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TECHNICAL NOTE

RECORDING EEG DATA IN HUMAN CENTRIFUGE CONDITIONS – PRELIMINARY REPORT

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Introduction: The objective of the study was to assess the possibility of recording EEG data and the quality of these data in human centrifuge conditions. The study was performed using equipment used in the clinical setting. A total of 10 male subjects aged 24 to 50 years took part in the study. As shown by the study results, the EEG signal strength increased with increasing acceleration; so did the number of artifacts within the EEG spectrum. It is possible to record EEG signals in the human centrifuge with no artifacts that might render the analysis of the EEG record impossible.

Keywords: gravity load, EEG, human centrifuge, hypoxia

Figures: 6 • **References:** 11 • **Full-text PDF:** http://www.pjamp.com • **Copyright** © 2015 Polish Aviation Medicine Society, ul. Krasińskiego 54/56, 01-755 Warsaw, license WIML • **Indexation:** Index Copernicus, Polish Ministry of Science and Higher Education

INTRODUCTION

The human centrifuge training simulator is a tool with versatile training, diagnostic and research applications that facilitates, for example, the training of anti-G straining maneuvers, subjects; introduction to the effect of high-gradient gravity loads and push-pull effects (i.e. positive gravity loads occurring directly after negative gravity loads), as well as simulator training in conditions similar to that of real-life flight. In addition, the training carried out in centrifuge facilitates the improvement and maintenance of optimum tolerance to gravity loads whenever performance of airborne tasks is impossible or contraindicated. This provides a safe alternative method for raising the pilots' awareness of the adverse effects of gravity loads, including G-force induced loss of consciousness (G-LOC) and spatial disorientation [2,4,6,9]. By performing centrifuge training using aircraft steering elements, one may efficiently and safely train e.g. navigation flights, elements of air combat and capture at high and rapidly increasing gravity loads. Constant improvement of the quality and efficacy of the training of military aircraft pilots in high gravity load conditions and optimum use of the distribution of attention remains an important element of aviation training. High and variable gravity loads reduce psychomotor capabilities of pilots, their ability to properly carry out in-flight tasks as well as the safety of the flight itself. Loads generated e.g. during turn maneuvers may be several times higher than the Earth's gravitational force and accompanied by various psychophysiological reactions of the body. Centrifugal forces generated during centrifuge runs cause an outflow of blood from the brain towards lower extremities, causing hypoxia and impeding proper supply of blood to the central nervous system. Cerebral hypoxia is also accompanied by visual disturbances including narrowing of the visual field. In extreme cases, this may lead to complete loss of vision upon maintained consciousness or to G-force induced loss of consciousness (G-LOC) [3,8,10].

In order to record certain brain activities during the use of the training equipment, we decided to use the electroencephalographic (EEG) measurement technique that records the spontaneous bioelectrical activity of the brain using electrodes attached to the head surface. According to current outlooks, EEG records the overall postsynaptic activity, i.e. postsynaptic excitation as well as postsynaptic inhibition. The functional potentials are too short and their summarized activity is difficult to obtain; in addition, they are diffused and suppressed upon transmission by the system comprising of cerebrospinal fluid, meninges, skull bones and skin. EEG is capable of recording only the synchronization of postsynaptic potential within cortical areas of at least several square centimeters. The size of the EEG signal is directly proportional to the area of synchronization and the degree of synchronization [1,5,7,11].

OBJECTIVE

The objective of this study was to perform practical evaluation of the possibility of recording electroencephalographic signals using a portable EEG device in a high gravity load training simulator, i.e. in variable gravity loads being exerted on pilot's body, mostly in the head-to-legs direction along the vertical body axis. Examinations were performed using equipment routinely used in the clinical setting. The methodology of the study included both the measurement of physiological parameters recorded during exposure to high gravity loads and the objective assessment of the performance of predefined in-flight tasks. A total of 10 male subjects aged 24 to 50 years took part in the study. The study group consisted of both inexperienced aviators who had freshly graduated from schools as well as of fully-trained fighter pilots. The experience was defined by the total number of hours in the air – from a dozen or so up to several thousand of total flight time.

