Research Square

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Assessment of child motor development through parent-completed surveys in families with children with Autism Spectrum Disorder. An observational, cross-sectional study

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Abstract

BACKGROUND: Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by deficits in communication and social interaction. Motor impairments appear early and often constitute the first warning signs reported by families. Parental concerns typically emerge around 23 months, although diagnosis may occur substantially later. The aim of this study was to examine motor development in children with ASD using an ad hoc caregiver survey and to describe family members' perceptions of motor development.

METHODS: This observational, cross-sectional study included 156 participants (mean age 4.90 ± 1.06 years), of whom 74% were male.

RESULTS: No children with 0 or 1 previously acquired milestones achieved independent walking before 12 months. Among those who walked before 12 months, 39.4% had achieved all prior milestones within the expected timeframe. Each additional milestone increased the odds of early walking by a factor of 2.5.

CONCLUSIONS: Motor development showed delays compared with normative data, particularly in head control and crawling patterns. Parental perceptions were consistent with the timing and number of milestones achieved.

1. Background

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by deficits in communication and social interaction domains[1,2] with sensory disturbances and restrictive and repetitive patterns of behavior according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5)[1,2].

Current prevalence is estimated at approximately 1 in 59 individuals by DSM-5 criteria[1]. Global prevalence has been estimated at 119.25 per 10,000 individuals by Zeidan *et al.*[3]. Variability across regions has also been documented[3,4]. For example, in Europe, the mean prevalence is 63.1 per 10,000, with a median of 47.4 per 10,000[3], whereas rates range from 4 per 1,000 children with ASD in New Jersey to 2 per 1,000 in Indonesia[4].

Regarding the age of identification, advances in screening and diagnostic practices indicate that autism can be reliably identified as early as 18–24 months, when core symptoms begin to differentiate from typical development[3,5].

However, the age at formal diagnosis remains substantially later. Martinez *et al.*[6] reported a mean age at diagnosis of 38.8 months. Similarly, a European sample (n = 1410) showed a mean diagnostic age of 42.16 months (SD = 13.42)[7].

Parental concerns are often the first warning signs. Höfer *et al.*[8] reported that, although parental concerns emerged earlier (mean age 23.4 months), diagnosis was established much later, at a mean age of 78.5 months.

Motor impairments in children with ASD appear from an early age, predominantly serving as the first warning signs families report[9]. Hyman *et al.* in 2020[2] and Lord *et al.* in 2018[10] described variations in muscle tone and alterations in coordination function as motor impairments that are not mentioned in DSM-5[1].

During childhood, differences in the timing of motor milestone acquisition tend to widen between children with ASD and their typical development peers[9]. Overall, this has been shown to negatively impact autonomy and participation[11, 12].

Nevertheless, by the time children are typically identified and referred for intervention during the second year of life[5, 13], the most foundational motor milestones of early development including head control, rolling, independent sitting, and the onset of independent ambulation have already been achieved[14, 15].

Direct observation of early motor milestones cannot always be performed in clinical settings, where motor development is typically assessed using standardized tools such as the Alberta Infant Motor Scale (AIMS)[15] and the Peabody Developmental Motor Scale, Second Edition (PDMS-2)[16] as well as broader developmental measures such as the Mullen Scales of Early Learning (MSEL)[17]. Given the importance of early motor development, reconstructing the chronological sequence of milestone acquisition becomes necessary. This process relies on parental reporting, a well-established methodological approach in early developmental assessment. In this context, caregiver-provided information is routinely collected through both qualitative methods, such as guided open-ended surveys[18], and standardized, validated instruments designed to document the timing and progression of developmental milestones. Examples include the Ages & Stages Questionnaire, Third Edition (ASQ-3)[19], the Modified Checklist for Autism in Toddlers (M-CHAT)[20] for early screening, and developmental history measures such as the Early Motor Questionnaire (EMQ)[21] and the Vineland Adaptive Behavior Scales (VABS)[22], all of which systematically capture parental observations relevant to early motor and behavioral development.

