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Cortical activity to painful and non-painful stimulation in amputees: a functional near infrared spectroscopy study

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The pathogenesis of phantom limb pain (PLP) remains a key focus in current pain research. However, investigations into cortical activity prior to amputation are still limited. The present research employed functional near-infrared spectroscopy (fNIRS) to examine cortical responses to painful and non-painful stimulation at different lower limb sites in both healthy individuals and pre-amputation patients.

Study 1 assessed 16 healthy participants and observe brain changes in oxyhemoglobin levels (HbO2) during painful and non-painful electrical stimulation of various lower limb sites. The results indicated no significant main effect of stimulation site on cortical HbO2 activity. However, significant interactions were observed among stimulation site, stimulation modality, and brain region. Specifically, painful stimulation to the left groin led to reduced neuro-metabolic activity in the prefrontal cortex and bilateral primary somatosensory cortex compared to non-painful stimulation, whereas painful stimulation to the right knee resulted in increased activity. These findings highlight the feasibility and potential of fNIRS in investigating pain mechanisms associated with stimulation of distinct lower limb regions.

Study 2 included 21 lower limb amputees and 10 healthy controls and explored differences between two groups in sensory thresholds and cortical activation patterns. Pre-amputation patients exhibited significantly higher pain tolerance thresholds, potentially due to peripheral nerve damage associated with underlying pathologies. Furthermore, compared to healthy controls, altered global hemodynamic responses in the patient group suggested impaired neurovascular coupling and reduced cerebral blood flow, with the dorsolateral prefrontal cortex and sensorimotor cortex being implicated in pain processing. Subgroup analyses revealed that patients who later developed PLP showed significantly elevated hemodynamic responses to the painful stimulation on the amputated side preoperatively, suggesting increased central excitability may contribute to PLP onset. However, the precise mechanisms remain to be fully elucidated.

Taken together, both studies emphasize the key role of cortical activity in lower limb pain processing and the impact of the interaction between different factors on hemodynamic response. These findings also demonstrate the feasibility and potential of fNIRS in investigating the neural mechanisms underlying lower limb pain.