The Brain on Bikes: Voluntary Performance and Hemodynamic Response in the Prefrontal Cortex During Exhaustive Exercise

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Abstract: Cardiovascular and peripheral muscle efficiencies have been largely investigated as valid predictors of physical performance. In sports medicine, maximum oxygen consumption (VO_{2max}) and lactate threshold (LT) are often used to quantify physical fitness in professional and recreational athletes alike. However, only few studies have attempted to establish if a association exists between brain activity and the successful exertion of physical exercise. In particular, it is unclear if factors such as motivation and resilience to fatigue (or lack thereof), which arguably originate within the brain, can be quantitatively related to physical performance. As a first step to improve our understanding of the role of the central nervous system in physical exercise, we investigated the association between cortical oxygenation measured with functional near infrared spectroscopy (fNIRS) and physical performance in healthy young adults during cycling.

Methods: Cortical oxygenation changes in bilateral prefrontal and motor cortices (PFC, MC respectively) were measures with a 16 x 16 (sources x detectors) fNIRS instrument (NIRScout, NIRx, USA). Consistently with previous studies, we hypothesized that PFC activity would be associated to motivation and decision-making on whether to increment or decrement the physical effort and was therefore selected as the main region of interest, while MC was probed as a control region. Prior to data collection, we recorded the location of all optodes and optimized their placement on the scalp using the custom-software PHOEBE developed by our group. Ten healthy volunteers carried out the exercise protocol on a Velotron cycling ergometer in which the workload wattage could be set arbitrarily by either the experimenter or the subject. The four-day protocol consisted in an incremental workload test to measure the fitness level of each subject in terms of exerted LT power (Day 1), followed by three attempts of a 20-minute time trial performed across different visits (Day 2, 3 and 4). Prior to each time trial, subjects were instructed to attempt maintaining the highest possible average power output for the entire twenty minutes, but were allowed to voluntarily alter the workload in 5 watt increments using an up/down button mounted on the handlebar, therefore indicating their intention to increase or decrease their physical effort. Each workload alteration marked a subject-generated event that was subsequently labeled as "up" or "down" depending on whether the workload was increased or decreased. In our analysis, we considered additional "pre-onset" and "post-onset" events respectively marked 5 seconds before and after to the actual onset, for a total of 6 event types ([pre, onset, post] x [up, down]). Data were analyzed using an ordinary least squared general linear model (GLM) based on a convolved Gaussian function where all events were attributed a duration of 35 seconds to observe the cortical response to a voluntary increase or decrease in workload in contrast to a 5 second baseline prior to the labeled event.

Our preliminary results showed that several subjects exhibited a PFC oxygenation change that was significantly different than the MC oxygenation during a voluntary decrease in power, although not all subjects decreased the workload during the time trials. In contrast, oxygenation changes associated to increase in power were not found to be significantly different between the PFC and MC. Considering the substantial physical effort involved in this protocol, scalp hemodynamics is likely to play a confounding role that we are addressing in our ongoing analysis.

References: T. Rupp and S. Perrey, "Prefrontal Cortex Oxygenation and Neuromuscular Responses to Exhaustive Exercise." European Journal of Applied Physiology 102.2 (2008): 153–163