The aim of this study is to examine the motor development in children with autism spectrum disorder using an a-hoc survey designed by the authors.

2. Methods

This study is an observational, cross-sectional descriptive study based on a self-administered caregiver survey, using a non-probability convenience sampling approach.

A total of 164 families of children aged 0–6 years with a clinical diagnosis of ASD participated in the study. Responses were screened for completeness and adherence to eligibility criteria; five incomplete questionnaires and three submissions that did not meet eligibility criteria were excluded, resulting in a final sample of N = 156.

Inclusion criteria required families to be living in Spain, having a child aged 0–6 years, and having a formal ASD diagnosis established by a mental health professional or a medical specialist. Exclusion criteria were the presence of additional neurological or motor conditions that could significantly affect motor development (e.g., epilepsy, Down syndrome, cerebral palsy, fragile X syndrome), as well as visual or hearing impairments.

This study was conducted following the Declaration of Helsinki and approved by the Research Ethics Committee, specifically the Subcommittee on Human Samples and Studies in Humans of XXX, and all caregivers provided informed consent before participating.

Motor development and diagnostic information were assessed using a caregiver-reported, self-administered survey, developed by the authors of the study and implemented through Microsoft Forms (An additional file shows this in more detail [see Additional file 1). Caregivers of children with ASD and representatives from autism associations were consulted during the development of the survey to ensure the relevance and clarity of the items. The instrument comprised multiple item formats designed to capture both early developmental milestones and current motor abilities in children diagnosed with autism spectrum disorder.

The demographic section included closed categorical questions assessing birth date, sex, and age at ASD diagnosis. The motor development section consisted of ordered closed-choice items documenting the ages at which children achieved key gross motor milestones, including:

- Head control, the child is able to keep the head in the midline.
- Rolling from supine to prone.
- Sitting without support, the child independently achieves and exits a sitting position and is able to balance the weight of the trunk while playing for up to 10 seconds.
- Crawling, considered hands and knees crawling when the child's stomach does not touch the supporting surface[23].
- Alternative modes of mobility (creeping, bottom shuffling, rolling, bear crawling...)
- Walking alone, the child shows the capacity to take more than six steps without holding on and can change direction without losing balance.

Data collection occurred between May and August 2025. The online survey was disseminated through early intervention centers, social media platforms (LinkedIn and Instagram), relevant associations, and printed posters in assistive centers for children. Caregivers accessed the survey through a secure link and completed it independently.

Upon accessing the survey, participants were first presented with detailed information about the aims and procedures of the study and provided electronic informed consent before proceeding. The average completion time for the full instrument was 6 minutes and 51 seconds, indicating low participant burden.

Data analysis consisted of descriptive statistics aimed at characterizing the sample and all study variables. Categorical variables (e.g., sex, age ranges for milestone acquisition) were summarized using frequencies and percentages. Age was described using the mean.

A new variable was created summarizing the number of milestones prior to walking (head control, rolling, sitting, and crawling) that were acquired before the estimated normative age, named *'previous milestones'*, and another variable which included the five milestones assessed on the survey named '*motor development indicator*'. The association between previous milestones and the age of walking acquisition was analyzed using the Pearson chi-square test, and the linear trend was additionally evaluated using the linear-by-linear association test. A binary logistic regression was performed to examine the association between the number of milestones acquired before the expected age and the probability of achieving independent walking before 12 months. Results were expressed as odds ratios with 95% confidence intervals. The relationship between the motor development indicator and parental perception of MD was analyzed using Spearman correlation.

Statistical analyses were conducted using SPSS 29.0.2.0.

3. Results

A total of 156 participants were eligible, mean age 4.90 ± 1.06. 74% of participants were male. The predominant diagnosis age was between two years and two years, eleven months. Mothers were respondents in 90% of the surveys. For more results see Table 1.

Table 1
Demographic and diagnostic characteristics of the sample.

