorder. *J Autism Dev Disord*. 2021;51(1):243-254. doi:10.1007/s10803-020-04536-x

25. Ramos-Sánchez CP, Kortekaas D, Van Biesen D, Vancampfort D, Van Damme T. The relationship between motor skills and intelligence in children with autism spectrum disorder. *J Autism Dev Disord*. 2022;52(3):1189-1199. doi:10.1007/s10803-021-05022-8

26. Licari MK, Alvares GA, Reynolds JE, Uljaveric M. Motor impairment should be a "specifier" for autism spectrum disorder. *Autism Res*. 2022;15(11):2010-2011. doi:10.1002/aur.2819

27. Ketcheson LR, Pitchford EA, Staples KL, MacDonald M, Ulrich DA. Supporting the need for the motor domain to be included in the definition of autism spectrum disorder: a response to Bishop et al.'s critique of Bhat (2021). *Autism Res*. 2022;15(10):1796-1798. doi:10.1002/aur.2811

28. Bhat A. Why add motor to the definition of ASD: a response to Bishop et al.'s critique of Bhat (2021). *Autism Res*. 2022;15(8):1376-1379. doi:10.1002/aur.2776

29. Crippa A. Motor abilities as a possible specifier of autism: A response to Bhat (2021). *Autism Res*. 2022;15(10):1794-1795. doi:10.1002/aur.2805

30. Miller HL, Licari MK, Bhat A, et al. Motor problems in autism: co-occurrence or feature? *Dev Med Child Neurol*. 2024;66(1):16-22. doi:10.1111/dmcn.15674

31. Bishop SL, Wickstrom J, Thurm A. Insufficient evidence for inclusion of motor deficits in the ASD diagnostic criteria: a response to Bhat (2021). *Autism Res*. 2022;15(8):1374-1375. doi:10.1002/aur.2775

32. Belmonte MK. Motor symptoms in the ASD diagnostic criteria: a conservative perspective. *Autism Res*. 2022;15(9):1582-1584. doi:10.1002/aur.2793

33. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. Fourth Edition, Text Revision. American Psychiatric Association; 2000.

34. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. Fifth Edition. American Psychiatric Association; 2013.

35. Baio J, Wiggins L, Christensen DL, et al. Prevalence of autism spectrum disorder among children aged 8 years - Autism and Developmental Disabilities Monitoring Network, 11 sites, United States, 2014. *MMWR Surveill Summ*. 2018;67(6):1-23. doi:10.15585/mmwr.ss6706a1

36. Maenner MJ, Shaw KA, Baio J, et al; EdS1; PhD-7. Prevalence of autism spectrum disorder among children aged 8 years - Autism and Developmental Disabilities Monitoring Network, 11 sites, United States, 2016. *MMWR Surveill Summ*. 2020;69(4):1-12. doi:10.15585/mmwr.ss6904a1

37. Hughes MM, Shaw KA, DiRienzo M, et al. The prevalence and characteristics of children with profound autism, 15 sites, United States, 2000-2016. *Public Health Rep*. 2023;138(6):971-980. doi:10.1177/00333549231163551

38. Furnier SM, Ellis Weismer S, Rubenstein E, et al. Using adaptive behavior scores to convey level of functioning in children with autism spectrum disorder: evidence from the Study to Explore Early Development. *Autism*. 2024;28(5):1135-1149. doi:10.1177/13623613231193194

39. Loubersac J, Michelon C, Ferrando L, Picot MC, Baghdadli A. Predictors of an earlier diagnosis of autism spectrum disorder in children and adolescents: a systematic review (1987-2017). *Eur Child Adolesc Psychiatry*. 2023;32(3):375-393. doi:10.1007/s00787-021-01792-9

© 2025 American Medical Association. All rights reserved, including those for text and data mining, AI training, and similar technologies.

Downloaded from jamanetwork.com by University of Wisconsin -Madison user on 04/21/2025

40. Rattaz C, Loubersac J, Michelon C, et al. Factors associated with age of diagnosis in children with autism spectrum disorders: report from a French cohort. *Autism*. 2022;26(8):2108-2116. doi:10.1177/13623613221077724

41. National Center for Health Statistics. U.S. Census populations with bridged race categories. Accessed June 25, 2019. https://www.cdc.gov/nchs/nvss/bridged_race.htm.

42. Lott A, Reiter JP. Wilson confidence intervals for binomial proportions with multiple imputation for missing data. *Am Statistician*. 2020;74(2):109-115. doi:10.1080/00031305.2018.1473796

43. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet*. 2007;370(9596):1453-1457. doi:10.1016/S0140-6736(07)61602-X

44. Micai M, Fatta LM, Gila L, et al. Prevalence of co-occurring conditions in children and adults with autism spectrum disorder: a systematic review and meta-analysis. *Neurosci Biobehav Rev*. 2023;155:105436. doi:10.1016/j.neubiorev.2023.105436

45. Kirby AV, Bilder DA, Wiggins LD, et al. Sensory features in autism: findings from a large population-based surveillance system. *Autism Res*. 2022;15(4):751-760. doi:10.1002/aur.2670

46. Imm P, White T, Durkin MS. Assessment of racial and ethnic bias in autism spectrum disorder prevalence estimates from a US surveillance system. *Autism*. 2019;23(8):1927-1935. doi:10.1177/1362361319827510

47. Healthy People 2030. Increase the proportion of children who receive a developmental screening — MICH-17. US Department of Health and Human Services. Accessed July 24, 2024. https://health.gov/healthypeople/objectives-and-data/browse-objectives/children/increase-proportion-children-who-receive-developmental-screening-mich-17

© 2025 American Medical Association. All rights reserved, including those for text and data mining, AI training, and similar technologies.

Downloaded from jamanetwork.com by University of Wisconsin -Madison user on 04/21/2025