SHORT COMMUNICATION

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ANALYSIS OF THE SPEED OF RESPONSE TO ACOUSTIC STIMULI IN ISCHEMIC HYPOXIA AND ORTHOSTATIC STRESS-INDUCED CONDITIONS AT THE ORTHO-LBNP TRAINING SYSTEM

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Introduction: Lower body negative pressure (LBNP) is a method used to induce physiological stress in the human body, especially in the cardiovascular system. In response to physical stressors, including pressure reduction in the lower half of the body, the human cognitive function deteriorates. The speed of response to stimuli is one of the indicators of the speed of hidden cognitive processes involved in the performance of a specific task. The aim of the presented tests at the ORTHO-LBNP system was to assess the time of reaction to sound stimuli due to pressure changes and verticalization.

Methods: The research was carried out on a group of 17 cadets of the Polish Air Force Academy in Dęblin, aged 23-29. During the experiment, single sound signals were presented to the tested subjects at intervals of about 20 seconds, to which they were supposed to react as soon as possible through pushing a button. Average response times to stimuli in individual phases of the study and in the phase without experimental impact were calculated.

Results: Single-factor analysis of variance with repeated measurement did not reveal statistically significant differences between mean measurements of response times in the four test phases ($P > 0.05$). The response rate, which is an indicator of the cognitive efficiency of the cadets, remained at a comparable level throughout the study and was independent of pressure and orthostatic stimuli.

Figures: 2 • **Table:** 1 • **References:** 8 • **Full-text PDF:** http://www.pjambp.com • **Copyright** © 2017 Polish Aviation Medicine Society, ul. Krasińskiego 54/56, 01-755 Warsaw, license WIML • **Indexation:** Index Copernicus, Polish Ministry of Science and Higher Education

Discussion: The duration of ORTHO-LBNP exposure was not long enough or the stimuli generated during the experiment were not strong enough to obtain differences in the speed of response of the tested subjects to sound stimuli. However, due to the influence of reduced pressure on human cognitive efficiency documented in the literature, it is justified to continue the studies using the ORTHO-LBNP system.

Keywords: LBNP, hypoxia, orthostatic stress, reaction time, training, pilots

INTRODUCTION

Lower body negative pressure (LBNP) is a technique recognized in scientific circles used to induce physiological stress in the human body, especially in the cardiovascular system. LBNP is most commonly used to simulate haemorrhages, stress due to gravitational load, changes in quiescent voltage, and manipulation of baroreceptor function. In the course of experiments, the consequences of changes in pressure in the lower part of the body, such as cardiac acceleration, may be observed under fully controlled conditions, making the technique a safe research tool. Many laboratories around the world have developed LBNP chambers for use in research environments, and several models of this type of devices are also available commercially. However, it is not easy for those interested in this research area to find design plans for lower body negative pressure generating equipment, as well as research projects using LBNP chambers [3].

In research conducted all over the world using, among others, LBNP chambers and verticalization tables, attempts are made to experimentally check whether there is a relationship between human mental (cognitive) activity and tolerance to the phenomenon of orthostatic stress, i.e. the occurrence of pre-faint symptoms and fainting as a result of body verticalization [4,5]. Researchers involved in the discussed subject state that in response to physical stressors, including pressure reduction in the lower part of the body, the human cognitive function deteriorates [8].

The response time to specific stimuli, i.e. the mean, maximum, minimum and individual variability of the response time, allows to conclude on the speed of the hidden cognitive processes involved in the performance of a specific task [6]. On this basis, it can be assumed that the speed of response to acoustic stimuli recorded during experimental hypoxia (i.e. lowering of pressure) in the LBNP chamber can be an indicator of the level of cognitive performance of the pilot, including reception, recognition and processing of information and appropriate response to it, under conditions of brain hypoxia and pressure changes.

The main objective of the research carried out at the ORTHO-LBNP research and training system was to assess cardiovascular reactions and changes in brain parameters under conditions of reduced pressure around the lower part of the body, and orthostatic stress. Detailed descriptions and analyses of the physiological signals recorded during the experiment will be included in separate works.

Due to the specific design of the LBNP chamber, which significantly limits the freedom of movements and forces a fixed body position, the authors also attempted to assess the mood and anxiety of the people participating in the experimental studies [1].

This article presents only a small part of the research conducted at the ORTHO-LBNP system, in which one parameter, i.e., the speed of response to acoustic stimuli was analyzed. The aim of the presented tests was to assess whether changes in the speed of response to acoustic stimuli occur under conditions of ischemic hypoxia and orthostatic stress. Based on the data available in the literature [8], it was predicted that the reaction times would be prolonged as a result of pressure decrease in the lower part of the body.

