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HEMODYNAMIC REACTIONS TO MONOTONOUS WORK PERFORMED IN SILENCE AND IN NOISE OF 70 dB (A)

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Abstract. Hemodynamic parameters (cardiac contraction rate, ejection volume, arterial blood pressure and total vascular peripheral resistance) were evaluated in women during 4-hours' monotonous work, connected with a moderate exercise, or monotonous visual work performed in laboratory conditions. Next, the capacity of noise of 70 dB(A) to modify changes of hemodynamic parameters caused by work was checked. It was found that the noise did not affect work efficiency, but it did result in an increase of ejection volume and a rise in arterial (especially diastolic) blood pressure. Noise of 70 dB(A) brings about an increase of physiological effort of work.

INTRODUCTION

An acoustic stimulus brings about different changes in the functioning of many organs and systems of the organism, mainly through the influence on the central and autonomic nervous systems (3, 6, 14, 15, 16). The role of acoustic information for the safety and preservation of the whole organism and even life, resulted in the formation of numerous junctions between the organ of hearing and centres controlling homeostasis, such as e.g. limbic system and reticular formation which regulate the activity of the autonomic nervous system. Acoustic stimulus is a typical stressor for the human organism. Reactions of organs and systems of human organism provoked by acoustic stimuli are produced by the excitation of sympathetic part of the autonomic nervous system — acceleration and deepening of respiration, suppression of peristalsis, intensified activity of the adrenal cortex and adrenal medulla, stimulation of the general metabolism, and in the circulatory system, contraction of peripheral blood vessels, and to a lesser degree, an increase in blood pressure and the cardiac contraction rate. It is held that a long-term

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exposure to noise may result in arterial hypertension and coronary heart disease (5, 12).

Noise is an inherent agent of the working environment in industry. The majority of observations of the effect of noise on the human organism deal with high intensity acoustic stimulus (90—100 dB). In industry, the noise intensity at many work-stands reaches this level or even surpasses it. Generally, however, it can be assumed that working in industrial plants where noise intensity is lower than 70 dB occurs very rarely. The effect of systemic noise of such an intensity is not so evident and dramatic as noise of 90 dB, however, already at a noise intensity which equals 65 dB, some reactions can be observed which indicate changes in autonomic nervous system activity and the occurrence of emotional disorders (9, 19, 28).

The aim of the present study was to evaluate the effect of industrial noise of 70 dB(A) on cardiac activity. Two of the most important physiological factors which make it possible to evaluate cardiac activity are cardiac contraction rate and ejection volume, both of which can be used to determine minute heart volume. Every stress to the organism may lead to changes in circulatory system activity, and the type of change is often specific to the kind of workload. Therefore, the estimation of workload often requires the measurement of changes in cardiac and circulatory system activity, especially the assessment of the cardiac contraction rate and arterial blood pressure (4, 8). For instance, a typical symptom of workload monotony is a decrease in the cardiac contraction rate as the time of work passes (8). Since noise can induce a contrary action, i.e. it can increase the cardiac contraction rate and build up arterial blood pressure (1, 2, 5, 13, 15, 18), it proved useful to assess to what extent industrial noise of 70 dB modifies changes of cardiac activity and arterial blood pressure caused by monotonous work such as collecting products or passing on elements (monotype movements of the upper extremities and lifting the load) or fitting up small elements (monotype movements of the upper extremities and visual work). The aim of the study was to evaluate changes in ejection volume, cardiac contraction rate, minute heart volume and arterial blood pressure as affected by two types of monotonous work (with and without physical workload) and the estimation of the effect on performance during this work of noise of 70 dB(A).

MATERIAL AND METHOD

The study was carried out in two groups of women performing two sorts of work in laboratory conditions for 4 hours (8.00 a.m. — 12.00).

The common features of both types of work were monotony resulting from monotypic movements of the upper extremities, an absolute lack of any purpose in the work, a reclining position of the body, and a free, unrestricted work rate. The difference, however, consisted in the fact that in the first case work was connected with a physical workload (monotonous physical work-MPW), while in the latter — it was a monotonous visual work (MVW). Each group of women performed their work twice — with and without noise, i.e. under normal laboratory acoustic conditions, and in noise of 70 dB(A) characteristic of industrial conditions emitted through earphones from a tape recorder (noise emitted by looms). Fifty percent of the examined women in each group started work in noise, and the remaining 50% — in silence.

