Acute exercise modulates EEG resting microstates

UNIL | Université de Lausanne
Institut des Sciences du Sport de l'Université de Lausanne

LEMANIC NEURO SCIENCE

Jérôme N. Spring[1], Miralena I. Tomescu[2], Jérôme Barral[1]
[1]ISSUL, Institute of Sport Sciences, University of Lausanne, Switzerland
[2]Functional Brain Mapping Laboratory, Department of Fundamental Neuroscience, University of Geneva, Switzerland

INTRODUCTION

Multichannel electroencephalography (EEG) recording during relaxed wakefulness is a promising method to explore spontaneous brain activity changes after exercise. Until now, resting EEG studies that investigated the post-exercise electrical brain state were restricted to power spectral analyses and have neglected the dynamics of brain function.

The present study suggests to quantify the overall cortical dynamics immediately after exercise by using microstate analysis. EEG activity is seen as a series of momentary brain electric filed that varies over time[1]. Microstates correspond to brief period (i.e. 80-120 milliseconds) of stability characterized by a high synchronized electrical activity. As different spatial configurations are generated by different neural elements, the microstate topography analysis would reflect the functional state of the related neurocognitive network.

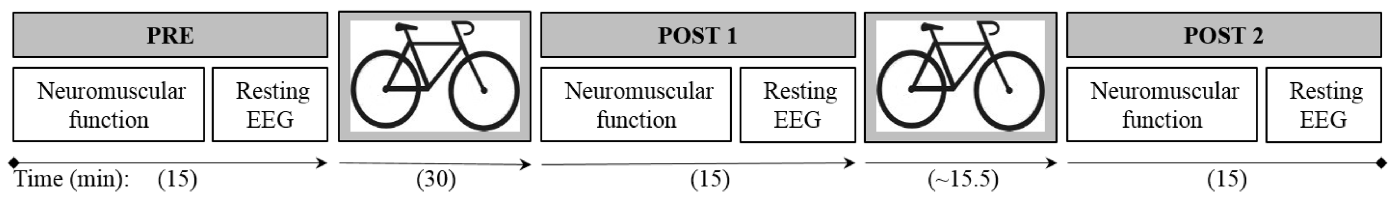
PURPOSE

Investigating the effect of two cycling exercises on the four microstate configurations described in the literature[2] and their temporal features.

Since neuromuscular fatigue might modulate brain activity[3], conventional neuromuscular measurements were collected and associated with EEG changes.

METHOD

Twenty trained male athletes performed a heavy cycling exercise during 30 minutes, followed by a severe 10-km all-out time trial. Neuromuscular function and resting EEG were recorded before exercising (PRE), after the heavy (POST1) and severe (POST2) exercise.



Variable	MEAN ± SD
Age (years)	30.8 ± 6.9
Weight (kg)	73.1 ± 6.0
Height (cm)	179 ± 5
Total Baeck score	9.27 ± 0.73
$\dot{V}O_2$ peak ($ml \cdot min^{-1} \cdot kg^{-1}$)	63.1 ± 7.1
Maximal aerobic power (watt)	381.9 ± 43.7
Heavy exercise mean power (watt)	227.9 ± 21.8
RPE at the end of heavy exercise	14.9 ± 1.6
Time trial mean power (watt)	279.2 ± 32.1
RPE at the end of time trial	19.7 ± 0.5

Neuromuscular function

Volunteers performed 2 maximal isometric knee contractions, superimposed by a 100Hz paired stimuli during the plateau and a potentiated 100Hz doublets at rest to identify:

- Maximal voluntary contraction force (MVC)
- Voluntary activation level (VAL, reflects the ability of the CNS to drive the muscle)
- Paired stimuli force (P100Hz, reflects the excitation-contraction coupling)

