

ICSV14

Cairns • Australia

9-12 July, 2007



THE EFFECTS OF LOW-FREQUENCY VIBRATIONS ON CONTROL PROFILE OF BLOOD

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Abstract

Vibrating platforms are widely employed in sport facilities and fitness clubs to help people develop muscles and improve their physical condition. The applied vibration frequencies ranged from 30 to 60 Hz and vibration's amplitudes were regarded as "considerable".

There are few reports in literature on the potential applications of low-frequency vibrations in therapy (e.g. Military Hospital in Busko, Poland). Therefore, a research program was undertaken at the AGH University of Science and Technology to investigate the effects of low-frequency vibration on selected parameters of control profile (urea, creatine, bilirubin, transaminase ALT, transaminase AST, alkaline phosphatase, albumin, total protein, calcium, phosphorus) of human blood. Cyclic fluctuations of bone loading were induced by the applied harmonic vibration 3.5 Hz and amplitude 4 mm.

The experiments utilising two vibrating platforms were performed in the Laboratory of Structural Acoustics and Biomedical Engineering AGH-UST. The applied vibrations were harmless and not annoying, in accordance with the standard PN-EN ISO 130901-1, 1998. 28 women volunteers had 19 sessions on subsequent working days, at the same time of day. During the tests the participants remained passive, in the standing position.

This paper is the continuation of the study covering the effects of low-frequency vibrations on selected physiological parameters of the human body. The experiments were conducted to find to answer whether vibration's exposure (total duration of training sessions 6 hours 20 min) should produce any changes in control profile of blood.

Research data showed that low-frequency vibrations can be treated as isometric physical training and might be well applied to support the therapy of numerous civilisation-related diseases, such as: overweight, hypertension, osteoporosis and anaemia.

Research data also reveal a statistically significant decrease of phosphorus, total protein and bilirubin levels in blood serum.

1. INTRODUCTION

Body vibration training has become popular in sports training, fitness activity, though it still remains a rare form of physical rehabilitation [1-2]. Test data available in the database MEDLINE reveal the potential applications of whole body vibration (WBV) training to physical rehabilitation of patients suffering from multiple sclerosis [3], cerebral paralysis [4], patients after stroke [5] and patients with Parkinson disease [6].

The whole body vibration training is taken to be a new method of sensory motor stimulation and the results of training are comparable or even better than the results of health programs involving physical exercises, routinely applied to improve the muscle strength, posture control and everyday activity levels. This stimulus, considered so far to have produced negative impacts in long-term exposure to WBV at work, when administered for therapeutic reasons in small, short-lasting doses will stimulate and strengthen the bone and muscle system, enhance the levels of testosterone and growth hormone in blood, thus preventing sarcopenia and osteoporosis [7,8].

Cyclic variations of bone loading lead to increased flow rate of fluids in bone canaliculus (canals) and change of stresses in bones. The flows are intensified, making up a more efficient mechanism of transport between supplied blood and osteocytes. Bones are made of compressible material which deforms under loading, bone canaliculus change their spatial dimensions and by so doing activate the pumping effect in the central flow system. When the load is removed, fresh nutritive fluids are absorbed from Havers canals to capillary vessels. Cyclic loading of bones leads to increased bone mass and thickness and supports healing processes.

It seems justified to suppose that WBV training can become a substitute of physical exercise, yet eliminating the drawbacks associated with overstraining of the motor system and hence the circulatory system. Cyclic contractions and decontractions of skeletal muscles excited by vibration applicators induce the adaptation of the whole motor system, activating most advantageous neural and humoral mechanisms [5].

Since there only few reports in literature exploring the potential applications of low-frequency vibrations in therapy or in sports, the authors launched this experimental program to determine how low-frequency vibrations should affect the hepatic profile of human blood. Vibrations might improve blood circulation, partial pressure of oxygen, saturation levels of haemoglobin and utilisation of oxygen in the body tissues. These benefits might be attributable to the widening of blood vessels, improved blood circulation (particularly micro-circulation systems) and improved hydrodynamic properties of blood (as a result the risk of clotting is vastly reduced). Through the control of these parameters, the membrane potential on the cell surface is normalised, the metabolism rate can be improved and immune system stimulated.