Monotonous physical work (MPW) was carried out by 14 women aged 29.0 ± 2.3, of body weight — 58.0 ± 8.5 kg, height — 160.0 ± 6.4 cm, with maximum oxygen absorption amounting to 29.1 ± 7.08 ml/kg/min. The work consisted in passing boxes weighing 0.567 kg through a window cut out in a plate placed vertically to the front plane of the boxes. The examined persons made about 30 monotype movements of the upper extremities per minute, which resulted in the shifting of 2850 kg during 4 hours.

Monotonous visual work (MVW) was performed by a group of 17 women aged 29.3 ± 3.2, of body weight 56.3 ± 8.3 kg, height — 161.5 ± 4.8 cm and maximum oxygen absorption — 36.07 ± 8.9 ml/kg/min. The work consisted in stringing small elements of full diameter = 2—3 mm and an aperture diameter = 0.5—0.7 mm onto a silicon thread. The examined persons made about 60 monotype movements per minute. Nine women performed both kinds of work, i.e. they belonged to both examined groups.

Before work and at the end of every successive hour of work arterial blood pressure was measured at the same time as ECG from a precordial lead using polyphysiograph and rheographic curve was being differentiated using a Rheoplethysmograph produced in the USSR and electrodes made in Poland. The ECG record rendered it possible to calculate cardiac contraction rate. Taking into account the rheographic curve, ejection volume was measured as a mean value of at least 10 successive cardiac contractions, using the formula modified by Kubick (10). Minute heart volume was calculated by multiplying cardiac contraction rate by ejection volume.

Fig. 1 presents cardiac contraction rate, ejection volume and minute heart volume — in successive hours of monotonous work connected with physical workload and monotonous visual work performed without noise and in noise of 70 dB(A) — as a percentage of the resting value. Fig. 2

