700. Investigation of static balance before and after physical activity

A. Kilikevičius[1], **J. Griškevičius**[2], **P. Tamošauskas**[3], **V. Morkūnienė**[4], **D. Višinskienė**[5]
[1, 2] Vilnius Gediminas Technical University, Department of Machine Building
J. Basanavičiaus str. 28, LT-03224 Vilnius, Lithuania
[3, 4, 5] Vilnius Gediminas Technical University, Department of Physical Training
Saulėtekio al. 28, LT-10223 Vilnius, Lithuania
E-mail: [1]*akilikevicius@gmail.com*,[2] *julius.griskevicius@vgtu.lt*, [3] *hinst@vgtu.lt*, [4]*valdakind@gmail.com*, [5] *hinst@vgtu.lt*

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Abstract. This article aims at investigating and comparing the parameters of static balance in healthy adults (20-25 year-olds) before and after physical activity by means of accelerometric measurements. The research evaluates how the internal stability (homeostasis) of the human body changes under physical activity on the basis of the amplitude of oscillations before and after performing certain movements.

Keywords: static balance, physical activity, accelerometer.

Introduction

Balance of the human body. The coordination and spatial orientation of the human body depends on balance, vision, movement analysers and the level of physical ability.

Coordination is when all organs and body systems are working in harmony, which is determined by the agreement of stimulation and suppression processes in central neural system (CNS). The coordination of a movement is the ability of a body to quickly acquire new movements, join those into combinations, as well as perform them with precision under both standard and changing conditions. The strength, order and frequency of the nerve impulses are transmitted to muscles. Coordination is the physical ability encompassing balance.

Balance is the form of coordination that depends on the harmony of the acuteness of the sensation and the intramuscular coordination. Balance may be defined as the ability of the human body to maintain stable body position or maintain the required body position performing various movements aimed at different parts of the body while it performs motor activities at different levels of speed [1]. Balance may be classified into two main types. Static balance is the ability of the body to maintain equilibrium for one position without moving [2] and according to Sharkey and Gaskill (2006) it is the ability to maintain balance while stationary. Dynamic balance is the ability to maintain and regain balance while in motion performing exercises and their combinations, under the influence of different outer stimulus [2] and according to Sharkey and Gaskill (2006) it is the ability to maintain equilibrium while performing different movements. Dynamic balance may be further grouped into balance while performing the movements under normal conditions with precise designated order and the balance, attained while body moves under changing conditions [2].

Both types of balance presented above depend on the ability to utilize visual signals, and those coming from inner parts of the ear as well as muscle, joint receptors. Nevertheless, static and dynamic balances do not have much in common. For example, man who is able to properly maintain static balance could appear not being able to perform simple movement and man, able to stand on one leg can struggle to go downhill on skis etc.

Balance can also be subdivided, according to R. C. Schafer (1987), M. Ferdjallah (1999) and others, not only into static and dynamic, but also to active and passive depending on muscular system function, i.e., ability to maintain stability. Balance requiring muscular strength is called active and balance, attained while all the gravitational centers of body segments are allocated so that the surface of the joints are not affected by gravitational power, passive. The latter type of balance does not surface while body takes natural standing position. Usually the position of man, standing for quite a long time, is asymmetric [3].

Periodically changing the position of a body, man maintains relatively stable body position. The most prominent researchers in this area, M. Duarte, V. Zatsiorsky, M. Guerraz, C. de Lucia, claim that changes in body position while standing still can be caused by venous stasis. According to other hypothesis, the transfer of body weight from one leg to the other while standing still for long periods of time can aid and support joint fluid circulation. So mere standing is not the simplest mechanical process. During it an active interaction between the subject and its surroundings is taking place and it can vary depending on the changes of body position and outer influences [4]. The muscles are exerted more while a person is in standing than in sitting position. Standing is a suspended fall, i.e. when taking stationary position, man is as if about to surge forward and the exerted muscles prevent that.