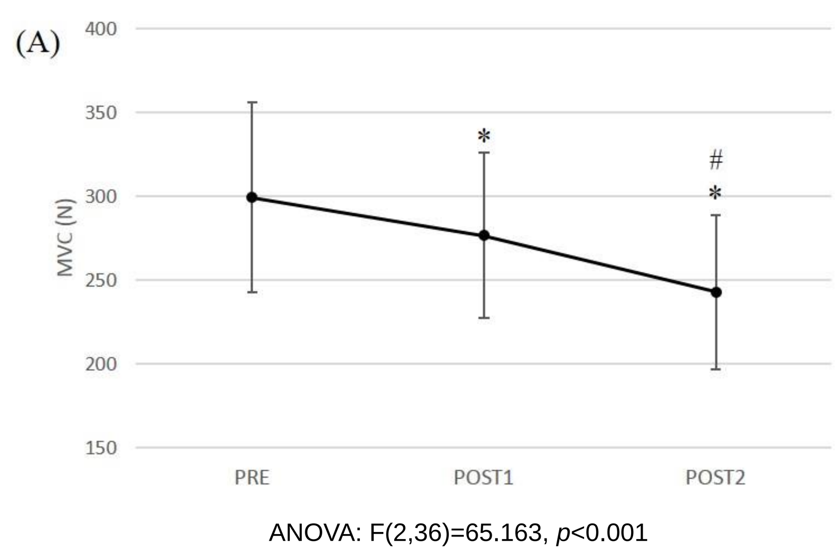
Resting EEG

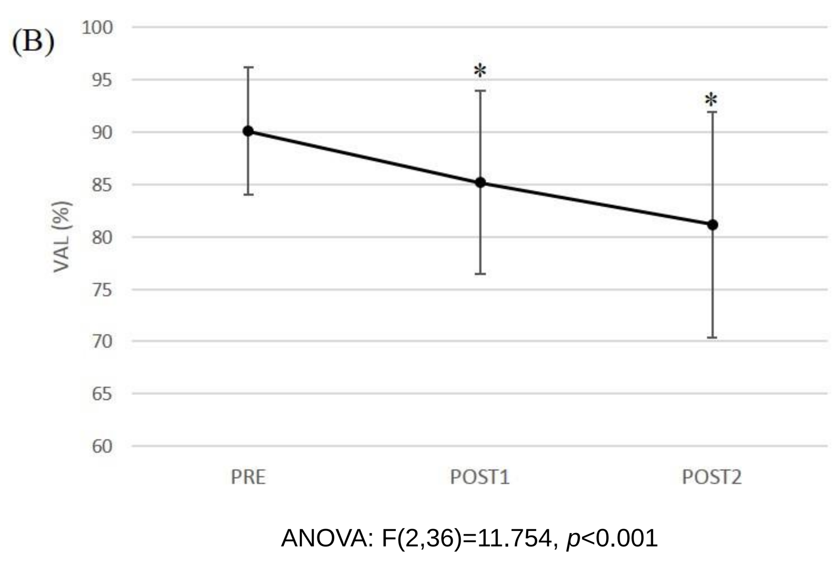
Surface EEG (64-e) was recorded during 3 minutes. After the pre-processing the 3 initial datasets (i.e. PRE, POST1, POST2) were concatenate into 1 file and the topographies with highest Global Filed Power (GFP max) were submitted to a k-means clustering to identify the most representative topographies for each volunteers. The best maps of each subject were then used to compute a grand clustering to obtain the 4 conventional map topographies. The spatial correlation was computed between the topographies within the initial datasets and the 4 representative map templates identified by the grand clustering to obtain the following parameters:

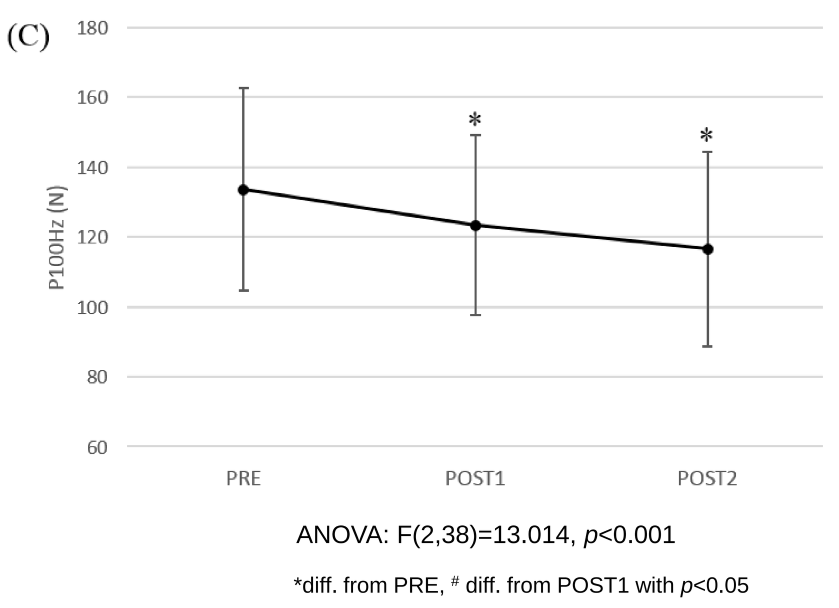
- Global Explained Variance (GEV, sum of the explained variances of each microstate weighted by the GFP)
- Mean duration (average time in millisecond covered by a given microstate)
- Time coverage (percentage of time covered by a given microstate)
- Frequency of occurrence (mean number of distinct microstate that occurs within 1 second)
- Transition probability (occurrence frequency of transition from one map to the three others)

