THE NEUROMAGNETIC ACTIVITY OF THE SOMATOSENSORY CORTICES AND THE ANKLE FORCE CONTROL IS ALTERED IN CHILDREN WITH CEREBRAL PALSY

Max J. Kurz, David J. Arpin, Elizabeth Heinrichs-Graham, Katherine M. Becker & Tony W. Wilson

Munroe-Meyer Institute, University of Nebraska Medical Center, Omaha, Nebraska
College of Medicine, University of Nebraska Medical Center, Omaha, Nebraska
Email: mkurz@unmc.edu Web: http://www.unmc.edu/mmi/

INTRODUCTION

It well recognized that children with cerebral palsy (CP) have somatosensory processing deficits that limit their proprioception, stereognosis, and tactile discrimination. Since CP involves damage to both the sensory and motor systems, it is unclear whether the noted sensory deficits contribute to the motor impairments seen in these children, or if they are more independent symptoms that share a common cause (i.e., perinatal brain damage). Results from diffusion tensor imaging (DTI) has provided some insight on this symptomatic relationship, by showing that the damaged thalamocortical tracts are related to the reduced muscular strength seen in children with CP [2]. Further understanding of how the somatosensory processing deficits interact with the motor impairments will be critical for improved understanding of the motor control problems seen in these children.

Magnetoencephalography (MEG) is a quantitative neurophysiological imaging technique that provides a direct measure of neuronal activity by measuring the minute magnetic fields that are generated by local electrical oscillations in activated neuronal populations. A considerable amount of research has used MEG to quantify the activation and organization of the primary and secondary somatosensory cortex through the use of evoked magnetic field paradigms [5]. Outcomes from these studies have confirmed that the somatosensory cortex is organized into well-defined “homunculus” like boundaries (i.e., foot, arm, hand, leg, tongue, lips, etc.). In a recent exploratory investigation of four children with CP, we demonstrated that the responsiveness of the primary somatosensory cortices was diminished [4]. Furthermore, we have additionally shown, in a small cohort of children with CP, that the responsiveness of the primary somatosensory cortices is altered after gait training and that these neuromagnetic changes are accompanied by mobility improvements [3]. Together these results imply that the integrity of the somatosensory cortices is important for the motor control of the leg musculature.

Variability or error is present in all voluntary contractions and impacts the precision and control of the motor performance. Children with CP have greater variability in the lower extremity joint’s performance when trying to hold an isometric force at a submaximal target [1]. We suspect that these greater errors may be partly due to deficiencies in the sensorimotor integration process for correcting the muscular force to match the prescribed target value [6]. Potentially, the breakdown in the error checking process may reside in the responsiveness of the primary somatosensory cortices to the external afferent feedback from the periphery.

The purpose of this investigation was 1) to evaluate the response of the somatosensory cortices of children with CP to an external stimulus, 2) to determine if the control of the ankle joint force is reduced in children with CP, and 3) to determine if there is a relationship between the activity of the somatosensory cortices and the amount of variability in the ankle joint’s steady-state isometric force production.

METHODS

Eight children with spastic diplegia CP (Age = 11 ± 4 yrs.) and eight TD children (Age = 13.2 ± 3 yrs.)
participated in this investigation. An isokinetic dynamometer (Biodex Inc., Shirley, NY) was used to measure the steady-state isometric torques generated by the ankle joint plantarflexors. The motor task involved matching and holding a target torque that was 20% of the child’s maximum voluntary torque for 15 seconds. The target and the torque exerted by the child were displayed on a large monitor positioned ~1 m away. The coefficient of variation (CV) was used to assess the amount of variability in the ankle joint’s force production. A greater amount of variability was assumed to indicate greater errors in the adjustment of the motor plan to remain at the target value.

A whole-head 306-sensor MEG system (Elekta Neuromag, Helsinki, Finland) was used to assess the oscillatory activity of the somatosensory cortices as a small air bladder stimulated the bottom of the foot at the first metatarsal phalangeal joint. A linearly-constrained minimum variance vector beamformer algorithm was used to calculate 3D images that reflect the local power of neuronal current. The single images generated were derived from the cross spectral densities of all combinations of MEG sensors averaged over the 4-14 Hz frequency range from 25 to 275 milliseconds.

RESULTS AND DISCUSSION

The children with CP had a larger CV while attempting to sustain the steady-state torque values (CP = 18.8 ± 9%; TD = 2.5 ± 0.5%; p = 0.01), implying that they had greater errors in their ability to adjust the force output to remain at the target value.

The beamformer imaging results showed that the children with CP had a lower amount of activity in the medial wall of the postcentral gyrus (p < 0.05, cluster-corrected). Further inspection of the data revealed that the somatosensory cortices of the children with CP desynchronised when the stimulus occurred, while the somatosensory cortices of the TD children had a synchronized response to the stimulus. These results indicate that the responsivenes of primary somatosensory cortices to the external afferent feedback was weaker and aberrant in the children with CP. In addition, there was a negative correlation between the CV and the amount of activity in the somatosensory cortices (r = -0.60; p=0.008), indicating that greater errors in matching the target force were related to less activity in the somatosensory cortices.

It is well established that the control of movement is based on an internal model that contains the desired muscular performance and the sensory information that should be returned as the motor plan is executed [6]. Comparisons between the actual afferent sensory information and the internal model’s sensory predictions are used to detect errors in the motor performance. The reduced and aberrant response of the somatosensory cortices in the children with CP suggests that the neuronal groups that represent the foot may lack the ability to properly translate the external feedback for such comparisons. Based on this perspective, the increased amount of variability in the ankle’s force production may be partly explained as a breakdown in the error correction networks.

REFERENCES