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The Effect of Acoustic Noise on Postural Sway in Male and Female Subjects

by

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Acoustic sensitivity of women's and men's postural stability system was tested in the set of experiments. Eighty subjects: 40 males and 40 females (mean age 22,5±1,4), students of the Academy of Physical Education participated in the experiment. Their postural stability was evaluated on the force platform. Spontaneous body sway was assessed during fourteen experimental trials each lasting 25,6 sec. During the trial subjects were asked to stand still in the upright position either with their eyes open or eyes closed. During the trials subjects were exposed to white noise signals or specific audience applause applied through the headphones. The experiment schedule consisted of silence, followed by three different noise volume trials (60, 80, 100 dB SPL). The research documented diverse acoustic sensitivity in male and female stability systems. The most significant differences were registered in experiments without vision control. Under conditions of relative silence, female students showed clearly better results than male subjects. The difference was noticed with and without visual control.

Keywords: *postural sway, acoustic sensitivity, posturography, noise*

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Introduction

Sounds are inherent elements of our natural environment that have undoubtedly direct impact on our life. Some of them are being identified as signals which may carry significant information, while other sounds are just meaningless and simply create an acoustic background.

Influence that sounds may have on human beings is diverse and it might be considered in positive as well as negative aspects. However, one cannot ignore the existence of sounds that are unwanted, harmful, having a negative impact on human organism and are classified as noise (Valentin 1985, Jethon 1997, Marcinkowski 1997). A continuous exposure to high intensity sounds may lead to a permanent hearing damage. Excessive noise – apart from the specific effects – may also affect many other human reactions. Usually it acts as a strong stressor impacting the central nervous system, psyche, cognitive processes as well as the functioning of internal organs (Czeskin 1972, Harazin et al. 1990, Dembowski 1991, Dudek et al. 1991, Dembowski et al. 1993, Kantor 1996, Jethon 1997). Thus environmental noise may interfere with numerous biologically and socially important activities of everyday life resulting in difficulties in learning, intellectual work as well as recovery (Jethon 1997).

Unfortunately from early years of our lives we are being exposed to a high level noise which may pose a serious threat for ontogenetic development. It has been proven in many research projects that noise intensity at schools is unacceptably high (Kono et al. 1979, Berglund et al. 1984, Koszarny, Gorynski 1990, Koszarny 1992, Koszarny, Jankowska 1994, 1995, 1996, Polechonski 2001, Slezynski, Polechonski 2001).

On the other hand, there are well known positive effects of low intensity noise on a human being. It has not been until recent times when sound has been applied in medicine, psychology and pedagogies (Czeskin 1972, Kuprijanowicz 1976, Cesarz 1988, Galinska 1988, 1990, 1998). Interesting results have been revealed in recent studies concerning the influence of noise on the nervous system. In the past few years experiments have shown that noise of a particular structure may nonlinearly improve perception and transmission of a low intensity useful signal. The effect is formally known as the stochastic resonance (Gammaitoni et al. 1998, Petracchi et al. 2000, Usher and Kosinski 2002).

There are primary proves for a positive influence of noise on the human movement control system. (Van Gemmert, Van Galen 1997, 1998, Checko et al. 2002, Priplata et al. 2002, Polechonski et al. 2003, Polechonski, Blaszczyk 2004, Polechonski 2005).

Due to various influence of noise on a human being and because of the common coexistence of noise and human motor activity it is intriguing and seems to be highly useful to direct research onto the influence of noise on human kinetics. Considering well known effects of noise exposure of a human body one must admit there are links confirming significant noise influence on coordination abilities. Their control is located within the central nervous system and is modulated by the sensory systems which are under continuous stimulation from the environment. (Szopa 1993a, 1995, Szopa et al. 1996, Gierat, Górska 1999, Raczek et al. 2002). This also refers to hearing stimuli. (Czeskin 1972, Harazin et al. 1990, Zalewski, Konopka 1996, Jethon 1997).

