Limb's Vibrations Exercise Monitoring with MEMS Accelerometer to Identify Influence of Cardiovascular System

M Venslauskas[1], V Ostasevičius[2] and V Marozas[3]
[1] Faculty of Mechanical Engineering and Mechatronics, Department of engineering design, Kestucio St. 27, LT-44312 Kaunas, Lithuania
[2] Institute for Hi-Tech Development, Studentu St. 65, LT-51369 Kaunas, Lithuania
[3] Biomedical engineering institute, Studentu St. 65, LT-51369 Kaunas, Lithuania

E-mail: [1] mantas.venslauskas@ktu.lt, [2] vytautas.ostasevicius@ktu.lt,
[3] vaidotas.marozas@ktu.lt

Abstract. Katsuzo Nishi in 1927 proposed the capillarity exercise based on limbs vibrations to compensate obstruction of blood circulation. Research was made to identify influence of vibrations to human's physiological parameters. There were made an exercise regarding to Nishi methodology and imitation of exercise with one arm on vibration stand while monitoring physiological parameters and accelerations. Detected parameters' changes were significantly smaller when vibrating only one hand. Future plans are to imitate exercise while vibrating all limbs and make a stand to imitate cardiovascular system to identify vibrations influence in blood flow rate.

1. Introduction

Human's vibration therapy date back to ancient Greece. It is becoming more frequently used nowadays to improve muscle strength, power and flexibility as well as coordination or even cardiovascular system. It is known that vibrations exercises has effect of preventing parasites and other germs from invading the body and at the same time helping to activate a suitable degree the various organs of the body [1]. There were made many researches of vibration effect to human's biological processes. It was determined that whole body vibrations affect increase of artery blood flow, heart rate and other parameters [2, 3].

Katsuzo Nishi [4] introduced his Nishi system in 1927. It was based on his own studies and practice of what would amount to some 360 types of folk cures and health methods, both ancient and contemporary Oriental and Occidental. He included his own theories of dynamics of the human body based on the mechanical science. His theories are characterized by the idea that humans' internal organs are basically the same as those evolved for the mammalian and human two-legged life style causes certain structural strains on the human bone structure. These cause obstruction problems of the food flow through intestines. Furthermore Nishi refuted the heart-driven blood circulation theory of William Harvey. Nishi stated that the capillaries provide the true driving force of the circulatory system. To compensate obstruction of circulation in human's limbs because of two-legged life he proposed the capillarity exercise. In paper [5] new models of the micro dosing elements are presented. Hybrid experimental-numerical analysis techniques are used for investigation of micro spray systems. Experimental analysis of the investigated systems is based on laser holographic interferometry which is used for the identification and optimization of working regimes of the system.

The aim of this study was to identify vibration's influence to cardiovascular system with future vision to develop a device for heart stimulation via limbs vibrations.

2. Capillary influence

There were made number of studies about vibration's influence to human's cardiovascular system and muscle strength. Previous studies of Institute of training science and sport informatics has showed that

[1] Corresponding author

vibration training is an effective training method in order to improve maximal strength and flexibility. There was also identified that more capillaries are probably opened in order to keep a necessary level of cardiac output needed for the body. This might be one of the reasons for the various potential beneficial effects of vibration training. [6] For the further studies it is important that blood vessels could be treated as a rigid tubes and the blood could be treated as incompressible uniform Newtonian fluid [6]. The positive effect of training capillarity could be proved that the mechanical equivalent of heat for kinetic energy and pressure of blood flow is reported that high speed (sometimes turbulent) blood flow enters to the capillary vessels, and the energy of blood flow turns into heat by frictions (collisions), and therefore, pressure of blood flow decreases approximately up to zero at the vena cava and the entrance of the right atrium [7]. Results following 10 minutes of vibration therapy. Laser Doppler studies revealed a consistent increase in blood supply [8].

3. Methods

The capillarity exercise methodology: first must lie flat on the back, raise the head slightly by placing a pillow under it. Stretch forward as straight as possible both arms and legs. The soles of the feet should be parallel to the bed of the floor. With this body position (Figure 1) limbs should be given a vibratory movement. The exercise should be kept up for one or two minutes in the morning and also in the evening.

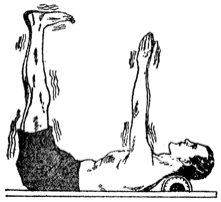

Figure 1. The capillarity exercise.

This exercise which gives rise to capillary phenomenon will prove fruitful regulating properly the valves of the veins in the limbs, so as to stimulate the flow of the blood, and also promoting the movement and renewal of the lymphatic fluid.

As this exercise gives rise to capillarity in the limbs and draws the blood there, it naturally follows that the improvement of the general blood circulation will ensue [1].

The amplitude and frequency of limbs movement is unknown so first of all it was decided to measure limbs accelerations bandwidth. The results will be necessary for making a further research on a vibration stand.