METHODS

The research at the ORTHO-LBNP system was carried out on a group of 17 cadets of the 5th year of the Polish Air Force Academy (WSOSP) in Dęblin, specializing in piloting jet planes (PSO) and helicopters (PŚM). The group included 14 men and 3 women, 14 people from the PŚM specialty and 3 people from the PSO specialty, aged 23-29 (M = 24.12; SD = 1.62). Good health was a condition for participation in the study. The participants had a valid medical certificate for categories ZIA and ZIC. The average height in the group was 176 cm (SD = 8.50), the average body weight was 73.59 kg (SD = 14.03).

The tests were of a voluntary nature. The respondents were volunteers who were informed about the purpose and nature of the tests, signed an agreement to participate in it and for their image in the form of photographic materials to be used for scientific and research purposes.

The research was approved by the Ethics Committee which issues opinions on biomedical research at the Military Institute of Aviation Medicine in Warsaw (Decision No. 18/2015).

The ORTHO-LBNP research and training simulator, constructed by ETC-PZL Aerospace Industries Sp. z o.o., consists of an electrically driven verticalization table designed to induce orthostatic stress (ORTHO) and an underpressure chamber integrated with the table, which serves to reduce the pressure in the area of the lower part of the body, i.e., forcing blood accumulation in the lower limbs of the body (LBNP) [2]. The chamber generates a pressure with a maximum value of -100 mmHg in relation to the atmospheric pressure. During the test, the device provides the possibility to change the position of the lying surface of the table and the underpressure chamber with a speed of 45°/s between +80°and -45°. The drive system of the verticalization table was registered at the Patent Office of the Republic of Poland [7]. The system has also been equipped with modules for monitoring biomedical parameters during research and training. The prototype of the system was developed at the 9th technology readiness level and proposed for implementation in the procedures of selection of candidates in military aviation.

The ORTHO-LBNP test took place in four stages:

1. Lowering the pressure in the LBNP chamber to -100 mmHg in nine 15-second steps; maintaining the pressure at -100 mmHg for 2 minutes; quickly returning the pressure to its initial state; waiting 3 minutes for stabilization of physiological parameters.
2. Verticalization without lowering the pressure in the LBNP chamber: inclination of the table to -30º; holding for 15 seconds at -30º; raising the table to +75º within 21 seconds; maintaining the table in the +75º position for 2 minutes; returning the table to the 0º position; waiting 3 minutes for stabilization of physiological parameters.
3. Verticalization with pressure reduction in the LBNP chamber to -60 mmHg: inclination of the table to -30º; holding for 15 seconds at -30º; returning the table to 0º within 6 seconds; raising the table to +75º for 15 seconds with simultaneous linear pressure reduction to -60 mmHg; maintaining the table in the +75º position for 2 minutes with a pressure value of -60 mmHg; return of the table to the Oº position and of the pressure to its initial state; waiting 3 minutes for stabilization of physiological parameters.
4. Stabilization of physiological parameters (neither pressure nor orthostatic stimuli).

An example of a test at the ORTHO-LBNP research and training system is shown in figure 1.

