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RESEARCH ARTICLE

The simultaneous effects of thermal stress and air pollution on body temperature of Tehran traffic officers

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Abstract

Purpose Global warming and air pollution are among the most important problems all over the world. Considering the key role of traffic officers who saliently deal with traffic management and are in full, constant and direct exposure to thermal stress and air pollution index, this study aims to investigate the simultaneous effects of these factors on the body temperature of traffic officers in the main squares of Tehran.

Methods This study was conducted among 119 traffic officers who were working in 29 squares of Tehran, located near the active pollutant's stations during 2017. Samples were selected by the census method. Environmental parameters such as air temperature (dry and wet), radiation temperature, the level of air pollution in the main squares and characteristics of officers such as body temperature and the Wet-Bulb-Globe-Temperature (WBGT) index were evaluated. Data were analyzed through independent samples t-test and factorial ANOVA with a p value of $p \leq 0.05$ in SPSS software.

Results There was no significant relationship between air pollution and ear temperature, but there was a statistically significant difference between the wet-bulb temperature and the ear temperature ($t = 26.4$, $P < 0.001$). The interaction effect of air pollution and wet-bulb temperature on the ear temperature was also significant ($F = 3.98$, $P = 0.048$).

Conclusion Exposure to heat and air pollution affects body temperature, with its greatest impact on the temperature of the ear. More studies are recommended to be conducted in these field and other factors such as demographic and environmental factors at different times of the year should be investigated. Accordingly, some interventions should be implemented to reduce the vulnerability of officers based on the findings of the research.

Keywords Stress · Heat · Air pollution · Traffic officer

Introduction

Along with global population growth, natural energy consumption, especially heat, has increased in developing countries [1]. One of the most harmful factors in the work environment, which is known to damage the health of workers in the working environment, especially in developing countries, is heat stress [2] and exposure to this factor is considered a major health problem in many countries of the world [3]. Working in hot environments causes stress in workers and, in addition to reducing their ability to perform their work, it can lead to several diseases. Moreover, heat is a risk factor for cardiovascular disease and can increase work-related accidents [4]. Heat stress is imposed as a combination of thermal load and environmental and individual factors [5]. The effects of exposure to heat are initially the physiological response of the body to temperature. Increased heart rate, increased deep body temperature, reduced blood flow in the cerebrospinal fluid and increased vascular resistance, are some of the symptoms of physiological responses to the heat. Long-term exposure to heat leads to muscle cramps, thermal fatigue, thermal syncope, heat loss, decreased physical and mental performance, reduced productivity, increased incidence of accidents and decreased levels of safety in work environments [6–9].

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On the other hand, the extraordinary expansion of cities and urbanization, as well as the growth of the industrial sector, especially in the vicinity of large and densely populated cities and combining them with a set of natural and climatic factors, not only have increased the air pollution of the cities but also have caused changes in the climate that have been highly at the center of attention of scholars and planners in recent years. Air pollution, one of the major environmental hazards, is considered one of the problems and concerns of today's societies. By reducing the level of air pollution, countries can reduce the burden of stroke-related diseases, heart diseases, lung cancer, and chronic and acute respiratory diseases, including asthma [10, 11]. Although events such as volcanoes and fire may release various pollutants in the environment, human activities are among the main causes of environmental pollution. Hazardous chemicals may occasionally enter the environment, but the amount of airborne pollutants that come from industrial activities is constantly entangled and can cause adverse effects on human health and the environment. By definition, 'pollutant' refers to any substance that could harm humans, animals, or vegetation. As far as humans are concerned, air pollutants can increase the risk of mortality, dangerous diseases or potential health risks for humans [12, 13].

The World Health Organization has issued an "air quality guideline" for assessing the effects of air pollution on health and the determination of harmful levels of pollutants. According to this guideline, in 2014, 92% of the world's population lived in poor air quality. Air pollution has been the cause of more than 3 million premature deaths worldwide in 2012. 72% of the deaths associated with air pollution have been due to ischemic heart disease and stroke, 14% have been due to chronic obstructive pulmonary disease or acute respiratory infections, and the remaining 14% have been due to lung cancer [10]. People living in low-income countries experience the burden of air pollution problems by 87%, and the most striking of which reported by the WHO is associated with the Western Pacific and Southwest Asia [10, 14]. Many studies have been done on air pollution in different countries [15–17]. Kampa and Castanas (2007), Scammell (2010) and Oakes et al. (2014) have reported the effects of air pollution on health [12, 16, 18]. Health and environmental protection centers have also continuously been publishing their reports on the effects of harmful air pollutants on human health and the environment [19, 20]. Air pollution has already become one of the problems of the day in Iran, and almost all the metropolises of the country are somehow involved with this problem [21]. Tehran is one of the most polluted cities in the world. According to Tehran's environmental studies, 70% of deaths are due to respiratory and cardiac problems, which are directly or indirectly related to Tehran's air pollution [12, 22].

