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The Influence of General Low Frequency Vibration on Posture Stability

Z. Damijan[a,*] and A. Uhryński[b]

[a]AGH University of Science and Technology, Faculty of Mechanical Engineering and Robotics
Department of Mechanics and Vibroacoustics, al. A. Mickiewicza 30, 30-059 Krakow, Poland
[b]AGH University of Science and Technology,Faculty of Mechanical Engineering and Robotics
Department of Machine Design and Technology, al. A. Mickiewicza 30, 30-059 Krakow, Poland

The work presents the research and analysis concerning general low frequency vibration and its influence on posture stability. The research was conducted in two phases: a group exposed to vibration — August 2006, a control group: November 2006 in Krynica-Zdrój. An exposed group (29 participants/took part in 19 training sessions, each lasting 20 min, of low frequency vibration, standing position) applied to each participant at fixed time of the day. The low frequency vibration amplitude was 4 mm, while the frequency was 3.5 Hz. Before and after the session the posturographic examination of posture stability was conducted. The control group (33 participants) also took part in 19 everyday 20 min sessions with no vibrations and only measurements conducted. The results were analyzed concerning statistics using Statistica. For the sake of the analysis the significance level was $p = 0.05$, the parametric t-test and the nonparametric Kolmogorov–Smirnov tests were used for two groups of independent variables. Having conducted the research and analysis, one can state that 20 min exposure to low frequency vibration results in significant changes in posture stability and 19 day long vibration training changes significantly the posture stability among the participants. The observed changes were of positive nature. The work introduces research on the possibility of using low-frequency vibration to improve human stability. The results presented concern biophysics in rehabilitation of posture stability and are not often met in specialist literature.

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1. Introduction

One may indicate that whole body vibration is the equivalent of physical effort, however, without overloading movement organs and circulatory system, which from the point of view of a contemporary man suffering from a lack of time, should be interesting. Rhythmical contraction and de-contraction of skeletal muscles forced by the machine applying vibration generates the reaction of the whole body and then, beneficial mechanisms in it follow [1–7]. Keeping body in upright position is the result of very precise nervous-muscles coordination of all body segments, following the activity of dynamic processes beyond human consciousness. A human keeps balance due to skeletal muscles controlled by nervous system. That system, basing on received information, recruits motoric units, chooses proper stimulation and braking values of separate muscles and regulates coordination. Although we know a great deal about the control of human posture stability, we do not have specific data concerning the influence of vibration of a whole body on keeping balance. The research on that issue we have is ambiguous. It was suggested that the influence of low-frequency general vibration on human stability is positive, insignificant, or even negative [8, 9]. Stability means the ability to regain balance, to return to a typical body position in space which was lost due to destabilizing factors [2]. Some researchers, like Bautmans and others [1], used measurements not very accurate, like: test “time up and go” — the ability to perform a complex kinetic function in due time. There has been some improvement among older population, however as one can see, the posture stability could be improved indirectly by the growth of muscle force [1, 2].

2. Methodology of research

In order to generate cyclic changes in bones overload it was suggested to use harmonic vibration correlating with human run (about 210 steps per minute which gives ≈ 3.5 Hz), as the most suitable from the physiological point of view.

The assumption was that vibration be safe and non--disturbing. The researchers of the above had the permission from Bioethics Commission of Medical Academy in Łódź. The stimulus applied was safe following the instruction concerning tests and experiments involving people PN-EN ISO 13090-1: 2002, exposed to general mechanic vibration and repeatable shocks, described by ISO 2631-1:1997 [10].

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[*] corresponding author; e-mail: `damijan@imir.agh.edu.pl`

The research was conducted in two stages: a group exposed to vibration — August 2006, a control group — November 2006 in Krynica-Zdrój, Poland. The exposed group (29 participants) took part in 19 training sessions, each lasting 20 min, of low frequency vibration (standing position) applied to each person at a fixed time of the day. The stimulus was applied to the whole body in standing position, through legs — general vibration. During each session the participants were wearing the same clothes and were barefoot to prevent the vibration damping.

