



Assessment of Physical Exercise Benefits on Brain Health for Long-Duration Spaceflight

Sleep and exercise

Executive Summary

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Picture:**Motivation:**

Poor sleep on the ISS remains one of the major factors, which affect negatively the performance and psychological resilience of astronauts. The development of novel effective countermeasures for sleep loss, performance decrements and psychological deficits during space missions is needed.

Methodology:

During manned space missions physical exercise is used to counter the effects of osteoporosis during weightlessness in space. However, using exercise in space may also lead to marked improvement of cognitive functions and psychological state, which are crucial during long-term flights. The aim of this project is to address the hypothesis that the benefits of exercise for the brain can complement or even partially replace cognitive and psychological benefits provided by sleep. We performed recording and analysis of brain activity (electroencephalogram and neuronal spiking) in laboratory mice during wheel running behaviour and during sleep. We performed sleep deprivation to investigate whether stereotypic wheel running counteracts the increase of sleep need during prolonged wakefulness. Then, we investigated whether running wheel availability directly affects subsequent sleep. Finally, we used complex wheels, to investigate whether stereotypic locomotion and learning a novel motor skill have differential effects on sleep.

Results:

- We found that running wheel activity correlated positively with wake duration, suggesting that the build-up of 'sleep need' occurs at a slower rate during running, thus enabling longer wakefulness;
- We observed an overall suppression of neuronal activity in the neocortex of mice during stereotypic running. This suggests that parts of the brain which are not directly involved in locomotion can rest during exercise;
- We demonstrate that the animals tolerate extended wakefulness better and have reduced tendency to sleep, if they have an opportunity to run during sleep deprivation. We interpret this result as a counteraction of sleep pressure provided by stereotypic running.
- We report that in ~2/3 of animals, sleep latency was decreased after a period of running on a complex wheel, and overall sleep was increased by almost one hour. This result supports our hypothesis that voluntary stereotypic running is associated with decreased sleep need, as compared with waking dominated by demanding cognitive activities.

Publications:

Fisher, S.P., Cui, N., McKillop, L.M., Gemignani, J., Bannerman, D.M., Oliver, P.L., Peirson, S.N., and Vyazovskiy, V.V. (2016). Stereotypic wheel running decreases cortical activity in mice. *Nature Communications*, *in press* (DOI: 10.1038/NCOMMS13138)

Highlights:

Our data suggest that stereotypic waking behaviours may either counteract the build-up of sleep pressure, or even provide some of restorative functions, typically provided by sleep. This new perspective opens novel opportunities for renormalisation of brain function in conditions where it is difficult to obtain sufficient sleep, such as throughout long-duration space missions. Our work will lead to the development of specific training schedules, which can improve cognitive functioning and provide psychological benefits to astronauts during spaceflight.