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Spatiotemporal Characteristics and Their Variability During Running in Girls With Intellectual Disabilities

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ABSTRACT

Background and Objectives: Balance and gait capacity are key aspects of mobility that are often impaired in individuals with intellectual disabilities. This study examined spatiotemporal parameters and step-to-step variability during running in children with intellectual disability (ID) compared to typically developing (TD) peers.

Methods: This descriptive cross-sectional study involved 16 girls with ID (aged: 7–13 years) and 17 age-matched TD peers. ID was diagnosed according to DSM-5 criteria and official school psychological records. Participants ran at a self-selected pace while crossing a 15-cm obstacle. Then, spatiotemporal parameters and their variability were recorded using a Vicon motion capture system synchronized with Kistler force plates. The obtained data were processed with standard filtering methods, and the coefficient of variation was used to quantify variability. Finally, group, task, and foot effects were analyzed using a repeated-measures analysis of variance (ANOVA) at the P<0.05 significance level.

Results: Running speed, with and without obstacle crossing, was significantly lower in the ID group compared to controls (P=0.008). Furthermore, foot clearance performance during running and obstacle crossing was significantly different between groups (P=0.038). Moreover, the variability of most spatiotemporal parameters, particularly during obstacle crossing tasks, was significantly higher in children with ID than in controls (P<0.05).

Conclusion: Overall, running speed was most sensitive to cognitive impairments in children with ID. Increased variability, especially during obstacle crossing, may increase the risk of falls. In addition, the observed reduction in running speed among children with ID may represent an adaptive strategy to enhance safety when negotiating obstacles.

Keywords: Intellectual disability (ID), Running, Obstacle crossing, Variability

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What is "already known" in this topic:

Children with ID demonstrate impaired balance, delayed motor skills, and altered spatiotemporal gait parameters compared with typically developing peers. Most studies have examined walking, often in individuals with Down syndrome, with inconsistent results. Accordingly, evidence on running performance and variability in children with non-syndromic ID remains scarce.

What this article adds:

The findings highlight that running speed is significantly lower and variability is markedly higher in the ID group, especially during obstacle crossing. These results suggest that reduced running speed may serve as an adaptive strategy to enhance safety. The study provides novel insights into designing targeted interventions to improve motor performance while reducing fall risk in this population.

Introduction

Intellectual disability (ID) is a developmental disorder characterized by distinct physiological and anatomical features that set affected individuals apart from typically developing (TD) populations [1]. ID can result from diverse genetic and environmental factors [2]. When associated with a specific genetic syndrome, such as Down syndrome (DS), specific physical characteristics (including ligamentous laxity and muscular hypotonia) can impair static and dynamic balance, increase postural control variability [3], and delay the acquisition of fundamental motor skills [4]. However, motor performance is also impaired in children and adults with ID without genetic etiologies. According to some studies, individuals with ID demonstrate significant delays in the average age of walking onset compared to TD peers [5, 6]. Furthermore, cognitive impairments are directly related to motor performance, such as deficits in executive functions [7], sensory systems [8], and underdevelopment of the central nervous system [9]. They have been identified as major contributors to poorer balance [10], reduced postural control, and increased risk of falling in children with ID [11].

Additionally, previous studies have suggested that individuals with ID may exhibit a high prevalence of balance and gait problems influenced by multiple underlying mechanisms [12, 13]. The first factor contributing to mobility limitations is the stopped or incomplete development of the nervous system, which affects both cognitive and motor functions [14]. The second influential factor is premature aging across various body systems. Mobility-related issues in these individuals emerge earlier and more frequently than in age-matched peers without ID, potentially leading to reductions in muscle strength and sensory functions (e.g. visual, proprioceptive, and vestibular) over time [10]. A third factor is the relatively inactive lifestyle often observed among individuals with ID, resulting in decreased physical capacities (e.g. endurance, balance, and muscular strength) compared to their TD counterparts [15]. Some studies have indicated that children with ID exhibit approximately 65% lower motor competence in performing fundamental motor skills than TD children [16, 17]. Moreover, these children demonstrate inferior motor skills relative to their same-aged peers without intellectual impairments [18]. Research findings consistently indicate that children with ID experience delays in fundamental motor skill acquisition, sensory-motor dysfunction, retardation in motor development, deficits in movement control, impairments in motor sequencing, reduced attention span, and poor perceptual abilities [19].