Variable	Category	n	%
Sex			
	Male	116	74.4
	Female	40	25.6
Respondant			
	Mother	141	90.4
	Father	3	1.9
	Both	10	6.4
	Other family member	2	1.3
Age at diagnosis			
	0–23 months	30	19.2
	24–35 months	68	43.6
	36–47 months	32	20.5
	48–59 months	16	10.3
	60–71 months	5	3.2
	≥ 72 months	5	3.2
Note: percentages are calculated based on the total sample (n = 156).			

In the motor development questions, 50% of participants achieved head control before three months of age. Regarding rolling from supine to prone, 63% initiated this milestone before they were six months. Additionally, 89% of children were sitting without support before ten months of age. Crawling was reported in 83% of participants (n = 129), with 44 children acquiring this skill before nine months of age. Finally, 81% began independent walking after 12 months. Further details are presented in Table 2.

Table 2
Age of acquisition of early motor milestones.

Milestone	Category	n	%
Head control			
	Before 3 months	78	50.0
	After 3 months	58	37.2
	Do not remember	20	12.8
Rolling over (supine–prone)			
	Before 6 months	99	63.5
	After 6 months	57	36.5
Sitting without support			
	Before 10 months	139	89.1
	After 10 months	17	10.9
Crawling			
	Before 9 months	44	28.2
	After 9 months	85	54.5
	No crawling	27	17.3
Walking alone			
	Before 12 months	29	18.6
	After 12 months	127	81.4
Note: percentages are calculated based on the total sample (n = 156).			

No children with 0 or 1 previously acquired milestones achieved independent walking before 12 months. Among those who achieved walking before 12 months, 39.4% corresponded to children who had attained all previous milestones within the expected timeframe. Further details are presented in Fig. 1 and Table 3.

Figure 1. Independent walking before and after 12 months according to the number of previous motor milestones

Table 3
Association between previous motor milestones and independent walking before 12 months

Previous milestones	Walking < 12 months		Walking ≥ 12 months		Total
	n	%	n	%	
0	0	0.0	10	100.0	10
1	0	0.0	26	100.0	26
2	6	15.4	33	84.6	39
3	10	20.8	38	79.2	48
4	13	39.4	20	60.6	33
Total	29	100	127	100	156

Note: Percentages are calculated within each level of previous milestones. Chi-square test: $\chi^2 = 18.082$; $p = 0.001$

The number of previous motor milestones acquired at the expected age was significantly associated with independent walking before 12 months (OR = 2.518; 95% CI: 1.564–4.055; p < 0.001). For each additional milestone achieved at the expected age, the odds of early walking increased by a factor of 2.5. The model was globally significant (p < 0.001) and showed adequate fit according to the Hosmer–Lemeshow test (p = 0.442).

A positive correlation was observed between parental perception of motor development and the number of milestones acquired at the expected age (Spearman's rho = 0.433; p < 0.001).

4. Discussion

Age of diagnosis.

In the present sample, 43.6% of ASD diagnoses were established between 24 and 35 months of age, indicating an early concentration of diagnoses. The age at diagnosis of ASD has been widely discussed in the literature. While initial parental concerns are typically reported around two years of age[24] and reliable diagnosis can be achieved as early as 18 months[3,5], the average age at diagnosis remains considerably higher. For instance, Martinez *et al.*[6] reported a mean age at diagnosis of 38.8 months. Similarly, Salomone *et al.*[7] described a mean age of 42.16 months in Europe, while higher ages have been reported in other regions, such as 58 months in Nepal[25] and 7.2 years in Japan[26]. In comparison, the distribution observed in the present study suggests a trend toward earlier diagnosis relative to these reports. This earlier pattern of diagnosis may reflect increased awareness, improved screening practices, or differences in access to diagnostic services.

Head control

The analysis of **head control as** the earliest milestone is limited by scarce normative data. Standardized assessments as the AIMS[15], indicate that 50% of infants achieve this ability by one and a half months of age and 90% by almost three months. In the same position, ASQ-3[19] reports typical acquisition of head control between two and four months. Furthermore, the PDMS-2[16] considers head control when the baby is held in the arms, but age stills at one month. In our sample, only 50% reached this milestone before three months, while 37.2% had not achieved it by that age, suggesting a 4:1 ratio of participants with delay in head control acquisition. Compared with normative references, this represents a markedly increased proportion of later acquisition. However, these findings should be interpreted cautiously, as retrospective parental reporting may be affected by recall bias, particularly for early motor behaviors.

