Abstract

Title: Prolonged apnea: monitoring brain activity in freedivers

Objectives: The aim of this study is to monitor the brain electrical activity during the prolonged apnea in freedivers. Prolonged apnea in the water and prolonged dry apnea were compared to each other and also to a resting state before the apnea, all states with the eyes closed. Brain activity was obtained from the scalp EEG and evaluated using the sLORETA program.

Methods: The research was conducted in 11 healthy men at the age of 23 – 51. The data was obtained from the scalp EEG. The record was first taken at a resting state before the apneas with eyes closed, then at maximum prolonged dry apnea with eyes closed and finally at maximum prolonged apnea in the water with eyes closed. The lenghts of the prolonged apneas ranged from 2:15 minutes to 5:30 minutes in idividual probands. There were pauses of at least three minutes between each apnea as by the proband's needs. The compared pair groups were following: prolonged apnea in the water against prolonged dry apnea, prolonged apnea in the water against resting state before the apnea and finally prolonged dry apnea against resting state before the apnea, all with the eyes closed. Selected sections of EEG record without artefacts were processed by sLORETA program. In the statistical module of the program, the statistical difference when comparing the individual states was calculated using a paired t-test with a logarithmic transformation of the data with smoothing parameter of 0,2. Data was randomized with a value of 5000 at a significance level $p \leq 0,10$ with a correlation for retesting. For each frequency band the source activity was then displayed in the 3D Talaraich Atlas.

Results: The obtained data proved statistically significant difference in brain activity in all three compared pair groups. The current density differences by voxels in the beta and gamma frequency bands was decreased when comparing the state of prolonged dry apnea with resting state. The reduction in activity was particularly in areas of premotor, motor and somatosensory functions and in limbic system. The increased current density differences by voxels was in the delta frequency band, where cortex regions responsible for somatosensory functions, regions functionally associated with voluntary respiratory

control, proprioceptive stimulation, and deep visceral perception was activated. Comparison of the prolonged apnea in water with the resting state showed similar results within the beta, gamma and delta frequency bands as in the case of prolonged dry apnea. In addition, areas associated with the processing of auditory stimuli, attention, inhibition processes or internal speech have been activated. Only in prolonged breath hold in the water, activity within areas associated with the processing of negative emotions, proprioception, pain prediction or motor executive behavior control was increased within the theta frequency band. The increase in alpha frequency band activity with localization in the frontal areas of the cerebral cortex also showed lower statistical significance. We can assume here a connection with the so-called flow states. The state of prolonged breath hold in the water versus prolonged breath hold on dry land shows an increase in delta activity and of lower statistical significance also in theta frequency band. In the case of prolonged apnea in the water, areas associated with somatosensory, emotions and their processing or self-reflection have become more active.

Keywords: freediving, prolonged apnea, apnea, EEG, sLORETA, hypoxia, hypercapnia, Brodmann areas