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The Impact of Sound on a Fixed Spectrum and Intensity on Selected Parameters of Stability

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Abstract

Introduction: *Maintaining body balance requires integration of vestibular, proprioceptive and visual information. The effectiveness of postural control system has great importance in humans life – it is an essential condition of security of moving and doing life important activities. Stability disturbances could be a result of individual activity, as well as it could be an effect of interaction with the environment.*

The aim of this study was to assess an influence of auditory stimuli on selected parameters of body stability, which was measured among young, healthy and physically active subjects.

Methods: The research was carried out on a group of 60 people; aged 19-25 (21±1,67).

The force platform, Cosmogamma, was used to examine static maintenance of postural stability in variety of auditory conditions (relative silence; with music through headphones; immediately after music exposure).

The analysis of results showed a statistically significant influence of music (with established spectrum) on the following stability parameters: Mean Loading Point (plane X and Y), Average Speed, Lateral Speed and Subtended Area. However, the difference between postural stability of female and male had insignificant influence only (without dependence on auditory conditions).

Key words: *balance, postural stability, posturography, acoustic stimulus, acoustic sensitivity.*

Introduction

The balance control system can be regarded as a control system with three entry points, including: vestibular system, visual system and deep sensory receptors. The obtained information is provided and processed by the central nervous system and then passed to the effector organs – muscles of a trunk and extremities as well as eyeballs, resulting in the posture coordination reactions [1,2,3].

The research showed that for healthy persons, the postural stability in space, in the conditions of even, hard ground, 70% depends on the proprioreceptors located in muscles, tendons, joints and skin. Other systems provide subsequently: 20% (vestibular system) and 10% (visual system) of the information. However, when the ground is changed for uneven, less stable, the key role in the stability control is played by the deep sensory receptors and the visual system over the vestibular system [4,5]. If the information from the proprioreceptors and the visual system is incorrect or it is significantly reduced (e.g. in the situation of standing or walking in the dark, especially on soft and irregular surface), the vestibular system will play the key role in the balance control process [5,6].

In the static posturography, most often the basis to assess balance involves the analysis of small, involuntary movements of the centre of gravity of a body while standing still. These movements i.e. sway of the body, usually cause the view of the centre of gravity oscillate within a radius of a few millimetres to several centimetres. They are usually associated with the change of the position of the centre of gravity (COG), the view of which, in upright posture, is in a small specific area of a supporting surface. This area is approximately 5 cm forward in relation to the lateral malleolus of the ankle joint. Due to the significant cost, time-consuming and low availability of the measurement of oscillation of the centre of gravity of a body, it seems to be beneficial to replace it with a measurement of displacement of the centre of foot pressure (COP). In the case of free standing, the passes of both signals are very close (their compliance is up to 97%), and the sways amplitude is burdened with a negligible error

[2,7,8,9,10,11]. A posturographic platform is a device commonly used in the research of body posture, in static conditions, i.e. a small plate equipped with a set of three or four sensors, recording pressure forces and moments of these forces, exerted by feet to the ground. The supports equipped with these sensors record a displacement of the centre of gravity of a body of a researched person in the platform plane. The value of displacements is automatically subjected to computer analysis, and currently displayed on a monitor. Based on the data obtained, the computer calculates the location of the centre of foot pressure (in static conditions also with the view of the centre of gravity of the body), and its sways are presented in a graphic form, as statokinesiogram. The registration of the centre of feet pressure, executed in time, allows to follow and measure the momentum of sways of the whole body (stabilogram). In order to avoid errors in the interpretation of the data, the computer analysis is applied, taking into account the patient's weight and height. The application of such a processing system allows to calculate a series of parameters: speed of sways of the body, mean sways value, maximum sways amplitude, expanded surface field and Romberg indicators (analysed in the case of two consecutive tests: with open and closed eyes) [12,1,13,14,15].

It was not easy to define standards for posturographic variables. A serious obstacle constitutes a lack of population without postural defects and dysfunctions, because these disorders influence the result of the posturographic research. On the one hand, narrowing of the researched group to persons without any loss prevents from the specification of "standards", and on the other hand, its extension influences the substantial enlargement of the range of variation of the measured parameters.

The purpose of this work is to specify the influence of the acoustic stimuli on selected parameters of stability of standing posture of young, healthy and physically fit persons. The following was assessed: average load point, maximum sway, mean sway, average speed, lateral speed, antero-posterior speed, subtended area, speed area, time within circle R13 and R25 mm.