Impairments in balance and gait are commonly associated with ID. However, the current literature is relatively scarce in research specifically addressing running and its various parameters in individuals with ID. Most existing studies have primarily focused on gait variables, particularly among individuals with DS. These studies have yielded contradictory findings due to differences in the severity and type of intellectual impairment, as well as variations in assessment conditions and methodologies. According to some reports, individuals with ID show reduced swing time, shorter step durations, narrower step widths [20], shorter step and stride lengths, and lower gait speeds and cadences compared to TD peers [21]. Conversely, other studies have reported increased step and stride widths, prolonged stance time, increased double-support time [22], greater stride and step lengths [20], and higher gait speed [23] compared to control groups.

Additionally, Azadian et al. found no significant differences in spatiotemporal parameters between ID and control groups during normal walking. However, they observed a significant increase in variability under more challenging conditions, such as obstacle crossing [24]. These inconsistencies highlight the need for further research to clarify the nature of locomotor characteristics in children with ID.

Walking and running are fundamental locomotor skills that serve as the critical indicators of overall body coordination and motor development [25]. Given that running is inherently more complex than walking and requires greater degrees of freedom and coordination among lower-limb segments, examining its specific characteristics could provide deeper insights into motor control mechanisms in individuals with ID. In the only known study addressing this issue, Kınacı-Biber et al. reported significant differences in running parameters (e.g. stride length, step width, and swing phase duration) between children with DS and TD controls [26]. However, to the best of our knowledge, no study has systematically examined running characteristics in children with non-syndromic ID.

Studying the spatiotemporal parameters of running can provide deeper insights into motor control in this population, as running is a more complex skill than walking and requires greater coordination. This gap in the literature highlights the importance of investigating running characteristics in children with non-syndromic ID, as it may provide valuable insights into their motor control strategies and potential risks. Thus, this study primarily aims to investigate the spatiotemporal characteristics of running and the impact of obstacle crossing on these parameters in children with ID compared to TD peers.

Variability in motor tasks is a well-established risk factor for falling among individuals with neurological impairments and has received considerable attention from researchers [27]. Based on previous evidence, individuals with ID, especially those with IQ scores below 75 or cognitive function limitations, are particularly vulnerable to falls [28]. According to criteria defined by the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), individuals with ID share fall-risk factors (e.g. reduced muscular strength and balance) with elderly populations, suggesting they may experience falls at earlier ages [29]. Rigoldi et al. demonstrated that individuals with DS reduced the variability of their gait parameters by limiting the degrees of freedom during walking [30]. In contrast, other researchers have shown that adolescents with DS exhibit greater variability than adults with DS, reflecting a less organized motor control strategy [31]. Despite these findings, research examining the variability of running characteristics in children with ID, particularly in non-syndromic cases and under challenging conditions (e.g. obstacle crossing), remains scarce. Thus, addressing this gap can provide important insights into motor control strategies and potential fall-related risks in this population. Therefore, this study also seeks to examine the variability of spatiotemporal running characteristics and evaluate the effects of obstacle crossing on this variability among children with ID compared to TD peers.

Materials and Methods

Study participants

This descriptive cross-sectional study included 33 female students aged 7-13 years (ID group: 11.33±1.94 years; control group: 11.88±2.03 years). Sixteen girls with ID (without associated genetic disorders) were included in the study. The diagnosis of ID was based on DSM-5 criteria, and IQ scores ranging from 50 to 70 were obtained from each participant's official school psychological records. These records, available in the students' files, were determined by trained school psychologists using the Wechsler Intelligence Scale for Children, a standardized instrument commonly employed in Iranian educational and psychological services. In addition, 17 age-matched girls with typical development were recruited from local elementary and middle schools using convenience sampling to form the control group. The inclusion criteria for all participants were the absence of neurological disorders (other than ID for the ID group), absence of chronic medical conditions, normal or corrected vision and hearing, and no history of lower-limb injuries within the previous six months [32].

Study procedure

In this study, a Vicon motion capture system (Oxford Metrics, Oxford, UK) with 6 T-series cameras (sampling rate of 100 Hz) and two Kistler force platforms (Type 9281, Kistler Instrument AG, Winterthur, Switzerland; sampling rate of 1000 Hz) were utilized to measure the relevant kinematic and kinetic parameters. Sixteen reflective spherical markers (14 mm in diameter) were bilaterally attached to the anatomical landmarks of the participants' lower limbs according to the Plug-in Gait Marker Set model (Vicon Peak, Oxford, UK) [33]. Moreover, data from the force platforms were used to identify gait events. Participants initiated their runs approximately three steps before and finished three steps beyond the calibrated area, thereby eliminating acceleration and deceleration effects [34]. Due to the 3-m length of the calibration volume, each participant completed at least one full stride cycle (left and right steps) within it. It should be noted that participants performed two running tasks along the predefined path. At the same time, kinematic data were recorded: Running at a self-selected speed and running combined with obstacle crossing. They conducted each task 6 times, with a one-minute rest interval between trials. Three successful trials from each task were selected for motion analysis. The obstacle used in this study was a foam block (15 cm high×60 cm long×6 cm wide) positioned centrally within the calibrated running path.