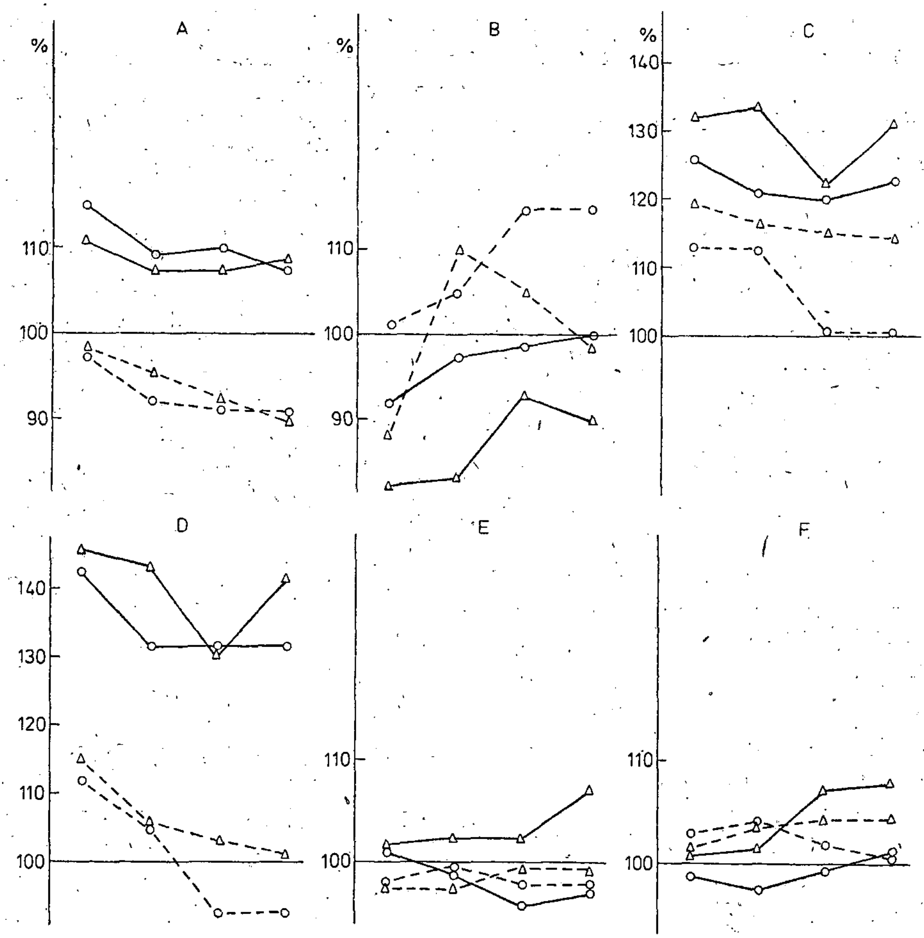

Fig. 1. Changes of hemodynamic parameters in successive hours of work, expressed as a percentage of resting value. A — heart contraction rate, B — total peripheral resistance, C — ejection volume, D — minute heart volume, E — cystolic blood pressure, F — diastolic blood pressure. Continuous line — monotonous physical work (MPW). Broken line — monotonous visual work (MVW). Circles — work performed without noise. Triangles — work performed in noise of 70 db(A).

shows mean values for 4 hours of work. During both MPW and MVW, a decreasing frequency of cardiac contraction rate was observed as the time passed. In the case of the physical workload, the cardiac contraction rate was always greater than at rest ($p < 0.01$ — $p < 0.001$), while for monotonous visual work which did not involve a physical workload, cardiac contraction rate was lower than at rest, and starting with the 2nd hour of work, it was statistically remarkable ($p < 0.05$ — $p < 0.001$). The decrease in the cardiac contraction rate as the work continued (the difference between cardiac contraction rate in the 1st and the 4th