Cyclic fluctuations of bone loading were induced by the applied harmonic vibration with the frequency of man's running, as they seem most appropriate from the point of view of physiology. The applied vibrations should be safe and perceived as not annoying.

2. METHODOLOGY

The purpose of this study was to determine how low-frequency vibration exposure should affect the control profile of blood.

The main hypothesis has it that short-term low-frequency vibration exposure might bring about the changes of control profile of blood, including: urea, creatine, bilirubin, transaminase ALT, transaminase AST, alkaline phosphatase, albumin, total protein, calcium,

and phosphorus. It was expected that variations in the values of selected parameters would be more significant under the low-frequency vibrations exposure than during its absence.

These views seemed justified by the assumption that these vibrations would be treated as a physical exercise for the human body. Exposure to vibrations would clearly induce shock absorption by the muscles and bone systems, leading to isometric functioning of muscles in the conditions of variable forces acting upon the bones [9, 10, 11].

Experiments were continued from 31.01.2005 till 25.02.2005 at the AGH-UST in Kraków, Poland. A detailed procedure of participants' selection was applied before the experiments. Participants (28 women volunteers) were acquainted with the test procedure and gave their consent. The participants being appropriately selected, their blood analyses were taken. Biochemical analyses were performed in the Laboratory of Medical Analysis in the University Health Centre in Kraków. The experimental program involved 19 training sessions on subsequent working day, at the same time of day for each participant. Each training session lasted 40 minutes, including 20 minutes' exposure to vibrations with frequency 3.5 Hz and amplitude 4 mm. Vibrations were assumed to be perceptible yet not annoying, vibration parameters were lower than those presupposed by the standard PN-EN ISO 13090-1, 1998. During each training session selected physiological parameters were monitored (before and after the session) and the ECG signal acquisition was performed on an online basis. The experimental procedure being over, the biochemical tests were performed again and the results were analysed numerically.

The participants would stand on the platform with their shoes removed, to eliminate vibration damping by shoe soles.

This study is restricted to the effects of low-frequency vibrations on control profile of blood. The remaining research data shall be published shortly.

Utilised in the tests were two vibrating platforms specially designed and engineered for the purpose of this research programme. A kinematic diagram of the vibrating platform is shown in figure 1.

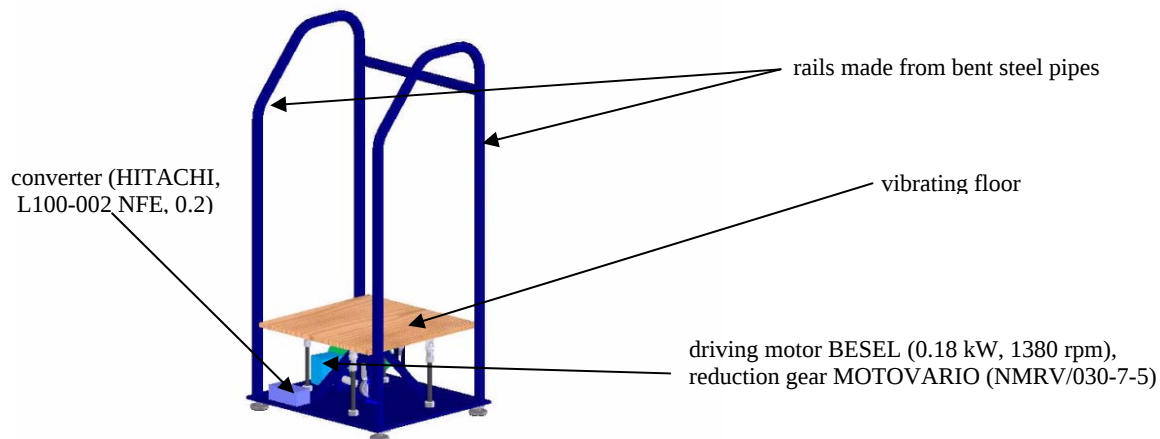


Figure 1. Vibrating platform

The preliminary test procedures involved the Thayer test, measurements of response time, measurements of diastolic and systolic pressure, pulse rate, adipose tissue, body mass, temperature inside the ear canal and thermogram of legs. After that the main tests were performed, completed by close-up activities (similar to preliminary test procedure).