Before and after the exposure to vibration the posturograph study of posture stability was conducted. The control group (33 participants) also took part in 19 everyday 20 min sessions with no vibration and measurements taken.

The results were analysed concerning statistics using Statistica. For the sake of analysis the significance level was $p = 0.05$, the parametric t-test was used or nonparametric Kolmogorov–Smirnov test for two groups of independent variables. To measure normal distribution the Lilliefors and W–Shapiro–Wilk tests were used (standard tests to measure normal distribution). The zero hypothesis for every variable was as follows: exposure of a human body to vibration does not cause any changes in analysed variable.

The posture stability was estimated with the help of posturograph. It is used for objective measuring and estimating the condition of functional system of a human using static-kinetic-metric tests and to register displacement of foot pressure centre (COP) in frontal and sagittal planes, in static and dynamic conditions. The researchers used PRO-MED Twin 99 Posturograph with WinPod software which enables the research estimate to be multi-parametric. Figure 1 shows posturograph used in the research.

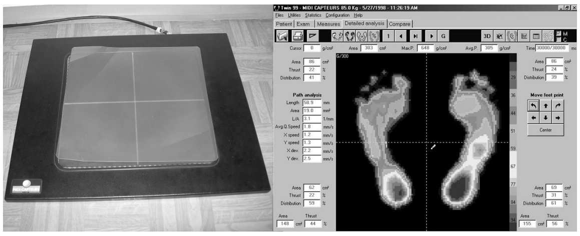

Fig. 1. PRO-MED Twin 99 Posturograph and a window from the WinPod program.

The results of statistic analysis are introduced in Figs. 2–5. The red colour indicates these dependent variables whose level differences before and after the stimulus turned out to be statistically significant ($p < 0.05$).

The charts with results include: diagram presenting the difference of levels before and after the stimulus action of examined variable and p-test probability value, vertical graph presenting percentage change trend of examined variable (how many people reacted with increase or decrease of a given parameter), a diagram showing the level of examined variable before and after the exposure to vibration as well as in following measurements taken from 1st to 19th day of the experiment.

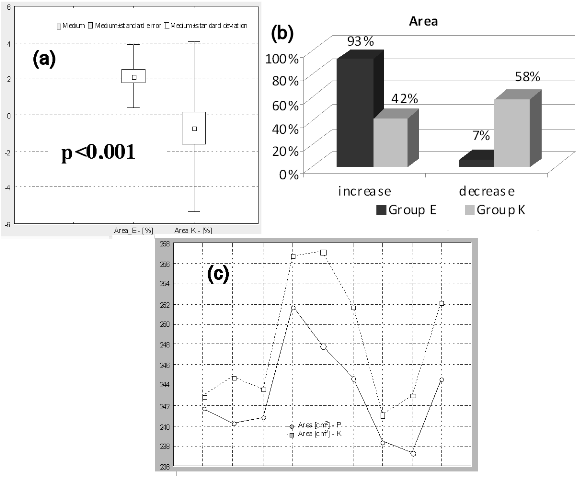

Fig. 2. Analysis of variable “ area”. (a) Changes between E and K groups and a level of statistic significance “p”; (b) percentage trend of changes in E and K groups; (c) changeable value before and after stimulus during 19 day long experiment for E group.

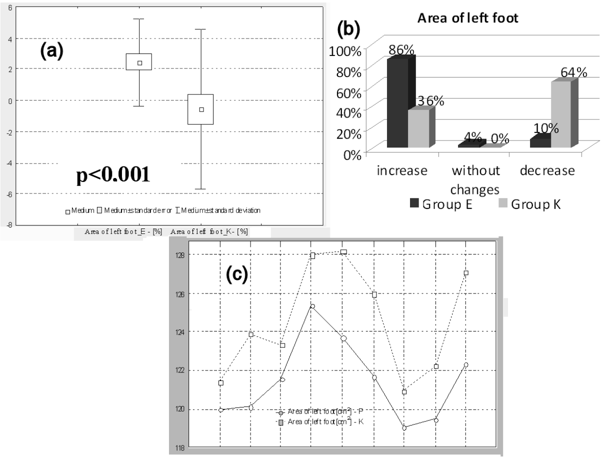

Fig. 3. Analysis of variable “area of left foot”. (a) Changes between E and K groups and a level of statistic significance “p”; (b) percentage trend of changes in E and K groups; (c) changeable value before and after stimulus during 19 day long experiment for E group.

