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Evaluating combined effect of noise and heat on blood pressure changes among males in climatic chamber

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Abstract:

INTRODUCTION: Exposure to noise and heat causes individuals to experience some changes in the function of cardiovascular system in workplaces. This study aimed to find the combined effect of heat and noise on systolic and diastolic types of blood pressure in experimentally controlled conditions.

METHODS: This quasi-experimental study was performed with 12 male students in a climatic chamber in 2014. Blood pressure including systolic and diastolic was measured in the following conditions: 15 min after rest in exposure to heat (40°C, relative humidity [RH]: 30%), exposure to noise with 75, 85, and 95 dB rates in thermal comfort condition (22.1 ± 0.9 wet-bulb globe temperature), and combined exposure to heat (40°C, RH: 30%) and noise with 75, 85, and 95 dB. Friedman test was used to analyze the data.

RESULTS: The mean change of systolic blood pressure was different significantly before and after exposure to heat and noise levels including 75, 85, and 95 dB ($P = 0.015$, $P = 0.001$, $P > 0.001$, $P = 0.027$, respectively). Although systolic and diastolic blood pressures changed drastically, it was not significantly different in simultaneous exposure to heat and noise.

CONCLUSION: Both systolic and diastolic blood pressures decreased in exposure to heat, while exposure to different levels of noise elevates systolic and diastolic blood pressures. However, when exposed to a combination of heat and noise, subtle changes of blood pressure were traced, which can be characterized as average, considering heat-only and noise-only tension situations.

Keywords:

Blood pressure, heat stress, noise

Introduction

Noise and heat tension, as the harmful physical agents in workplaces, exists in petrochemical, steel, and glass-making industries. They can cause fatigue and weakness and reduce productivity. The increase of errors, the contemplation of accidents, and also the prevalence of diseases are partly induced by heat and noise. The impact of noise over health is classified into auditory and nonauditory factors. Acute and chronic exposure to noise may lead to the regression of hair cell or the organ of Corti and, consequently, leads

to hearing loss.^[1] Nonauditory effects also cause blood pressure increase, heartbeat rapid elevation, and fatigue.^[2]

Over 600 million people around the world are exposed to dangerous noise in workplaces, while 50–60 million of whom live in European and North American countries.^[3] In Iran, the design of controlling this sort of noise in the workplace was provided and implemented by the Work and Environment Health Center of Health and Medical Education Ministry in 2000. This was done to reduce and control the rate of exposure to the noise, whereas the problem was not widely controlled. According to the national statistical figures, in 2006 in Iran,

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738,953 active workshops were involved in industrial, mineral, and agricultural fields with 2,747,738 people working in them. Moreover, 17% (90,594 workshops) of these workshops had at least 22% of their workers exposed to harmful agents.

One of the other harmful agents in the workplace is heat exposure. Heat exposure is defined as physiological responses of the human body to stress. They include muscular cramp, heat fatigue and heat stroke, productivity reduction, heartbeat, body deep temperature, body superficial temperature, and sweating increase.^[4,5]

The increase in heat stress accompanied by body deep temperature leads to the disorders associated to heat, including heat cramps, heat stroke, heat shock, and change in blood pressure.^[6] The exposure to heat stress enhances blood circulation in the superficial layers of the skins to discharge produced heat out of the body to the environment through the exchange of heat. This, subsequently, results in developing cardiac output and heartbeat and also decreasing blood pressure.^[7,8]

Some surveys have evaluated the individual effect of noise and heat on blood pressure and fatigue. Neghban *et al.* studied the chronic impacts of noise over the workers of petrochemical complex. They found that the workers exposed to noise faced hearing loss and blood pressure increase.^[9] Smith studied the body physiological responses within exposure to loud noise. They came to the conclusion that this repeating and chronically continuous exposure caused psychological and physiological disturbances in human and also made a change in his heartbeat and blood pressure.^[10] Ising and Michalak compared the impacts of noise over the studied cases in experimental and actual conditions. They found that exposure to the noise louder than 95 dB made physiological and psychological changes among more than half of the studied people.^[11] The study of heat effect on the cases investigated by Stotz *et al.* showed that low blood pressure and high heartbeat happened as physiological responses in the environments with a temperature higher than 30°C.^[12] The studies of Barnett *et al.* demonstrated that through an increase of the internal environment temperature by 1°, the mean systolic blood pressure decreased by 31 mmHg.^[13] Chen *et al.* investigated the effect of heat stress among steel industry workers. They found that heat stress (heartbeat, systolic and diastolic blood pressure, skin temperature) was changed by an increase in heat stress.^[7] These harmful agents considerably affect the health of people. The change in blood pressure is one of those health turbulences which are caused by these agents over physiological system. Since hypertension is considered a cardiovascular disease risk factor, it is necessary to conduct comprehensive studies to support public

health. At the same time, focusing on the individual effect of noise and heat over the health of the person independently in previous studies, their simultaneous effect has been investigated less than expected. Hence, the present study tried to measure the reciprocal and simultaneous effects of heat and noise on each other and their interaction over the health of the studied cases.

