Methodology for Using Functional Near-Infrared Spectroscopy To Characterize Effects of Gait Interventions on Walking Automaticity

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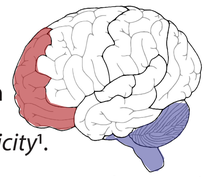
Locomotor control strategies range on a spectrum of automaticity

automatic ← → *cognitively demanding*



Atypical gait patterns demand more cognitive effort, and are associated with increased reliance on prefrontal cortex, or reduced *walking automaticity*[1].

fNIRS can be used to measure changes in prefrontal cortex activity to characterize walking automaticity[1-3].

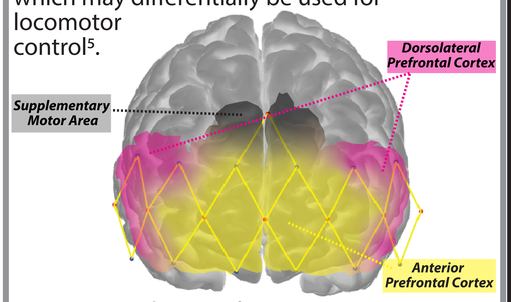
fNIRS indirectly measures cortical activity by comparing an experimental to a baseline condition, with walking most commonly characterized relative to standing[3].

However, walking and standing may activate different neural networks, which can introduce measurement noise[4].

Our primary aim was to evaluate the effects of characterizing walking using a standing versus walking baseline.

We hypothesized that compared to a standing baseline, use of a walking baseline would be associated with greater sensitivity for testing an effect, or reduced measurement variability across subjects.

Prefrontal cortex has functionally distinct subregions (e.g., dorsolateral and anterior), which may differentially be used for locomotor control[5].

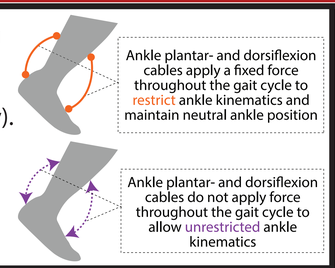


Our secondary, exploratory aim was to investigate the effects of characterizing walking automaticity in the dorsolateral and anterior subregions of prefrontal cortex.

How can functional near-infrared spectroscopy (fNIRS) be used to characterize changes in gait biomechanics on walking automaticity?

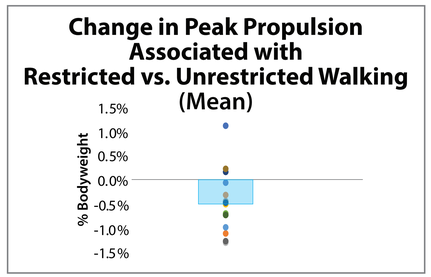
We used a cable-based robotic device that restricts unilateral ankle kinematics during walking to induce a biomechanically altered gait pattern with reduced propulsion. We hypothesized that altered gait would be associated with more cognitively demanding, less automatic locomotor control (i.e., increased prefrontal cortex activity).

N=15 healthy adults each performed two randomized treadmill walking paradigms (I. Standing Baseline and II. Walking Baseline) to measure changes in prefrontal cortex activity associated with walking with restricted ankle kinematics (i.e., *Restricted*) compared to walking with unrestricted ankle kinematics (i.e., *Unrestricted*).



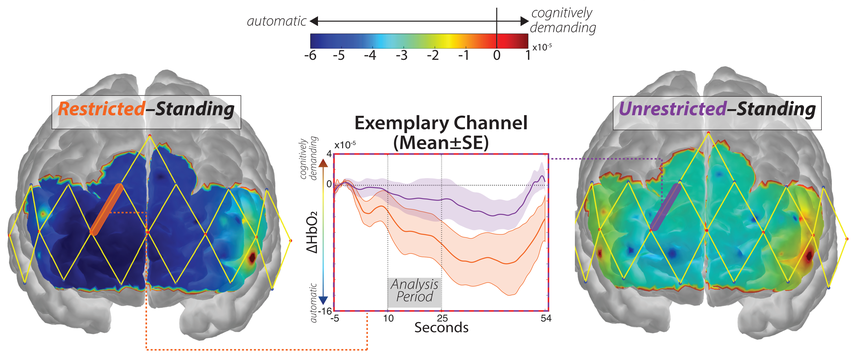
I. *Standing* Baseline Paradigm

Change in Peak Propulsion Associated with Restricted vs. Unrestricted Walking (Mean)