Materials and methods

The researched group consisted of 60 people: 19 men (31.7%) and 41 women (68.3%) aged 19-25 (average 21±1.67). All people expressed their written consent to the research. The research of balance for the assessment of static posture of a patient was executed on Cosmogamma balance platform (Figure 1). The system consists of a stability-metric platform and a computer connected to it, with a suitable computer program. In addition to the listed equipment, the research stand has a CD player and widely available inner ear canal type earphones (Philips SHE9503). A song, unknown to the researched persons, was used as the auditory stimulus. Spanish lyrics prevented from focusing on the words and singing. A spectral characteristic of the song as a potential source of balance interference was developed at the Institute of Physics, University of Rzeszow (Figure 1).

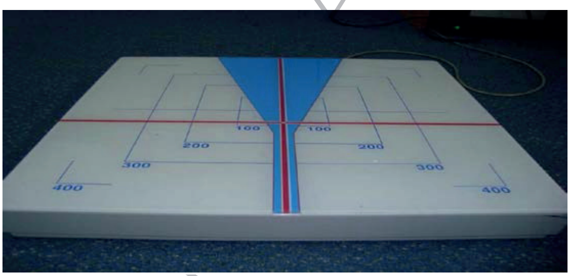

Figure 1. Cosmogamma platform ready for operation

Cosmogamma platform is a system that monitors changes in the position of the centre of foot pressure (CFP) by providing a variety of assessment parameters, such as: graphical representation of the oscillation of the CFP (static-dynamic diaphragm), graphical representation of the oscillation in the antero-posterior direction (static diagram), load distribution and frequency spectrogram based on Fourier analysis (FFT). This device is characterised by high repeatability of executed measurements and is considered a good method for the balance assessment [16]. The stability-metric research was executed in accordance with the recommended methodology. During the first test, the conditions of relative silence were assured. The researched persons stood on the platform barefoot, in upright position, with their hands along a torso and a head towards. Just a few metres away, vertical straps were attached on a wall (Figure 2, Figure 3).

Figure 2. A – Correct positioning of feet, the view from the top. B – Correct positioning of feet, the view from the side

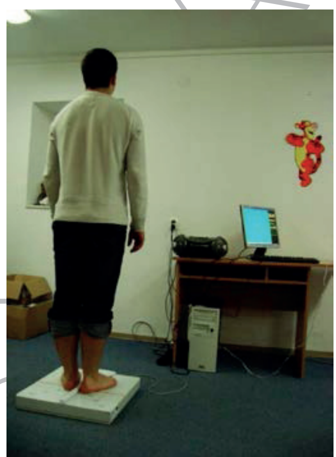

Figure 3. The research stand during the measurement

The computer screen was reversed to prevent from possible visual control of the oscillation of the COP (feedback) during the test. Particular attention was paid to the correct positioning of the patient's feet, the recommended distance of 2 cm between heels was kept, feet were positioned at an angle of 30°, lateral ankles were positioned on the horizontal red line (Figure 2A, B). The justification of such rigorous compliance with the methodology of positioning is to provide conditions for the accuracy of the measurements, because only if they are met, the centre of gravity of the posture lies in the sagittal axis of the platform. In order to facilitate correct positioning, the form of feet positioning was used. The research stand is shown in Figure 3.

The research procedure included three subsequent tests, which were executed while standing on both feet, with open eyes, in the sagittal plane of the platform. The test period was subsequently: 1 min. (conditions of relative silence), 2 min. (music administered directly into the ear canal by earphones), 1 min. (the earphones in ears, no music). All three tests were executed directly after each other, and the researched persons were each time informed about the beginning and end of the test. In order to assure the repeatability of the method, the scale of the panel sensitivity of all researched persons was the same, i.e. 200 mm. Similarly, the volume of the heard song during the tests with music was the same for all researched persons. Before the measurements were executed, all the participants had been informed about the progress and the appropriateness of the experiment being executed, and the use of its results. In addition, the harmlessness of the executed research was assured.

Research results

The obtained results of the survey and the stability were entered to MS Excel, in which the initial analysis was executed. In order to carry out a thorough analysis, Excel file was imported to Statistica 6.0 PL. In the work, the commonly used methods of descriptive statistics were employed, which allowed to specify the compatibility of the results with the normal distribution. Arithmetic mean, median and standard deviations were calculated. Minimum and maximum values of individual parameters were specified, as well. Mutual relations between the tests were researched using non-parametric tests.