Experimental data were subject to statistical analysis in the environment Statistica 7.1. Kolmogorov-Smirnoff tests were applied with Lilliefors and W-Shapiro-Wilk corrections (these are standard tests to check the normal distribution). The significance level in statistical

analyses was taken to be $p=0.05$, which is a value widely adopted in biology. The null hypothesis for each of the variables was as follows: exposure to low-frequency vibrations does not lead to any changes of the analysed variable.

3. ANALYSIS OF RESULTS

Tests revealed that analysed variable: urea, phosphatase, phosphorus, calcium, total protein and albumin follow the normal distribution. The likelihood that tested variable changes should be significant was found using the t-test (since two groups of variables are compared, measurement scales of dependent variables are quantitative whilst the distribution is normal).

The non-parametric Wilcoxon test was applied to creatine, bilirubin, AST and ALT data that do not have the normal distribution.

Variation fractions were computed too, expressed as the size of population that displays the desired statistical feature to the whole sample size (increase or decrease of values of analysed parameters following the vibrations exposure). Results are shown in tables 1- 5.

Table 1. T – test for dependent samples

VARIABLES:	T - test for dependent samples					
	Mean val.	Std. dev.	Difference	Std. dev. difference	t	p
UREA-B [mmol/l]	5,76	1,21	0,18	1,10	0,87	0,39
UREA-E[mmol/l]	5,58	1,38				
PHOSPHATASE-B [UI/l]	72,44	17,00	-0,63	14,12	-0,23	0,82
PHOSPHATASE-E [UI/l]	73,06	21,62				
PHOSPHORUS-B [mmol/l]	1,22	0,11	-0,15	0,15	-5,28	0,00
PHOSPHORUS-E [mmol/l]	1,37	0,12				
CALCIUM-B [mmol/l]	2,50	0,11	-0,04	0,20	-0,97	0,34
CALCIUM- E [mmol/l]	2,54	0,15				
TOTAL PROTEIN-B [g/l]	75,25	5,84	-2,89	5,84	-2,57	0,02
TOTAL PROTEIN-E [g/l]	78,14	4,14				
ALBUMIN-B [%]	59,68	2,55	-1,19	6,40	-0,93	0,36
ALBUMIN-E [%]	60,87	7,27				

Table 2. Wilcoxon test of significance for variable that do not follow a normal distribution

VARIABLES:	Wilcoxon test of pair sequencing		
	T	Z	p
CREATINE-B [umol/l] & CREATINE-E [umol/l]	53,00	3,27	0,001086
BILIRUBIN-B [umol/l] & BILIRUBIN-E[umol/l]	82,00	2,57	0,010151
AST-B [UI/l] & AST-E [UI/l]	118,00	1,71	0,088051
ALT-B [UI/l] & ALT-E [UI/l]	150,50	0,63	0,525462