Static balance test. Man’s static investigates the conditions under which human body stays stationary. The balance between gravity and support reaction develops in static position. Body static is started being evaluated from the centre of mass. The general centre of mass position depends on the condition of the body. The general centre of mass of a person standing straight is in the middle plane [1].

Projective vertical descending from the centre of mass hits the human plane, which is confined by feet. As soon as this vertical passes the boundaries of the supporting plane, the balance becomes disrupted and man falls. The place of the centre of mass depends on constitution of a body, sex, age and individual variety. The centre of mass of a man is a bit higher than that of a woman, because of their constitutional properties of broader shoulder line and chest areas; whereas the centre of mass of a woman is lower because of they have slimmer upper part of the waist and larger pelvic area. The centre of mass in children varies depending on their age and is relatively higher in younger children. While standing straight the centre of mass vertical goes through the Atlanto-occipital joint cross-axes before spine, behind hip joints and through ankle-joint cross-axes. The posture depends on the structure of passive motion apparatus pertaining to a particular person where an important role is played by the vertebral incurvation and the static pressure of certain muscle group in resisting gravity.

The centre of mass of a solid body is fixed whereas the position of the centre of mass of a human body depends on the posture. The centre of mass of man standing in the manner of natural posture is on the level of sacral vertebrae. Together with the change of body posture shifts the position of centre of mass. At some points, for example when bending forward (before the javelin high jump or doing somersault) the centre of mass might overreach the boundaries of a human body.

Experimental test

Triaxial accelerometers used during accelerometry are attached to the waist and limbs of the person being tested and connected to a computer to examine the signals measured. Accelerometers measure the speed and acceleration of the movement of certain parts of the body [1, 5, 6]. In measuring the acceleration using accelerometers it is extremely important to make sure that the sensors are in parallel with the axis of movement. During the research accelerometers were attached to special metal cube, which was connected to a metal plate and fastened to two belts, preventing from accelerometers tilting.

The test was carried out using “Bruel & Kjaer” measuring equipment: three seismic (uniaxial) accelerometers 8344, which traced the oscillation amplitude of human centre of mass for the axes *X*, *Y* and *Z*. Technical characteristics of the accelerometer 8344 are as follows: sensitivity 250±20% mV/ms^{-2}, measure range ±26 ms^{-2}, frequency range 0,2–3000 Hz. During

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the test portable computer with special software package "Pulse", electrical signal input and processing device 3660-D was used.

During the test subjects were asked to stand still for a 60 sec with eyes open and then with eyes closed. After the first trial of quiet standing, subjects were performing physical activity in the form of riding the veloergometer for a 3 min with constant speed and moderate intensity. After performing the physical activity subject was asked to stand still again for a 60 sec and the oscillations of his body mass center were recorded using accelerometry. Before and after the tests the heart rate of the subjects was recorded using wireless heart rate measurement device.

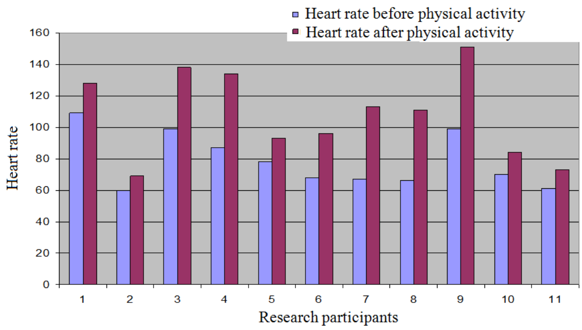
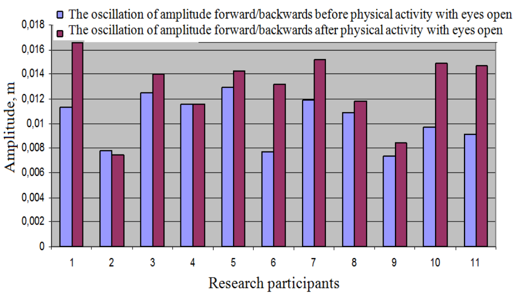