Different studies have examined heat stress in various occupations and their relationship with physiological parameters of the body, which indicate the effect of heat on the physiological responses of the body [23–27]. On the other hand, studies that examine the association of air pollution with health problems and the occurrence of diseases also show a statistically significant relationship between these variables [12, 28–31]. Despite numerous studies conducted on this topic in Iran and worldwide, no study was found which has examined the simultaneous effects of heat stress and air pollution variables on body temperature. On the other hand, high-risk groups, such as traffic police officers, whose work environment is in open spaces and undergo a lot of heat during the warm seasons of the year, are in full, permanent and direct exposure to pollution and heat. Air pollution, and in particular, air pollution associated with traffic, affect people's health. One of the high-risk groups is traffic officers who, by virtue of their job nature, are continuously subject to air pollution. This group may be exposed to these contaminations for several years, so traffic officers are expected to show more health problems. Traffic officers in Iran are exposed to high levels of air pollution and health problems. Since traffic officers often do not use masks or protective equipment and are often in the process of performing their duties in such environments for a long time, this vulnerable and at-risk population was selected to conduct the study. On the other hand, according to our knowledge, no study has been conducted on this phenomenon among this group. Therefore, this study was conducted to investigate the simultaneous effects of thermal stress and air pollution on the body temperature of traffic officers in the main squares of Tehran.

Methods

This descriptive-analytic study was conducted among traffic officers based in various squares of Tehran during 2017. In order to determine the thermal stress, all main squares of Tehran ($N = 29$) located near the active pollutant's stations were considered. The census method was used to select traffic officers and 119 people were selected and included in the study. In this study, environmental variables such as air temperature (dry and wet), radiation temperature and air pollution in the squares were measured. The Wet-bulb-globe-temperature (WBGT) index was calculated using atmospheric factor data such as normal thermometer, helical thermometer, and wet-bulb thermometer. The air pressure was measured using a digital barometer, and according to ups and downs as well as elevation in Tehran, a geographic criterion was also considered. The amount of air pollution was also evaluated using reports of the environmental organization from the pollutant stations. The air quality index was measured and reported by determining the concentration of major pollutants in the active stations measured in Tehran. Furthermore, the demographic characteristics of officers including age and work history were investigated. The skin temperature of the officers

exposed to heat was measured by skin thermometer (four areas were included: ear, forehead, neck and hands).

This study is part of a major project that is being conducted in the field of health of traffic officers with the support of the Research Support Fund (Iran National Science Foundation) and the University of Social Welfare and Rehabilitation Sciences.

Data analysis

In order to investigate the research objectives, first, the temperature of the air was divided into two groups of normal (temperature equal to or less than 35) and higher than normal (temperature higher than 35) [32], and similarly the condition of air pollution was divided into two groups of pollution higher than the standard level (AQI > 100) and unpolluted air (AQI = 0–100) [33]. Then the temperature of the ear was checked with wet-bulb temperature and air pollution. Independent-samples t-test and factorial analysis of variance were used to investigate the main and interaction effects of air pollution and wet-bulb temperature on the ear temperature. Data were analyzed using SPSS software with a p value of ≤0.05.

Ethical considerations

The ethical issues considered in this study include: obtaining a research ethics permission from Tehran University of Social Welfare and Rehabilitation Sciences (ethical code: IR.USWR.REC.1396.76), expressing research objectives for the samples, obtaining informed consent, observing the confidentiality and anonymous of the information and announcing to individuals that whenever they wish they can cancel their participation in the research.

Findings

The results showed that the mean (±SD) age of the samples was 27.8 ± 6.5 and the average work experience was 4.87 ± 0.69 years. The mean (±SD) height and weight in the samples were 176.8 ± 6.7 cm and 75.12 ± 13.5 kg, respectively. On average, the samples have been working 6.8 ± 0.7 days per week in the squares (Table 1).

Table 1 Demographic characteristics of the samples

Demographic Factors	Mean	Standard Deviation
Work history	4.87	0.69
Age	27.78	6.47
Height (Cm)	176.79	6.74
Weight (Kg)	75.12	13.53
Working days in a week	6.82	0.71

According to the results, the mean temperature of the ear in the exposed group to the air pollution was 36.91 (SD = 0.77) and the other group was 36.84 (SD = 0.72). Based on the results of the independent samples t-test, there was a statistically significant difference between the two groups in terms of the temperature of the ear. Moreover, the average temperature of the ear subjects exposed to the high temperature was 37.06 (SD = 0.641) and the other group was 36.46 (SD = 0.844). Based on the results of the t-test, two independent samples were significantly different in terms of the temperature of the ear between the two groups (Table 2).