Rolling

Ozonoff *et al.*[27] examined parental reports in children with ASD and typically developing peers, distinguishing between ASD with and without regression; in both groups, the reported age of **rolling** was below six months.

In the AIMS[15], 50% of infants achieve **rolling from supine to prone** between five and seven months. The PDMS-2[16] reports a similar range, assessing this skill at 7 months, while the ASQ-3[19] evaluates it at 6 and 8 months. Our findings are consistent with these instruments and align with those reported by Ozonoff *et al.*[27] in ASD populations, as 63.5% of participants (n = 99) were reported to roll before six months, based on parental responses.

One possible explanation is that parental concern about delayed head control may have prompted professional guidance, increased tummy time exposure, and promoting autonomous motor exploration, thereby facilitating earlier rolling acquisition.

Sitting

During the survey, **sitting** was defined as the ability to independently assume and exit the position which is a demanding criterion aligned with PDMS-2 (10 months)[16] and AIMS (50th percentile at 9 months; 90th at 11.25 months)[15]. Notably, 10.9% of children in our sample had not achieved this milestone by 10 months.

In contrast, Ozonoff *et al.*[27] reported mean ages of 6.8 months in children with ASD without regression and 5.9 months in those with regression, both higher than typically developing peers (5.17 months), although their measure was limited just to maintaining the sitting position.

Overall, our findings align more closely with motor assessment frameworks such as the PDMS-2[16] and AIMS[15] than with the data reported by Ozonoff *et al.*[27], likely reflecting differences in how this milestone is operationalized across instruments and professionals. Specifically, maintaining a seated position differs from the ability to independently assume and exit that position.

Crawling on hands and knees.

The study carried out by the World Health Organization (WHO) in 2006[14] aimed to generate windows of achievement and to present the actual windows for six milestones (sitting without support, standing with assistance, standing alone, hands and knees crawling, walking with assistance, walking alone) in typical development children. A previous study preceding and outlining these six milestones used by the WHO defined[23] **crawling on hands and knees** as **crawling** with the stomach not touching the supporting surface. However, this is not considered an essential milestone, as infants may use alternative locomotion strategies (creeping, bottom shuffling, rolling, bear crawling...). The WHO[14] defines non-crawlers as infants who do not use hand-and-knees crawling as defined and reports a prevalence of 4.3%. In our sample, the proportion of non-crawlers (17.3%) was approximately four times higher than that reported in the WHO study[14]. These alternative locomotion strategies were frequently observed within this group; notably, more than 50% of non-crawlers used other forms of forward movement on the floor rather than upright ambulation.

Across the sources consulted, a relatively consistent age range for the acquisition of **hands-and-knees crawling** is observed. The WHO Study[14] reports the 90th percentile at 10.5 months, while the PDMS-2[16] falls within this range, initiating assessment of crawling at 9 months. The AIMS[15] extends the 90th percentile to 13 months.

In accordance with the WHO study[14] and PDMS-2[16], Ozonoff *et al.*[27] reported a mean crawling age of 10.9 months in typically developing children, which was higher than in children with ASD, regardless of regression (8.31m without regression; 7.32m with regression). In contrast, our findings indicate that children with ASD in our sample achieved crawling later compared with WHO Normative data[14]. Specifically, only 28.2% of the total sample had acquired crawling by 9 months, whereas the WHO Study[14] places the 75th percentile at approximately 9.3 months.

Independent walking.

In our study, independent walking was defined as the ability to take at least six steps and change direction without losing balance. The PDMS-2[16] and the WHO Study[14] describe the ability to take at least five steps, a criterion comparable to that used in our survey. Both PDMS-2[16] and the WHO Study[14] report a mean age of **independent walking** of 12 months. Ozonoff *et al.*[27] reported earlier mean ages in typical development children (10.0 months) compared with children with ASD (13.44 months without regression; 12.17 months with regression). Similarly to Ozonoff's results[27], 81.4% of children in our study had not achieved independent walking by 12 months, indicating a substantial delay relative to standardized developmental expectations.