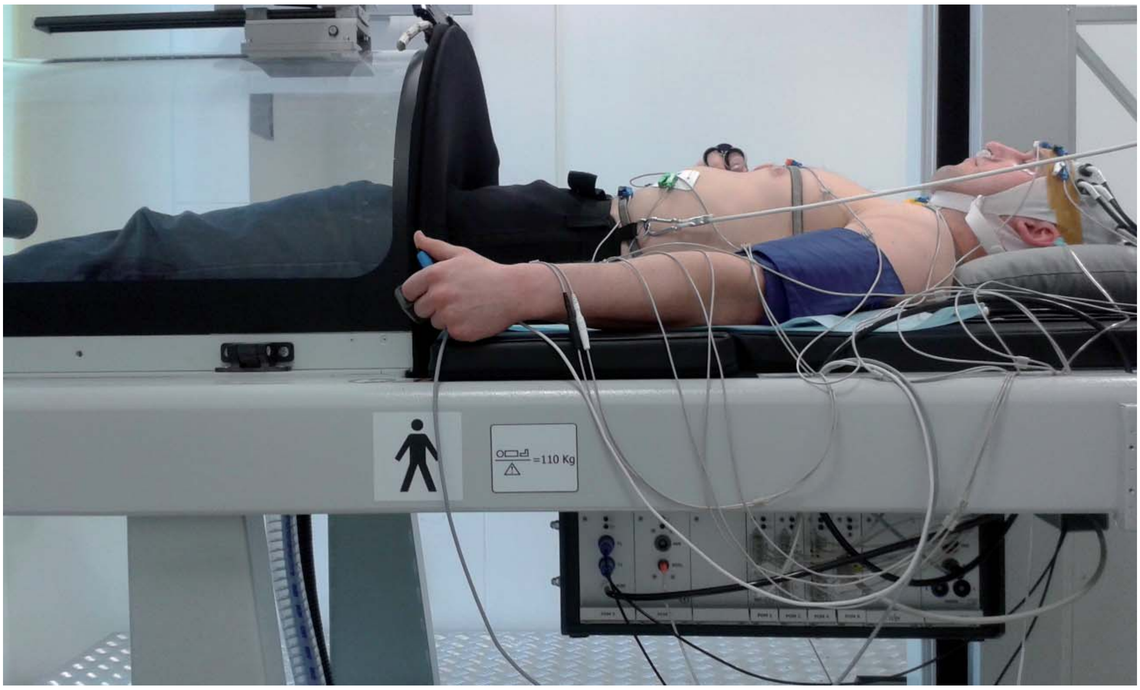

Fig. 1. Examination at the ORTHO-LBNP research and training system (the examined subject provided consent to the presentation of the photograph).

During the study, the following physiological signals were continuously recorded: impedance signal (REO) from the chest area, electrocardiographic signal (ECG), blood pressure signal, respiratory signal, arterial blood saturation signal (SpO2), brain tissue oxidation signal by Near-Infrared Spectroscopy (NIRS), electromyographic signal (EMG), skin conductance signal, body temperature signal.

During the whole course of the test, single sound signals at the 440 Hz frequency and with a duration of 1 second were presented to the subject tested at the ORTHO-LBNP system in about 20-second intervals (± 10% randomly). The task of the participant was to press the button held in the left hand as soon as possible in response to the audible signal. A total of 37 acoustic stimuli were presented during the 13-minute experimental procedure. The aim of this task was to assess the speed of response to sound signals, and thus the vigilance of attention, during the experimental research.

For statistical analysis of the results, the SPSS program in version 24 was used. The Shapiro-Wilk Test was used to assess the normality of variable distribution of response time in individual phases of the study. In order to check whether there are differences between the average response times in the individual phases of the test, i.e., depending on the applied pressure and orthostatic stimuli, a single-factor analysis of variance (ANOVA) with repeated measurement was used.

RESULTS

The first stage of the analysis was to determine average response times to acoustic stimuli in the four phases of the ORTHO-LBNP test, i.e., pressure reduction, verticalization, verticalization with pressure reduction and stabilization of physiological parameters (neither pressure nor orthostatic stimuli). Average response times were calculated for all the recorded responses to the presented sound stimuli at individual stages of the test. The phase of stabilization of physiological parameters, in which the examined person laid freely and was not subjected to any experimental influences, was to serve as a reference for the conditions in which the pressure in the LBNP chamber was manipulated and the position of the examined body was changed from horizontal to vertical and vice versa (verticalization).

Basic descriptive statistics of the reaction time variable, determined in the four phases of the research, are presented in the table below (Tab. 1).

In the first phase, in which the pressure in the LBNP chamber was decreased, the distribution of the variable followed the normal distribution ($P > 0.05$). In other phases, the distribution curves of the tested variable slightly deviated from the normal distribution curve ($P < 0.05$).

Table 1 shows that the average reaction time to sound stimuli in the group of cadets was the shortest in the phase of simultaneous impact of pressure and orthostatic stimuli, and the longest in the second phase of the study, i.e., during a sudden change of the body position (verticalization). In order to better illustrate the speed of reaction of cadets to incoming acoustic stimuli during the ORTHO-LBNP exposure, the following figure shows the average reaction times in the studied group.

ANOVA did not show statistically significant differences between average reaction time measurements in the four phases of the test ($F(3, 48) = 0.81$; $P = 0.493$; $P > 0.05$; $eta2 = 0.05$). This means that the experimental conditions did not differentiate the subjects' speed of response to sound stimuli. In other words, the reaction time, which is an indicator of the cognitive performance of the cadets, remained at a comparable level throughout the experimental investigation and was independent of the pressure and orthostatic stimuli administered.

DISCUSSION AND CONCLUSION

The research at the ORTHO-LBNP research and training system, presented in this paper, was aimed at evaluating changes in the cognitive function of WSOSP cadets in response to changes in pressure in the lower part of the body and body verticaliza-

Tab. 1. Basic descriptive statistics of the reaction time variable (expressed in seconds) in four phases of the ORTHO-LBNP examination.