Marker trajectories were processed in Vicon Nexus 1.8.2, with missing data filled using pattern, spline, and rigid-body methods, followed by smoothing with the Woltring quintic spline filter. Furthermore, a fourth-order zero-lag Butterworth filter was applied to kinematic (6 Hz) and kinetic (25 Hz) data [35]. Subsequently, cadence, running speed, step length, stride length, step time, and stride time were calculated using Vicon Polygon software, version 3.5.1. Finally, the variability in running parameters was assessed using the coefficient of variation (CoV) expressed as a percentage, computed by Equation 1 [36]:

1. $\mathrm{CoV}=\frac{\sum \mathrm{SD}}{\mathrm{X}}\times 100$

, where X represents the mean value of each parameter, and ∑SD denotes the summed standard deviation across trials.

Statistical analysis

The normality of data distribution was verified using the Shapiro-Wilk test. Given the normal distribution of data, parametric statistical methods were applied in this study. A three-way repeated-measures analysis of variance was separately conducted for each parameter to evaluate the effects of group (ID vs control), task (running with and without an obstacle), and foot (right vs. left), as well as their interactions. Eventually, statistical analyses were performed using SPSS software, version 26.0 (IBM SPSS Statistics; Armonk, NY, USA) at the $P<0.05$ significance level.

Results

Participants' demographic data are presented in Table 1. No significant differences were observed between the two groups regarding these characteristics.

Spatiotemporal parameters

Table 2 provides the results of the factorial analysis for spatiotemporal parameters. According to these findings, none of the studied factors had a significant effect on cadence ($P>0.05$). However, in both tasks, cadence was consistently lower in the ID group than in the control group (Figure 1).

For running speed, the main effect of group was significant ($P=0.008$). Based on pairwise comparisons, running speed in both tasks (with and without an obstacle) was significantly lower in the ID group than in the control group. Furthermore, the foot×group interaction was significant for running speed ($P=0.038$). Within-group analysis revealed that the running speeds of the leading and trailing limbs during obstacle crossing were similar in the ID group. In contrast, the leading limb speed was significantly higher than the trailing limb speed in the control group. Moreover, step time and stride time were longer in the ID group than in the control group (Figure 1), although these differences did not reach statistical significance. Overall, none of the examined factors, except for the task factor in step time, had a significant effect on these variables. Based on the results (Table 2), step time increased significantly during obstacle-crossing tasks in both groups ($P=0.002$).

Factorial analysis for step length confirmed a significant foot×group interaction ($P=0.030$). Within-group comparisons revealed significant differences between the leading and trailing limbs during obstacle crossing in the control group. In contrast, the ID group exhibited asymmetry in step length between the right and left feet during running without an obstacle. For stride length, the task factor had a significant effect ($P=0.035$), with pairwise comparisons indicating a significant increase during the obstacle crossing running task (Figure 1). Finally, no other factors or interactions had significant effects on stride length or step length ($P>0.05$).

Variability in spatiotemporal parameters

Factorial analysis revealed that variability in running speed was significantly influenced by the group factor ($P=0.001$) and by the task × group interaction ($P=0.040$). Pairwise comparisons showed significantly greater variability in running speed during obstacle crossing than during normal running in the ID group (Figure 2). Nonetheless, cadence variability was not significantly affected by any factors or their interactions ($P>0.05$). Detailed factorial analysis results for variability in running parameters are listed in Table 3.

Table 1. Demographic characteristics of the study participants

Variables	Mean±SD		P
	ID Group (n=16)	Control Group (n=17)	
Age (y)	11.33±1.94	11.88±2.03	0.43
Weight (kg)	45.30±12.24	48.81±9.09	0.24
Height (m)	1.54±0.13	1.57±0.09	0.81
Body mass index (kg/m²)	19.39±4.07	19.56±5.58	0.83

Note: No significant differences were found between groups in demographic variables (P>0.05).

According to the findings, both the group (P=0.039) and the task (P=0.019) factors had significant effects on step-time variability. Pairwise comparisons showed that the ID group exhibited significantly greater step time variability than the control group. Additionally, step-time variability during obstacle crossing was significantly greater than during normal running. Nevertheless, no factors had a significant effect on stride time variability (P>0.05). The analysis of step length variability revealed the significant effects of the group factor and the task × group interaction (P=0.036, Figure 1). Specifically, the ID group indicated significantly greater step length variability than the control group (P=0.019), with variability being notably higher during obstacle crossing than during normal running (Figure 2).