3. Conclusions

Having conducted the research and comparative analysis (presented in Table and Figs. 2–5) between the exposed and control groups we can state that even 20 min exposure to general low-frequency vibration generates significant changes in posture stability and 19 day vibration training session changes the posture significantly.

TABLE

Significance test and descriptive statistics.

Variable	Descriptive statistics					
	p	Average	Minimum	Maximum	Standard deviation	Standard error
area_E [%]	< 0.001	2.171	−0.953	7.902	1.734	0.322
area_K [%]		−0.888	−8.318	9.746	4.490	0.782
area of right foot_E [%]	> 0.1	1.667	−3.390	5.063	2.045	0.380
area of right foot_K [%]		0.297	−10.000	12.227	5.188	0.903
maximum presure_E [%]	> 0.1	−0.737	−6.380	4.417	2.895	0.538
maximum presure_K [%]		−0.125	−18.349	13.348	8.153	1.419
average presure_E [%]	< 0.03	−1.490	−4.126	0.675	1.139	0.211
average presure_K [%]		0.302	−8.079	6.126	4.026	0.701
area of left foot_E [%]	< 0.001	2.450	−2.309	10.875	2.810	0.522
area of left foot_K [%]		−0.984	−8.532	15.676	5.089	0.886
participation of left foot_E [%]	> 0.1	0.162	−3.037	2.239	1.426	0.265
participation of left foot_K [%]		0.071	−7.477	8.889	3.740	0.651
participation of right foot_E [%]	> 0.1	−0.106	−2.261	3.495	1.497	0.278
participation of right foot_K [%]		0.214	−7.273	8.602	3.619	0.630
length of way_E [%]	> 0.1	3.381	−29.202	34.639	14.520	2.696
length of way_K [%]		2.610	−23.998	36.001	14.482	2.521
surface of rectangle_E [%]	> 0.1	122.713	−79.176	880.292	270.967	50.317
surface of rectangle_K [%]		36.637	−85.149	775.000	151.540	26.380
length to time ratio_E [%]	> 0.1	4.606	−29.032	32.680	14.610	2.713
length to time ratio_K [%]		2.429	−23.684	46.154	14.338	2.496
surface of closed elipse on oscillogram_E [%]	> 0.1	31.579	−57.895	194.175	61.392	11.400
surface of closed elipse on oscillogram_K [%]		8.647	−76.744	250.000	60.067	10.456
length to surface ratio_E [%]	> 0.1	−12.153	−52.436	50.000	22.281	4.137
length to surface ratio_K [%]		13.249	−57.042	229.630	57.063	9.933
"average quadratic" speed_E [%]	> 0.1	12.826	−30.556	163.636	40.426	7.507
"average quadratic" speed_K [%]		1.425	−23.864	36.515	13.979	2.433
average deviation Y_E [%]	> 0.1	23.515	−51.457	284.743	63.261	11.747
average deviation Y_K [%]		10.231	−80.995	109.804	45.144	7.859
average speed Y_E [%]	> 0.1	11.661	−42.489	178.393	42.444	7.882
average speed Y_K [%]		−0.421	−33.659	34.118	17.120	2.980
average deviation X_E [%]	< 0.05	45.485	−44.465	394.385	92.218	17.124
average deviation X_K [%]		9.473	−68.586	202.174	60.798	10.584
average speed X_E [%]	> 0.1	6.224	−22.781	46.395	16.303	3.027
average speed X_K [%]		2.086	−26.500	56.548	17.079	2.973

