

CHILDREN WITH CEREBRAL PALSY REQUIRE MORE STRIDES TO DISSIPATE DISTURBANCES PRESENT IN THEIR WALKING PATTERN

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INTRODUCTION

Cerebral palsy (CP) is a neurologic disorder that is a result of a defect or lesion in the immature brain. Although the brain lesion does not progressively worsen, there is often an accumulation of musculoskeletal impairments that result in insufficient muscular force generation, contractures, spasticity, and skeletal deformations. These musculoskeletal problems can create disturbances in the voluntary control of the walking pattern, and are one of the main reasons that children with CP stop walking or seek new surgical and rehabilitative treatments [2]. If the disturbances present in their walking pattern are not alleviated, they may cause a loss of balance and falls. A high frequency of falls may result in bodily harm, a reduction in physical activity, and a diminished social acceptance by the child's peers [2]. Although the clinician readily acknowledges these factors, limited investigations have been conducted to quantify the nature of the disturbances present in the walking patterns of these children. This scientific knowledge is necessary for shaping the current surgical and rehabilitative trends that are directed toward restoring walking function and balance in these children. The specific aim of this investigation was to provide the initial framework for quantifying the disturbances present in the walking patterns children with CP.

METHODS

Eight children with spastic diplegic CP (Age= 7.8 ± 2.8 yrs.), and seven typically developing children (Age = 8.0 ± 2.4 yrs.) walked on a treadmill for two minutes. The walking speed used by all the participants was based on the Froude number for children with CP who are community ambulators [3]. The children with CP had a Gross Motor Function Classification (GMFC) level between 1 and 2, and walked on the treadmill while wearing

their prescribed ankle-foot-orthoses [4]. None of the children had surgical interventions or Botox injections within the last two years.

A motion capture system (120Hz) was used to determine the three-dimensional angular rotations of the lower extremity joints. The position data for all markers were filtered using a zero-lag Butterworth filter with a 6 Hz cut-off.

A state vector (S) was created for each of the respective lower extremity joints (Eq 1.)

$$S(t) = [\theta \ \phi \ \psi \ \dot{\theta} \ \dot{\phi} \ \dot{\psi}] \quad \text{Eq 1.}$$

where θ is flexion-extension, ϕ is abduction-adduction, ψ is internal-external rotation, and $\dot{\theta}$, $\dot{\phi}$, $\dot{\psi}$ are the respective derivatives. The state space data were partitioned into their respective strides and were normalized to 101 samples. Poincare maps were created for every sample of the stride, and the Floquet multipliers (FM) were calculated for each map [1]. The FM quantified the rate of dissipation of small disturbances that were present in the joint's movement pattern. It was assumed that the mean of the limit cycle trajectories (S^*) represented the preferred joint movement pattern, and deviations away from this limit cycle from one stride (S_n) to the next (S_{n+1}) represented disturbances in the joint's kinematics (Eq 2).

$$[S_{n+1} - S^*] = J(S^*)[S_n - S^*] \quad \text{Eq 2.}$$

The rate of change in the joint's movement from one stride to the next was quantified by the Jacobian ($J(S^*)$). The FM were the eigenvalues of the Jacobian. The largest FM across the stride was used to quantify the dissipation rate of the disturbances present in the joint's pattern. A FM that was further away from zero signified that it took longer to

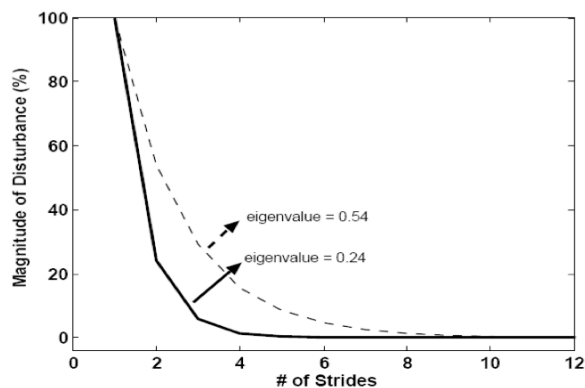


Figure 1: The smaller eigenvalue (0.24) indicates that disturbances dissipate at a faster rate while the larger eigenvalue (0.54) dissipates disturbances at a relatively slower rate. According to Floquet theory, the faster rate at which disturbances are dissipated, the more stable the walking pattern.

dissipate disturbances present in the joint's movement pattern (Figure 1). A mixed ANOVA design was used to discern differences in the FM for the lower extremity joints of children with CP and the typically developing children.

RESULTS AND DISCUSSION

There was a significant between group main effect for the largest FM ($p < 0.0001$), indicating the aggregate of the joints' FM for the children with CP (0.71 ± 0.1) was significantly larger than the aggregate of the joints' FM for the typically developing children (0.58 ± 0.1). This indicated that children with CP required more strides to dissipate the disturbances present in their gait pattern. Furthermore, this suggests that the children with CP had poorer walking balance and may be more susceptible to a fall. This notion concurs with clinical gross motor function balance tests of children with CP, and the high prevalence of falls noted in these children [2,5].

Although the FM values for all the respective joints were larger for the children with CP (Figure 2), no significant joint by group interaction was found ($p > 0.05$). We suspect that the lack of significant differences may be due to where the musculoskeletal impairments were in the leg for each individual child. For this investigation, we did not recruit our subjects based on a specific joint musculoskeletal abnormality. Rather the children were recruited based on a GMFC level. We are optimistic that if we narrow our focus to certain types of joint musculoskeletal impairments (e.g.,

skeletal torsions, joint contractures, foot deformities, etc.) that we will be able to further quantify the disturbances seen in the joint movement patterns of the various CP clinical classifications.

CONCLUSIONS

Children with CP require more strides to dissipate the disturbances present in their walking pattern. Most likely the inability to dissipate these disturbances is related to the lower extremity neuromusculoskeletal impairments that often accompany CP. Further studies are warranted to quantify the musculoskeletal tenants that may be augmenting these gait disturbances and hindering their dissipation. This scientific knowledge will help to shape the current surgical and rehabilitation treatments that are aimed at restoring walking function and balance in children with CP.

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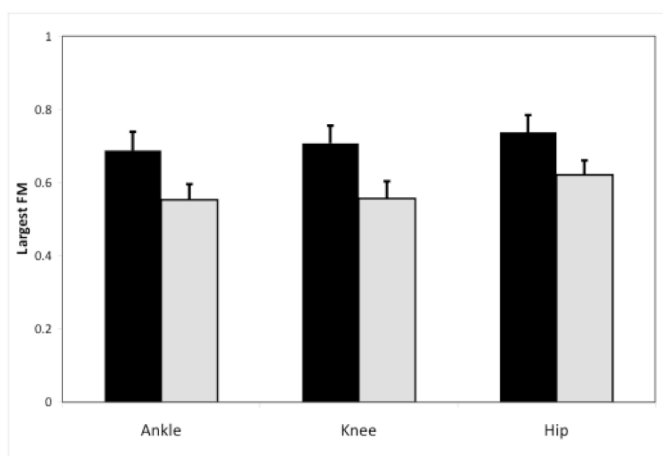


Figure 2: Mean (\pm SEM) FM for the respective lower extremity joints. The black bars are the FM for the children with CP and the grey bars are the FM for the typically developing children.