Methods

This quasi-experimental study was done in the heat chamber of Health School in Isfahan University of Medical Sciences in 2014. Twelve male students participated in the present investigation. The studied cases were selected through the following process: After summoning, the body mass index (BMI) of the volunteers was measured and normal ones (BMI between 18.5 and 25 kg/m²) were chosen. To assure the health condition of the volunteers, physicians performed practical (audiometer and spirometer) and also medical and clinical examinations to check the participants' cardiovascular, respiratory, and auditory systems. The inclusion criteria included the absence of any cardiovascular, respiratory (asthma), diabetes mellitus, epilepsy, hearing loss, and musculoskeletal disorder, not taking any heartbeat-affecting drug, absence of any history of exposure to noise, smoking, and not being a professional athlete. The exclusion criteria included having the authority to quit the study whenever the studied cases got too exhausted, not being able to tolerate the activity continuation or reaching their heartbeat rate up to maximum level (age – 220), when they were exposed to noise while doing the activity. This study approved in ethics committee of Isfahan university of medical sciences.

The process of simulating thermal and noise condition: heat chamber which has been applied in different researches was used to provide heat and dry thermal condition. Using heat plants, temperature and humidity were regulated 40°C and 30%, respectively. Monitoring of heat condition environment was done by wet-bulb globe temperature (WBGT) (Casella model) as the measuring plant of the index. To make noise, a tape recorder recorded the noise of a compressor with wide frequency band. Sound pressure level was regulated in the chamber by the use of a sound level meter (Casella 450) and a loudspeaker with 75, 85, and 95 dB in network A. The frequency distribution of octave band of the noise announced by the loudspeaker is shown in Figure 1.

After selecting the samples according to inclusion criteria, the time schedule of exposure to heat and noise was given to everyone. They were also told to take enough rest the night before exposure, and not having coffee, alcohol, and fatty and heavy meals is essential. To equalize the

effect of cloth on heartbeat, all the studied cases wore sports gear before entering the laboratory. Then, their weight and height were measured, and belt-like sensor of heartbeat monitoring machine was fastened on their chest. Its monitoring screen was fastened on their wrist just like a wristwatch. After 15 min of resting (in a prone position on the examination bed), systolic and diastolic blood pressures were measured. Then, they were directed to heat chamber. In the first phase, they faced dry and warm conditions (40°C and 30% of relative humidity [RH]). They also experienced 75, 85, and 95 dB levels of noise individually in the second, third, and fifth phases, respectively. Meanwhile, they were exposed to the physical activity with 2.8 km/h within 120 min in thermal comfort condition (WBGT = 22.1 ± 9). Blood pressure was measured and recorded in 30-min intervals during exposure. In the fifth, sixth, and seventh phases, they were exposed to 75, 85, and 95 dB noise levels and dry and warm conditions (40°C and 30% of RH) simultaneously. The rate of physical activity and exposure time were unchanged in all sessions (2.8 km/h and 120 min, respectively) [Table 1].

However, in the fourth and seventh levels (in turn, exposure to 95 dB of noise and simulations exposure to heat and 95 dB of noise level), the duration of exposure was lowered to 40 min. Because, according to Iranian nationwide rules, the exposure time is decreased down to the half for every 3 dB of noise increase if the person is supposed to be exposed to 85 dB or more level of noise within 8 h. Blood pressure was recorded during exposure in 30-min intervals.

Freedmen test was used to compare the difference between mean systolic and diastolic blood pressures before and after exposure and also the changes in each session. All analyses were done using SPSS software version 20 (IBM Corp.: Armonk, NY). The level of significance was considered 0.05 for all tests.