Table 3. Statistical test data

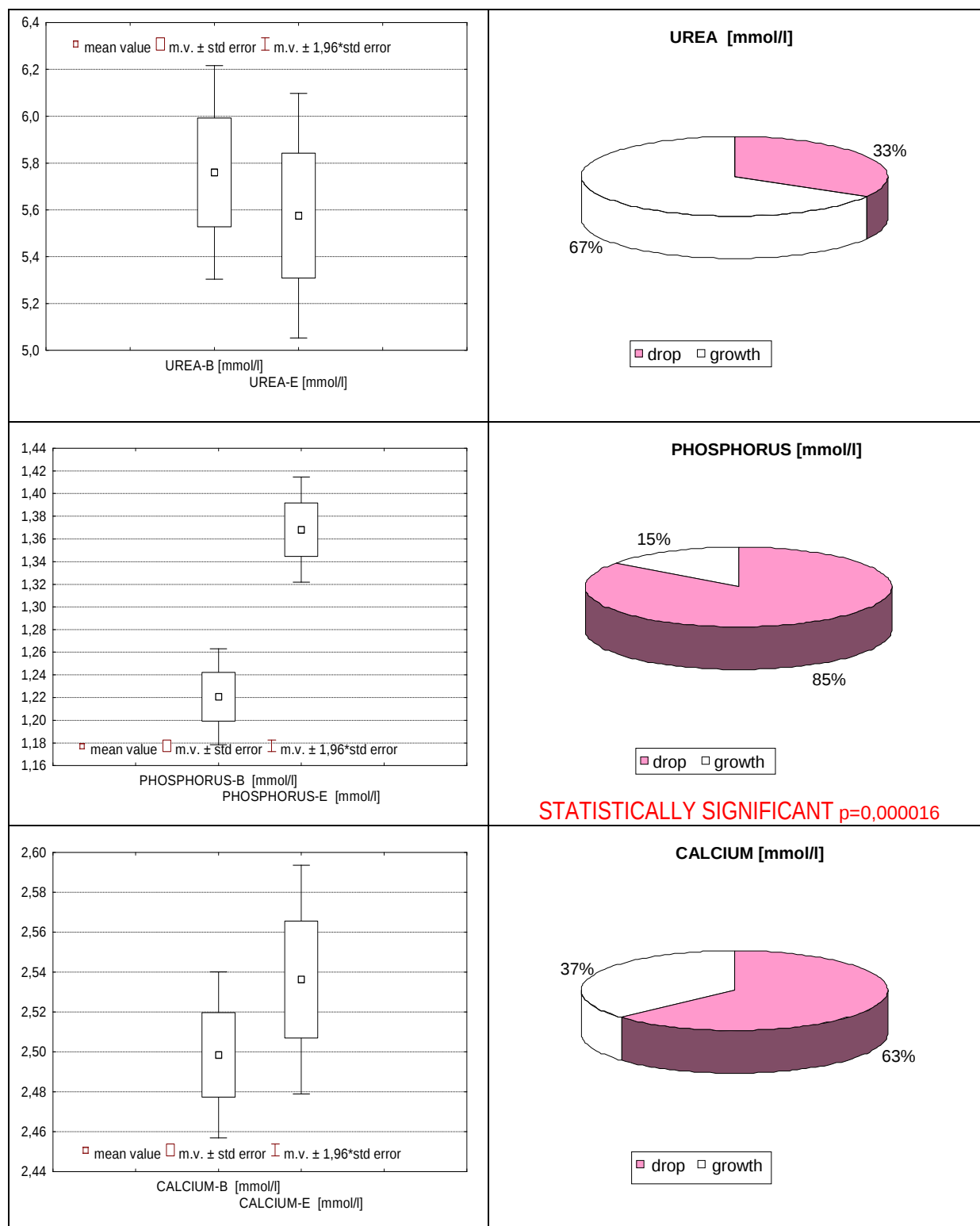


Table 4. Statistical test data