In the researched population, parameter changes were assessed in terms of postural stability during three subsequent tests – in conditions of relative silence, during the operation of the acoustic stimulus, and immediately after stopping. The basis of the assessment involved the parameters generated by the centre of feet pressure on the platform. An original survey was the source of the information on the researched group. The largest portion of the respondents started listening by earphones approximately 2-3 years ago (Figure 4).

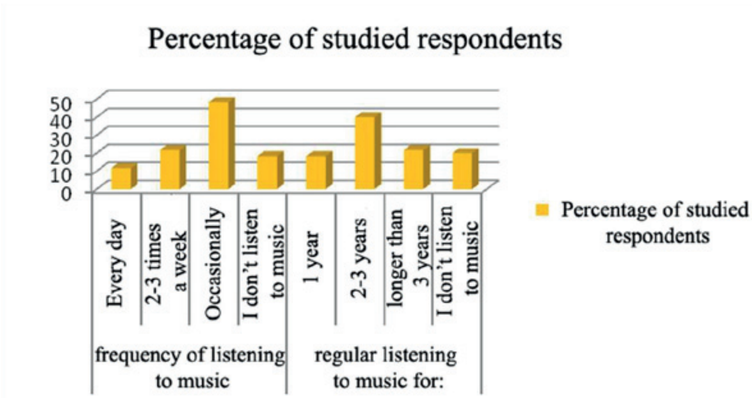

Figure 4. The frequency of listening to music by the respondents

Analysed parameters of posturogram

The non-parametric Wilcoxon matched pairs test was executed in order to specify the relationships between the various parameters.

Null hypothesis – H0: the results of the analysed parameters do not differ. Alternative hypothesis – Ha: the results of analysed parameters are different.

In the research, statistically significant variables were with the significance level of $p=0.05$, $p<0.05$ (Figure 5).

The difference in the mean load point in the lateral plane of the platform between measurement II (with music) and measurement I (conditions of relative peace) is statistically significant (Figure 5). The significance level is equal to 0.04. The mean value of the load point in the lateral plane is higher in the conditions of relative silence (2.62). The sways range of the mean load point in the lateral plane of the platform for the tested group is from 5 mm to 10 mm for measurement I and -5 mm to 5 mm for measurement II (Figure 6).

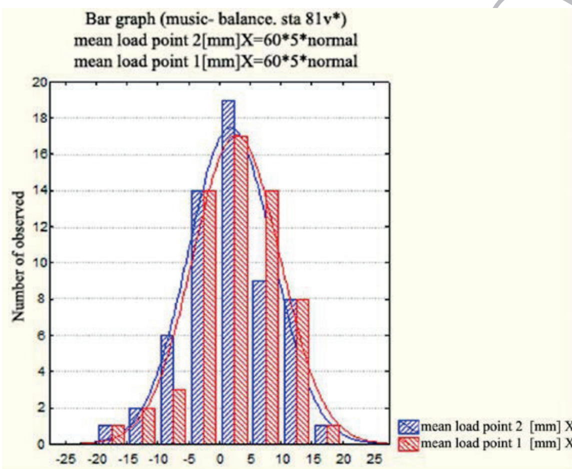

Figure 5. The difference in the mean load point in the lateral plane of the platform between measurement II (with music), and measurement I (conditions of relative silence)

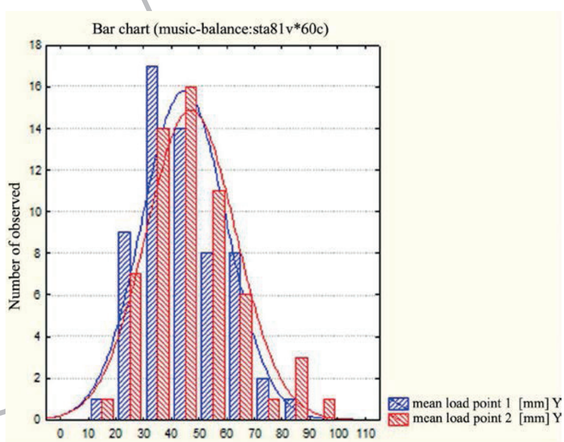

Figure 6. The difference in the mean load point in the anterior-posterior plane, between measurement II (with music), and measurement of I (conditions of relative silence)

The difference in the mean load point in the anterior-posterior plane between measurement II and I is statistically significant (Figure 6). Statistical significance is 0.003. The average value of the analysed parameter is higher in measurement 2 (with music). The sway range of the mean load point in the anterior-posterior plane for the researched group is in the range of 30-50 mm for measurement I and 30-60 mm for measurement II.