According to the results of the factorial ANOVA, the main effect of air pollution on the temperature of the ear was not statistically significant ($P = 0.60$); the main effect of wet-bulb temperature was statistically significant ($F = 10.68$, $P < 0.001$); and the interaction effect of these two variables on the ear temperature was statistically significant ($F = 3.98$, $P = 0.048$) (Table 3). Based on the wet-bulb temperature and air pollution, the temperature condition of the ear is presented in Table 4 and Fig. 1.

Discussion

The aim of this study was to investigate the simultaneous effects of thermal stress and air pollution on the body temperature of traffic officers in the main squares of Tehran. This group has been working in a hazardous environment and has been in direct exposure to pollution. The results revealed no statistically significant difference between air pollution and ear temperature, but there was a significant difference between wet-bulb temperature and ear temperature. In line with the results of the present study, a number of previous studies have been conducted to investigate simultaneously the effects of air pollution, heat and health indicators. For example, the study conducted by Cizao Ren et al. in 2011, which examined the relationship between temperature, air pollution and pulse changes in the elderly in Boston and Massachusetts, showed that higher temperatures were associated with pulse reduction during the warm months of the year. However, no relationship was observed in the cold months of the year. This relationship was significantly higher in the warm months of the year when ozone levels were higher in the air, but no connection was observed with ambient fine particulate matter (−2.5 lm) [34]. The results of this study are consistent with the results of the present study which needs further discussion. In the present study, there was a significant relationship between heat, pollution and body temperature. The similarity of the results appears to be due to the effect of heat on body temperature. Given that the heat of the external environment can increase the body temperature, the human body uses the sweating mechanism to maintain its natural temperature, but when this sweetening is not done adequately, the temperature of the

Table 2 The correlation of officer's ear temperature, air pollution, and wet-bulb temperature

Variable		Samples	Mean	Standard Deviation	t	P value
Air Pollution	Unpolluted Air (AQI = 0–100)	41	36.84	0.722	0.499	0.618
	Air Pollution above standards (AQI > 100)	71	36.91	0.796		
Wet-bulb Temperature	Temperature ≤ 35	37	36.46	0.844	4.26	0.0001
	Temperature > 35	82	37.06	0.641		

body increases, which can cause the effects of heat stress in the person. As has been confirmed in both studies, air pollution may be a factor in exacerbating this increase and there is evidence of a further increase in body temperature in the presence of air and heat pollution. O'Neill et al., in 2005, have also probed the impact of air pollution control and respiratory epidemics on the relationship between air temperature and daily mortality in Mexico City and Monterey. For air pollution, they have considered ozone and pm 2.5 factors. Results showed that the mortality rate in Mexico City increased in cold days, but without controlling air pollution and epidemics, it almost doubled. In Monterrey, the effect of heat on deaths was one-third lower and the impact of heat on children's deaths was even lower, but concerning cold temperature, a similar effect to Mexico City was observed. The results of the study showed that even with the control of such factors as air pollution and respiratory epidemics, there was a relationship between climate and health. Therefore, the lack of control of the abovementioned factors cause an overestimation of the effect of hot days by 50%, but this control has not had a significant effect on the mortality rate on cold days, with the exception of children [35]. Although the study performed by O'Neill et al. reviewed the relationship between mortality rate, air pollution and air temperature, the results of their study can be compared with the findings of the present study. Similar to the previous study, in this study, the effects of exacerbating pollution and environmental heat on the body temperature of the person can be discussed. Another study done by Orru Ebi and Forsberg in 2017 examines the interactions between climate change and air pollution on health. The study reported that although most studies have shown that ozone and other pollutants are associated with climate change, mortality is expected to increase, but depending on location, climate scenario, and factors such as population and context the results can be different [36].

Although the results of that study have examined the effects of air pollution and climate change on mortality, it can be stated that the results are consistent with the findings of the present study. Chen et al. (2018) examined the bilateral effects of air pollution and temperature on the normal mortality rate or deaths caused by cardiovascular disease in eight European metropolitan areas between 1999 and 2013. The results of their study showed a direct relationship between air pollution and mortality. It has been also claimed that the higher the air temperature, the higher the incidence rate has been observed. In days with high air pollution (higher than 50%), the risk of death associated with hot and cold weather increased. In general, the results of this study indicate that high temperatures can exacerbate the impact of air pollution on daily mortality, and high air pollution may also increase the effects of high temperatures [37]. The results of the study of Chen et al., despite the difference in goals and the research questions, are consistent with the results of the present study. In both studies, air pollution was considered as a factor exacerbating the effects of air temperature on human health. Qin et al. (2017) also assessed the effects of air pollution and temperature on mortality in the city of Hefei, a polluted and hot city in China. The results of the study showed that there was a stronger correlation between air pollution and mortality at higher temperatures than normal temperature. These differences were statistically significant with the deaths caused by PM10 and among all pollutants and respiratory mortality. There was no clear trend in this relation to the age variable. There was also an observed effect of the pollutants and an increase in the temperature on the mortality rate in Hefei, which was more pronounced in women and illiterates than in men. This can be due to behavioral differences that affect the exposure of individuals at higher temperatures [38]. The results of this study can be compared with the present study. The results of this study, similar to the studies mentioned above, show the simultaneous effects of pollution and heat on health. Breitner et al. (2014) also studied the effect of temperature on mortality and the intervening impact of air pollution on this variable in three Bavarian cities in southern Germany.