For stride length variability, factorial analysis demonstrated the significant effects of the group factor (P=0.031), the task×group interaction (P=0.027), and the group×foot interaction (P=0.044). According to pairwise comparisons, stride length variability increased by approximately 95% during obstacle-crossing tasks in the ID group compared with normal running. In contrast, the presence of an obstacle led to a 17% decrease in the stride-length variability compared with normal running in the control group.

Discussion

This study investigated the spatiotemporal characteristics and their variability during obstacle crossing in children with ID without genetic disorders, compared with TD peers. Our findings revealed significant differences between the ID and TD groups in several spatiotemporal running parameters and their variability. Among the evaluated parameters, running speed was significantly lower in the ID group compared to the TD group under both running conditions (with and without an obstacle). Additionally, between-group differences in stride time and stride length approached statistical significance. These findings align with the recent results of Kınacı-Biber et al., demonstrating significant differences in running speed, stride length, step width, and swing-phase percentage between children with DS and TD controls. Moreover, they identified significant associations among muscle thickness, cadence, and step length. They suggested that reduced running speed and stride length in the DS group might be attributable to muscle weakness [26]. Given the mobility limitations associated with impairments in cognitive functions, such as executive functioning deficits [14], as well as the typically inactive lifestyle [15] among individuals with ID, their physical capacities (including endurance, balance, and muscular strength) are likely compromised compared to those of their TD peers. Overall, these factors could have contributed to the observed reductions in running speed among participants with ID.

Another notable finding in the present study was the similarity in running speed between the lead and trailing limbs during obstacle crossing in the ID group. Contrarily, the control group demonstrated lower speed in the trailing limb and higher speed in the leading limb. Given known balance deficits in individuals with ID [37], maintaining similar running speeds on both feet appears to be a deliberate strategy to preserve body stability. Conversely, the TD group reduced the speed of the trailing limb to ensure appropriate positioning before obstacle crossing, followed by an accelerated movement of the lead foot over the obstacle.

In the present study, the increase in stride time and decrease in stride length observed in the ID group relative to controls did not reach statistical significance. In contrast, Kınacı-Biber et al reported significant differences in these parameters [26]. This discrepancy is likely due to differences in the severity and type of ID among participants: Their study involved individuals with DS, whereas ours included individuals with educable ID without genetic disorders. Based on our findings, running speed—among the various spatiotemporal parameters evaluated—was the most sensitive parameter to cognitive impairments under both obstacle and non-obstacle running conditions. Therefore, running speed may serve as a practical and effective marker of cognitive impairment.

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Table 2. Factorial analysis of spatiotemporal running parameters in tasks with and without obstacle crossing