RESULTS

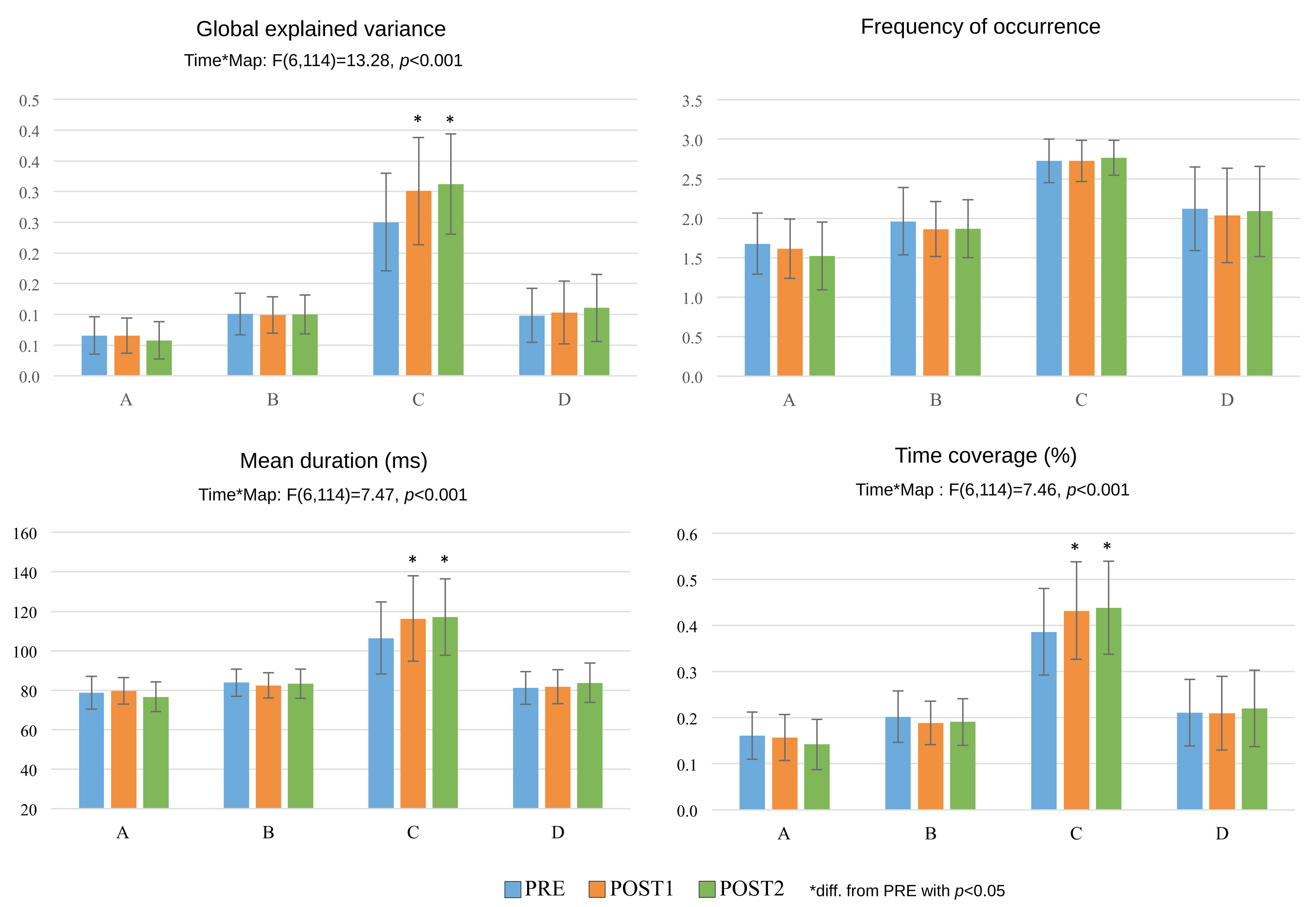
Compared to the PRE condition, the exercise induced significant neuromuscular fatigue, resulting in a reduction in **MVC** force (panel A) associated with a reduction in **VAL** (panel B) and **P100Hz** (panel C).