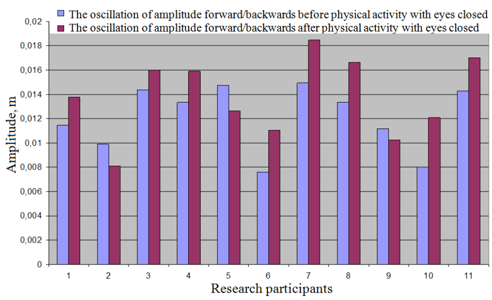
Fig. 1. Heart rate before and after physical activity

The average heart rate before physical activity is 78,54 and after 108,18. Heart rate after physical activity increased 1,4 times.

As can be seen form Fig. 1, the participants of the experimental research were healthy young subjects, because "the heart rate of the student age youth in still state ranges from 70-95 b/min, when heart rate 100-150 b/min shows physical activity of middle intensity. When the pulse reaches 180-200 b/min, the physical activity is considered to be marginal (R. Hedman, 1980)".



a)

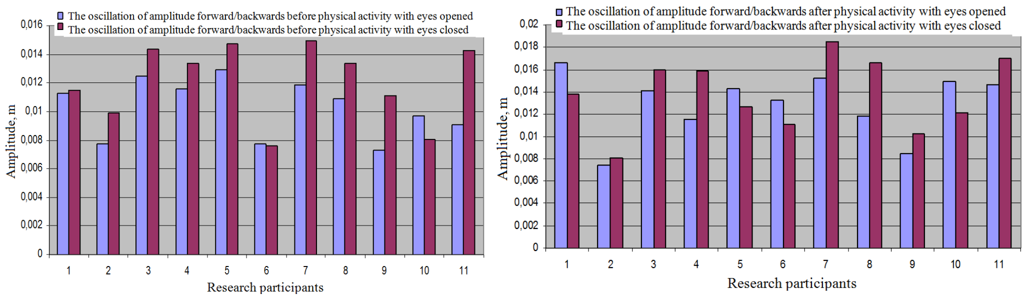


b)

Fig. 2. (a) The amplitude of oscillation forward/backwards before and after physical activity with eyes open and (b) The amplitude of oscillation forward/backwards before and after physical activity with eyes closed

From Fig. 2 (a) we can clearly observe that the amplitude of oscillation forward/backwards after physical activity with eyes open has increased. The average of amplitude of oscillation forward/backwards with eyes open was 0,010 m and after physical activity - 0,0129 m. When comparing the amplitude of oscillation forward/backwards before and after physical activity with eyes open one can notice that the oscillation of amplitude after physical activity with eyes open increased by 22,48 %. The maximal amplitude forward/backwards before physical activity with eyes open was 0,0129 m and after physical activity with eyes open was 0,0165 m. The minimal amplitude forward/backwards before physical activity with eyes open was 0,0073 m and after physical activity with eyes open was 0,0074 m.

Fig. 2 (b) shows that the amplitude of oscillation forward/backwards after physical activity with eyes closed has increased. With eyes closed, the average of amplitude of oscillation forward/backwards before physical activity was 0,0120 m and after physical activity it was 0,0141. When comparing the amplitude of oscillation forward/backwards before and after physical activity with eyes closed it can be observed that the amplitude of oscillation after physical activity with eyes opened has increased by 14,99 %. The maximal amplitude forward/backwards before physical activity with eyes closed was 0,0149 m and after physical activity with eyes closed was 0,0185 m. The minimal amplitude forward/backwards before physical activity with eyes closed was 0,0076 m and after physical activity with eyes closed was 0,0081 m.



a) b)

Fig. 3. (a) The oscillation of amplitude forward/backwards before physical activity with eyes opened/closed (b) The oscillation of amplitude forward/backwards after physical activity with eyes opened/closed