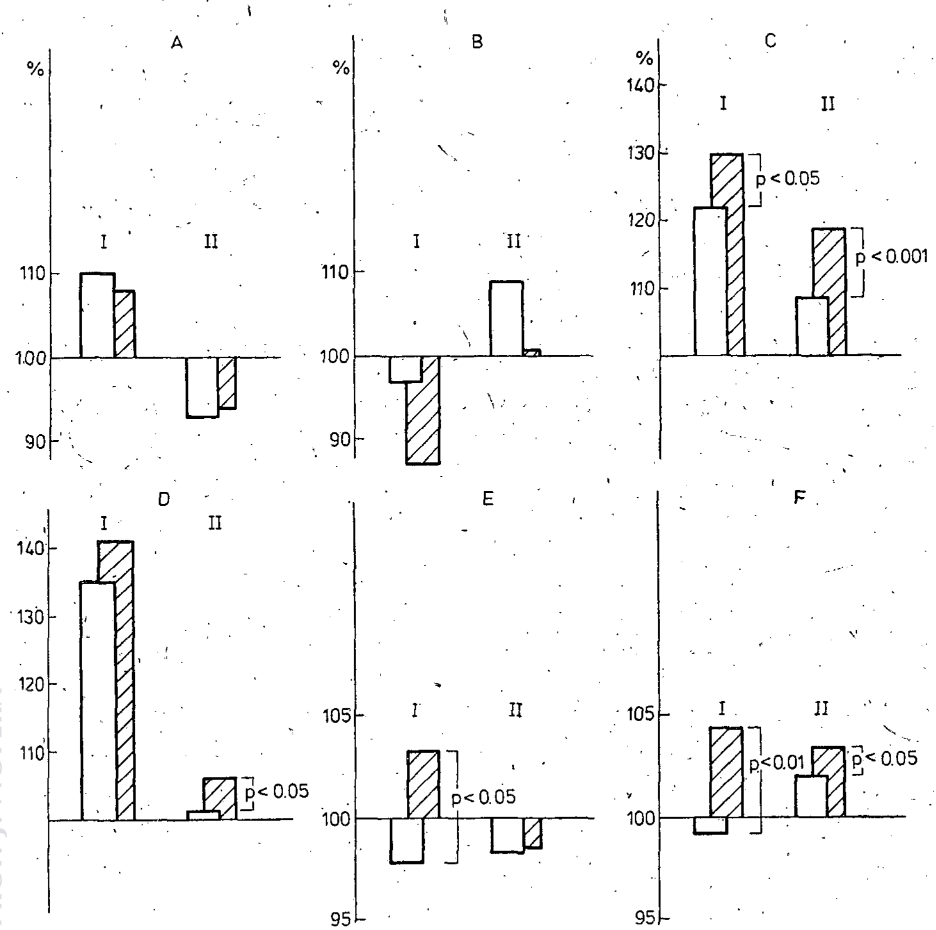

Fig. 2. Mean values of hemodynamic parameters for 4 hours' work, expressed as a percentage of resting values. A — heart contraction rate, B — total peripheral resistance, C — ejection volume, D — minute heart volume, E — systolic blood pressure, F — diastolic blood pressure, I — monotonous physical work (MPW), II — monotonous visual work (MVW). Empty bars — work performed without noise. Lined bars — work performed in noise.

hours of work) was statistically significant, except MPW performed in noise, where the decrease was not statistically remarkable. Noise of 70 dB(A) resulted in an increase in the cardiac contraction rate, in contrast to conditions free from noise, in which the cardiac contraction rate increased only during the 1st and 2nd hours of MVW ($p < 0.05$).

Ejection volume during MVW in every hour of work was statistically more remarkable than at rest ($p < 0.01$ — $p < 0.001$), while during MPW, ejection volume was statistically more significant than at rest during the 1st, 2nd and 4th hours of work ($p < 0.05$); during the 3rd hour it was greater than at rest, but the difference was not statistically significant. Noise at work resulted in an increase in ejection volume both during MPW and MVW.

The mean heart ejection volume during the 4th hour of MPW performed in noise was statistically more significant ($p < 0.05$) than without noise. Minute heart volume was statistically more noticeable than at rest ($p < 0.001$) during MVW in every hour, while during MPW it was statistically more remarkable than at rest during the 1st, 2nd and 4th hours of work. The group of 17 women who performed MVW was divided into subgroups: 9 women exposed to noise for the second time (they carried out their MPW in noise) and 8 women who were working in noise for the first time. Heart ejection volume in both subgroups was measured. No difference in heart ejection volume in women working in noise for the first time and exposed to noise for a second time was observed.

The changes in arterial blood pressure are presented in Fig. 3. Monotonous physical work performed without noise brought about a decrease in arterial systolic blood pressure as the work continued, so that in the 3rd and 4th hours of work it was significantly lower than at rest ($p < 0.05$), while arterial diastolic blood pressure was not affected by any statistically remarkable changes. A continuous increase in both systolic and diastolic blood pressure during the performance of the same work in noise was observed, so that in the 4th hour of work, the two

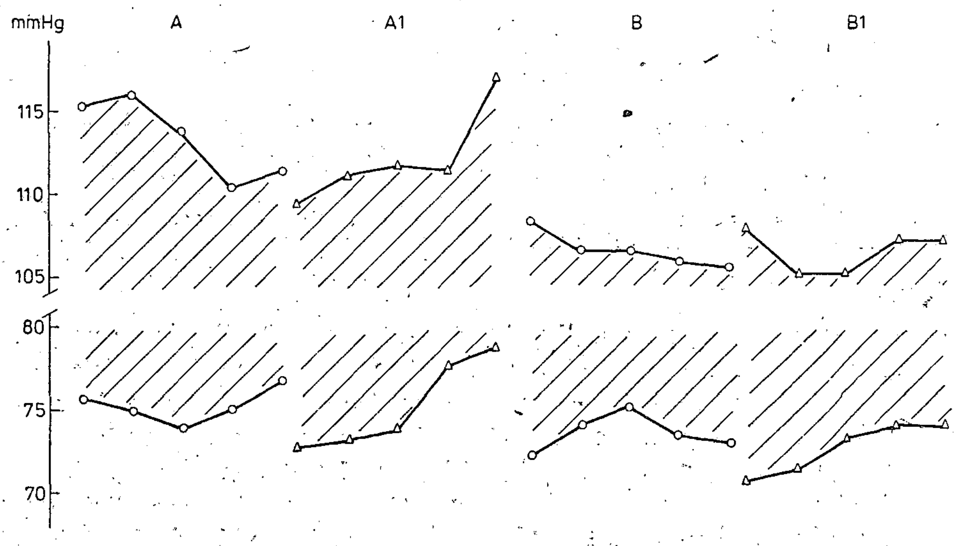

Fig. 3. Arterial blood pressure at rest and in successive hours of monotonous work: A — physical without noise, A_1 — physical in noise of 70 dB(A), B — visual without noise, B_1 — visual in noise of 70 dB(A).