METHODS

AURA24 (ambulatory universal recording amplifier) Holter device (Grass Technologies, USA) was used for the recording of EEG spectra. The study procedure consisted of three stages. In the first stage, test centrifugation of empty centrifuge was performed to examine, e.g. the effect of the conditions throughout the centrifugation process on the quality and clarity of records (the number of artifacts). The next stage consisted of test recording of EEG spectra in simulated flight (no centrifugation). Satisfactory results obtained in both initial stages that showed no technical artifacts that might disqualify the recording technique allowed us to proceed to the main stage of the study, i.e. to the recording of EEG signals in the study group subjects exposed to simulated flight conditions involving the gravity loads. All signals were recorded using 10-mm gold cup electrodes attached to the skin of the head using EC2 adhesive paste. Before electrode attachment, the skin

Fig. 1. Electrodes being attached to the subject's skin.

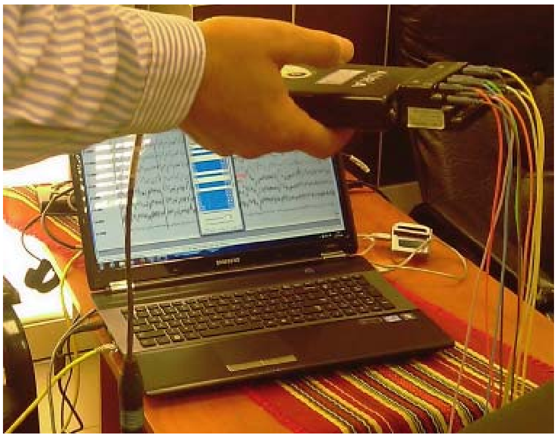

Fig. 2. Calibration of the EEG record.

of the head was prepared using Nuprep abrasive gel (Fig. 1.).

Biological calibration of EEG record was performed in resting condition before the centrifuge test (Fig. 2.). Calibration included suppression of alpha activity; in addition, the subjects were asked to blink their eyes and grit their teeth. Conversations were recorded as well. When entering the gondola of the centrifuge, the subjects received a push button they were to press in order to signal the start of exposure, i.e. the increasing gravity load. While in the centrifuge, the participants were subjected to tests applied according to two types of high-gravity profiles: an automated mode, with gravity load increases being controlled by the centrifuge software, as well as dynamic flight simulation mode when the subjects were in control of the rudder and made autonomous decisions regarding the onset and duration of gravity loads during the simulated flight. Subjects pressed the signaling button before increase acceleration loads in the automatic mode as well as upon entering the Dynamic Flight Simulation mode. Besides recording the EEG signals, routine measurements of other physiological parameters were performed, including heart rate, oxygen saturation (HR) (SaO_2), and pulsatility index.

In addition, all subjects wore one of two types of standard anti-gravity suits/trousers (American-made CSU-13 or Russian-made PPK-3) that reduced the outflow of blood from the brain into the lower limbs.

RESULTS

EEG signals from different electrodes were analyzed during centrifugation, particularly from the long bipolar electrodes F4-O2 and F3-O1 due to their range that included the overall activity of the brain for the left and the right hemisphere, respectively. Fig. 3. presents the EEG record acquired during linear escalation of the gravity load to +7G (the top part shows a 120-second course of the EEG wave while the bottom part shows the corresponding DSA plot) showing an increase in the EEG signal strength upon increasing gravity load. This was a broad-band phenomenon and no characteristic frequencies could be identified.