One of the coordination abilities which acoustic stimuli may influence significantly includes the posture equilibrium system (posture stability system). Maintaining a stable upright posture requires complex processes taking place in the nervous system. Stability disturbances may occur as a result of individual activity as well as being the effect of the interaction with the environment (Blaszczyk 1993). The postural stability factor is a body sway, which in fact is a set of minor fluctuations of a body’s center of foot pressure (COP) being registered during the quiet stance on the posturography platform. The effectiveness of the human equilibrium system is highly dependent on the close cooperation of the vestibular system, cerebellum, sense of vision and the deep tissue receptors (proprioceptors) located in muscles and joints (Latkowski 1996, Latkowski et al. 1997, Konturek 1998, Kubiczkowa 1998, Blaszczyk 2004).

Direct vicinity of the hearing sensors and the labyrinth being involved in postural stability control, allows to assume that vibrations transmitted through the hearing tracts may interfere with the analyzing system of stability control mechanisms. There is data confirming this notion (Dieterich et al. 1989), and the syndrome is called the Tullio phenomenon. Recent studies prove that humans react this way only when they are exposed to a high intensity noise of a particular frequency (Russolo 2002). Regardless of the mechanism of noise influence on the human body – the vestibular system or the general emotional state – acoustic stimuli do affect body sway and motor control in general.

It is beyond any doubt that sounds can modify the functioning of the central nervous system especially considering stimulus level analysis and thus affecting arousal. Yet the span and the direction of the influence is still uncertain and needs to be accounted for. The following study is a part of a wider research project on acoustic influence on upright posture stability. The main objective of the study was to determine whether gender may affect acoustic sensitivity of the equilibrium system?

Material and methods

Eighty male and female students of the Academy of Physical Education in Katowice (mean age 22,5±1,4) participated in the experiment. To exclude any possible hearing impairments which might influence the results, a simple diagnostic speech test was applied. This method is commonly used in the medical diagnosis for particular professions as well as in military primary medical diagnosis (Taniewski 1986, Pruszewicz, Swidzinski 1994, Latkowski 1996, Latkowski et al. 1997). Neurological disorders that might have had an impact on the results were also excluded in the process of interviewing the subjects.

A static posturography, being nowadays commonly used for evaluating the human stability system, was applied in the experiment (Blaszczyk 1993, Blach 2001, Jagusz 2001, Michalski 2001, Najsarek 2001, Piestrak 2001, Sienkiewicz 2001, Sikora 2001, Szymanska 2001, Taniewski et al. 2001, Waszczak 2001). The WinPosture 2000 system (QFP/Medicapteurs France) consisting of a posturographic force platform linked to a computer were used to access postural sway. The sway parameters have been calculated on-line by the software associated with the platform. The effect of the acoustic stimuli on postural stability has been documented by changes in sway path total length.

The postural sway data was collected during fourteen 25,6sec trials, while subjects were standing quiet. The sampling frequency was set at 40 Hz. During trials with headphones on, acoustic stimuli of two types were applied to subjects. The sound from an audiometer ZELMED AAD-80 was a standardized white noise. The noise from a CD player on the other hand was a digitally modified, yet authentic crowd applause. This particular noise was recorded in a sport arena during a competition prior to the research project. Afterwards a randomly chosen 5 sec part of the recording was copied and compiled into one continuous applause sound. The procedure described above allowed researchers to precisely define the volume of the noise as well as to maintain the characteristics of the sport events applause.

The experimental setup (Fig. 1) consisted of the following elements: posturographic platform, PC unit, audiometer, CD player and stereophonic headphones.

