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Balance analysis of autistic children during beam walking

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1. Introduction

Autism Spectrum Disorder (ASD) is characterised by persistent deficits in communication and social interaction, as well as restricted, repetitive patterns of behaviour, interests, or activities. Although not included among the diagnostic criteria, motor disorders are also part of the clinical phenotype of ASD, and their origins are largely under-researched (Mosconi et al., 2015). Among these motor disorders, specificities in postural control and gait initiation have been identified (Benchekri et al., 2023), suggesting that balance mechanisms are impacted by ASD. Walking on a narrow beam requires the ability to maintain balance with a reduced base of support (BoS) along the medio-lateral (ML) direction. When balance is challenged, humans can use various strategies to increase stability, such as increasing the size of the BoS to enhance the whole-body centre of mass (CoM) shifts and/or rotating segments to modulate whole-body angular momentum (AM) (Hof, 2007). To rely on the “extend the BoS” strategy is limited when walking on a beam. Authors have shown that the main stabilisation strategy during this type of task focuses on regulating the AM of different body parts (Chiovetto et al., 2018) and also that a significant

active control is required to stabilise motion especially along the ML axis (Bauby & Kuo, 2000).

Assuming that children with ASD exhibit unique balance characteristics in motor tasks, it is important to explore the extent of their particularities by analysing their performance during challenging balance tasks such as beam walking.

The aim of our study was then to characterise the balance of children with ASD and typically developing (TD) children by examining their global and segmental AM while walking on a beam.

2. Methods

2.1 Population

15 ASD children (8.7 ± 1.9 years old, 1.33 ± 0.16 m, 28.7 ± 12 kg) were recruited at the Limoges University Hospital and La Rochelle Hospital, and 15 age- and size-matched TD children (8.4 ± 1.4 years old, 1.34 ± 0.90 m, 29.8 ± 6 kg) were recruited in Poitiers.

2.2 Protocol

All children completed five walking trials at self-selected speed on a 4 m long and 8 cm wide beam. A Vicon 3D motion-capture system with 15 cameras sampled at 100 Hz recorded the trajectories of 36 reflective markers placed on anatomical landmarks according to the Conventional Gait Model version 2.4.

2.3 Data treatment

Data were filtered with a Butterworth low-pass filter, with a 10 Hz cut-off frequency. Gait cycles were then identified according to the method from Fonseca et al. (2022).

2.4 Angular Momentum (AM) computation

The body model used was a kinematic chain composed of twelve segments (trunk, pelvis, left and right upper arms, forearms+hands, thighs, shanks, and feet).

The AMs of each segment i , (\vec{H}_M^i) were computed as the sum of the local angular momentum and a transfer term following:

$$\vec{H}_M^i = I_i \vec{\omega}_i + \vec{r}_i \times m_i \vec{v}_i$$

with I_i the inertia tensor of segment i , $\vec{\omega}_i$ its angular velocity vector, \vec{r}_i and \vec{v}_i its relative position and velocity of segment CoM relative to the whole-body CoM (M) and m_i the mass.

The whole-body AM (\vec{H}_M) was computed as the sum of all \vec{H}_M^i :

$$\vec{H}_M = \sum_{i=1}^{12} \vec{H}_M^i.$$

\vec{H}_M was normalised as:

$$\vec{H}_{Mn} = \frac{\vec{H}_M}{h_s m_s \sqrt{g h_s}}$$

with h_s and m_s the height and mass of the participant and g the acceleration of gravity.

2.6 Data analysis

The root mean square (RMS) for each segment $\overrightarrow{H_{Mn}^l}$ and for the whole-body $\overrightarrow{H_{Mn}}$ was computed for each gait cycle along the anteroposterior (AP), ML, and vertical (V) axes. RMS was used to estimate the amount of rotational movement present during the task as proposed by Stein & Mombaur (2022).

Because the data did not follow a normal distribution, a non-parametric Mann-Whitney test was used to compare the RMS between the two groups, with a p value < 0.05 considered to be statistically significant.

3. Results and discussion

Table 1. H_{Mn} and H_{Mn}^{Trunk} (trunk segment) for ASD and TD children

RMS AM	Mean RMS (unitless *10 ⁻³)			<i>p</i> -value
	ASD	TD		
H_{Mn} AP	2.11	1.93	0.26	
H_{Mn} ML	3.17	3.09	0.87	
H_{Mn} V	1.09	1.24	0.38	
H_{Mn}^{Trunk} AP	0.45	0.54	0.03	
H_{Mn}^{Trunk} ML	0.83	0.88	0.71	
H_{Mn}^{Trunk} V	0.34	0.44	0.04	

Lower RMS were found for the trunk segment in the ASD children, compared to TD children, around the AP and V axes (Table 1). No difference was found between ASD and TD children for the other segments, nor for the global $\overrightarrow{H_{Mn}}$.

Individuals who struggle with walking on a narrow beam tend to have larger AM (Chiovetto et al., 2018). Our results show the opposite for ASD children, who seem to limit their trunk movements. Together with the absence of difference between our groups in $\overrightarrow{H_{Mn}}$, our results suggest a potential adaptative strategy used by ASD children to manage stability through the “rotating segments” strategy. If this strategy helps reduce the potential destabilizing impact caused by the trunk segment's large inertia, it may also hinder the ability to benefit from the trunk segment's large inertia to recover stability in the ML direction and, consequently, prevent potential falls.

Indeed, ASD is characterized by motor disorders (Mosconi et al., 2015) and specificities in postural control and gait initiation (Benchecri et al., 2023). It is possible that ASD children face greater challenges in maintaining balance, leading them to reduce their movements to avoid increasing their risk of falling.

4. Conclusions

In summary, our study shows that ASD children exhibit similar overall AM when compared to TD children, except for the trunk segment. This decrease in AM may suggest a lack of ease in beam walking task, with a need to increase stability to cope with an

underlying issue. The origin and why ASD children rely on this strategy require further research. This could lead to a better understanding of the motor disorders of ASD children.

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Conflict of Interest Statement

None of the authors have competing interests.

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