Fig. 4. presents the same fragment of the EEG record acquired during linear escalation of the gravity load to +7G (the top part shows a 120-second course of the EEG wave while the bottom part shows the corresponding plot of slow delta and theta wave trends and the ratio of the total power of these waves to the overall power of the entire record), reflecting the artifacts caused by the subject's movements. Upon the maximum load of +7G, the contribution of delta waves is reduced while the contribution of the theta waves increases. Unfortunately, these observations could not be confirmed in all records. Of note is the reduced ratio of combined delta and theta wave power to the overall power of the entire EEG record. It illustrates the increasing power of the faster elements that correspond to the increasing muscular function and artifacts generated by this function that fit into the fast EEG activity range. Fig. 5. presents the same EEG record acquired during linear escalation of the gravity load to +7G (the top part shows a 120-second course of the EEG wave while the bottom part shows the corresponding aEEG plot) showing a clear increase in amplitudes of both plots. The measurements show an increase in the peak-to-peak EEG amplitude from ca. 80 μV before starting the training to more than 400 μV

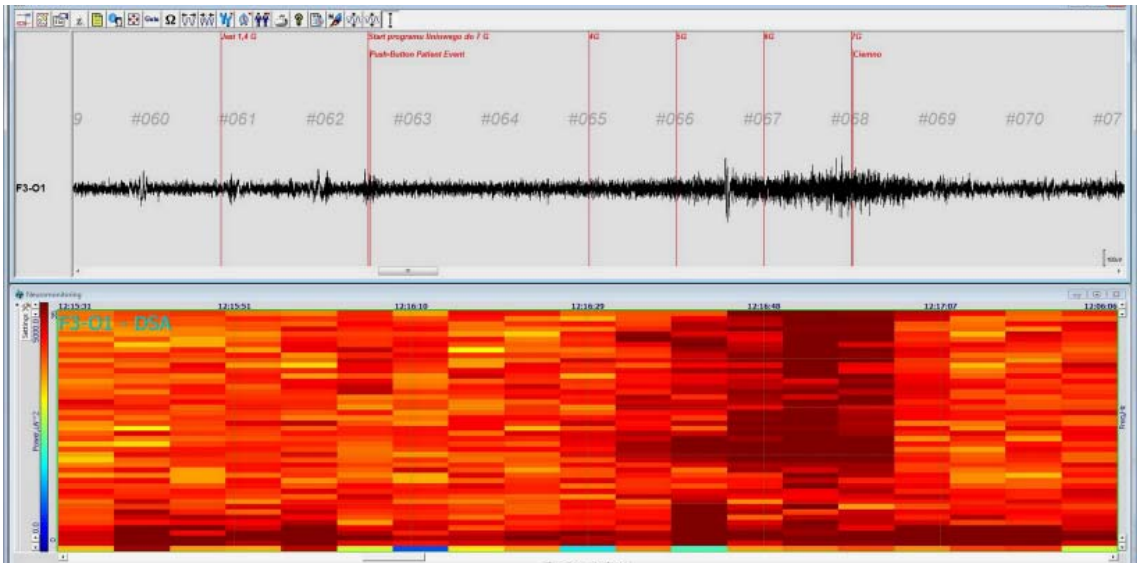

Fig. 3. Example EEG plots recorded during linear escalation of the gravity load to +7G.