Results

In this study, 12 male students participated by the following specifications: 30.5 ± 6.72 years of mean

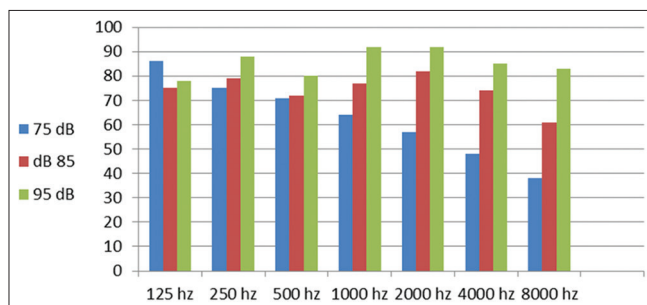


Figure 1: The frequency distribution of the announced noise in 75, 85, and 95 dB

(standard deviation) age, 176 ± 6.44 cm of height, 73 ± 6.51 kg of weight, and 25.52 ± 1.21 kg/m² of BMI. They were exposed to heat (40°C and 30% of RH) and different noise levels and fixed physical activity (2.8 km/h on the treadmill) in all phases of the study.

According to Table 2, Freedman test showed that the mean change of systolic blood pressure was different significantly before and after exposure to heat and noise levels including 75, 85, and 95 dB ($P = 0.015$, $P = 0.001$, $P > 0.001$, $P = 0.027$, respectively). Although systolic and diastolic blood pressures changed drastically, it was not significantly different in simultaneous exposure to heat and noise.

The mean change of systolic blood pressure decreased 3.75 mmHg in exposure to heat and increased 5.58, 9.75, and 6.83 mmHg in exposure to 75, 85, and 95 dB, respectively. This was also elevated to 3.5, 4.66, and 2.33 mmHg, respectively, when the studied cases were exposed to heat and 75, 85, and 95 dB of noise level [Figure 2a-c].

According to Table 2, Freedman test showed that the mean diastolic blood pressure was significantly different among various sessions before and after exposure to heat, exposure to noise levels including 75, 85, and 95 dB and also exposure to simultaneous noise and heat ($P = 0.011$, $P > 0.001$, $P > 0.001$, $P = 0.027$, respectively). However, there was not any significant difference in exposure to noise and heat ($P = 0.185$, $P = 0.351$, $P = 0.052$, respectively).

The mean changes of diastolic blood pressure decreased 1.75 mmHg in exposure to heat and increased 3.33, 4.16, and 3.33 mmHg in exposure to noise levels including 75, 85, and 95 dB, respectively. The mean changes of this sort of blood pressure increased 1.66, 2.5, and 2.83 mmHg, respectively, in simultaneous exposure to heat and 75.85 and 95 dB of noise levels [Figure 2a, d, and e].

The gradual increase of systolic and diastolic blood pressures was seen in the first session (exposure to

Table 1: Different conditions of exposure in the study

Temperature (°C) and relative humidity (%)	Activity level (km/h)	Noise level (dB)	Exposure time (min)	The number and session of exposure
40, 30	2.8	None exposure	120	1
23, 30	2.8	75	120	2
23, 30	2.8	85	120	3
23, 30	2.8	95	40	4
40, 30	2.8	75	120	5
40, 30	2.8	85	120	6
40, 30	2.8	95	40	7

Table 2: The mean and changes of systolic diastolic blood pressure in exposure to heat and different noise level and also simultaneous exposure to noise and heat

Exposure condition	Before exposure (mmHg)		After exposure (mmHg)		The difference between before and after		P	
	Systolic BP	Diastolic BP	Systolic BP	Diastolic BP	Systolic BP	Diastolic BP	Systolic BP	Diastolic BP
The exposure to heat	115.92±13/35	68.08±5/50	112.17±11/25	65.33±3/99	-3.75	-1.75	0.015	0.011
Exposure to 75 dB noise level	113.08±14/8	66.33±5/77	118.67±15/75	69.67±69/67	5.58	3.33	0.001	<0.001
Exposure to 85 dB noise level	111.67±8/60	66.33±5/77	121.42±6/64	70.50±5/64	9.75	4.16	<0.001	<0.001
Exposure to 95 dB noise level	114.58±9/37	67.33±4/71	121.42±12/27	70.67±6/05	6.83	3.33	0.027	0.027
Simultaneous exposure to 75 dB noise levels and heat	115±10/00	67.58±5/12	118.15±12/50	69.25±6/40	3.15	1.66	0.108	0.185
Simultaneous exposure to 85 dB noise levels and heat	114.33±11/04	67.50±5/88	119/00±14/08	70/00±7/13	4.67	2.50	0.18	0.351
Simultaneous exposure to 95 dB noise levels and heat	108.67±12/78	64.33±6/39	111.83±11/57	65.83±5/79	2.33	2.83	0.103	0.052

BP=Blood pressure

heat-only) within the first 40 min. However, they dropped apparently in the second 40-min episode and, especially, the last episode of this exposure. In the second phase, exposure to 75 dB of noise-only caused a gradual increase in both blood pressures. The blood pressure also increased gradually in the third phase in comparison to the second one. The blood pressure also increased in the fourth phase (exposure to 95 dB of noise level) although the duration of exposure was less than the time during which the cases were exposed to 85 dB of noise. As a result, the increase of blood pressure was lower than the second situation (exposure to 85 dB) when systolic and diastolic blood pressures changed drastically, but it was not significantly different in simultaneous exposure to heat and noise.