Global motor development analysis.

In our sample, the number of participants who achieved independent walking before 12 months increased with the number of previous motor milestones acquired at the expected age. No children who had achieved only 0 or 1 previous milestones attained independent walking before 12 months. A significant association was observed between the number of milestones achieved and the age of independent walking acquisition, with each additional milestone increasing the odds of early walking by a factor of 2.5.

These findings are consistent with those reported by Lloyd *et al.* (2014)[28], who identified associations between earlier sitting and walking and better gross motor proficiency in toddlers with ASD. Similarly, Pokoski *et al.* (2025)[29] highlights the importance of early motor development in the early identification of ASD.

Parental perception of motor development.

Better parental perception of their children's motor development was associated with higher scores on the motor development indicator. This suggests that parents perceive motor development more positively when children achieve a higher number of milestones at the expected age.

Further investigations should include larger and more representative samples, as well as prospective observational studies following children at risk of ASD from birth. Given the substantial heterogeneity of ASD, larger samples would help capture a wider range of developmental profiles and increase the generalizability of the findings. Particular attention should be paid to the motor milestones identified in this study as being most frequently altered, including head control, crawling, and independent walking. In addition to recording the timing of milestone acquisition, future studies should assess movement quality, as qualitative differences may provide valuable information regarding early motor development and improve the identification of ASD-related motor patterns. Although the sex distribution observed in this study is consistent with previous literature, the slightly lower proportion of males compared with previous reports may be attributable to sample characteristics and recruitment procedures.[1,3,4,18,24,30–33].

These findings contribute to the understanding of early motor development in children with ASD. The proportion of non-crawlers was four times higher in the ASD group than in the typically developing group reported by the WHO study[14]. Furthermore, the observed association between early motor milestone attainment and independent walking suggests that motor development may play a significant role in the timely acquisition of walking, with each additional milestone increasing the odds of early walking by a factor of 2.5. Early physiotherapy intervention may therefore support motor development and facilitate the achievement of independent walking in children at risk of ASD.

5. Conclusion

Motor development in children with ASD, as reported through caregiver-provided records, showed notable differences compared with normative references. Specifically, there was a markedly higher proportion of later acquisition of head control. Differences were also observed in the proportion of crawlers versus non-crawlers. Additionally, discrepancies in the acquisition of crawling and walking, as well as a reduced number of milestones acquired, suggest an overall delayed developmental pattern in our cohort. Furthermore, families' perceptions of their children's development were consistent with the timing and number of milestones acquired.

Abbreviations

- **ASD**
Autism Spectrum Disorder
- **DSM-5**
Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition
- **AIMS**
Alberta Infant Motor Scale
- **PDMS-2**
Peabody Developmental Motor Scale, Second Edition
- **MSEL**
Mullen Scales of Early Learning
- **ASQ-3**
Ages & Stages Questionnaire, Third Edition
- **M-CHAT**
Modified Checklist for Autism in Toddlers
- **EMQ**
Early Motor Questionnaire
- **VABS**
Vineland Adaptive Behavior Scales
- **WHO**
World Health Organization

Declarations

- **Ethics approval and consent to participate.**

This study was conducted following the Declaration of Helsinki and approved by the Research Ethics Committee, specifically the Subcommittee on Human Samples and Studies in Humans of San Pablo–CEU University with protocol code 997-25 126 on 22 April 2025.

- **Informed Consent Statement.**

Written informed consent was obtained from the parents or legal guardians of all subjects involved in the study before starting answering the survey.

- **Consent for publication.**

Not applicable.

- **Data availability**

The datasets used and/or analysed in the current study are available from the corresponding author upon reasonable request.

- **Competing interests**

The authors declare that they have no conflicts of interest.

