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► To cite this version:

Aurélie Benchekri, Romain Tisserand, Christel Bidet-Ildei, É Lemonnier, A Amestoy, et al.. Slow anticipatory postural adjustments during gait initiation in autistic children. 48eme Congrès de la Société de Biomécanique, Oct 2023, Grenoble, France. pp.249_250. hal-04289109

HAL Id: hal-04289109

<https://hal.science/hal-04289109>

Submitted on 16 Nov 2023

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Slow anticipatory postural adjustments during gait initiation in autistic children

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1. Introduction

Autism Spectrum Disorders (ASD) are part of neuro-developmental disorders characterized by persistent deficits in communication and social interactions, and restricted and repetitive behaviors, interests, or activities. Motor disorders are also part of the clinical phenotype of ASD (Mosconi et al. 2015). Yet, because they remain poorly investigated and because the diagnosis still takes time to set up, it remains unknown whether the study of motor tasks may improve the process of identifying ASDs.

By transitioning between posture and movement, gait initiation (GI) is a challenging motor task for balance control. The quality of posture-movement coordination during GI can be estimated by characterizing the anticipatory postural adjustments (APAs), a specific coordination that fulfills two complementary mechanical roles. First, they create a disequilibrium during the loading phase, through a backward and a lateral (towards the future swing foot) displacement of the Center of Pressure (CoP). This initial imbalance provokes a center of mass (COM) motion forward and towards the stance foot. Second, the COM motion is stabilized during the unloading phase, where the CoP moves towards the stance foot. Previous results of APAs performed by ASD children during GI reported a reduced mediolateral (ML) displacement of the CoP, suggesting a reduced ML stability (Fournier et al. 2010). However, the authors did not distinguish the two APAs phases, thus leaving the mechanisms of reduced stability unclear.

The objective of our study was to characterize APAs during GI in ASD and typically developing (TD) children by distinguishing the two phases.

2. Methods

2.1. Population

25 children diagnosed with ASD (10 girls, 8.7 ± 1.9 years old, 1.33 ± 0.16 m, 28.7 ± 12 kg) were recruited at the Limoges University Hospital and 31 age-matched TD children (15 girls, 8.4 ± 1.4 years old, 1.34 ± 0.90 m, 29.8 ± 6 kg) were recruited in Poitiers.

2.2. Task and equipment

All children completed five GI trials. During each trial, children started from an upright standing posture, with each foot positioned on one force plate and their arms at their side. After at least 3s of quiet standing, children were verbally instructed to start walking at a comfortable speed to reach a ground mark about 3 metres away. Initial position of the feet was marked on the ground to ensure initial position repeatability.

Ground Reaction Forces (GRF) were recorded using two adjacent force plates (Sensix® in Poitiers and Kistler® in Limoges) sampled at 1000 Hz. A Vicon 3D motion-capture system with 20 cameras sampled at 100 Hz recorded the trajectories of four reflective markers placed on foot anatomical landmarks (lateral and medial malleoli, second metatarsal head, and calcaneus).

2.4. Data analysis

The vertical component of the GRF (F_z) extracted from the force plate located underneath the stepping foot was used to identify three key instants (Fig. 1, left): APAs Onset (AO), as the first instant when F_z amplitude was larger than its mean + 3 SDs measured during the 3s of quiet standing; Foot-Off (FO), as the first instant when F_z was inferior to 2.5% of the child's weight; and Beginning of Unloading (BU), as the instant when F_z was maximal between AO and FO. These instants were then used to compute three durations: the total APAs (between AO and FO); the loading phase (between AO and BU); and the unloading phase (between BU and FO). Also, the trajectory of the CoP was extracted from the two force plates (Fig. 1, right). After filtering the CoP using a 2nd order Butterworth filter with a 10 Hz cut-off frequency, its trajectory was characterized by its amplitude, in the AP and ML directions during the loading phase, and in the ML direction during the unloading phase. These amplitudes were normalized by the size of the base of support, estimated as the foot length and the feet width, measured from the feet markers, respectively in the AP and ML axes. AP and ML velocity peaks were also extracted during the loading and unloading phases, by taking the maximum of the time-derivative of the trajectory.