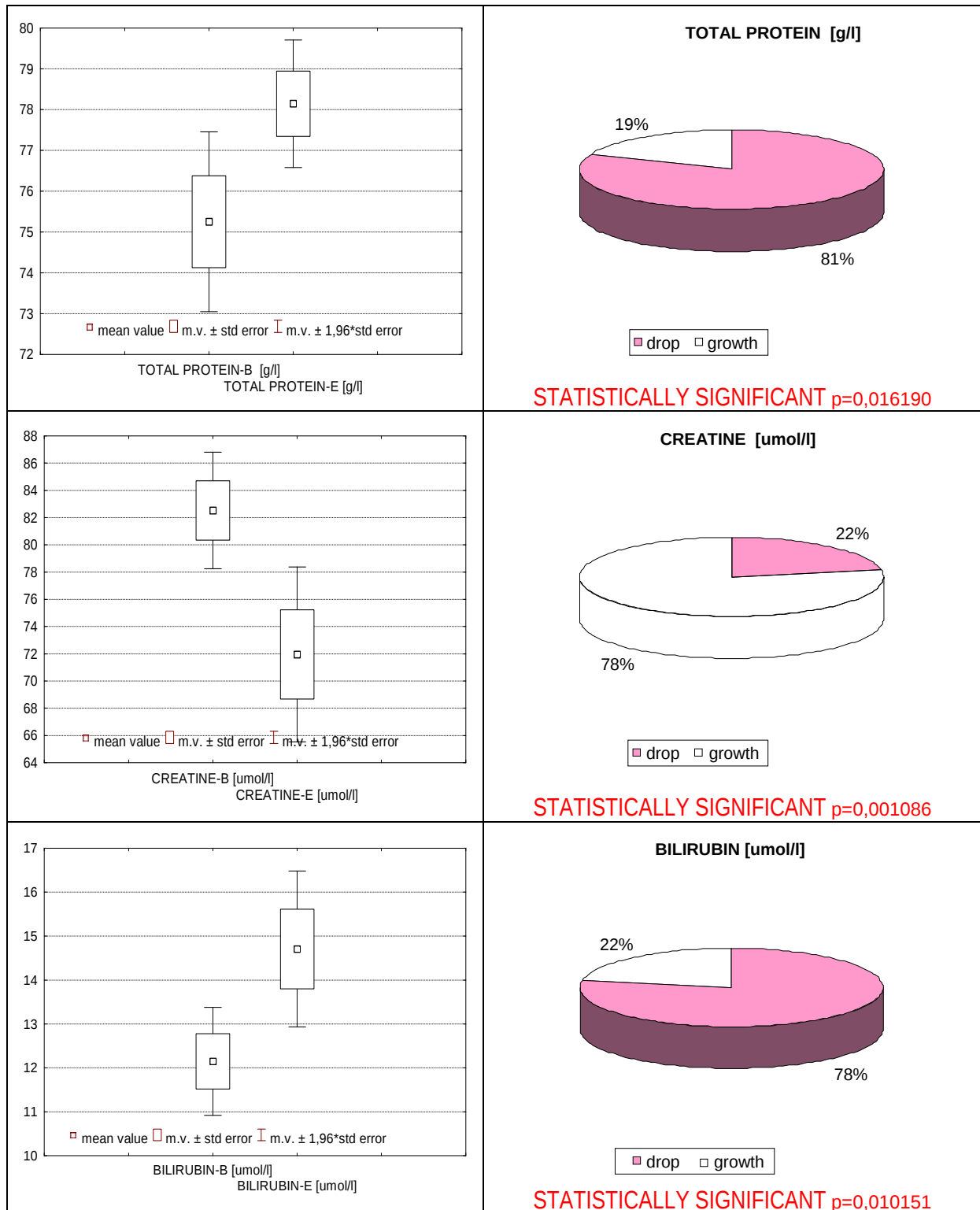
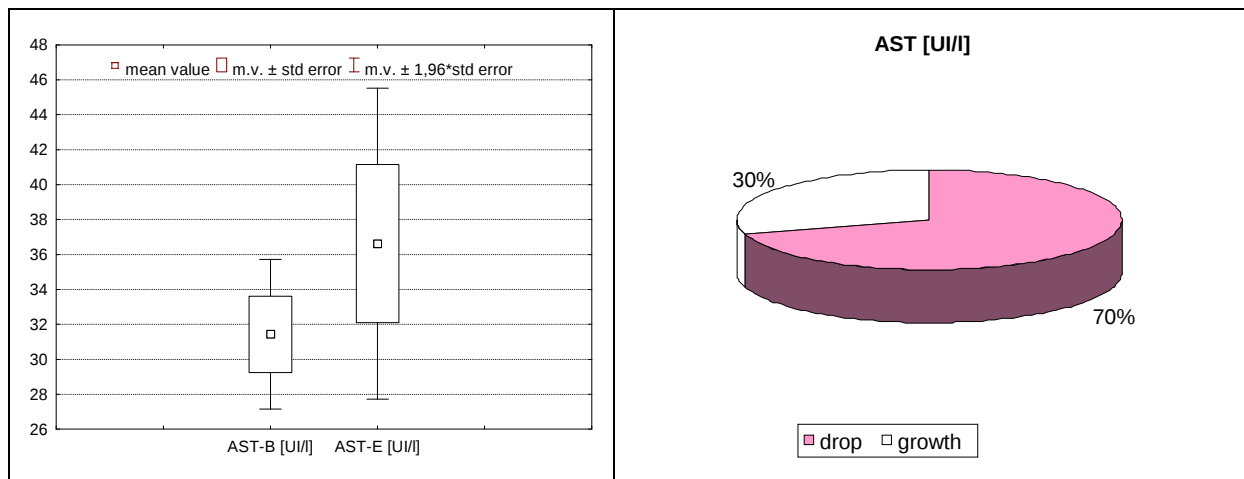