kinds of pressure were noticeably higher than in the 1st hour ($p < 0.001$). At the same time, the increase of diastolic blood pressure was more substantial than the increase of systolic pressure. During MVW without noise, a continuous decrease in systolic and diastolic blood pressure (statistically unimportant) was noticed, while during the same kind of work performed in noise, between the 1st and 4th hours of work, a slight (statistically unimportant) increase of systolic blood pressure and a statistically significant increase in diastolic blood pressure ($p < 0.05$), were registered. In the 4th hour of work in noise, expressed as a percentage of resting values, systolic blood pressure was statistically remarkably higher than it was during MPW without noise, whereas diastolic blood pressure was statistically significantly higher at MPW than at MVW. From the mean arterial blood pressure and minute heart volume, the value of total vascular resistance was calculated (Fig. 1). No distinct differences in vascular resistance during work in noisy and noise-free conditions were observed. Also, no decided differences between the effectiveness of MPW and MVW performed in noise and without it were documented.

DISCUSSION

Monotony brings about a decrease in the cardiac contraction rate as work continues (8). During MPW and MVW performed without noise, a decrease in the cardiac contraction rate typical of monotonous work depending on the physical workload was reported. This phenomenon was observed to different extents during MPW, the cardiac contraction rate was always higher than at rest, while during MVW, the cardiac contraction rate was lower than at rest (Fig. 1). Noise of 70 dB, reported at MVW, accelerated cardiac activity during the 1st and 2nd hours of work, as compared to the conditions without noise, but it did not alter the influence of work monotony; thus the cardiac contraction rate decreased as work continued. On the other hand, during MPW no decrease in the cardiac contraction rate was reported, the difference between its value in the 1st and 4th hours of work was not statistically significant. The combination of two agents which stimulate the cardiac contraction rate, i.e. noise and physical workload (neither of which, taken separately, dominated over the monotony of work which decreased cardiac action) exceeded this monotony. This fact should be taken into account when assessing the workload based on cardiac contraction rate when work performance is connected even with a slight exercise and exposure to noise. Noise of 70 dB prevented the cardiac contraction rate from decreasing but it had no decisive effect upon the mean (4 hours of work) cardiac contraction rate both during MPW and MVW.

Work monotony resulted in decreasing arterial blood pressure (systolic during MPW and both systolic and diastolic during MVW) as the work was being performed. Exposure to noise of 70 dB(A) caused a gradual increase in arterial blood pressure during both MPW and MVW. In both cases diastolic blood pressure increased most, which is confirmed by other studies in which a decrease in arterial blood pressure (especially diastolic) was observed as a result of exposure to noise (short-term but of high sound intensity) (2, 19, 20). There are numerous data referring to the possible development of hypertension in persons exposed to noise of great intensities (1, 2, 5, 12, 20, 22) for a long time. The results of our study indicate that even in exposure to noise of a relatively small intensity (70 dB), arterial blood pressure can be higher than during the same sort of work performed without noise.

During both MPW and MVW in noise, a distinct, statistically significant increase in ejection volume was observed as compared to the ejection volume reported during the same work without noise.

During MVW in noise, the mean ejection volume was 10% higher than during work without noise: during MPW this volume was 7% higher. The increase in ejection volume in noise also resulted in an increase in minute heart volume, which in the case of MVW was 6.8% and of MPW — 7.1% higher for work in noise than without noise.

