Review of: "Sustained Muscle EMG Activity to Contractile Failure During Incremental Exercise and Intense Constant Load Cycling: No Evidence of a Central Governor"

Vignesh Ravichandran[1]

1 University of Rhode Island

Potential competing interests: No potential competing interests to declare.

Introduction and Background: The paper begins with a well-structured introduction that effectively sets the context for the study. The authors provide a comprehensive overview of the Central Governor Model (CGM) and its implications for exercise physiology. The literature review is thorough, covering key studies that both support and challenge the CGM. The authors do an excellent job of identifying the gap in the literature, specifically the need to investigate muscle EMG activity during intense exercise to volitional failure. This clear problem statement naturally leads to the purpose of their study. The introduction could be slightly improved by more explicitly stating the potential implications of their research for exercise physiology and sports performance.

Methodology: The researchers have clearly put considerable effort into creating a protocol that thoroughly tests their hypotheses. The use of both incremental VO2max testing and multiple constant load critical power (CP) trials provides a comprehensive examination of muscle activation patterns across different exercise intensities and durations. This multi-faceted approach strengthens the validity of their findings.

The participant recruitment process and inclusion/exclusion criteria are well-defined, ensuring a suitable sample for investigating high-intensity exercise responses in trained cyclists. The sample size (n=14) is adequate for the primary analyses, though it becomes a limitation for some secondary analyses, particularly for the gluteus maximus data during CP trials.

The data collection methods are state-of-the-art, utilizing surface electromyography (sEMG) alongside gas exchange data. The detailed description of the EMG signal processing is particularly commendable, as it allows for reproducibility and critical evaluation of their methods. However, the inability to analyze data from the biceps femoris and medial gastrocnemius due to poor signal resolution is a limitation that could be addressed in future studies.

The statistical analysis is thorough and appropriate for the data collected. The use of repeated measures ANOVA and post-hoc analyses with correction is a rigorous approach to data interpretation. The researchers' decision to adjust their analysis plan due to data quality issues (e.g., for the gluteus maximus during CP trials) shows adaptability and transparency in their approach.

Results and Data Presentation: The results section is clear and well-organized. The authors present their findings in a logical sequence, moving from descriptive statistics of the participants to the detailed EMG results for both the VO2max and CP trials. The use of figures and tables is effective, particularly Figure 1, which provides raw data examples that help the reader understand the nature of the EMG signals being analyzed.

The statistical results are reported in detail, with appropriate use of F-values, degrees of freedom, and p-values. The authors clearly state which comparisons were statistically significant, aiding in the interpretation of the results. The presentation of the EMG slope data for different segments of the exercise bouts (Figures 3 and 4) is particularly illuminating, clearly showing the sustained increase in muscle activity up to the point of exhaustion.

Discussion and Interpretation: The discussion section is comprehensive and thoughtful. The authors do an excellent job of interpreting their results in the context of existing literature and the predictions of the CGM. They convincingly argue that their findings of sustained increases in muscle EMG activity up to the point of volitional exhaustion are inconsistent with the predictions of the CGM.

The discussion of limitations is honest and thorough. The authors acknowledge the challenges of interpreting sEMG data in terms of motor unit recruitment and the specificity of their findings to trained cyclists.

Areas for Improvement: While the study is generally excellent, there are a few areas where it could be enhanced:

1. The paper could benefit from a more detailed discussion of the practical implications of their findings for exercise physiology and sports performance. How might this new understanding of muscle activation patterns during intense exercise inform training strategies or performance optimization?
2. The authors could explore alternative or complementary techniques to sEMG (e.g., decomposition EMG or high-density EMG) that might provide more direct evidence of motor unit recruitment patterns. While this would likely require additional studies, discussing these possibilities would strengthen the paper's impact.
3. The generalizability of the findings could be addressed more extensively. While the authors acknowledge that their results are specific to trained cyclists, they could discuss how these findings might apply to other populations or exercise modalities, and suggest directions for future research.

Conclusion: In conclusion, this paper represents a significant contribution to our understanding of neuromuscular fatigue during intense exercise. The authors have conducted a well-designed study that challenges prevailing theories and opens up new avenues for research. While there are some areas for potential improvement, these are relatively minor compared to the overall strength of the work.

Influence on Training Strategies and Performance Optimization: The findings of this study, particularly the sustained increase in muscle activation up to the point of exhaustion, have several potential implications for training strategies and performance optimization in sports:

1. High-Intensity Interval Training (HIIT): The study's results suggest that athletes may be able to push themselves harder than previously thought without a central "governor" limiting their effort. This could lead to more intense HIIT protocols. For example, cyclists might incorporate shorter, more intense intervals (e.g., 30 seconds at 160% of

ventilatory threshold power) into their training, knowing that their muscles can sustain high activation levels for these durations. This could potentially lead to greater adaptations in both central (cardiovascular) and peripheral (muscular) systems.

2. Resistance Training: While the study focused on cycling, the principles could apply to resistance training. Bodybuilders or powerlifters might be encouraged to push closer to muscular failure in their sets, knowing that neural drive to the muscles can be sustained even as fatigue sets in. This could lead to greater hypertrophy and strength gains.
3. Mental Training: The study's findings emphasize the role of peripheral fatigue rather than central limitations. This could shift the focus of mental training strategies. Instead of trying to "overcome" a central governor, athletes might be trained to better tolerate the sensations of peripheral fatigue. Techniques like mindfulness or cognitive reframing could be employed to help athletes push through the discomfort associated with high levels of muscle activation.
4. Recovery Strategies: Given the emphasis on peripheral fatigue mechanisms, recovery strategies might be adjusted to focus more on addressing metabolic byproducts in the muscles. This could involve more targeted use of techniques like active recovery, thermal stimuli, compression garments, or specific nutritional strategies to address intramuscular metabolite accumulation.

Applicability to Other Populations and Future Research Directions While the current study focused on trained cyclists, the findings could potentially apply to various other populations and exercise modalities.

1. Untrained Individuals: Investigating whether similar patterns of sustained muscle activation occur in untrained individuals could provide insights into how training status influences neuromuscular fatigue. This could inform exercise prescription for beginners and help in developing more effective strategies for improving fitness in sedentary populations.
2. Elderly Population: Studying muscle activation patterns in older adults during high-intensity exercise could provide valuable insights into age-related changes in neuromuscular function. This could have implications for maintaining muscle mass and function in aging populations, potentially informing strategies to prevent sarcopenia.
3. Different Sports Modalities: Extending this research to other endurance sports like running, swimming, or rowing could help determine if the findings are specific to cycling or generalizable across endurance activities. Similarly, investigating intermittent sports like soccer or basketball could provide insights into how muscle activation patterns change during repeated high-intensity efforts interspersed with periods of lower intensity.
4. Strength and Power Athletes: Examining muscle activation patterns during maximal strength efforts (e.g., powerlifting) or explosive movements (e.g., Olympic weightlifting) could provide insights into neuromuscular fatigue in these different types of activities.
5. Longitudinal Training Studies: Conducting longitudinal studies to examine how muscle activation patterns change over the course of a training program could provide insights into the neuromuscular adaptations that occur with training.