CHILDREN WITH CEREBRAL PALSY GENERATE MINIMAL NET WORK BY TRICEPS SURAE ABOUT THE ANKLE

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INTRODUCTION

Children with cerebral palsy (CP) are notably inefficient in generating ankle power and work during the pushoff phase of gait [1]. However, net joint measures do not necessarily reflect the output of individual muscle-tendon units, particularly when contractures and co-contraction are present. Our labs are investigating the use of shear wave tensiometry to track muscle-tendon force during walking [2]. Tensiometers measure fluctuations in wave propagation speed along the tissue, which is used to infer the tensile load transmitted by the tendon [3]. Tendon force can be plotted against muscle-tendon length to visualize a work-loop which characterizes the functional behavior of the muscle-tendon unit. We investigated the work done by the triceps surae about the ankle in children with CP who exhibit equinus and/or crouch gait.

CLINICAL SIGNIFICANCE

The data illustrate how tensiometry can facilitate the quantitative assessment of muscle-tendon behavior in gait pathologies which could prove useful in planning treatments for gait disorders.

METHODS

Eleven children with CP (4F, 8-16 yrs) and 15 typically developing controls (9F, 8-17 yrs) participated. Children with CP were included if they had spastic diplegia, GMFCS Level I or II status, and evidence of equinus (<5° dorsiflexion angle) and/or crouch (>20° knee flexion angle) gait patterns. Reflective markers and EMG sensors were placed over the lower limbs. A shear wave tensiometer was secured over the Achilles tendon. All subjects walked overground at their preferred speed; controls additionally walked at slower and faster than preferred speeds [4]. A subject-specific calibration procedure was used to estimate Achilles tendon force from shear wave speed [2]. The excursion of the triceps surae about the ankle was calculated from ankle angle and tendon moment arm [2]. Forces were normalized to body weight and excursion to leg length. Work-loop plots [5] were used to evaluate net work of the triceps surae about the ankle.

RESULTS

Net work was significantly lower in children with CP compared to controls walking at their slow speed ($p = 0.02$) (Fig 1). Controls did more positive net work with increased speed ($p < 0.001$). Children with CP showed an altered work-loop pattern as well as earlier medial gastrocnemius EMG activation compared to controls (Fig 2).

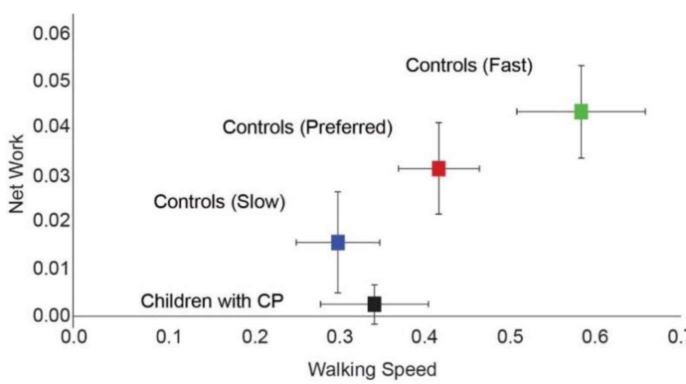

Figure 1. Average net work by triceps surae (SD error bars).

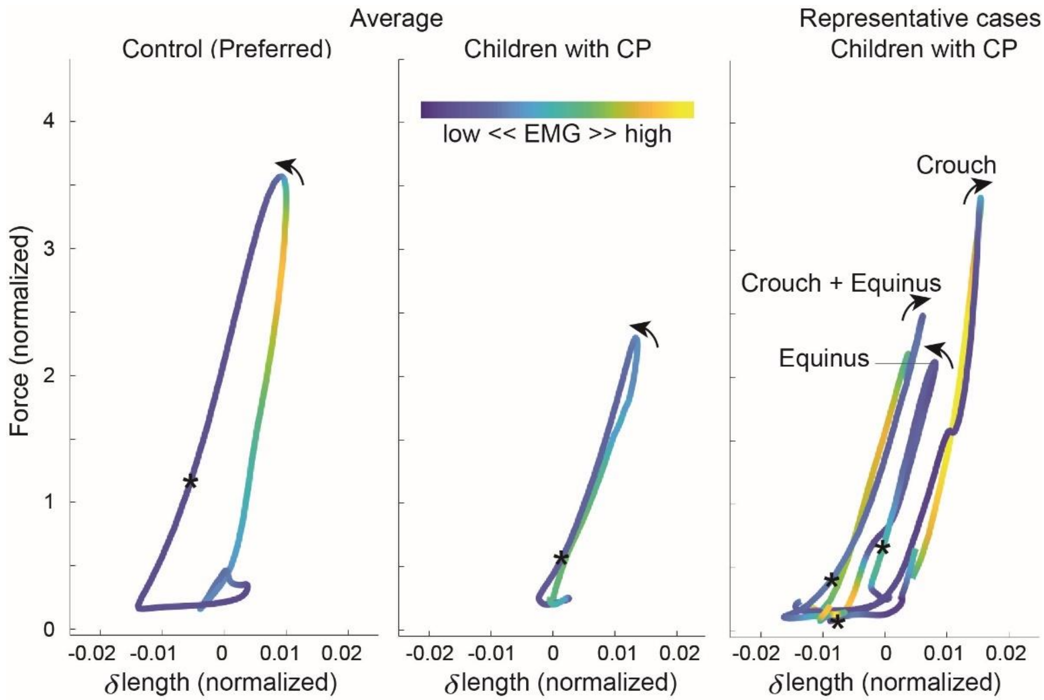

Figure 2. Work-loops for both groups were net positive on average (left). Despite unique gait patterns (as shown with representative cases on the right), children with CP showed similar spring-like work-loops. * = foot off.

DISCUSSION

This study utilized shear wave tensiometry, kinematics, and EMG to assess the triceps surae work patterns underlying gait in children with CP. These analyses revealed substantial and profound differences in triceps surae behavior among a heterogenous group of children with CP. Controls showed a net positive work-loop over the gait cycle, indicating the triceps surae about the ankle is acting like a motor [5]. In contrast, the children with CP showed an upward sloped force-length curve with no net work, indicative of more spring-like behavior. The timing of muscle activation is particularly important in the efficiency of gait [6]. Thus, the diminished work production could, in part, arise from spasticity and deficiencies in selective motor control [7]. Indeed, the net work loop plots of individuals with CP often exhibited early gastrocnemius activation relative to controls (Fig. 2). This work-loop approach provides new insight about functional muscle-tendon behavior by integrating excitation, kinematic and novel tendon kinetics, which are challenging to infer from traditional joint kinematics and kinetics plots.

REFERENCES

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DISCLOSURE STATEMENT

J.A.M. and D.G.T. are co-inventors on a patent for tensiometer technology.