Discussion

Since the number of studied cases is inadequate and also gathering necessary data is difficult, recognizing the impact of some harmful agents in workplaces is seriously challenging.^[14] Studies in line with the present research are very few; however, they all show that the simultaneous exposure to temperature under 10°C and WBGT over 32°C and noise has inappropriate impacts while the temperature role is bolder.^[15] The result of this investigation showed that both types of blood pressure decreased when exposed to 40°C temperature and 30% humidity level. In exposure to heat, the blood circulation increases in the surface of the skin so that the produced heat can be sent out of the body through heat exchanges. This also increases cardiac output which results in increasing heartbeat and diminishing blood pressure.^[7,8] Hence, our findings confirmed previous studies' results. The studies of Stotz *et al.* showed that low blood pressure

and high heartbeat are the physiological responses in the environments with temperature over 30°C.^[12] The result of Barnett *et al.* studies also indicated that 0.31 mmHg systolic blood pressure decreased for every degree of temperature increase in the internal environment.^[13] Based on Figure 2a, the blood pressure increased in the first 40-min episode of exposure to heat, but it dropped in the last 40-min episode. Ruki Niimi *et al.* as well showed that heat stress caused to amplify the activity of the muscles sympathetic nerve and the temperature of eardrum, while the level of noradrenaline and arginine vasopressin in plasma increased in exposure to heat. As a result, skin blood circulation and heartbeat augmented so that it led to increased cardiac output and diminished blood pressure.^[16]

The blood pressure increased significantly when the studied cases were exposed to 75, 85, and 95 dB of noise level. As shown in Figure 2b and d, there were increases in both types of blood pressure, and the highest increase was observed in exposure to 85 dB rather than two other levels of noise. This blood pressure increase was due to shorter duration of exposure to 95 dB noise level (40 min exposure).

Different investigations have shown that exposure to noise causes a number of short-term physiological responses induced by autonomic nervous system and also activates some physiological reactions such as heartbeat and blood pressure increase, superficial vascular constriction, and as a result, increases the blood pressure in these vessels.^[17,18] It is also proven that exposure to industrial noise with high severity is associated with noradrenalin and adrenalin augmentation. Some studies also reported the increase in cortisol level through exposure to