The mean value of the average speed of the centre of feet pressure on the ground is slightly higher in measurement I (Figure 7). The range of values for the analysed parameter is from 6 mm to 12 mm for both tests.

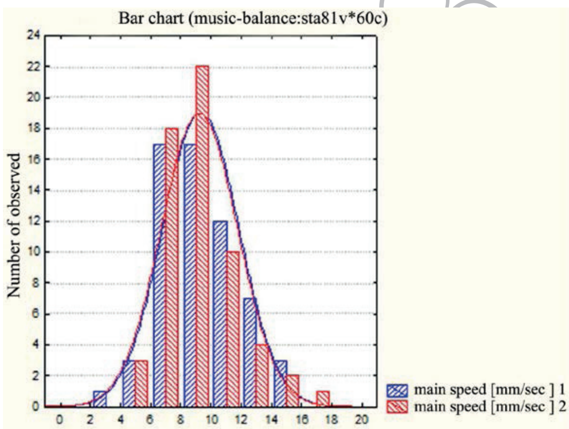

Figure 7. The difference in the average speed between tests I and II

The significance of the difference of the average speed between measurements I and III was measured (Figure 8). It is statistically significant. The significance level is equal to 0.0009. The mean value of the average speed is higher in the group of the researched persons in the conditions of relative silence compared to the group of persons with earphones in their ears, without music played. The range of the analysed parameter for test I is from 6 mm to 12 mm, while in test III: from 6 mm to 10 mm.

The significance of the difference of the average speed between measurements II and III was measured (Figure 9). It is statistically significant for the level of significance equal to 0.03. The mean value of the lateral speed is higher in the group of the researched persons listening to music compared to the group of persons with earphones in their ears, without music played. The range of the analysed parameter for tests II and III is from 2 mm to 5 mm.

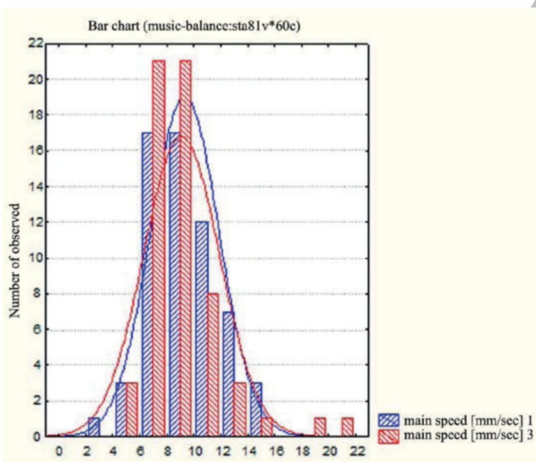

Figure 8. The difference in the average speed between tests I and III

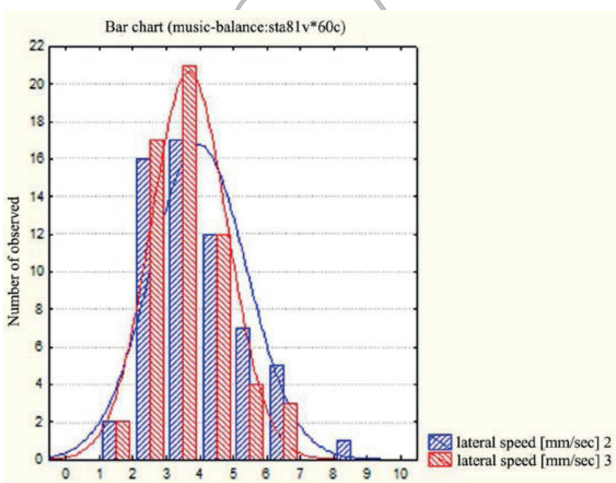

Figure 9. The difference in the lateral speed between measurement I and III

In addition, the difference in the lateral speed in two measurements: in the conditions of relative silence (measurement I) and in the conditions of silence, with earphones in their ears (measurement III) was measured and illustrated in Figure 10. The mean value of the analysed parameter is higher for the group of persons in the conditions of relative silence. The range of the analysed parameter for measurement I is from 3 mm to 5 mm, while for measurement III: from 2 mm to 5 mm (Figure 10).