4. Used equipment

First of all it was used the device with a tri-axial accelerometer [9] to identify limbs (hand) vibrations. The accelerometer model that fulfils measurement range and bandwidth requirements is LIS331DLH [9]. The accelerometer cannot operate on its own so device that utilizes it was developed Figure 2.

The device contains Micro Controller Unit (MCU) to hold all the logic, LIS331DLH MEMS accelerometer to measure 3D accelerations, MicroSD card to save measured data samples, battery to power up everything, some light emitting diodes (LEDs) to display the state the device is in and USB connector so the data can be downloaded to the personal computer for further processing. The final acceleration range requirement was selected to be ±8g.

To identify the effect of capillarity exercise the blood pressure monitor was used before and after exercise. Microlife BP A100 [7] model was chosen because of high accuracy.

For physiological parameters monitoring Cardio Logger device was used. Device monitors ECG from 4 points of body, tracks heart rate from three points (head and two hand fingers). There are also integrated accelerometers in the fingers pulse oximeters. Computer software is used for observation of quality of the signals. There are 8 channels sent at a time.

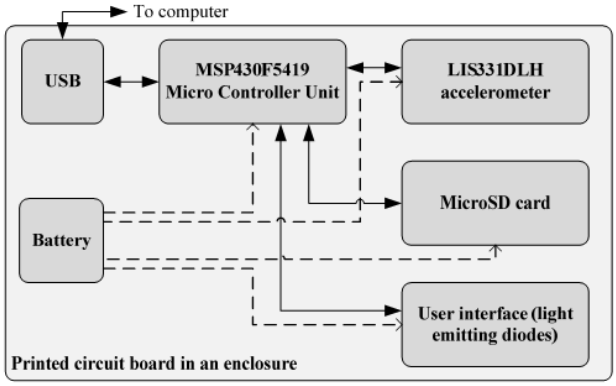

Figure 2. Principal scheme of the acceleration measurement device [11].

Experiments to test human's body reaction to vibrations were conducted in the Centre of Mechatronic Science, Studies and Information at Kaunas University of Technology with equipment showed on Figure 3.

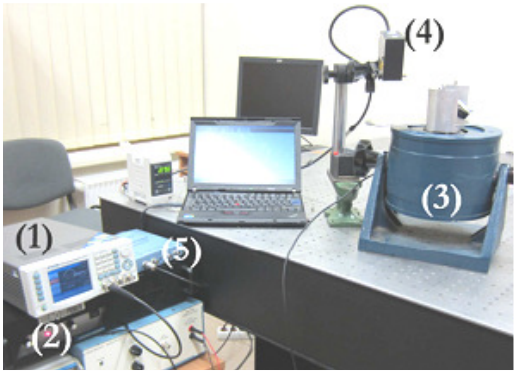

Figure 3. Developed device validation experimental setup.
1 – Frequencies generator Tabor Electronics WW5064 50Ms/s;
2 – Power amplifier VPA2100MN;
3 – Vibration stand Veb Robotron Type 11077 with developed device mounted on top;
4 – Displacement measurement unit laser Keyence LK-G82 with controller Keyence LK-GD500;
5 – ADC Picoscope 3424.

Figure 4. Experiment in the Centre of Mechatronic Science, Studies and Information at Kaunas University of Technology.

5. Experiment protocol

Two types of experiments were made. First experiments were made by changing the frequency (1st: from 1Hz to 40Hz; 2nd: from 1Hz to 8Hz; 3rd: from 2Hz to 12Hz) during the experiment. The next were made with constant frequency. These were made as the nearest imitation to natural movement (4Hz). Below detailed description of each:

Right hand. Time: 120s; Frequency: from 1Hz to 40Hz; Peak to peak amplitude: 300mV;

Right hand. Time: 120s; Frequency: from 1Hz to 8Hz; Peak to peak amplitude: 500mV;
Right hand. Time: 600s; Frequency: from 2Hz to 12Hz; Peak to peak amplitude: 1V.
Right hand. Time: 120s; Frequency: 4Hz; Peak amplitude: 1V;
Right hand. Time: 120s; Frequency: 4Hz; Peak amplitude: 1V;
Right hand. Time: 600s; Frequency: 4Hz; Peak amplitude: 1V.

6. Results

Using MEMS accelerometer it was identified limbs vibrations bandwidth. Regarding to the results it was decided to use 4Hz frequency on the vibrations stand and 1V peak amplitude.

Before and after the exercise blood pressure was measured (Table 1). The significant change of diastolic pressure value was recorded.

Table 1. Blood pressure changes before and after experiment

Period	Systolic blood pressure	Diastolic blood pressure
Before the experiment	133	61
5min. after the experiment	132	71
10min. after the experiment	139	71

The experiment using vibration stand and static frequency showed different results (Table 2). The change of systolic pressure value was recorded.

Table 2. Blood pressure changes before and after the 10min. experiment on vibration stand.