Study phase	N	Descriptive statistics of the reaction time variable (s)			
		Minimum	Maximum	Mean	Standard deviation
1. Pressure reduction	17	0.324	0.579	0.462	0.064
2. Verticalization	17	0.348	0.809	0.468	0.129
3. Verticalization with pressure reduction	17	0.322	0.672	0.436	0.082
4. Stabilization phase (no stimuli)	17	0.322	0.749	0.456	0.118

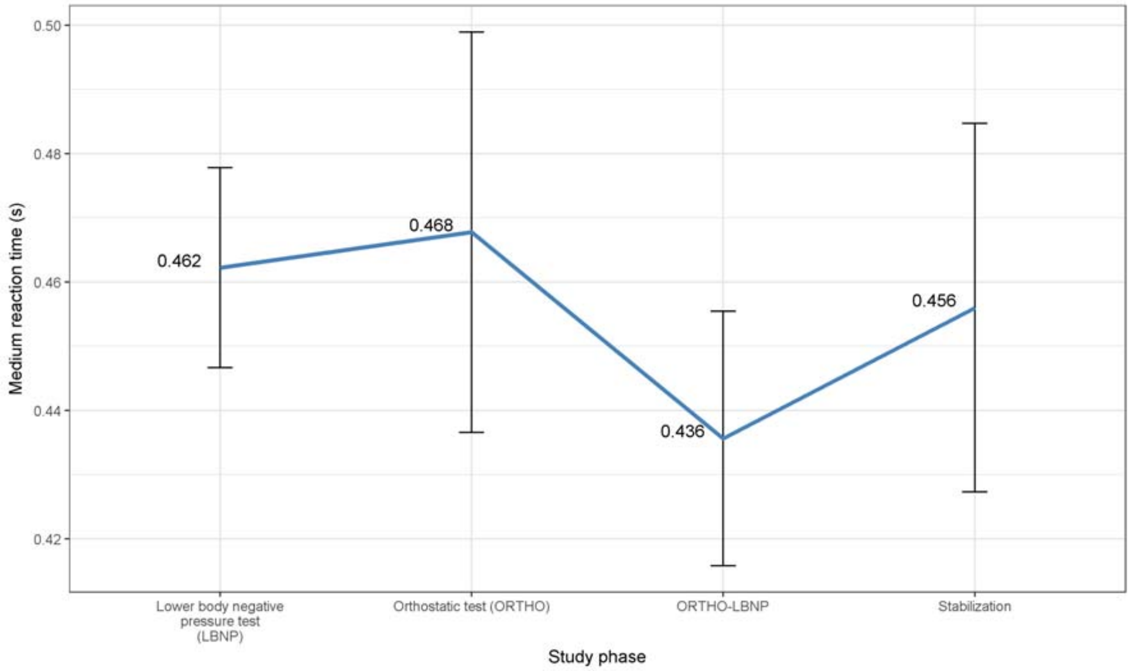

Fig. 2. Average reaction times to stimuli in individual phases of the ORTHO-LBNP test in the examined group (N = 17).

tion. The indicator of cognitive performance was the reaction time to sound stimuli.

The tests performed did not identify any differences in the speed of response to auditory stimuli related to reduced pressure and orthostatic stress ($P > 0.05$). The level of cognitive efficiency of the cadets during the experiment was comparable to the level obtained for the state without any experimental impact. On this basis it can be assumed that the duration of the ORTHO-LBNP exposure was not long enough or the pressure and vertical stimuli generated during the experiment were not strong enough to obtain the expected effect of weakening the cognitive efficiency of the examined subjects, in this case prolonging their response speed to the incoming sound stimuli.

It should be stressed that the main purpose of the ORTHO-LBNP examination was to assess cardiovascular reactions and changes in cerebral parameters in response to the stimuli given, and therefore the research protocol was chosen in such a way that it was possible to observe changes in cardiovascular parameters while maintaining the safety of the tests. For the purpose of determining differences in cognitive performance of the examined subjects, it seems justified to modify the proposed experimental protocol taking into account the intensity and duration of the pressure and orthostatic stimuli. At the same time, due to possible collapse of compensation processes which occur during the disturbances in cardiovascular parameters, such tests should be controlled by a physiologist in a special way.

Taking into account the data available in the literature, which indicate that cognitive performance is deteriorating as a result of pressure decline around the lower part of the body, and for reasons of quality and safety of in-flight operations, it is appropriate to continue research into the quality and speed of cognitive processes of pilots, e.g. thinking and making decisions, in conditions of ischemic hypoxia and orthostatic stress.

AUTHORS' DECLARATION:

Study Design: Łukasz Dziuda, Mariusz Krej, Paulina Baran; **Data Collection:** Mariusz Krej, Paulina Baran; **Manuscript Preparation:** Paulina Baran, Łukasz Dziuda, Mariusz Krej; **Funds Collection:** Łukasz Dziuda. The Authors declare that there is no conflict of interest.

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