Characterization of individual responses to partial sleep recovery in the context of sleep debt using time-varying autonomic markers

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Résumé

Introduction

In extreme endurance sports and military contexts, individuals face physical and cognitive challenges under conditions of severe sleep deprivation. It is well established that acute sleep deprivation impairs physical performance (1) and cognitive functions (2), potentially compromising task execution. These impairments are driven by physiological changes, particularly involving the autonomous system. Based on the concept of brain-heart interplay (3), autonomic dysregulation induced by sleep deprivation could be a likely factor to impaired executive functions. While sleep can help restore autonomic regulations and support optimal functioning, opportunities for rest are frequently restricted in both duration and frequency.

The present study investigates the effects of a 3-hour night sleep episode, following total sleep deprivation on cognitive performance and autonomic nervous system modulations in healthy young adults, with a focus on inter-individual variability.

Methods

A sleep restriction protocol was implemented over three days: 8 hours of monitored sleep (REF) on day one, total sleep deprivation (TSD) on the day two, and 3 hours of partial sleep recovery (PSR) on day three. Each day, 20 participants (12 males, 8 females; age = 32 $\pm$ 8.0 years) performed an experimental protocol consisting in performing 10min of MATB-II task involving high cognitive demand. Heart rate Variability (HRV) and Electrodermal Activity (EDA) signals were recorded. A performance marker was assessed by calculating the Root Mean Square Distance between the cursor and the target during the MATB-II tracking task. Workload perceived was collected using the NASA-TLX questionnaire.

*Intervenant

Autonomic nervous system responses were assessed by extracting time-varying index from EDA and HRV using variable frequency complex demodulation (VFCDM) (4). The TVSymp marker was used to quantify sympathetic responses derived from EDA. For cardiac autonomic modulation, LF-VFCDM and HF-VFCDM markers served as markers of sympathetic and parasympathetic modulations respectively.

The effects of TSD and PSR on markers were explored using one-way repeated measures ANOVAs or non-parametric Friedman tests followed by multiple pairwise comparisons or Conover post hoc comparisons.

To investigate individual variability in physiological responses, participants were split into two groups based on changes in performance between TSD and PSR. The ”recovery group” (n=14) improved performance after PSR, whereas the ”no recovery group” (n=6) demonstrated further performance decline.

Results & Discussion

Performance significantly dropped after TSD (p=0.047). The lack of significant differences between REF and PSR (p=1.000) combined with the marginal difference between TSD and PSR (p=0.066) supports the hypothesis that participants, on average, recovered following PSR.

Regarding physiological markers, a sleep debt effect was observed for HF-VFCDM ($Chi^2(2)=6.4$, p=0.041) with higher values recorded after PSR (p=0.047) compared to TSD. This finding is interpreted as parasympathetic reactivation (autonomic recovery) following PSR. The TVSymp showed significantly lower values after PSR (F(2,38)=7.119, p=0.002) compared to both REF (p=0.004) and TSD (p=0.008). Since this marker reflects pure sympathetic tone, the possible interpretation is that participants experienced significant sleep debt (about 52 hours total), shown by the marked drop-in sympathetic activity.

Interestingly, participants in the ”recovery group” demonstrated significantly better performance (p=0.017), higher HF-VFCDM (p=0.011), and lower TVSymp (p=0.015) and reported higher perceived effort (p=0.023) after PSD. These findings refine and confirm the results by highlighting individual differences, showing that HF-VFCDM and TVSymp are robust markers of sleep debt and recovery at the individual level.

Conclusion & Perspectives

This study demonstrates the potential of short sleep periods to promote functional recovery under conditions with limited rest opportunities. HF-VFCDM and TVSymp markers effectively reflect individual differences in sleep debt and recovery. Future studies should increase sample sizes to strengthen these findings and explore the effects of post-deprivation recovery under varying cognitive loads.

References

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