Parameters		Mean±SD		Group Effect	Task Effect	Task×Group	Leg Effect	Leg×Group	Leg×Task
		ID Group	Control Group						
Cadence	WOBS-left	181.24±28.45	194.37±24.71	P=0.101 F=2.86 η^2=0.085	P=0.148 F=2.2 η^2=0.066	P=0.910 F=0.013 η^2=0.001	P=0.331 F=0.977 η^2=0.031	P=0.341 F=0.937 η^2=0.029	P=0.946 F=0.005 η^2=0.001
	WOBS-Right	183.31±27.59	195.95±24.21						
	Trailing leg	174.68±24.13	190.35±19.23						
	Leading leg	180.72±24.12	188.85±25.58						
Speed	WOBS-Left	2.07±0.11	2.42±0.17	P=0.008* F=8.1 η^2=0.21	P=0.834 F=0.044 η^2=0.001	P=0.797 F=0.68 η^2=0.002	P=0.825 F=0.049 η^2=0.002	P=0.038* F=4.70 η^2=0.132	P=0.869 F=0.028 η^2=0.001
	WOBS-Right	2.08±0.11	2.38±0.16						
	Trailing leg	2.05±0.12	2.36±0.17						
	Leading leg	2.09±0.11	2.43±0.18						
Step time	WOBS-left	0.34±0.06	0.31±0.04	P=0.129 F=2.44 η^2=0.073	P=0.002* F=11.05 η^2=0.26	P=0.535 F=0.394 η^2=0.013	P=0.326 F=0.998 η^2=0.031	P=0.409 F=0.701 η^2=0.022	P=0.736 F=0.116 η^2=0.004
	WOBS-right	0.34±0.06	0.31±0.03						
	Trailing leg	0.36±0.08	0.33±0.04						
	Leading leg	0.34±0.05	0.33±0.05						
Stride time	WOBS-left	0.68±0.12	0.63±0.08	P=0.071 F=3.49 η^2=0.10	P=0.241 F=1.43 η^2=0.044	P=0.787 F=0.074 η^2=0.002	P=0.294 F=1.14 η^2=0.035	P=0.163 F=2.04 η^2=0.062	P=0.992 F=0.001 η^2=0.001
	WOBS-right	0.68±0.11	0.62±0.07						
	Trailing leg	0.71±0.09	0.64±0.06						
	Leading leg	0.68±0.08	0.65±0.08						
Step length	WOBS-left	0.67±0.08	0.74±0.09	P=0.155 F=2.12 η^2=0.064	P=0.110 F=2.71 η^2=0.08	P=0.481 F=0.51 η^2=0.016	P=0.933 F=0.007 η^2=0.001	P=0.030* F=5.16 η^2=0.14	P=0.284 F=1.19 η^2=0.037
	WOBS-right	0.72±0.15	0.73±0.07						
	Trailing leg	0.70±0.14	0.79±0.09						
	Leading leg	0.71±0.14	0.75±0.09						
Stride length	WOBS-left	1.38±0.21	1.51±0.16	P=0.093 F=3.01 η^2=0.088	P=0.035* F=4.86 η^2=0.14	P=0.776 F=0.082 η^2=0.003	P=0.282 F=1.2 η^2=0.037	P=0.367 F=0.837 η^2=0.026	P=0.563 F=0.341 η^2=0.011
	WOBS-right	1.36±0.15	1.47±0.15						
	Trailing leg	1.43±0.24	1.55±0.20						
	Leading leg	1.44±0.27	1.52±0.21						

ID: Intellectual disability.

Note: η^2: Effect size; WOBS: Running without obstacle; Trailing leg: The leg that initiates push-off before obstacle clearance during running with obstacle crossing; Leading leg: The leg that first contacts the ground after obstacle clearance during running with obstacle crossing; *statistically significant effects (P<0.05).