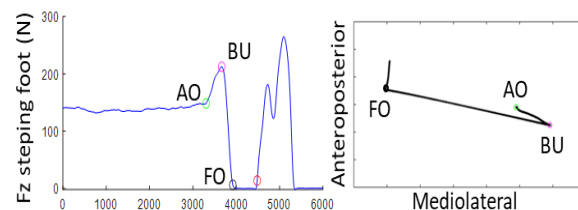


Figure 1. Temporal evolution of the stepping foot GRF during GI with the three key events AO, BU, and FO (left) and top view of the CoP trajectory during GI (right).

2.5. Statistics

Non-parametric Mann-Whitney tests were performed to compare the two groups for each dependent variable, with a threshold set at $p < 0.05$.

APAs		Mean (SD)		<i>p</i> -value (M-W)
		ASD	TD	
APAs Duration (ms)		590 (171)	511 (81)	0,05 *
Loading	Duration (ms)	306 (157)	292 (59)	0,25
	AP displacement normalized	0,27 (0,26)	0,31 (0,18)	0,16
	ML displacement normalized	0,22 (0,12)	0,32 (0,14)	0,004 *
	AP peak velocity (m.s ⁻¹)	0,20 (0,14)	0,26 (0,13)	0,06
	ML peak velocity (m.s ⁻¹)	0,27 (0,15)	0,45 (0,25)	0,003 *
	Duration (ms)	284 (102)	218 (85)	0,009 *
Unloading	ML displacement normalized	0,57 (0,31)	0,68 (0,18)	0,07
	ML peak velocity (m.s ⁻¹)	1,60 (0,63)	2,04 (0,66)	0,09

Table 1. Group effect on the different dependent variables. SD: standard deviation. M-W: Mann-Whitney test. AP: anteroposterior. ML: mediolateral.

3. Results and Discussion

ASD children displayed prolonged APAs during GI compared to TD children. This prolongation was principally consecutive to the lengthening of the unloading phase, during which the CoP also tended to move with reduced amplitude and velocity. Despite no duration difference between groups during the loading phase, the CoP of ASD children moved with reduced amplitude and velocity in the ML direction (Table 1). During the loading phase, laterally moving the CoP towards the future swing foot allows to drive the COM towards the future stance foot, increasing the mediolateral stability conditions at foot-off. With reduced amplitude and velocity during the loading phase, the mechanical consequences of APAs produced by ASD children should drive the COM with reduced velocity towards their stance foot. Consecutively, ASD children may need to wait longer during the unloading phase for the vertical projection of their COM to come close enough to the stance foot to be able to lift the swing foot. This may explain why, in line with previous research, ASD children displayed a prolonged unloading phase with reduced CoP movement compared to TD children (Fournier et al. 2010).

Together, our results suggest that the main difference between ASD and TD children resides in the ML direction for balance control of GI. These results seem to corroborate previous observations reporting differences between ASD and TD children in the ML

axis during maintenance of an upright standing posture (Lim et al. 2017). In the control of upright standing postures, it is assumed that hip muscles are mostly responsible for CoP lateral displacements. Therefore, ASD children may have difficulties with hip muscle force production and/or hip muscles coordination control (Lim et al. 2017). Difficulties in coordination control may also come from immature body representations consecutive to altered sensorimotor integration during motor tasks (Assaiante and Schmitz 2009). Among the neural structures involved in motor control, one of the best candidates for ineffective balance control if altered is the cerebellum because it is at the crossroads of ascending and descending sensorimotor functions (Mosconi et al. 2015).

4. Conclusions

In summary, we showed that ASD children have slow APAs during GI. This slowness suggests ASD children would end GI with reduced dynamic stability in the mediolateral direction. These balance deficits may be explained by alterations in hip muscles and/or sensorimotor control going through the cerebellum. GI seems to be a relevant paradigm to identify motor alterations in ASD children, yet more research is necessary to disentangle the origins of these impairments.

Acknowledgements

This work was supported by the Region Nouvelle-Aquitaine.

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Keywords: autism, gait initiation, anticipatory postural adjustment.

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