The changes observed were positive. Statistically significant 2.17% increase of a variable "foot area" in the examined group compared with the examined one — 0.89% — shows the adaptation of foot frontal and sagittal elements to the surface (Fig. 2). Closer adhesion of feet to the surface improves the posture stability due to increase of support square. Adaptation changes involved both feet — the right one, dominating (Fig. 3) and the left one — non-dominating (Fig. 4). Having compared the results with the control group (−0.89%) statistically significant changes of left foot area were presented: by 2.45%, usually non-dominating, having smaller muscle mass, therefore less trained, so more prone to vibration training (Fig. 3). The increase in posture stability is proved by the decrease of average foot pressure on the surface (Fig. 5) in the exposed group −1.49% (0.3% growth in control group) to low frequency vibration. It proves the adaptation of central analyzer of balance sys-

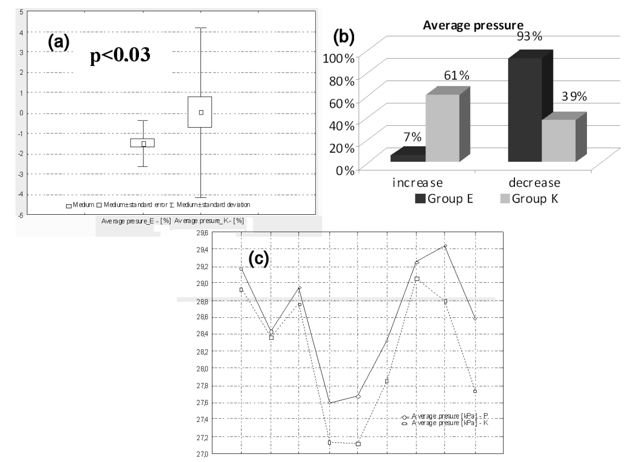

Fig. 4. Analysis of variable "average pressure". (a) Changes between E and K groups and a level of statistic significance "p"; (b) percentage trend of changes in E and K groups; (c) changeable value before and after stimulus during 19 day long experiment for E group.

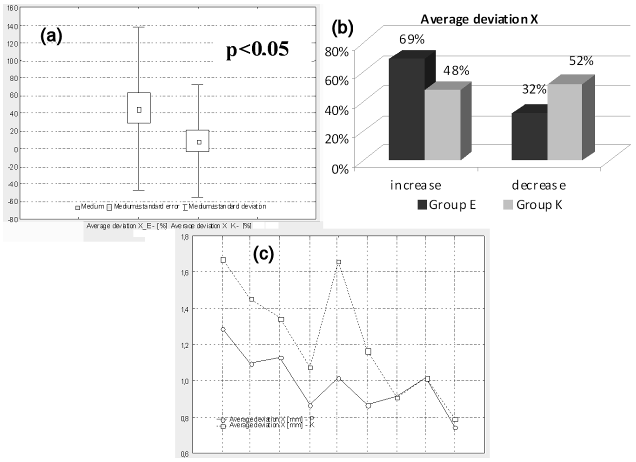

Fig. 5. Analysis of variable "average deviation x". (a) Changes between E and K groups and a level of statistic significance "p"; (b) percentage trend of changes in E and K groups; (c) changeable value before and after stimulus during 19 day long experiment for E group.

tem influenced by variable harmonic displacements in vertical axis and enforcement of such muscle tension and ligament of supporting system that arch of the foot be adhesive to the widest possible placement of pressure on separate parts of the whole system. That significance is also observed when compared to a control group (Fig. 4). The result of a study of average diversion in x axis (COP) (Fig. 5) shows statistically significant increase of average displacement amplitude in lateral plane (right-left) by 45.48% after 20 min exposure (9.47% in a control group). However, studying the diagrams of this parameter during 19 day session we can see that the trend is rapidly decreasing which proves the improvement of posture stability.

It seems to be proved by the experiment conducted by Torvinen and his team, who in 2002 observed decrease of average displacement amplitude of posture registered on posturegraphic platform after exposure to 4 min vibration. However, the studies by Polonyova and Hlavacka in 2001 showed that unilateral vibration of a calf muscle made the body lean backwards, but in the opposite direction than the vibrating muscle. Both works indicate direct influence of general vibration on posture stability. The results of our study prove that fact as well, concerning low frequency vibration [11, 12].

Acknowledgments

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