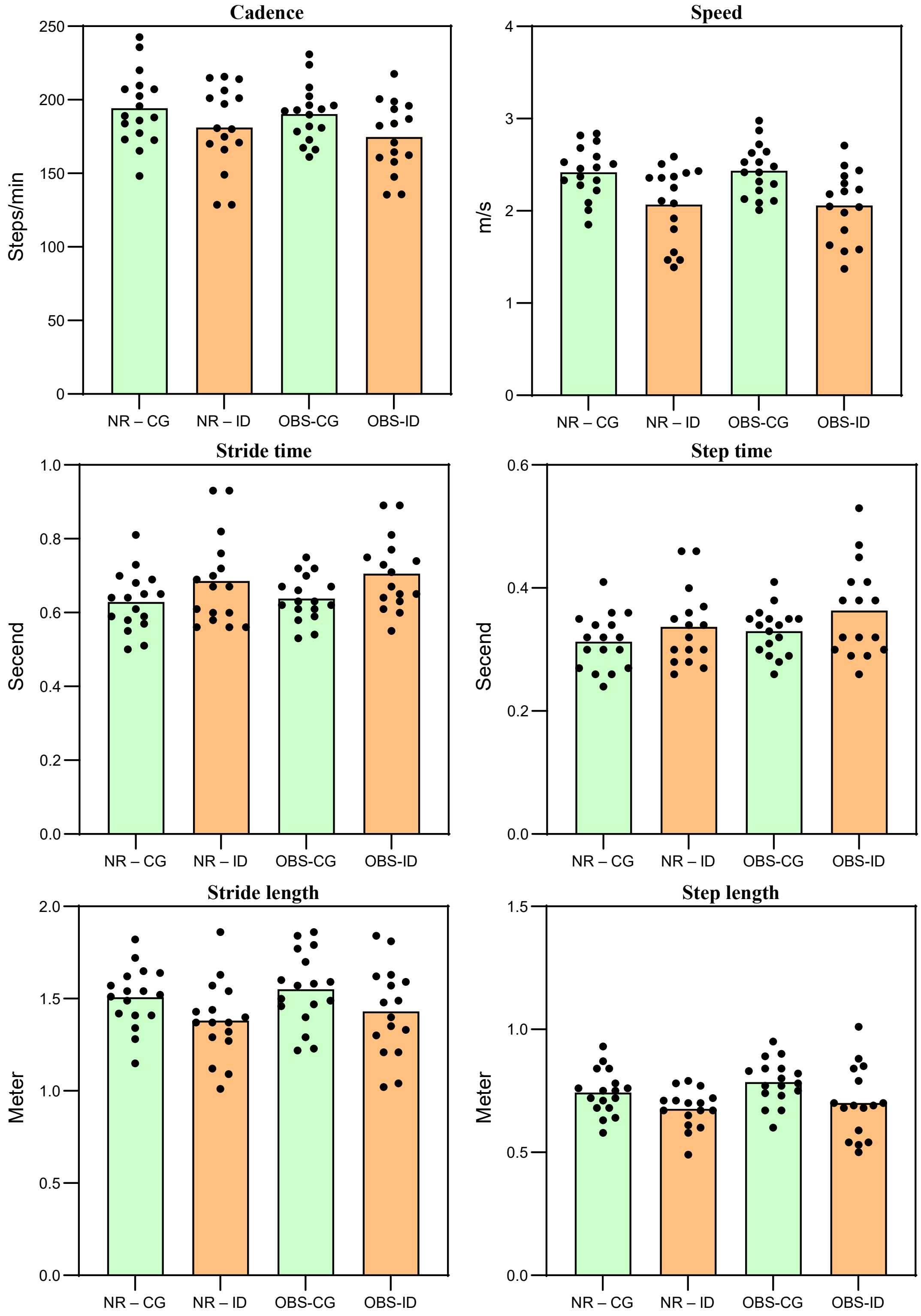

Figure 1. Comparison of spatiotemporal running parameters with and without obstacles in children with intellectual disabilities and their typically developing peers, for each variable

Abbreviations: ID: Intellectual disability; CG: Control group; NR: Normal running; OBS: Obstacle running.

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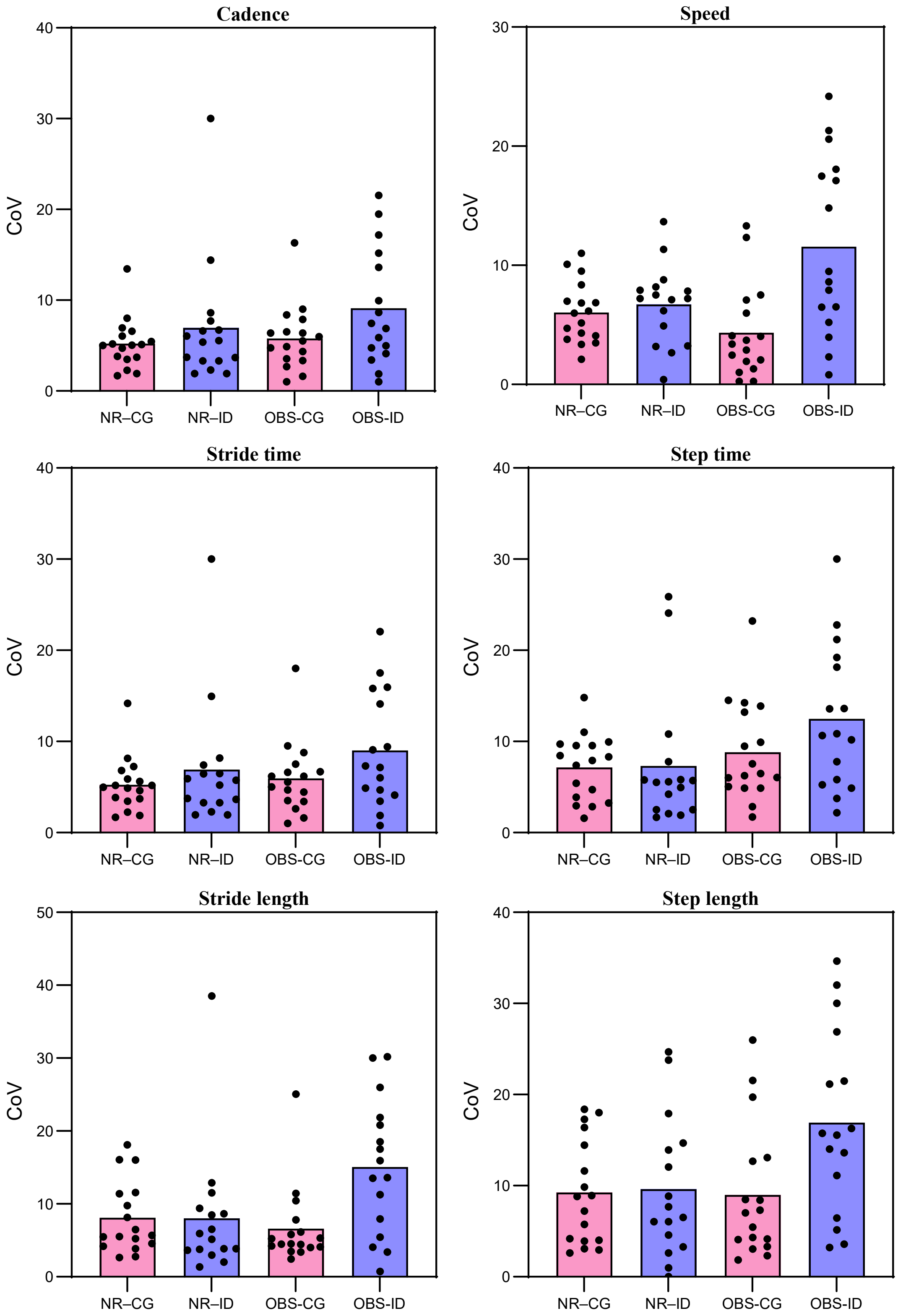