As shown in fig. 11, the measurement value of the subtended area is more than twice higher in the conditions of music (8.39) compared to the measurement in the conditions of relative silence (4). This difference is statistically significant for p=0.000<α (Figure 11).

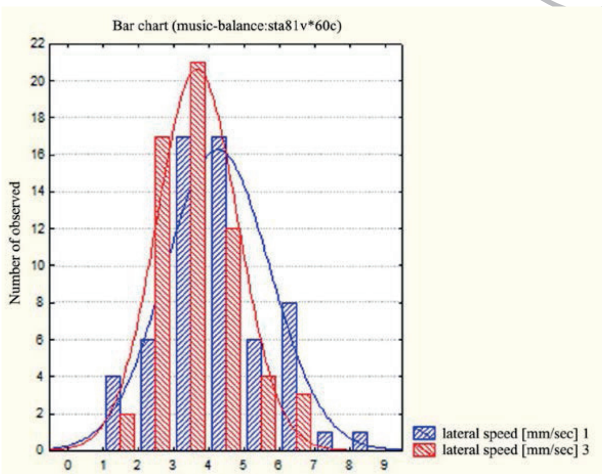

Figure 10. The difference in the lateral speed between measurement I and III

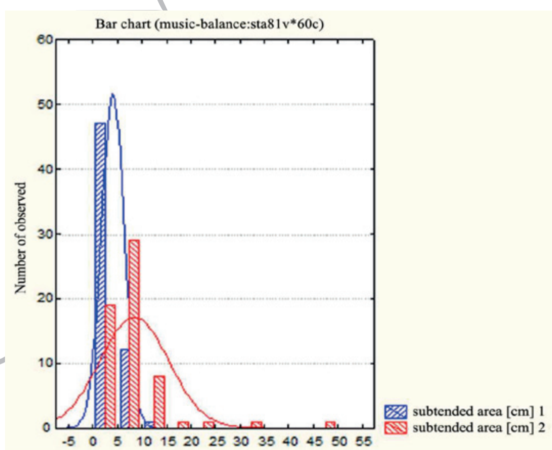

Figure 11. The difference of the subtended area between measurements I and II

In addition, the difference of the subtended area between measurement II and III was measured (fig. 11). In the test with music the mean value of this parameter is 8.39, while in test III: 3.75 (Figure 12).

The significance of any of the researched parameters is not lower than 0.05, that is, none of the parameters depends on gender.