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- **Authors' contributions.**

PUG: Conceptualization; methodology; writing: original draft, review, and editing; analysis, validation, and data processing.

FGMSJ and BCD: Conceptualization; methodology; writing: review, supervision, and editing.

ALRF: analysis, validation, and data processing.

EN: writing: original draft, review, and editing.

XGARD and AMI: Conceptualization; methodology.

All the authors read and agreed with the published version of the manuscript.

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References

1. American Psychiatric Association D-5 TF. *Diagnostic and Statistical Manual of Mental Disorders: DSM-5™., 5th Ed*. American Psychiatric Publishing, Inc.; 2013. doi:10.1176/appi.books.9780890425596

2. Hyman SL, Levy SE, Myers SM. Identification, Evaluation, and Management of Children With Autism Spectrum Disorder. Pediatrics. 2020 Jan 1 ;145(1):1–64.
3. Zeidan J, Fombonne E, Scorah J, Ibrahim A, Durkin MS, Saxena S, et al. Global prevalence of autism: A systematic review update. Autism research : official journal of the International Society for Autism Research. 2022 May 1
4. Pusponegoro HD, Efar P, Soedjatmiko, Soebadi A, Firmansyah A, Chen H-J, et al. Gross Motor Profile and Its Association with Socialization Skills in Children with Autism Spectrum Disorders. Pediatrics and neonatology. 2016 Dec 1; 57(6):501–7
5. Meng-Chuan Lai, Lombardo MV, Baron-Cohen S. Autism. Lancet. 2014 Mar 8; 383(9920):896–910.
6. Martinez M, Thomas KC, Williams CS, Christian R, Crais E, Pretzel R, et al. Family Experiences with the Diagnosis of Autism Spectrum Disorder: System Barriers and Facilitators of Efficient Diagnosis. Journal of Autism & Developmental Disorders. 2018 Jul 1; 48(7):2368–78.
7. Salomone E, Charman T, McConachie H, Warreyn P. Child's verbal ability and gender are associated with age at diagnosis in a sample of young children with ASD in Europe. Child: Care, Health & Development. 2016 Jan 1; 42(1):141–5.
8. Höfer J, Hoffmann F, Kamp-Becker I, Poustka L, Roessner V, Stroth S, et al. Pathways to a diagnosis of autism spectrum disorder in Germany: a survey of parents. Child and adolescent psychiatry and mental health. 2019 Mar 21; 13:16.
9. Harris S, Harris SR. Early motor delays as diagnostic clues in autism spectrum disorder. European Journal of Pediatrics. 2017 Sep 1; 176(9):1259–62.
10. Lord C, Elsabbagh M, Baird G, Veenstra-Vanderweele J. Autism spectrum disorder. Lancet. 2018 Aug 11; 392(10146):508–20.
11. Fournier KA, Hass CJ, Naik SK, Lodha N, Cauraugh JH. Motor Coordination in Autism Spectrum Disorders: A Synthesis and Meta-Analysis. Journal of Autism & Developmental Disorders. 2010 Oct 1; 40(10):1227–40.
12. Pokoski OM, Engel H, Furnier SM, Gangnon R, Powell P, Reyes N, et al. The Association Between Motor and Social Skills in Young Autistic Children Enrolled in the Study to Explore Early Development. Autism: The International Journal of Research & Practice. 2026 May 28; 1.
13. Zwaigenbaum L, Bauman ML, Stone WL, Yirmiya N, Estes A, Hansen RL, et al. Early Identification of Autism Spectrum Disorder: Recommendations for Practice and Research. Pediatrics. 2015 Oct 1; 136 Suppl 1:S10–40.
14. WHO Multicentre Growth Reference Study Group. WHO Motor Development Study: windows of achievement for six gross motor development milestones. Acta paediatrica (Oslo, Norway : 1992) Supplement. 2006 Apr 1; 450:86–95.
15. Piper MC, Spittle A, Darrah J. Motor assessment of the developing infant : Alberta infant motor scale (AIMS). 2nd ed. St. Louis (Missouri): Elsevier; 2021.
16. Mary Rhonda Folio, Rebecca Fewell. Peabody Developmental Motor Scales–Second Edition (PDMS-2). 2nd Ed. PRO-ED, editor. Austin, TX; 2000.