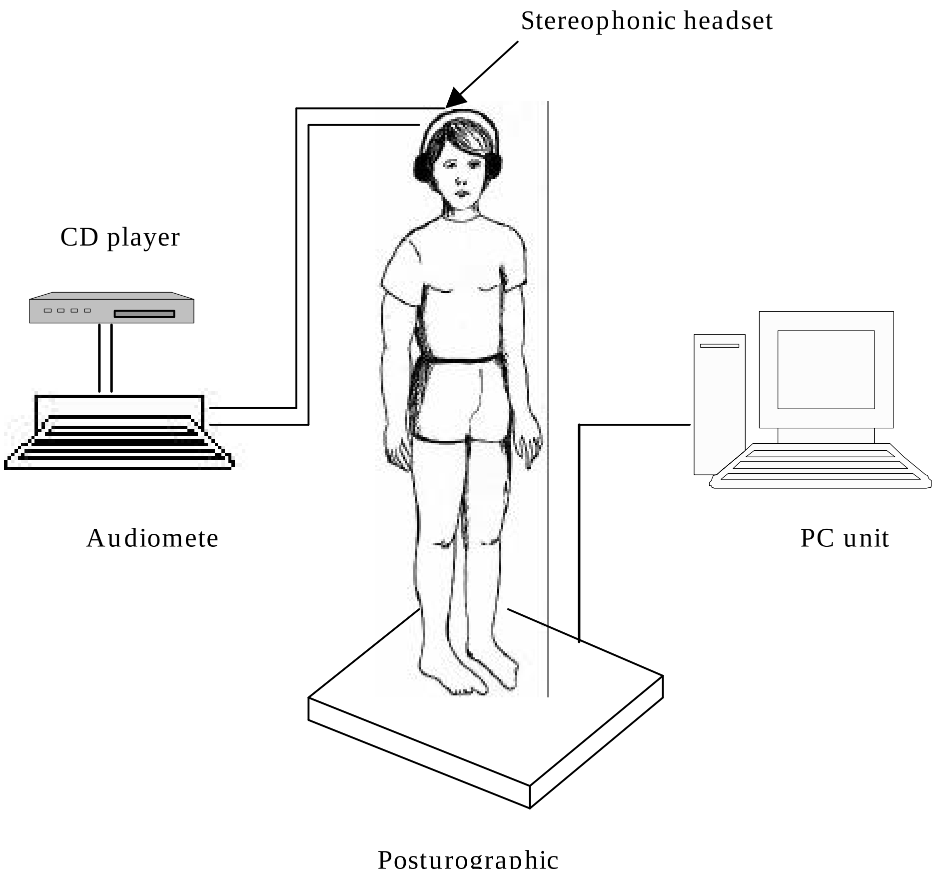

Fig. 1.

Research layout for evaluation of noise influence on the stability system.

Detailed research procedures were as follows:

I. Quiet stance, white noise applied to both ears 15 sec prior to the trial and whilst.

1. Eyes open, relative silence
2. Eyes closed, relative silence
3. Eyes open, white noise 60 dB
4. Eyes closed, white noise 60 dB
5. Eyes open, white noise 80 dB
6. Eyes closed, white noise 80 dB
7. Eyes open, white noise 100 dB
8. Eyes closed, white noise 100 dB

II. After a two minute break, quiet stance, crowd applause applied to both ears 15 sec prior to the trial and whilst

9. Eyes open, applause 60 db
10. Eyes closed, applause 60 db
11. Eyes open, applause 80 db
12. Eyes closed, applause 80 db
13. Eyes open, applause 100 db
14. Eyes closed, applause 100 db

To estimate the significance level of differences between male and female results non- parametric U Mann-Whitney test was applied, apart from descriptive statistics.

In order to eliminate individual variability, raw (absolute) data was replaced by its difference in relation to the first trial within the set (relative silence, both-feet stance, eyes open). The algorithm shown below was used to calculate that:

$$Xw_i = \frac{X_i - X_1}{X_1}$$

where:

X_w – relative displacement of the CoFP in the i-trial

X_i – displacement of the CoFP In the following trial

i = 1, 2, …….. 14 – following trials

1 – silence trial, both-feet, eyes open

X_1 – total sway displacement in the trial no.: 1 – quiet, both-feet stance, eyes open, relative silence.

Results

The results indicate that women are superior in stability control in comparison to men. The absolute sway displacement of the CoFP in the first trial being conducted under visual control conditions without any acoustic stimuli is significantly lower in female subjects (fig. 2, tab. 1). Similar differences were also observed in the second trial which was performed with eyes closed. Also in this case the value of displacement of the CoFP was lower in female then in male subjects (fig. 3, tab. 2). These results indicate a better postural stability system in females.

Table 1

Comparison of total displacement of the COFP factors in male and female students, upright stance, eyes open, silence (trial 1).