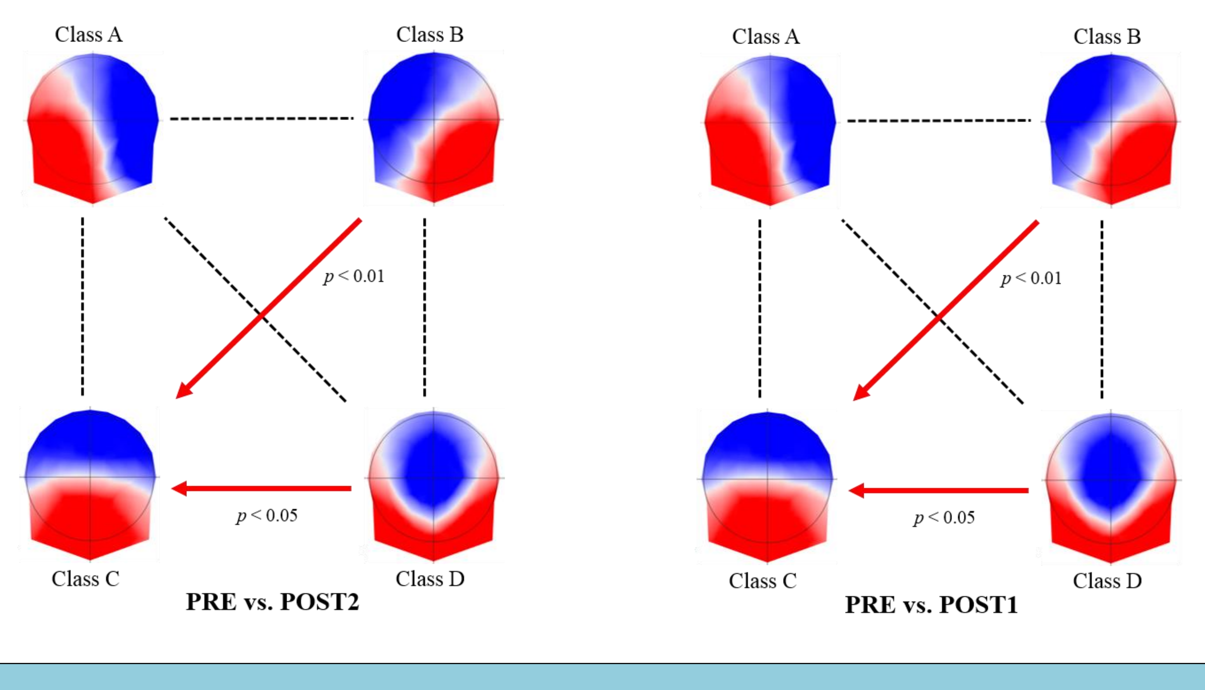




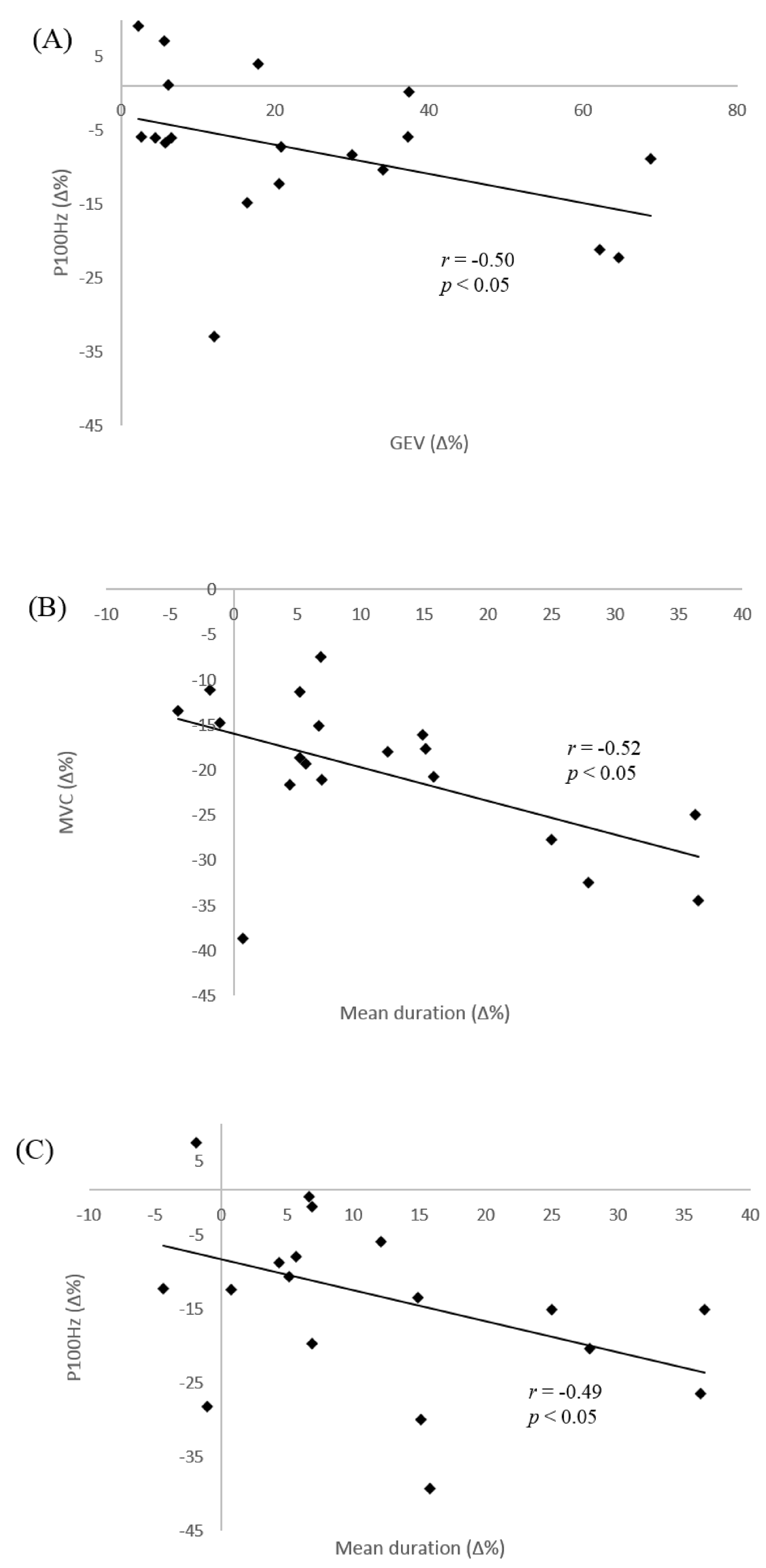
Microstate parameters changes for the **4 map topographies** (classes **A**, **B**, **C** and **D)** recorded in **PRE**, **POST1** and **POST2** condition.



Microstate map **configurations** and **syntax**. The transition probability of moving from microstate class B to class C, and from microstate class D to class C has increased in POST1 and POST2 condition, compared to PRE. Red arrows show the direction of the significant transition changes.



Correlations between **neuromuscular** and **microstate class C changes**, between PRE-POST1 (panel A) and between PRE-POST2 conditions (panel B and C).



CONCLUSION

After exercise, the duration and stability of the microstate class C were increased, as well as the transition probability of moving from microstate class B and D to the microstate class C. Map C has been associated with the salience resting state network (RSN)[4] and activity within the insula and cingulate cortex, two main structures receiving input from multisensory modalities[5]. Based on the significant correlation between peripheral muscle alterations (↓P100Hz) and increase in map C mean duration, we speculate that the post-exercise microstate pattern could be modulated by the muscle afferents that project into the saliency RSN. On the other hand, structures within saliency RSN (i.e. insula) appears to be interconnected with the motor cortex and might indirectly participate in modulating the motor output, as suggested by the significant correlation between the increase in map C mean duration and reduction in MVC force as reported in the present study.