Figure 2. Comparison of the variability of spatiotemporal running parameters with and without obstacles in children with intellectual disabilities and their typically developing peers

Abbreviations: CoV: Coefficient of variation; ID: Intellectual disability; CG: Control group; NR: Normal running; OBS: Obstacle running.

Table 3. Factorial analysis of variability (coefficient of variation) in spatiotemporal running parameters under normal running and obstacle-crossing tasks

Parameters		Mean±SD		Group Effect	Task Effect	Task× Group	Leg Effect	Leg× Group	Leg×Task
		ID Group	Control Group						
Cadence	WOBS-left	7.02±6.15	5.20±2.75	P=0.093 F=2.99 Eta=0.088	P=0.162 F=2.05 Eta=0.062	P=0.571 F=0.329 Eta=0.01	P=0.970 F=0.001 Eta=0.001	P=0.500 F=0.466 Eta=0.015	P=0.604 F=0.275 Eta=0.009
	WOBS-right	7.75±6.42	3.98±2.13						
	Trailing leg	9.10±6.32	5.74±3.62						
	Leading leg	7.56±6.29	7.86±4.97						
Speed	WOBS-left	6.71±3.31	6.53±3.93	P=0.001* F=13.64 η^2=0.31	P=0.851 F=0.036 η^2=0.001	P=0.040* F=4.58 η^2=0.129	P=0.844 F=0.039 η^2=0.001	P=0.984 F=0.001 η^2=0.001	P=0.188 F=1.81 η^2=0.055
	WOBS-right	9.34±7.53	6.43±4.78						
	Trailing leg	11.51±7.44	4.34±3.84						
	Leading leg	9.22±5.67	4.68±2.79						
Step time	WOBS-left	7.30±6.31	7.14±3.58	P=0.039* F=4.64 η^2=0.13	P=0.019* F=6.12 η^2=0.165	P=0.631 F=0.235 η^2=0.008	P=0.609 F=0.267 η^2=0.009	P=0.242 F=1.42 η^2=0.044	P=0.812 F=0.058 η^2=0.002
	WOBS-right	10.59±8.27	5.33±4.91						
	Trailing leg	13.36±10.33	8.83±5.45						
	Leading leg	13.16±8.64	9.42±6.57						
Stride time	WOBS - left	7.09±6.22	5.27±2.92	P=0.120 F=2.55 η^2=0.076	P=0.221 F=1.56 η^2=0.048	P=0.495 F=0.477 η^2=0.015	P=0.808 F=0.06 η^2=0.002	P=0.666 F=0.189 η^2=0.006	P=0.659 F=0.199 η^2=0.006
	WOBS - right	8.20±7.89	4.00±2.16						
	Trailing leg	9.01±6.25	5.90±3.97						
	Leading leg	7.65±6.23	8.07±5.39						
Step length	WOBS-left	9.60±8.48	10.32±8.48	P=0.019* F=6.14 η^2=0.165	P=0.143 F=2.26 η^2=0.068	P=0.036* F=4.81 η^2=0.134	P=0.138 F=2.31 η^2=0.069	P=0.372 F=0.821 η^2=0.026	P=0.134 F=2.36 η^2=0.071
	WOBS-right	10.14±8.14	9.10±8.66						
	Trailing leg	21.88±17.01	8.99±7.26						
	Leading leg	11.90±8.83	7.81±4.83						
Stride length	WOBS - left	8.04±6.65	8.09±4.91	P=0.031* F=4.93 η^2=0.123	P=0.115 F=2.63 η^2=0.078	P=0.027* F=5.36 η^2=0.147	P=0.091 F=3.05 η^2=0.089	P=0.044* F=4.39 η^2=0.124	P=0.271 F=1.26 η^2=0.039
	WOBS - right	6.45±4.70	8.30±5.65						
	Trailing leg	18.61±15.53	6.51±5.32						
	Leading leg	9.67±5.40	7.35±6.03						

ID: Intellectual disability.

