Neural activation associated with lower limb movements in children with hemiplegic cerebral palsy

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INTRODUCTION

- Evidence is building to link contralateral neural control to gains in lower limb function of children with hemiplegic cerebral palsy (HCP)
- Yet, little is known about lower limb neural control or neuroplastic change linked with changes in gross motor skills like walking and running9
- The lower limb representation in the motor cortex is small and deep, and precise images are required but are challenging to obtain7,8
- A new ankle dorsiflexion fMRI task (paradigm) can be used to represent walking during a functional magnetic resonance imaging (fMRI) scan
- Pilot studies in children with CP indicated that while promising, existing fMRI methodology required adaptation to consistently produce interpretable images5
- Objective: To establish whether we refined test procedures for the ankle dorsiflexion fMRI paradigm produce viable images to identify areas of lower limb cortical activity and hemispheric contributions for the affected and unaffected limbs in children with HCP

METHODS

- Three independently ambulatory children with HCP in GMFCS Level I (ages 8–10 years) were recruited
- A purpose-built apparatus was constructed to isolate ankle dorsiflexion to 5 degrees in a single plane of movement with adjustable resistance
- Children completed one active dorsiflexion movement every 16–18 seconds for a period of 4 minutes during the fMRI scan (repeated twice per leg)
- Neuroimages were analyzed in AFNI software using a standard preprocessing protocol. A general linear model was used to extract task parameters and produce statistical parametric maps for each child
- The hemispheric contribution to movement of each leg was evaluated by calculating the ratio of active voxels per hemisphere using the formula:

\[ \text{Laterality Index (LI)} = \frac{\text{contralateral}}{\text{ipsilateral}} \]

RESULTS

1. Areas of Activation

- Clear and measurable images were obtained for each participant using this protocol

2. Hemispheric Contribution: Laterality Indices (LI)

<table>
<thead>
<tr>
<th>Participant</th>
<th>LI Unaffected</th>
<th>LI Affected</th>
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<tbody>
<tr>
<td>Participant 1</td>
<td>+0.34</td>
<td>-0.14</td>
</tr>
<tr>
<td>Participant 2</td>
<td>+0.62</td>
<td>-0.25</td>
</tr>
<tr>
<td>Participant 3</td>
<td>+0.12</td>
<td>-0.10</td>
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- Positive LI's indicate greater extent of activation in the contralateral hemisphere
- Healthy adult values: dominant leg LI = +0.46 ± 0.05; non-dominant leg LI = +0.30 ± 0.04

CONCLUSIONS

- The dorsiflexion fMRI paradigm resulted in usable images for all participants
- Bilateral areas of activation were observed for ankle movements
- Areas of activation were predominantly in the unaffected hemisphere during both dominant and non-dominant limb movements
- These innovative findings advance clinical knowledge of fMRI and its use in identifying lower limb neural control strategies

FUTURE DIRECTIONS

- Cortical areas of activation will be analyzed to further assess between and within subject variability
- Clinical relevance of neural activity is currently being investigated by examining the association with gross motor skill outcomes
- The next development phase involves evaluating use of the LI to detect change in hemispheric contribution following interventions (linked feasibility RCT – AAPCPM Pedal-with-Pete Research Grant, 2016/17)
- Establishment of an fMRI paradigm to assess lower-limb neural activity in children with HCP provides a first opportunity to address important long-standing questions about the underlying neural mechanisms of improvement in gross motor skills

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References