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Author: Prof. Matthias Lochmann
Friedrich-Alexander University Erlangen-Nürnberg, Germany

ELECTROENCEPHALOGRAPHICAL, ELECTROMYOGRAPHICAL, AND BIOMECHANICAL INVESTIGATION OF ASTRONAUTIC MUSCLE TRAINING SYSTEMS IN WEIGHTLESSNESS

Abstract

In previous parabolic flight experiments we tested the properties of a special bicycle ergometer training system designed for countermeasures against muscle function decay in long term spaceflight missions. All test subjects exhibited different muscle activation patterns in weightlessness as compared to normal gravity. In order to gain more insight into the gravity dependent muscle coordination underlying this effect we employed in a follow – up parabolic flight experiment a bicycle ergometer with a mechanism enabling controlled locking and unlocking of the pedals. The test subject can thus exert cycling torque with the right and left leg independently. As this condition imposes an even greater demand on the coordination of the leg muscles in cycling, it is well suited for the investigation of changes induced by different gravity conditions.

Within the 13th parabolic flight mission of the German Aerospace Center (DLR) at the Novespace base at the airport of Bordeaux – Mérignac, France, we implemented experiments with the special bicycle ergometer mounted in the Airbus A – 300 Zero – G aircraft in all gravity phases (1g, 1.8 g, 0g) of 90 flight parabolas. 6 subjects carried out exercise at different cycling powers with the pedals locked and unlocked according to a defined experimental protocol. The subjects were fixed to the ergometer in a way as to prevent any floating of their body in the microgravity phase. The electromyographical activity of 5 muscles (tib. ant., gastrocn., vast. med., rect. fem., biceps fem.) of either leg, the ergometer pedal movement parameters, and a high resolution (64 electrodes) EEG were recorded. For the signal recording and processing we configured a special airborne measuring system and elaborated a dedicated software package including special statistical signal analysis procedures.

All 6 subjects met the experimental conditions in all phases of the parabolic flights without any difficulties even at physically exhaustive cycling power levels. In normal gravity (1 g) the activity pattern of all investigated muscles and the pedalling kinematics exhibited considerable differences as compared to exercise at the same cycling power in microgravity and, in particular, in hypergravity. The quality of the subject's body fixation to the ergometer device seems to take considerable effect on the muscle activation changes during the microgravity phase.

The results of this study confirm and specify our earlier findings that the exact properties of muscle training equipment for manned space flight can only be reliably evaluated in microgravity itself. This is important for the preflight planning of dedicated muscle training programs to be carried out during a long term stay in microgravity as on the International Space Station ISS. Bicycle ergometer exercise of any kind cannot, however, provide an adequate substitute for the missing natural muscle training of everyday terrestrial walk with its individually specific intermuscular coordination. It can rather be employed for non – specific muscular fitness training in the lower extremities and, of course, for cardiovascular training.