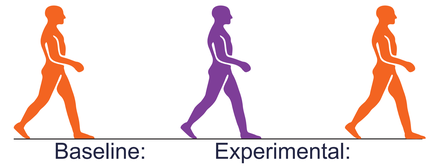


Walking with restricted ankle kinematics was only associated with increased cognitive effort when using a *Walking Baseline* and characterizing changes in *anterior prefrontal cortex* activity.

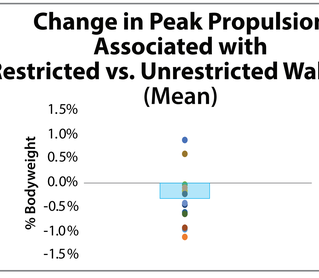
Δoxygenated hemoglobin concentration (ΔHbO₂)= ΔHbO₂ restricted – standing – ΔHbO₂ unrestricted – standing



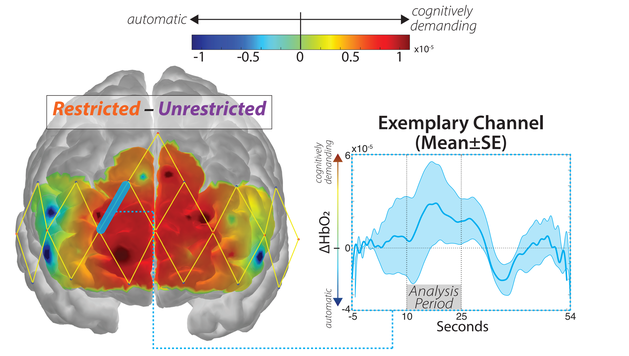
II. *Walking* Baseline Paradigm



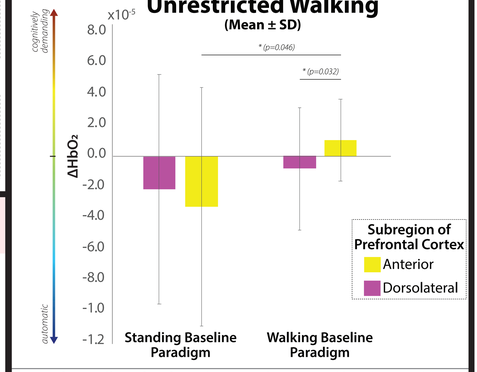
Change in Peak Propulsion Associated with Restricted vs. Unrestricted Walking (Mean)



Δoxygenated hemoglobin concentration (ΔHbO₂)=ΔHbO₂ restricted – unrestricted



Change in Prefrontal Cortex Activity Associated with Restricted versus Unrestricted Walking (Mean ± SD)



Significant effect of prefrontal cortex subregion and baseline condition

Individuals with neurological disorders and older adults have characteristically reduced walking automaticity, which may manifest as compensatory biomechanical gait patterns.

Emerging gait-restorative interventions, such as robotic exosuits, directly target deficits in kinetics and kinematics[6]. Measuring the effects of changes in gait biomechanics on walking automaticity can inform a more comprehensive and holistic approach to development and prescription of walking interventions[7].

This study provides foundational knowledge that can be used to effectively design future research that aims to characterize changes in walking automaticity associated with altered biomechanics.

References
[1]doi:10.3389/fnhum.2015.00246
[2]doi:10.1016/j.neubiorev.2017.10.002
[3]doi:10.1186/s12984-020-00797-w
[4]doi:10.1186/1743-0003-11-14
[5]doi:10.1152/ajpregu.00192.2021
[6]doi:10.1126/scitranslmed.aai9084
[7]doi:10.1093/ptj/pzab058

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