17. Mullen E. Mullen Scales of Early Learning. American Guidance Service, editor. Circle Pines, MN; 1995.
18. Müller A, Bába ÉB, Židek P, Lengyel A, Lakó JH, Laoues-Czimbalmos N, et al. The Experiences of Motor Skill Development in Children with Autism Spectrum Disorder (ASD) Reflected through Parental Responses. Children. 2024 Oct 1; 11(10):1238.
19. Squires J, Bricker D. Ages & Stages Questionnaires, Third Edition (ASQ-3). 3rd Edition. Baltimore, MD: Paul H. Brookes Publishing Co.; 2009.
20. Levick S, Staples AD, Warschausky S, Huth-Bocks A, Taylor HG, Gidley Larson JC, et al. Caregiver-reported infant motor and imitation skills predict M-CHAT-R/F. Child Neuropsychology. 2024 Oct 1; 30(7):1035–53.
21. Libertus, K., & Landa, R. J. (2013). The Early Motor Questionnaire (EMQ): a parental report measure of early motor development. Infant Behavior & Development, 36(4), 833–842. https://doi.org/10.1016/j.infbeh.2013.09.007
22. Bhat AN. Validating motor delays across the developmental coordination disorder-questionnaire and the Vineland adaptive behavior scales (VABS) in children with autism spectrum disorderASD: A SPARK dataset analysis. Autism research : official journal of the International Society for Autism Research. 2024 Oct 1; 17(10):2079–91.
23. Wijnhoven TM, de Onis M, Onyango AW, Wang T, Bjoerneboe G-EA, Bhandari N, et al. Assessment of gross motor development in the WHO Multicentre Growth Reference Study. Food and nutrition bulletin. 2004 Mar 1; 25: S37–45.
24. Chen W-X, Liu X, Huang Z, Guo C, Feng F, Zhang Y, et al. Autistic clinical profiles, age at first concern, and diagnosis among children with autism spectrum disorder. Frontiers in psychiatry. 2023 Aug 17; 14:1211684.
25. Shrestha R, Dissanayake C, Barbaro J. Age of Diagnosis of Autism Spectrum Disorder in Nepal. Journal of Autism & Developmental Disorders. 2019 Jun 1; 49(6):2258–67.
26. Kurasawa S, Tateyama K, Iwanaga R, Ohtoshi T, Nakatani K, Yokoi K. The Age at Diagnosis of Autism Spectrum Disorder in Children in Japan. International journal of pediatrics. 2018 May 7; 2018:5374725.
27. Ozonoff S, Young GS, Goldring S. Gross Motor Development, Movement Abnormalities, and Early Identification of Autism. Journal of Autism and Developmental Disorders. 2008 Apr 1; 38(4):644–56.
28. Lloyd M, Macdonald M, Lord C. Motor skills of toddlers with autism spectrum disorders. Autism: The International Journal of Research & Practice. 2013 Mar 1; 17(2):133–46.
29. Pokoski OM, Furnier SM, Gangnon RE, Howerton EM, Kirby AV, Protho T, et al. Prevalence of Motor Milestone Delays in Autistic Children. JAMA Pediatrics. 2025 Jul 1; 179(7):756–64
30. Curtin C, Anderson SE, Must A, Bandini L. The prevalence of obesity in children with autism: a secondary data analysis using nationally representative data from the National Survey of Children's Health. BMC pediatrics. 2010 Feb 23; 10:11.

31. Mohd Nordin A, Ismail J, Kamal Nor N. Motor Development in Children With Autism Spectrum Disorder. Frontiers in pediatrics. 2021 Sep 15; 9:598276.
32. Wu Y, Ding L, Zhang Q, Dong Y, Tao C, Li Z, et al. The effect of physical exercise therapy on autism spectrum disorder:a systematic review and meta-analysis. Psychiatry research. 2024 Sep 1; 339:116074.
33. Talantseva OI, Romanova RS, Shurdova EM, Dolgorukova TA, Sologub PS, Titova OS, et al. The global prevalence of autism spectrum disorder: A three-level meta-analysis. Frontiers in psychiatry. 2023 Feb 9; 14:1071181.