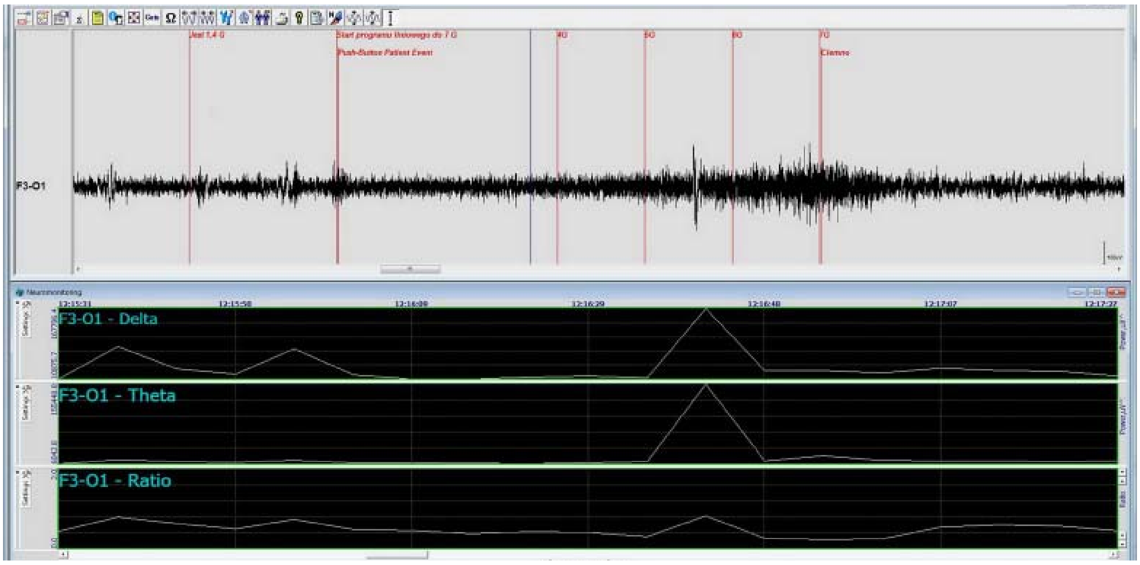

Fig. 4. Example EEG plots recorded during linear escalation of the gravity load to +7G.

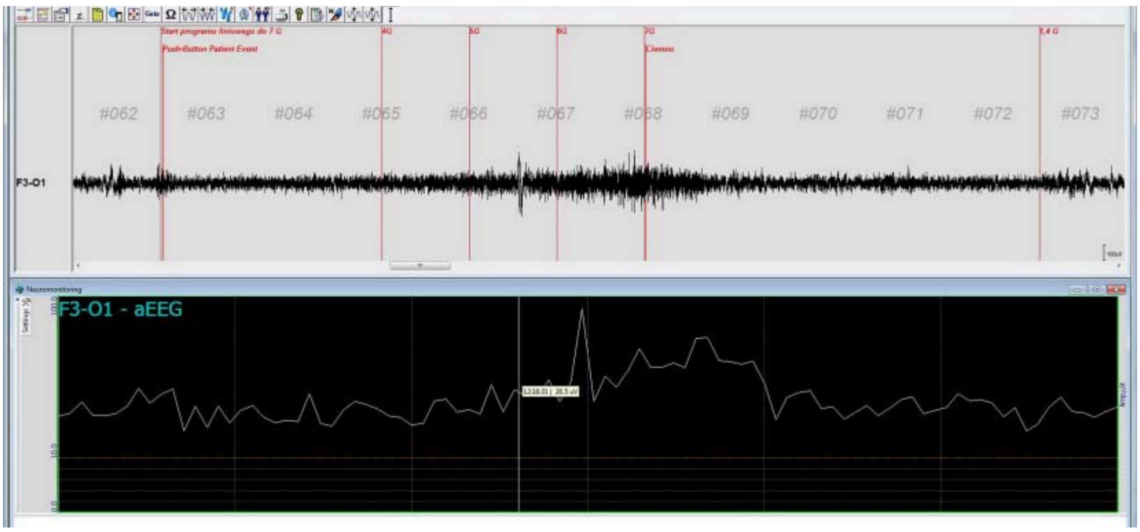

Fig. 5. Example EEG plots recorded during linear escalation of the gravity load to +7G.

upon the exposure to the gravity load of +7G. The wave spectrum calculated using the FFT method is a broad-band spectrum with peak frequency of ca. 15 Hz. Also detectable are small peaks at 1.2 and 6 Hz, fitting within the range of frequencies potentially responsible for changes occurring in the brain due to the high gravity load. However, it is too early to assume this responsibility at this stage of data analysis since the peeks are too low and not repeatable.