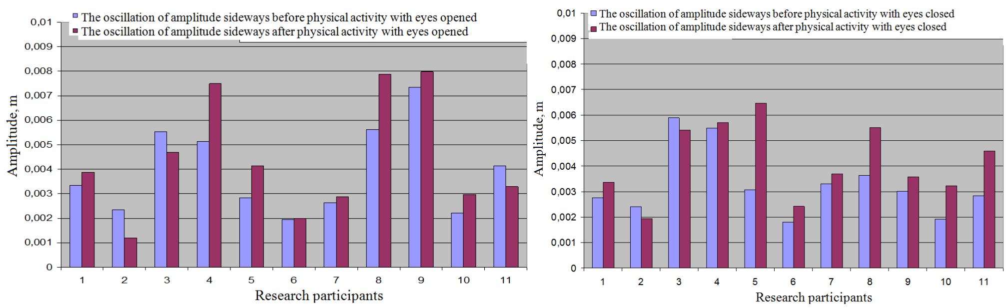
From Fig. 2 (a) and (b) it can be observed that physical activity affects body balance. During physical activity the internal stability (homeostasis) of the human body changes and because of this change a body is forced to adapt: to be able to function properly, several of its functions and systems have to adjust to the psychophysical loads, therefore, the amplitude of the oscillation after physical activity increases.

Fig. 3 (a) indicates that the oscillation of amplitude forward/backwards before physical activity with eyes closed has increased. With eyes opened, the average of amplitude of oscillation forward/backwards before physical activity was 0,010 m and before physical activity with eyes closed it was 0,012 m. When comparing the amplitude of oscillation forward/backwards before physical activity with eyes opened and closed, it can be noticed that the amplitude of oscillation with eyes closed before physical activity has increased by 16,70 %. The maximal amplitude forward/backwards before physical activity with eyes opened was 0,0129 m and before physical activity with eyes closed was 0,0149 m. The minimal amplitude forward/backwards before physical activity with eyes opened was 0,0073 m and before physical activity with eyes closed was 0,0076 m.

Fig. 3 (b) illustrates that the amplitude of oscillation forward/backwards after physical activity standing still with eyes opened/closed has increased. With eyes opened, the average of amplitude of oscillation forward/backwards after physical activity was 0,0129 m and with eyes closed it was 0,0138. When comparing the amplitude of oscillation forward/backwards after physical activity with eyes opened/closed it can be observed that the amplitude of oscillation after physical activity has slightly, by 6,53 %, increased with eyes closed. The maximal amplitude forward/backwards after physical activity with eyes opened was 0,0165 m and with eyes closed - 0,01847 m. The minimal amplitude forward/backwards after physical activity with eyes opened was 0,0074 and with eyes closed - 0,0081 m.

Comparing a) and b) of Fig. 3, the amplitude of oscillation forward/backwards before and after physical activity with eyes opened/closed, it can be stated that the visual perception of the surroundings has an impact on person's balance stability as testing balance with eyes closed, the amplitude of oscillation has risen. A significant balance disruption has been observed before and after physical activity. The average increase in forward/backwards amplitude before physical activity (with eyes opened/closed) is 1,5 times and after physical activity it is 2,5 times.

A significant research has been carried out investigating how vision is correlated with balance and motor skills. Visual information, assisting in performing specific movement, is integrated into information, spreading from vestibular apparatus and proprioreceptive signals received from reflex and volitional movement. The organization of these sensory signals plays a major role into successfully maintaining a certain body position and performing movement.



a) b)

Fig. 4. (a) The oscillation of amplitude sideways before and after physical activity with eyes opened, and (b) the oscillation of amplitude sideways before and after physical activity with eyes closed

Sensory organization, supported by information received from vision, proprioreceptors and vestibular sensation is responsible for synchronization, direction of movement and amplitude. Nashner and MeCollum have found that information necessary for controlling a movement is coming from visual images and also from proprioreceptive information on certain eye position. Therefore, static and dynamic balance requires several sensory characteristic one of which is vision.

