

# CENTER OF MASS KINEMATICS DURING GAIT INITIATION IN CHILDREN WITH CEREBRAL PALSY

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## Summary/conclusions

Kinematic variables describing center of mass (COM) trajectory in children with cerebral palsy (CP) differ from age-matched controls during gait initiation, suggesting that a simple task can destabilize their base of support and their response to this perturbation is reflected in the COM.

## Introduction

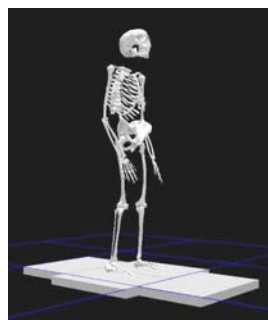
The whole-body COM represents the net result of all instantaneous limb movements and force production during a specific task, making it an ideal method of characterizing overall movement performance and the functional impact of gait impairment. Our previous investigation [1] discovered that the distance between the floor-projection of the COM and the center of pressure during gait initiation was significantly different between children with CP and age-matched controls, providing insight into dynamic balance strategies used by these children. As a separate analysis of the same subjects, the purpose of this study was to examine the kinematics of the three-dimensional COM trajectory in children and investigate the impact of CP on the ability of subjects to advance their COM in the intended direction.

## Statement of clinical significance

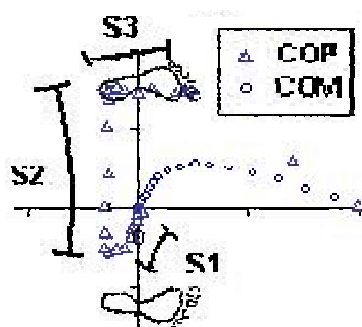
These findings support the use of whole-body COM recording for overall gait performance measurement and outcome assessment of therapeutic interventions, utilizing an easily reproduced gait task that is a necessary precursor to functional ambulation.

## Methods

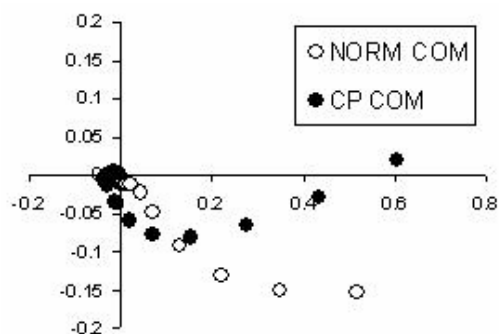
Subjects included 14 children with hemiplegic CP ( $9.1 \pm 1.8$  years) and their age-matched controls ( $9.0 \pm 1.9$  years). Each provided informed consent, donned a 36 target full-body reflective marker set, placed each foot on a separate force platform a comfortable distance apart (Fig. 1), and initiated gait on a visual cue. A 6-camera Vicon 512 motion capture system and an array of four Kistler force platforms were used for data capture. Each subject's COM was calculated in BodyBuilder™ using a Johan full-body model [2] modified for children, and was examined during three distinct periods of the gait initiation cycle [3], (Fig. 2). *S1* occurs during the initial loading of the stepping limb;



**Figure 1.** Position of the subject on force platforms.



**Figure 2.** Idealized right gait initiation showing *S1*– *S3* & approx. subject position



**Figure 3.** Normalized COM trajectories of a subject-pair during left-foot gait initiation.

S2 is marked by a weight shift towards the stance limb; S3 corresponds to single limb support while the stepping limb is advancing. Distances from the origin were normalized to the subject's base of support (standing ankle-ankle distance), allowing for comparisons between subjects of different ages and sizes (Fig. 3). These were numerically differentiated to calculate instantaneous COM velocities & accelerations. Variables were grouped by initiating limb (dominant or unaffected, vs. non-dominant or affected limb) and diagnosis (Table 1). Differences between and within subjects were compared using paired t-tests and results were Bonferroni-corrected for 4 pair-wise comparisons using an original  $\alpha$  of 0.05.

## Results

The results of this investigation are shown in Table 1 below.

**Table 1.** Normalized mean COM values during gait initiation in children with CP & controls

Init. Limb	Qty.	Subj.	S1			S2			S3		
			Disp	Vel	Accel	Disp	Vel	Accel	Disp	Vel	Accel
DOM	Max	Case	0.022	0.072	0.259	0.038	0.092	0.338	0.079	0.217	2.537
		Control	0.018	0.066	0.288	0.028	0.076	0.489	0.071	0.563	6.093
	Min	Case	0	0.028	-0.258	0.022	0.032	-0.084	0.039	0.071	1.235
		Control	0	0.015	-0.269	0.018	0.029	-0.050	0.020	0.065	-5.640
	Ave	Case	0.011	0.047	-0.032	0.029	0.059	0.099	0.055	0.121	0.436
		Control	0.009	0.034	-0.032	0.022	0.049	0.186	0.038	0.227	1.286
NON-DOM	Max	Case	<b>0.023</b>	<b>0.082</b>	0.250	<b>0.036</b>	0.078	0.340	0.069	0.237	1.474
		Control	<b>0.014</b>	<b>0.049</b>	0.208	<b>0.020</b>	0.050	0.299	0.047	0.176	0.947
	Min	Case	0	0.030	-0.276	<b>0.023</b>	0.023	-0.280	<b>0.031</b>	0.035	-0.521
		Control	0	0.020	-0.226	<b>0.014</b>	0.024	-0.153	<b>0.020</b>	0.029	-0.037
	Ave	Case	<b>0.012</b>	<b>0.056</b>	-0.021	<b>0.030</b>	0.046	-0.002	0.047	0.113	0.453
		Control	<b>0.007</b>	<b>0.032</b>	-0.010	<b>0.017</b>	0.035	0.055	0.030	0.087	0.407

■ Significantly different between children with CP and age-matched controls ( $\alpha_{\text{corr}} = 0.0125$ )

## Discussion

This study found that the COM trajectory of children with hemiplegic CP has a greater maximum and average displacement during the postural phase of gait initiation (S1 & S2) than their age-matched controls when the affected (non-dominant) limb is advancing. The COM of children with CP moved faster than controls during S1 (Table 1), yet achieved the same average COM acceleration throughout the task. Typically developing children appear to use a more controlled gait initiation strategy of shorter, slower-moving COM deflections, while the children with CP displace their COM faster and more abruptly. These findings are consistent with the notion that subjects with CP have less fine motor control of their COM than healthy peers and therefore complete simple balance tasks less efficiently. No significant asymmetry was found within groups, however, all significant differences between groups occurred when children with CP initiated with their affected side. This suggests that COM movement during gait initiation is most affected by control of the swinging limb, rather than stability provided by the stance limb.

## References

- [1] J.J. Carollo, et al, (2006), J Electromyogr Kinesiol, XVI ISEK Congress, Torino, Accepted for presentation
- [2] M.H.A. Eames, et al, (1999), Human Move Sci, 18, 637-646
- [3] C.J. Hass, et al, (2005), Arch Phys Med Rehabil, 86, 2172-2176