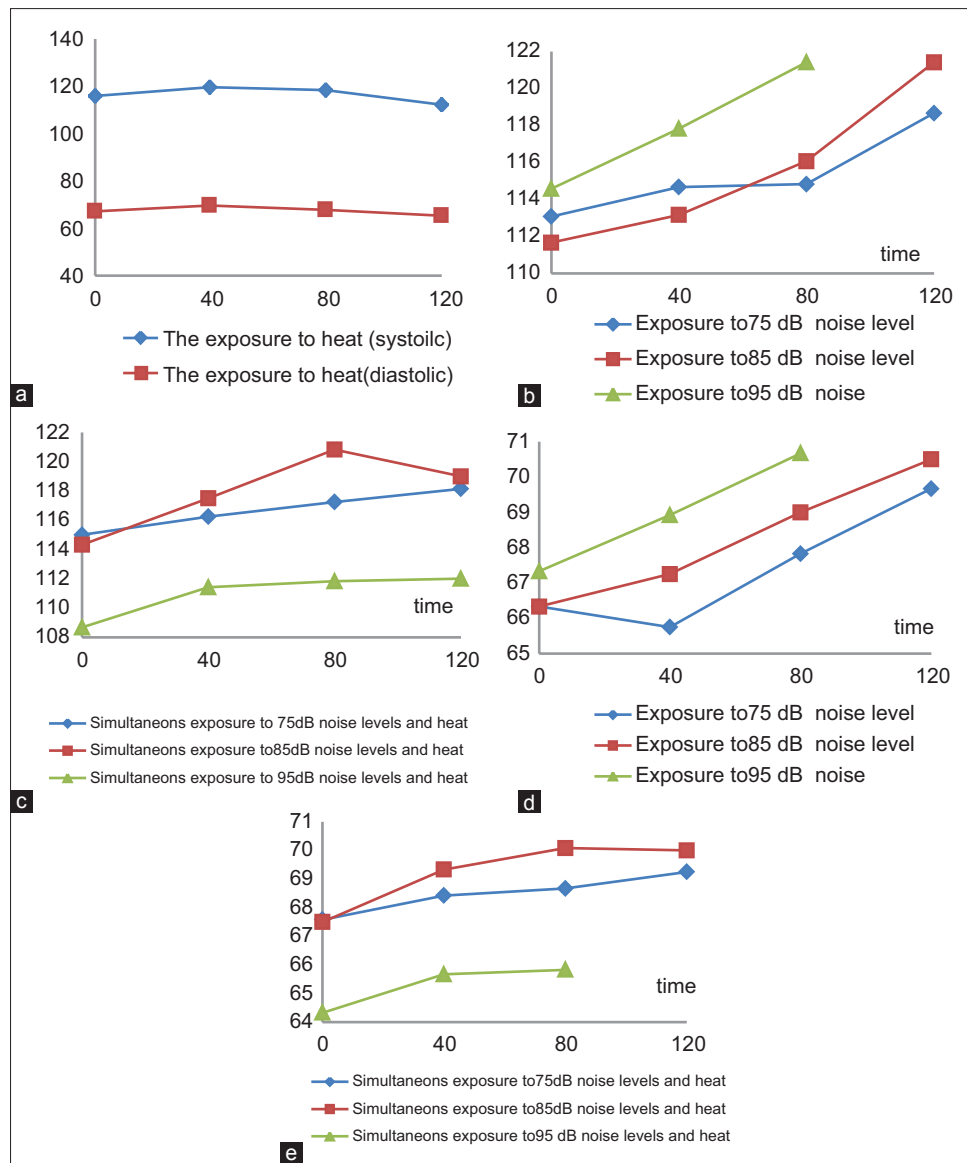


Figure 2: The mean and changes of systolic-diastolic blood pressure (blood pressure) in exposure to heat and different noise level and also simultaneous exposure to noise and heat. (a) The changes of systolic blood pressure in exposure to heat (40°C and 40% of humidity), (b) the changes of systolic blood pressure in exposure to different levels of noise, (c) the changes of systolic blood pressure in exposure to different levels of noise and heat simultaneously, (d) the changes of diastolic blood pressure in exposure to different levels of noise, (e) the changes of diastolic blood pressure in exposure to different levels of noise and heat

noise.^[19-22] It seems that high level of noise increases stress and, subsequently, makes adrenalin secretion, superficial vascular constriction, and also short-term physiological responses through autonomic nervous system. It can also activate some physiological reactions such as heartbeat and blood pressure increase.^[23,24] One study monitored the blood pressure of automobile-making industry workers within constant 16 h when they were exposed to the noise higher than 85 dB. It indicated that the mean systolic blood pressure of the workers in the mentioned situation was more than those exposed to the noise lower than 59 dB. In addition, the increase of 1 mmHg of systolic blood pressure for every 1 dB of noise level increase was measured in this project.^[25] Another study which was conducted among textile workers showed

that as the level of noise increased (more than 80 dB A), both types of blood pressure increased so that this had a significant association with the duration of exposure to the noise.^[25] Lusk *et al.* studied 376 workers who were exposed to the noise. Their findings illustrated that systolic and diastolic blood pressures increased in the workers exposed to the noise.^[2] In contrast, there are some investigations that have reached opposite results. For example, Yousefi *et al.* studied the impact of exposure to noise among Isfahan industries' workers. He found no significant relation between blood pressure of the studied cases and the exposure to noise.^[26] According to Figure 2c and e, the augmentation of blood pressure is less during simultaneous exposure to heat and noise rather than exposing to every one of these factors

individually. It seems that simultaneous exposure causes contrastive reactions in the body so that blood pressure reaches a balanced situation. Hence, a subtle increase of blood pressure happened which is a condition between being simultaneously exposed to heat and noise although it was not statistically meaningful. In spite of the fact that no other study proves it, it can be concluded that heat affects physiological parameters such as blood pressure more than noise. The results of this research could provide the necessary basis for improving the conditions in workshops, factories, and so on to prevent the creation of cardiovascular problems.

Conclusion

According to the result of the present study, both sorts of blood pressure increased first but they decreased in long-term exposure. This is in conformity with the previous studies in this regard. In addition, exposure to different noise levels including 75, 85, and 95 dB led to an increase in systolic and diastolic pressures so that they went up more, especially, as the level of noise elevated up to accepted occupational limitation (85 dB). However, simultaneous exposure to heat and noise causes a diverse reaction in the body. A minute blood pressure increase was observed which a condition between exposure to noise and heat is individually.

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Conflicts of interest

There are no conflicts of interest.

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