Women		Men		d	p
$\bar{x}$	SD	$\bar{x}$	SD		
255,515	57,573	313,695	82,691	-58,180	**0,001**

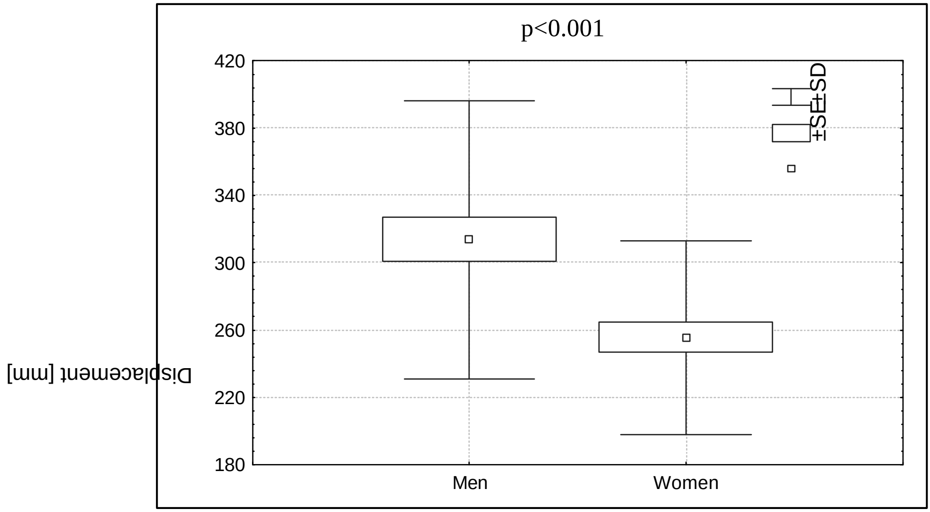

Fig. 2.
Total displacement of male and female COFP in the upright stance, eyes open, relative silence (trial 1).

Table 2

Comparison of total displacement of the COFP factors in male and female students, upright stance, eyes open, silence (trial 2).

Women		Men		d	p
$\bar{x}$	SD	$\bar{x}$	SD		
292,600	89,913	358,588	128,723	-65,988	**0,001**

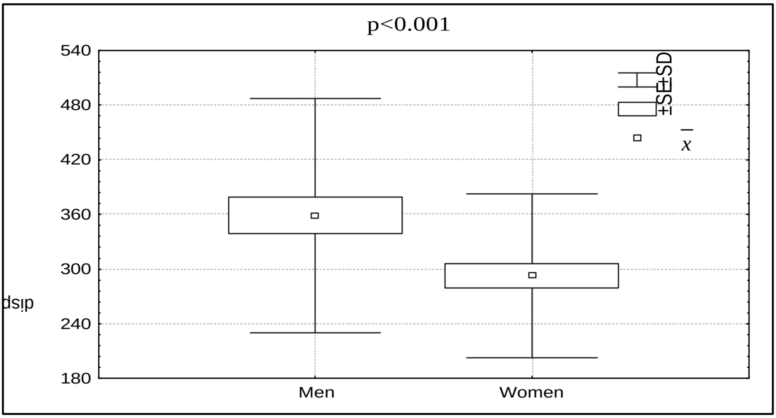

Fig. 3.

Total displacement of male and female COFP in the upright stance, eyes closed, relative silence (trial 2)

The main interest of the researchers, was however the acoustic sensitivity of women's and men's postural stability system. The key issue was to eliminate the individual differences in the area of research. Thus the data comparison analysis was made on relative values of variables that were taken into consideration (relative displacement). As the analysis show, nearly all the trials being conducted in the presence of noise prove a better postural stability in females. The exception was trial no. 7 – quiet stance, eyes open, white noise at the volume of 100 dB. Again the U Mann-Whitney test results confirmed significant differences in favor of women, which were visible in trials 3 (eyes closed, white noise, 80 dB), 10 (eyes closed, applause, 60 dB), 14 (eyes closed, applause, 100 dB). (fig 4, tab. 3)