Table 3 The relation between ear temperature with air pollution and wet-bulb temperature

Determinant	The sum of the squares	Degree of freedom	Mean of the squares	F	p value
Air Pollution	0.136	1	0.136	0.256	0.60
Wet-bulb temperature	5.49	1	5.49	10.68	0.001
Pollution × Wet-bulb temperature	2.05	1	2.05	3.98	0.048

Table 4 Ear temperature based on wet-bulb temperature and air pollution

AQI	Wet-bulb temperature	Mean	SD
Low	Low	36.72	0.45
	High	36.91	0.81
High	Low	36.34	1.07
	High	37.14	0.51

Furthermore, the effect of age and temperature on this relationship was studied. The results of this study showed that the relationship between temperature and mortality for all categories of mortality was due to a particular reason nonlinear showing an arc U or J shape. An increase of 20 to 24.8 degrees Celsius from the average two-day temperature led to an unconventional increase in mortality of 11.4% (95% CI: 7.6% - 15.3%). On the contrary, the temperature drops from −1.5 to −7.5 in a 15-day average, increased the temperature by 6.2% (95% CI: 1.8% -10.8%) and the thermal effects seemed to be more effective. Moreover, the results of this study showed some of the effects changed by ozone, but PM10 did not have any effect. In general, the results of this study showed that both high and low temperatures increase the mortality rate. The results of this study highlighted the importance of considering the intervening effects of age and ozone in the study of the effects of temperature on mortality [39]. As previously mentioned, no study which investigates the simultaneous effects of heat and pollution on body temperature was found. Therefore, the present study is different from the studies carried out in this area. But the results of these studies are in line with our results as far as the significant relation between pollution and heat with

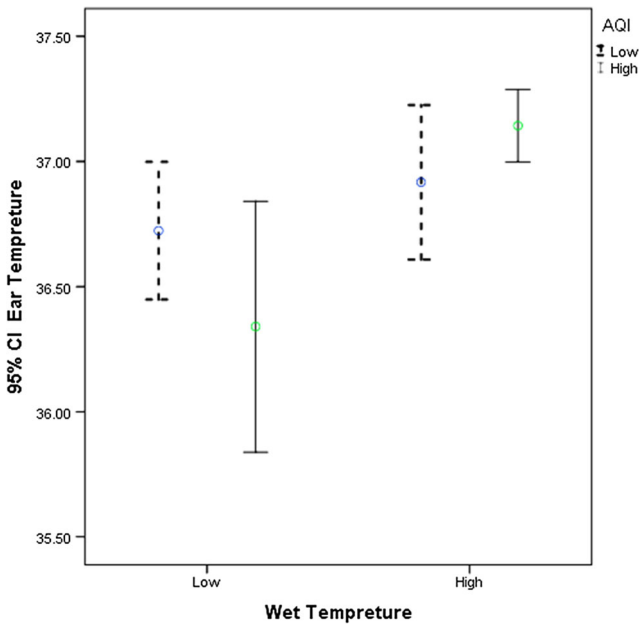

Fig. 1 The average temperature of the ear with the confidence interval of 95%, based on the Wet-bulb temperature and air pollution condition

health indicators of the body are considered. However, to the best of our knowledge, none of the studies conducted so far is exactly the same as our study, and it can be said that the present study is the first attempt evaluating the simultaneous effects of heat and air pollution on body temperature of traffic officers.

Conclusion

The results of this study, which aimed to investigate the simultaneous effects of heat and air pollution on the body temperature of traffic officers, reveal that in the presence of air pollution, the body temperature of the traffic officers also rises. This increase is greater in the ears compared to other parts which can be statistically discussed. According to the results of this study, due to the direct exposure of traffic officers to thermal stress and air pollution, other studies are recommended to be conducted and considering that only the temperature has been investigated in this study, other health indicators, different aspects of health or the impact of increased temperature on various aspects of health can be assessed in the future research. Since the present study only examines road traffic officers, it is recommended to study this topic in larger communities or other communities to compare different environmental conditions. Further studies are required to take into account demographic factors in order to better understand the issue and find out the extent to which the findings of the present study are reliable. It is also possible to design care plans or screenings for the timely detection of these occupations.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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