Note: η^2: Effect size; WOBS: Running without obstacle; Trailing leg: The leg that initiates push-off before obstacle clearance during running with obstacle crossing; Leading leg: The leg that first contacts the ground after obstacle clearance during running with obstacle crossing; *statistically significant effects (P<0.05).

Furthermore, our findings indicated significantly greater variability in most running parameters among children with ID than among controls. Adding an obstacle to the running path increased variability in speed, stride length, step length, and stride time for the leading limb in the ID group. However, in the control group, variability decreased only in stride length during obstacle crossing. Variability, or irregularity, is an inherent trait of the nervous system. It reflects the degree of adaptability and maturation of the motor control system [38]. Extremely low variability suggests reduced adaptability and increased predictability of movements, whereas excessively high variability indicates greater vulnerability to minor environmental perturbations [39]. Thus, moderate variability, proportional to individual capabilities, signifies a healthy degree of adaptability to environmental challenges.

Our results revealed significantly greater stride-to-stride variability in children with ID compared to the control group. This increased variability implies inconsistent control of degrees of freedom during joint movements, leading to higher overall variability [24]. Consequently, elevated variability may increase the risk of falling, particularly during obstacle-crossing tasks. Nevertheless, the observed reduction in running speed among children with ID could represent a strategic adaptation aimed at enhancing safety. In the TD group, stride-length variability, especially in the trailing limb, decreased during obstacle crossing. This decline in variability might be attributed to an obstacle that prompts increased precision in foot placement. The opposite pattern was observed in the ID group, suggesting that cognitive impairments contributed to inconsistent foot placement across trials.

From a clinical perspective, our findings have important implications for rehabilitation and educational programs for children with ID. The observed reduction in running speed, along with the higher variability in spatiotemporal parameters—particularly during obstacle crossing—suggests that these children may adopt compensatory strategies that prioritize safety over efficiency. Therefore, clinicians and educators should consider interventions that simultaneously enhance motor performance and ensure safety in dynamic environments. For example, incorporating task-specific training programs (e.g. obstacle-based exercises, agility drills, and balance training) may help children with ID to improve coordination, reduce variability, and strengthen adaptive strategies to prevent falls [10, 11]. Moreover, the results underscore the need for individualized exercise interventions that target both the motor and cognitive aspects of running and balance. Given the strong relationship between executive functions and motor performance in ID populations [7], rehabilitation strategies that combine physical training with cognitive tasks (dual-task training) can be particularly beneficial. Such approaches may reduce fall risk while improving participation in school and community activities, ultimately enhancing the quality of life. Finally, in applied settings, such as special education schools and pediatric rehabilitation clinics, the systematic assessment of running speed and variability could serve as practical markers for identifying children at higher risk of falls. Early identification may facilitate timely interventions, thereby supporting safer mobility and promoting long-term physical activity engagement among children with ID.

Conclusion

Our findings demonstrate that children with ID have significantly lower running speed than their TD peers. However, most parameters exhibit notably higher variability, especially during obstacle crossing. Although increased variability is considered a risk factor for falling, individuals with ID may mitigate this risk by reducing running speed as a safety strategy. Thus, it is recommended that environmental obstacles during running be removed to prevent potential injuries in this population. Furthermore, given the relationship between cognitive functions and movement variability, future studies should investigate the effects of cognitive training interventions on gait and running characteristics in individuals with ID.

Ethical Considerations

Compliance with ethical guidelines

This research was approved by the Ethics Committee of Islamic Azad University, Hamadan Branch, Hamadan, Iran (Code: IR.IAU.H.REC.1402.008). In addition, written informed consent was obtained from the parents or legal guardians of all participants before data collection.

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Authors' contributions

Conceptualization, methodology, resources, review, and editing Elaheh Azadian and Mahdi Majlesi; Data curation: Narges Mehmandoust; Formal analysis, and investigation: Elaheh Azadian and Narges Mehmandoust; Investigation: Elaheh Azadian and Narges Mehmandoust; Project administration: Elaheh Azadian; Software, validation and visualization Mahdi Majlesi; Supervision and writing the original draft: Elaheh Azadian.

Conflict of interest

The authors declared no conflict of interest.

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