Studies concerning the effect of noise upon ejection volume are very few and deal with short-term and low intensity noise (90—105 dB). On the basis of these studies, it was found that noise of 95 and 105 dB(A) lowered ejection volume in males, the ejection volume being assessed using rheography of the first five heart contractions after the action of acoustic stimulus (17). Other studies (13) proved that in some males 7 minutes' exposure to two kinds of noise (music or "white noise") of 90 dB resulted in a decrease of ejection volume evaluated using ballistocardiography, while in other males from the examined group, an increase in ejection volume was observed. In the literature available, no data on ejection volume in conditions of long-term exposure to noise of intensity amounting to 70 dB are mentioned. The results of our own studies indicate that ejection volume during 4 hours of MPW and MVW in noise of 70 dB(A) was greater than during the same sort of work, performed in silence. On the basis of our results, it can be stated that noise of relatively low intensity (70 dB/A) during work intensifies the physical effort connected with this work, as it involves the heart in more intensive work than is required to provide the proper blood flow in physical work or visual work without noise. Also, the higher arterial blood pressure indicates that the physiological effort of work is higher in exposure to noise.

Human responses to noise, the degree and type of changes in physiological functions, depend on the sound intensity, spectral characteristics of the noise and exposure duration, as well as on the age, general efficiency of the organism, motivation (positive or negative) in relation to the experienced sound perception and even on sex (7, 9, 15, 16, 18, 19, 25, 26, 27). Intensity of 65—70 dB is the lowest noise level at which the first observable reactions of the autonomic nervous system and emotions reactions can be registered (11, 15, 16, 28). During this exposure, the regulatory possibilities of vegetative reactions and the consistency of physiological reactions can still be preserved. The extent of the changes to vegetative reactions is characterized by a linear rise until an intensity of 90—95 dB(A) is registered. At noise intensities which exceed 90 dB, reactions start to become pathological, and as exposure is prolonged, an overburdening of the whole organism can be observed. At the same time, any proper control over somatic reactions becomes impossible (15, 16). A common example of such pathological reactions of the circulatory system is the decrease in ejection volume during exposure to noise of more than 90 dB. One of the organism's observable responses to increasing noise intensity is an increase in peripheral resistance (6, 19, 22). It is suspected that the increase of ejection volume and minute heart volume observed in women who perform work in noise of 70 dB(A) is a compensatory physiological reaction which prevents a decrease in blood flow through the peripheral vessels. However, no distinct differences between the values of total peripheral resistance during work in noise and without it, was reported. It is possible that such a reaction (an increase of ejection volume) may be connected with the sex of the examined persons, though it is difficult to confirm this hypothesis, as we do not know of any examination in which the ejection volume of males exposed to noise of 70 dB or females exposed to 90 dB has been measured. On the other hand, some differences have been reported concerning other physiological functions in males and females exposed to noise. Females, for instance, are less sensitive than males to hypocausia brought about by noise (25, 27), but more sensitive to sleep-disturbing noise (16). Neus et al (16) carried out examinations during which both males and females were exposed to traffic noise of 70 dB (changes in arterial blood pressure, pulse amplitude, determined using plethysmography, pulse rate, respiration rate and integrated EMG were measured). It was interesting to observe that the male response to noise was much stronger than the female. In males exposed to high noise levels (those exceeding 100 dB) at work, an increase of 17-OHCS in urine and no changes in 17-KS concentration were noticed (21, 24). In other experiments during which women exposed to similar noise levels were examined, no changes in 17-OHCS level in urine and an increase in 17-KS level, were reported (23).

It seems that the most probable reason behind the difference in heart ejection volumes (increase in females exposed to noise of 70 dB for 4 hours, and decrease in males exposed to short-duration noise of 90 dB or more) is the variation in exposure level (intensity, exposure duration), although sex-dependence cannot be excluded. The problem of the noise effect on ejection volume certainly calls for more advanced examination.

RESULTS

1. Noise of 70 dB(A) does not affect the effectiveness of monotonous work connected with a moderate physical effort and of monotonous visual work.

2. Noise of 70 dB(A) modifies the hemodynamic reactions which occur during the performance of monotonous work.

3. The hemodynamic indices of noise of 70 dB(A) during monotonous work are heart ejection volume and an increase in arterial (especially diastolic) blood pressure.

4. The character of changes in hemodynamic reactions indicates that noise increases the physiological effort of monotonous work.

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