Quantification of cortical activity during varying reaching tasks in childhood hemiparesis

Nayo Hill1,2, BS and Julius Dewald1,2,3, PT, PhD

1Department of Biomedical Engineering, 2Department of Physical Therapy & Human Movement Sciences, and 3Department of Physical Medicine & Rehabilitation, Northwestern University, Chicago, IL.

Introduction

- Childhood hemiparesis (CH) results from an early brain injury causing weakness and movement impairments primarily on one side of the body.
- Injury timing can impact the available descending motor control pathways at the cost of independent limb and independent joint control.
- Motor impairments in CH have been shown to vary based on timing of injury (Sukal-Moulton 2013).
- Cortical activity has been shown to shift ipsilaterally with an increased expression of the flexion synergy pattern in adult stroke (Chen 2014).
- Quantification of the flexion synergy and measurement of cortical activity during a motor task will give insight into the mechanisms behind cortical reorganization and altered motor control in CH.

Background

The brain initially has bilateral projections of the corticospinal tract coming from each hemisphere. The ipsilateral projections are withdrawn in the late stages of gestation leaving only the contralateral projections. Early injury to the brain can alter this developmental progression. Therefore, different pathways are activated in an attempt to produce the same motor output.

PRE-natal (Before Birth) Injury

POST-natal (After Birth) Injury

- 1st to 10 years old
- 1 to 4 years old

Objective

A unique experimental design combining robotics, electroencephalography (EEG), and electromyography (EMG) will investigate how the use of remaining neural substrates is dependent on timing and type of injury.

Presentation of Reach Deficits

Recruitment of Neural Resources

Joint Kinematics

Cortical Activity

Methods

Using a high density array of EEG electrodes, brain activity during a reaching task will be recorded in PRE-natal and POST-natal individuals. The subject uses the Arm Coordination Training 3D (ACT3D) haptic robot to perform 100 ballistic reaches for each condition.

Reach Conditions

1. Arm fully weight supported by a haptic table surface
2. Load between 35% and 50% of maximum shoulder abduction torque.

Hypothesis

With ↑ shoulder abduction load:

- PRE-natal paretic arms → maintained reach distance
- POST-natal paretic arms → reduced reach distance
- All PH subjects → ipsilateral shift in cortical activity

Cortical Activity Analysis

EEG data will be analyzed in the window 100ms before movement onset to isolate the cortical activity responsible for movement. The main outcome measure is a Laterality Index describing the relative contribution of each hemisphere in producing the measured cortical activity.

Significance

Two diagnoses of CH may look functionally similar while motor control relies on different neural backup systems. This work is motivated by the need to understand the underlying neural mechanisms responsible for weakness and losses of independent joint and limb control. This knowledge is expected to lead to the development of more targeted therapies that will address the cause of motor impairments in different subpopulations of CH. Therapies to actively increase the brain’s efficiency in using remaining neural systems have the potential to improve outcomes in ways that traditional therapies do not.

Acknowledgments


Contact: nayohill@u.northwestern.edu