Fig. 4 (a) shows that the oscillation of amplitude sideways after physical activity with eyes opened has increased. As mentioned before, physical activity has an impact on the stability of balance as the fatigue of low range can be felt after it and body balance returns to its normal mode after about 30 minutes. The average of amplitude of oscillation sideways before physical activity was 0,0032 m and after physical activity with eyes opened it was 0,0042 m. When comparing the amplitude of oscillation sideways with eyes opened before and after physical activity it can be seen that the amplitude of oscillation after physical activity with eyes opened has increased by 23,09 %. The maximal amplitude sideways before physical activity with eyes opened was 0,0058m and after physical activity with eyes opened 0,0064 m. The minimal amplitude sideways before physical activity with eyes opened was 0,0018 and after physical activity with eyes opened 0,002 m.

Fig. 4 (b) indicates that the amplitude of oscillation sideways after physical activity with eyes closed has increased. With eyes closed, the average of amplitude of oscillation sideways before physical activity was 0,0039 m and after physical activity it was 0,0044 m. When comparing the amplitude of oscillation sideways with eyes closed before and after physical activity it can be observed that the amplitude of oscillation after physical activity with eyes closed has increased by 11,37%. The maximal amplitude sideways before physical activity with eyes closed was 0,0058 m and after physical activity with eyes closed - 0,0064 m. The minimal amplitude sideways before physical activity with eyes closed was 0,0018 and after physical activity with eyes closed - 0,002 m.

Fig. 4 (a) and (b) compared, the amplitude of oscillation sideways before and after physical activity *with eyes opened* and the amplitude of oscillation sideways before and after physical activity *with eyes closed*, it has been noticed that the amplitude of oscillation sideways before and after physical activity with eyes opened has doubled.

Conclusions

Comparison of findings received from experimental study of oscillation amplitude of motion forward/backwards and sideways demonstrates the following:

1. The central vision enables to identify the surrounding objects, parts of the body and their parameters. Peripheral vision enables to identify the changes in the position of objects and parts of the body reciprocally providing with consciously intangible and inapprehensible information, which is of great importance in motor control (Klygytė, 1998).
2. Central and peripheral vision interacts in balance control (Nougier, 1998). Peripheral vision has a greater impact on oscillation forward/backwards than on left/right. Whereas central vision participates in oscillation control of both motion modes. Therefore, many authors (Giacomi, Sorace, Margini, 1998), investigating the impact of vision on balance control, maintain that balance control while standing is the most significantly influenced by central vision. Any disorder of central vision results in stronger lateral oscillations (Nougier, 1998).

References

[1] **Muckus K.** Biomechanikos pagrindai. Lietuvos kūno kultūros akademija. Kaunas, 2006, p. 300.
[2] **Stonkus S.** Sporto terminų žodynas. KMU leidykla, Kaunas, 2002, p. 739.
[3] **Duarte M., Harvey W., Zatsiorsky V. M.** Stabilographic analysis of unconstrained standing. Ergonomics. 2000, p. 24–39.
[4] **Riccio G. E., McDonald V.** Methods for investigating adaptive postural control. In: Proc. Satellite Meet. Soc. Neurosci. Los Angeles, CA 1998, p. 6–7.
[5] **Griškevičius J., Jarmalienė E., Šešok A., Daunoravičienė K., Kizilova N.** Evaluation of human postural balance in quiet standing by direct measurement of human body center of mass acceleration. Journal of Vibroengineering, 2009, p. 556–561.
[6] **Steele B. G., Holt R. N. L., Belza B., Ferris S., Lakshminaryan S., Buchner D. M.** Quantitating physical activity in COPD using a triaxial accelerometer. Chest 2000, p. 117.