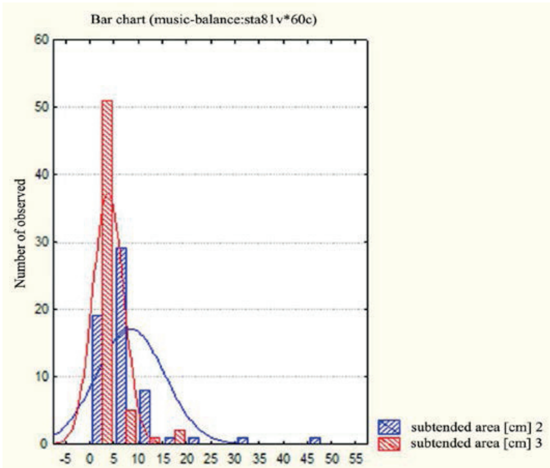

Figure 12. The difference of the subtended area between measurements II and III

Discussion

The smooth operation of the balance control system of a body is important in human life. It allows to safely and securely move and execute important activities. In case of any disturbances of ability to maintain a stable position, the risk of falling and injury increases. For this reason, it is justified to search for factors (extracorpereal and autosomal) influencing on increased and decreased stability. The efficiency of the balance system depends on the cooperation between labyrinth, cerebellum, eye, proprioreceptors located in muscles and joints, and feet touch receptors [2,17]. The constant interaction of various environmental factors, on which a human is exposed, tends to conduct research on their influence on the process of balance control. This work is an attempt of such searches. The most important aspect of the research was to specify the effect of acoustic stimuli on postural stability. The executed research indicates the appearance of the interaction between the acoustic stimuli, and the process of maintaining body stability. The influence of the acoustic stimuli on postural stability is related to the proximity of receptors, i.e. auditory and vestibular in inner ear. Their stimulation can be proved by results of the research the documented by Russolo, in which he observed decreased postural stability under the influence of the acoustic stimuli of high intensity (118.5 dB) and the particular characteristics of frequency (500 Hz) [18]. Similar results for the acoustic stimuli above 100 dB were documented in other works [19,20]. An interesting fact seems to be a positive influence of the acoustic stimuli on the quality control of postural stability. Polechoński stresses its increase under the influence of certain sounds. Based on the executed experiments, he proved that white noise (of continuous, sustainable characteristics of spectrum power) and supporters' applause of a certain intensity (60, 80, 100 dB), shortens the area of the resulting pressure point on the ground. In another research, the author used music as an acoustic stimulus. In this case, he recorded the improved stability in the conditions of exposure to music, as well. Despite the fact that the first and the second research were executed in static conditions, the author suggests that the successfully obtained results can be transferred to the conditions of dynamic stability. The research on motility issues support the thesis [19,20]. Bearing in mind the significant influence of the intensity of the acoustic stimulus on body stability, it seems necessary to specify it exactly. In executed own research, all persons were stimulated with the same music, with the same spectrum. The measurement of the mean intensity and the spectrum frequency is beyond the scope of this work. As it is known, three systems are directly involved in control of posture maintaining: the vestibular system, visual system and deep sensory receptors [2,3]. In addition to these systems, some researchers also emphasise an important role of hearing information coming from the surrounding (audio-feedback) to the process of maintaining stability. The research executed with patients with hearing loss within the vestibular system can prove the aforementioned statement. In order to assess the degree of relationship between hearing stimuli, and the stability of a body, other control systems (soft ground, limited visual control) were excluded. The only information about the posture sway involved auditory signals, the occurrence of which were the reason for improved postural stability [21]. The experiments executed in recent years suggest another possible interaction between auditory and postural stability – no recorded auditory influence [22]. In the case of own research, one can also observe this trend for selected parameters (no statistically significant difference). A probable cause of such a result can be the fact that the whole researched group consisted of young, healthy persons with high compensation abilities (no balance disorders). The influence of habituation phenomenon seems to be crucial; most researched persons had used earphones for listening to music for a long time, which probably largely excluded balance disorders. Tanaca stresses differences in maintaining balance in the elderly and the young, as a result of operation of the auditory signals. He researched two groups, a group consisted of young people (21.9 years old) and consisted of the elderly (68.9 years old). In the older group, under the influence of "moving" auditory stimuli, he recorded higher sways in the lateral plane than in the representatives of the young. In the light of these results, the author suggested that balance of the elderly largely depends on the auditory information, and therefore it is disrupted under the influence of such signals more easily [23]. An important aspect of the research was to specify the influence of gender on balance parameters. Different acoustic conditions of the tests allowed both to assess the comparative stability of women and men in the conditions of relative silence, and to compare the sensitivity of their posture to acoustic stimuli. Significant differences between postural stability for men and women did not appear, however, in the case of any of the analysed parameters, regardless of the acoustic conditions. Polechoński obtained completely different test results. In the executed experiments with closed and open eyes, in the conditions of relative silence, better stability was a feature typical of women, which was explained with their favourable body proportions [19,20]. However, some authors, pointing to anatomically smaller supporting area of women than men, do not notice the gender dimorphism in body balance [24,25]. To some extent, this was specified in further research executed by Polechoński with the acoustical stimulation. Based on the obtained results, one could not clearly state whether the sensitivity of the balance control system of body posture is dependent on gender (the results of most tests were similar). Significant differences appeared, however, in the measurements without visual control, suggesting higher sensitivity of the balance control system of women during exposure to acoustic stimuli [19,20]. The issue of the influence of the acoustic stimuli on postural stability is still not known. The executed research can be regarded as an introduction to further analyses, specifying their directions.

In the future, the researched group should certainly be extended in order to be considered as a representative of the population. The execution of the research not only in different acoustic conditions, but with limited access to information from other sources of postural control (variable conditions of visual control, a ground with different textures and hardness) seems to be beneficial. It is also interesting to research the relationship of the stability parameters and the auditory frequency. Executing a comparative analysis of the posturographic research results, one should remember that are often executed in different conditions, they involve a different procedure and the researched persons are of different age.

Conclusions

The research results allow to form the following conclusions:

1. Postural stability both in the conditions of relative silence, and the acoustic stimuli is not dependent on gender.
2. Music with a fixed spectrum has statistically significant influence on balance of the following parameters:
   - Mean load point X and Y
   - Average speed
   - Lateral speed
   - Subtended area, increasing their range.

3. The use of earphones without music (III test) significantly increased the parameters of the average and lateral speed compared with test I, where for a period of 1 minute, the time of absolute silence dominated.

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