Period	Systolic blood pressure	Diastolic blood pressure
1min. before the experiment	118	78
Right before the experiment	129	77
2min. after the experiment	121	72

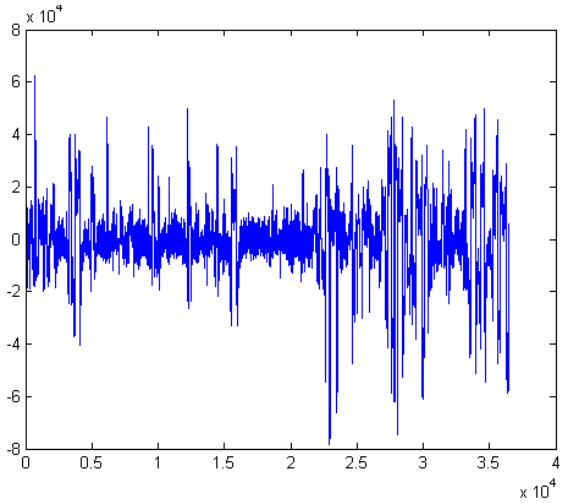

Figure 5. Respiration frequency changes during the 10min. peak to peak experiment with hand on vibration stand.

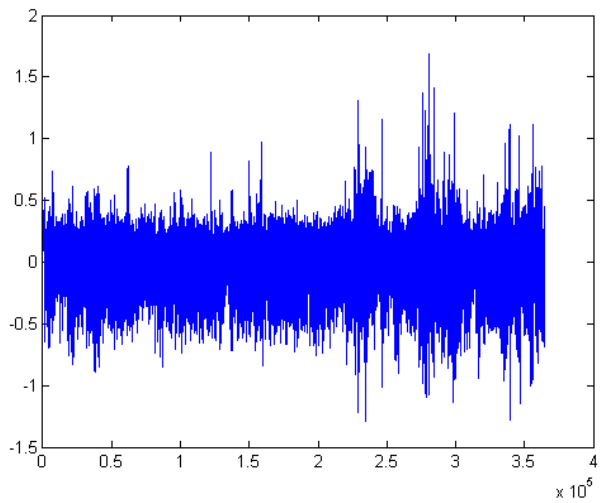

Figure 6. ECG changes during the 10min. peak to peak experiment with hand on vibration stand.

The 10 minutes duration peak to peak experiment showed some significant changes on respiration rate during the changes of frequency (especially on the highest values). The ECG curve also showed vibrations effect to human's cardiovascular system during the highest frequencies (Figure 5 and 6).

7. Future works

Regarding to the experiment results it was decided to prepare cardiovascular system imitation stand including peristaltic pump, pressure gauge, artificial blood vessels as well as capillaries and vibration stand. This stand will be a tool to identify vibrations influence in blood pressure on vessels and capillaries. Parallel to this in the near future it is planned to have a stand that would allow to make an imitation of the capillarity exercise without a human's effort. The mechanical device would vibrate all four limbs and that would allow identify influence of isolated vibrations effect excluding muscle effort.

After all it is desirable to invent a vibrating product (gloves and / or socks) that could keep heart working after a cardiac arrest while doctors try to revive the patient.

Acknowledgments

This research work was funded by EU Structural Funds project "In-Smart"
(Nr. VP1-3.1-ŠMM-10-V-02-012).

References

[1] Ailments 2012 Prevent Sickness Maintain Health Treat Nishi System http://www.nishiusa.eurocontrol.biz/index.php?div_id=4&sub_id=13

[2] Amy Mark, Maureen MacDonald, Mark Rakobowchuck, Christopher Gordon and Cameron Blimkie 2002 Metabolic and cardiovascular responses during whole body vibration (WBV) exercise: a pilot study Department of Kinesiology and Department of Radiology McMaster University Hamilton

[3] Yusuke Osawa and Yuko Oguma 2011 Effects of whole body vibration on physiological responses to one bout of resistance training *JEPonline* **14(2)** 36–45

[4] Katsuzo Nishi 2013 http://en.wikipedia.org/wiki/Katsuzō_Nishi

[5] Arvydas Palevicius, Kazimieras Ragulskis, Algimantas Bubulis, Vytautas Ostasevicius and Minvydas Ragulskis 2004 Development and operational optimization of micro spray system *Proc. of SPIE* **5390** 429–38

[6] Mester J, Kleinoder H and Yue Z 2006 Vibration training: benefits and risks *Journal of Biomechanics* **39(6)** 1056–65

[7] W S Topham 1969 Comparison of methods for circulation of left ventricular stroke volume *J Appl Physiol* **27** 767–9

[8] Ryan T J 2001 The effect of mechanical forces (vibration or external compression) on the dermal water content of the upper dermis and epidermis, assessed by high frequency ultrasound *Journal of Tissue Viability* **11(3)** 97–101

[9] STMicroelectronics 2013 http://www.st.com/jp/analog/product/218132.jsp

[10] Microlife 2013 http://www.microlife.com/products/hypertension/automatic/bp-a100/

[11] Benevicius Vincas, Ostasevicius Vytautas and Gaidys Rimvydas 2013 Human body rheology impact on measurements in accelerometer applications *Journal of Mechanics Mechanika* Kaunas University of Technology **19(1)** 40–5