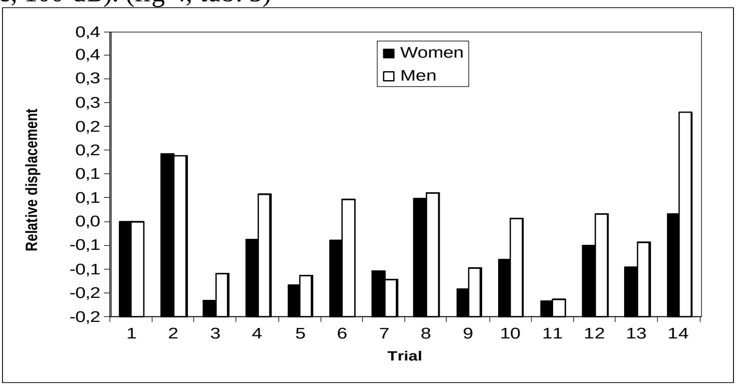

Fig. 4.

Relative displacement of the COFP in male and female students.

Table 3

Relative displacement of COFP in male and female students in concurrent trials.

Trial no.	Women		Men		d	p
	$\bar{x}$	SD	$\bar{x}$	SD		
2	0,142	0,208	0,138	0,230	0,004	0,810
3	-0,167	0,138	-0,111	0,158	-0,056	0,082
4	-0,039	0,188	0,058	0,214	-0,098	0,072
5	-0,134	0,166	-0,114	0,138	-0,020	0,538
6	-0,040	0,186	0,045	0,217	-0,085	**0,046**
7	-0,104	0,182	-0,122	0,150	0,018	0,729
8	0,048	0,271	0,060	0,243	-0,012	0,788
9	-0,142	0,135	-0,098	0,153	-0,044	0,119
10	-0,081	0,177	0,006	0,182	-0,087	**0,034**
11	-0,169	0,159	-0,164	0,127	-0,005	0,810
12	-0,050	0,279	0,015	0,211	-0,065	0,059
13	-0,096	0,190	-0,045	0,208	-0,051	0,256
14	0,016	0,228	0,231	0,296	-0,215	**0,002**

Discussion

Postural stability and its evaluation under relative silence conditions with eyes closed and eyes open came out clearly in favor of women. Similar results were achieved in other research of this kind (Juntunen et al. 1987, Ekdahl et al. 1989, Ojala 1989). Better stability maintenance of women may be justified by better body proportions. It must be pointed out here that men’s Center of Mass (COM) is located at around 56% of total body height measured from the bottom of the feet. Women’s COM, due to a greater size of the pelvis and buttocks and smaller shoulder girdle, is located at the level of 55% of total body height (Zagrobelny, Wozniewski 1999). At the same time despite the lower COM position, women have a smaller base of support (Raczek et al. 1998). Therefore authorities do not distinguish sex differences in stability, moreover some of them even point at men as the subjects with a larger stability margin (Kejonen et al. 2002, 2003).

Children aged 7-10 demonstrate very little non-significant sex differences in the area of stability (Holopainen 1985). According to Szopa (1993) posture stabilization efficiency shows very little dependency on sex. (dimorphism). When comparing results concerning stability, one must remember that many studies were conducted in different circumstances. This refers to the procedure as well as the age of the experimental groups.

The major aim of the research was to point to the acoustic sensitivity of male and female stability system. The applied here comparison of relative values of sway variables allowed to exclude possible influence of individual factors on research results. In nearly all trials performed under conditions of noise exposure, better results were exhibited in females. Significant differences were detected only in three out of seven trials conducted with eyes closed. Taking into account the obtained results it is hard to state whether acoustic sensitivity of the stability system is correlated with sex. It cannot be sustained even because of the fact that apart from three trials the results were similar. The slight difference which occurred under conditions of closed eyes indicate that acoustic sensitivity of stability mechanisms might be of a different nature in men and women, depending on the sort of noise and its volume. Considering the obtained results, showing the mobilizing role of noise in the efficiency of stability maintenance a following notion can be posted that women have a more sensitive stability system when exposed to noise (Polechonski et al. 2003, Polechonski 2005).

Conclusions

1. Under relative silence conditions female students show better postural stability than male subjects, irregardless to visual control.
2. The sensitivity of the postural stability system under eyes closed condition is different in women and men depending on the type of the acoustic stimuli and its intensity.
3. Considering the mobilizing influence of noise on postural stability, it can be assumed that female sensitivity to acoustic noise is higher.

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