Perspectives

To better understand the meaning of post-exercise microstates, it would be interesting to associate brain changes with other physiological consequences of physical effort, such as the sympatho-vagal balance response.

NEW FINDINGS

This study showed that a single-bout of exercise modulates the EEG resting brain dynamics and syntax. The four conventional map topographies are present after acute endurance exercise, but temporally reorganized. We suggest that the post-exercise microstate changes reflect interoceptive-autonomic activity adaptations.

References

1. *Michel, C. M. (2009). Electrical Neuroimaging. Cambridge University Press.*
2. *Lehmann, D., Strik, W. K., Henggeler, B., Koenig, T. (1998). Brain electrical microstates and momentary conscious mind states as building blocks of spontaneous thinking: I Visual imagery and abstract thoughts: Int. J. Psychophysiol. 29(1):1-11.*
3. *Boecker, H., Hillman, C. H., Scheef, L. & Strüder, H. K. (2012). Functional Neuroimaging in Exercise and Sport Sciences. Springer Science & Business Media.*
4. *Britz, J., Van de Ville, D., Michel, C.M. (2010). BOLD correlates of EEG topography reveal rapid resting-state network dynamics. NeuroImage 52 1162-1170.*
5. *Menon, V. (2015). Salience Network. In Brain Mapping (p. 597-611). Elsevier.*

Contact: jerome.spring@unil.ch