Table 5. Statistical test data



3. CONCLUSIONS

Theoretical analysis supported by experimental data reveal that low-frequency vibrations exposure will produce the following effects for the human body:

- statistically significant increase of:
 - phosphorus [mmol/l] from 1.22 ± 0.11 to 1.37 ± 0.12 for 85% of participants, the probability level being $p < 2 \times 10^{-5}$,
 - total protein [g/l] from 75.25 ± 5.84 to 78.14 ± 4.14 for 81% of participants, the probability level being $p < 2 \times 10^{-3}$,
 - bilirubin level [umol/l] from 12.15 ± 3.27 to 14.71 ± 4.71 for 78% of participants, the probability level being $p < 2 \times 10^{-2}$,
- statistically significant decrease of creatine from 82.53 ± 11.35 to 71.96 ± 17.01 for 78% of participants, the probability level being $p < 2 \times 10^{-3}$.

Phosphorus level concentration depends on the **absorption rate in intestines, efficiency of excretion in kidneys and osteolysis**. The first two processes are controlled by D3-vitamin whose value increases in direct proportion to insolation. Phosphorus and calcium levels depend on absorption rate in intestines, excretion level in kidneys and bonding or unchaining from bony tissue, which might be attributable to the **increase of osseus circulation through aggravation of bone creation, stimulated by exposure on vibrations**.

Total protein level is controlled by two main fractions: albumins created in liver and globulins created by lymphocytes. **Its decrease is typical of physical effort**. Relative but statistically significant increase of albumins, which determines about 60% of total protein, is responsible for oncotic plasma's pressure and hormon transmission. It also **determines adaptability to physical effort** (in hospitalized and inactive patients the albumin levels are slightly lower). Increase of total protein concentration (hipoproteinemia) is generally evoked by a decrease of albumin concentration or intercellular space irrigation (oedema). Hence we get a different response to vibratory stimulus than to physical exercise, due to still undefined neural and humoral mechanisms.

Bilirubin is a final product of the decay of haemoglobin contained in erythrocytes. A statistically significant increase of bilirubin level might be attributable to: 1) blood haemolysis, 2) impaired liver function (uptake and linking to glucuronic acid) 3) impaired secretion to bile ducts 4) excretion duct in the digestive system. Vibrations might be

responsible for minor blood haemolysis, particularly in lower limbs (refer to haemoglobinuria during marching). There are reports of an experiment conducted by Ishitake (1999) who discovered that activity of the digestive system can be impaired by vibrations. These effects might be due to reduced elimination of bilirubin in the digestive system or to potential effect that bio-resonance frequencies might have on the liver functions.

The experiment results seem promising and further systematic research is fully merited. The problems still remain open. Would the prolonged exposure time, the change of frequency or acceleration cause greater changes in the parameters? The answer can be obtained in further, planned, experiments.

This experiment was a part of the research project no. 11.11.130.629 and 10.10.130.140, partially sponsored by Kosciuszko Foundation and the American Centre for Polish Culture through the funds granted by Alfred Jurzykowski Foundation.

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