Figures

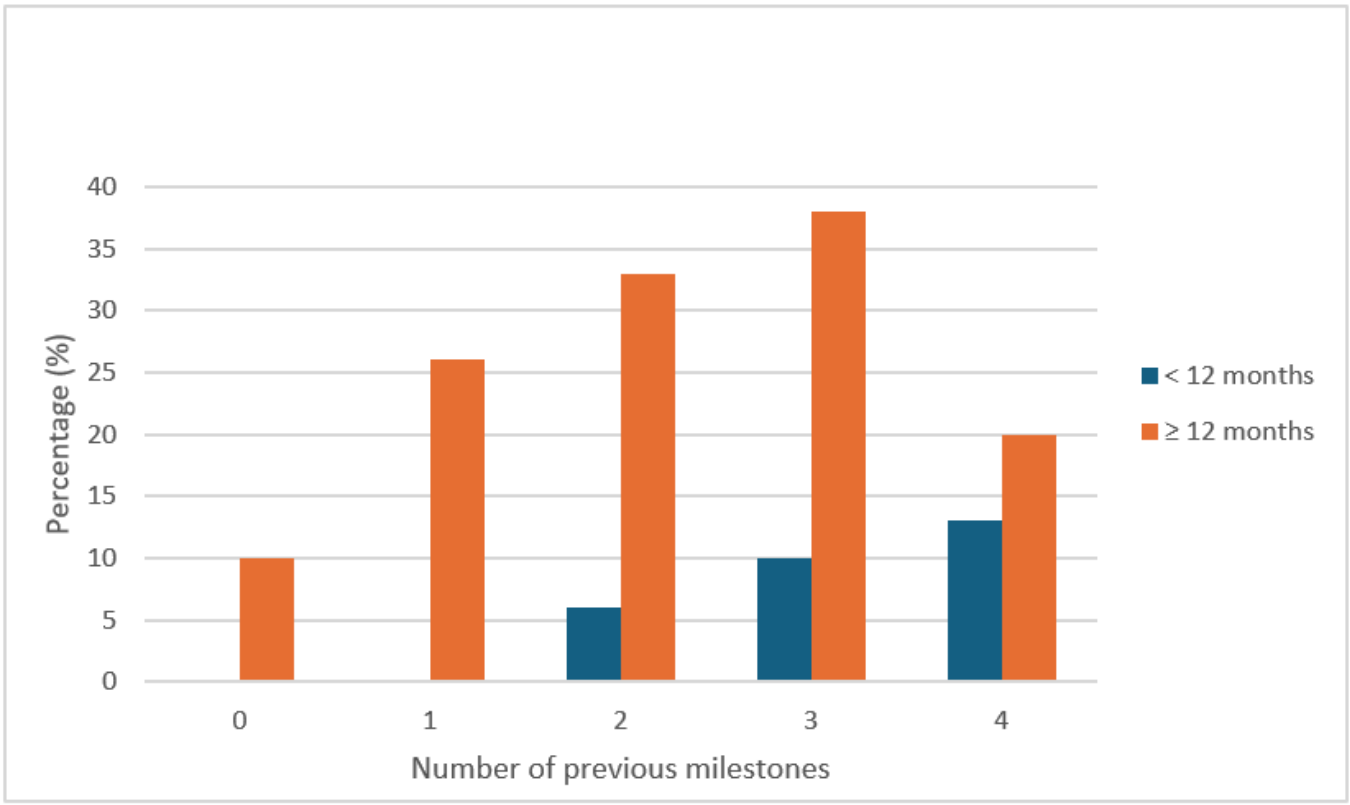

Figure 1

Independent walking before and after 12 months according to the number of previous motor milestones

Supplementary Files

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- Additionalfile1.pdf