CONCLUSIONS

During high-gravity centrifuge training, the measured EEG activity is significantly masked by muscle activity and movement-related artifacts. The amplitude of these artifacts increases in proportion to the increasing gravity load. However, it is possible to record EEG spectra in the centrifuge as the device generates no artifacts that might render the analysis and interpretation of the record impossible. EEG records obtained in the small range of gravity loads (+2G to +3G) are readable for visual analysis. On the other hand, when the subject is exposed to higher gravity loads (+5G to +6G), the record contains a high number of biological artifacts generated by the tension of lower limb and abdomen muscles during the anti-G straining maneuvers as well as by the tension of neck muscles. More readable results require a better method for the recording or the analysis of signals so as to further eliminate the artifacts. Further studies are also required, both in static and dynamic loading conditions, to determine the effect of gravity loads on EEG activity. However, the obtained results are promising and continuation of the study is planned in a larger population of subjects with varied piloting experience to examine the repeatability of observations made in this study.

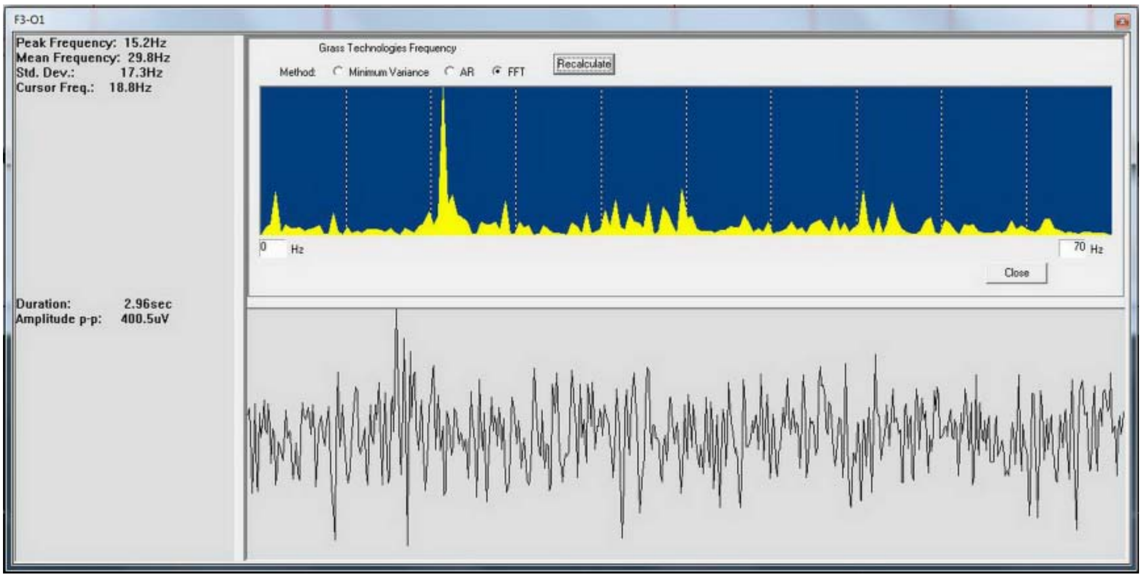

Fig. 6. Example wave spectrum calculated using the FFT method.

AUTHORS' DECLARATION:

Study Design: Krzysztof Kowalczuk, Marcin Strojek, Piotr Walerjan; **Data Collection:** Krzysztof Kowalczuk, Marcin Strojek, Piotr Walerjan; **Statistical Analysis**: Krzysztof Kowalczuk, Marcin Strojek, Piotr Walerjan; **Manuscript Preparation:** Krzysztof Kowalczuk, Marcin Strojek, Piotr Walerjan; **Funds Collection:** Krzysztof Kowalczuk, Marcin Strojek, Piotr Walerjan. The Authors declare that there is no conflict of interest.

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