Research Paper

The Cognitive and Physiologic Effects of Occupational Heat Exposure on Operational Field Workers: An Exploratory Study

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ABSTRACT

Background: Exposure to heat stress is considered one of the most prevalent occupational hazards affecting performance. This study was conducted to investigate heat stress and its impact on the physiological and cognitive functions of operational field workers at a power plant.

Methods: This study was conducted on 150 male power plant personnel with 41.34±2.91 years (conducted in the summer of 2023). Physiological parameters were measured, and the assessment of heat stress (based on the Wet Bulb Globe Temperature (WBGT) index) and environmental monitoring were performed according to International Organization for Standardization (ISO) 7243 standards. Also, cognitive performance was investigated using the continuous performance test (CPT).

Results: Based on the results, individuals were exposed to heat stress conditions, and the mean WBGT index at the workstations was reported as 31.50±0.31 (above the standard limit). It was observed that all physiological indices in the exposed group increased significantly compared to the controls ($P<0.05$). The mean commission and omission errors showed a significant difference between the non-exposure and exposure groups. Also, the reaction time in the presence of occupational heat differed significantly from the mean reaction time in the absence of exposure ($P<0.05$).

Conclusion: Based on the results and considering the importance of the power generation industry, the exposure of employees to heat stress and the subsequent physiological and cognitive performance disorders can have significant implications for health and safety outcomes. Therefore, attention to occupational exposures, the functional status of employees, and influencing factors are necessary as part of control and management strategies.

Keywords: Heat stress, Occupational exposure, Cognitive, Physiologic effect, Worker

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Introduction

In various work environments, especially industrial ones, workers are exposed to different occupational and environmental hazards, such as noise, heat stress, vibration, and radiation, which can potentially threaten human health, productivity, and performance [1, 2].

Dealing with adverse weather conditions, particularly regarding heat and humidity, is one of the most significant and common occupational exposures, especially outdoor. Occupational exposure to heat can occur as a result of work processes or due to exposure to environmental weather factors [3, 4]. A hot work environment not only decreases the body's natural performance but can also trigger numerous physiological responses [4].

By creating comfortable thermal conditions, the best physiological performance of the body can be predicted. In this regard, deviating from comfortable thermal conditions and experiencing thermal stress leads to physiological changes in the human body, a state referred to as "heat strain". Moreover, if the amount of heat received and generated exceeds the amount that the body can expel, the body's internal temperature rises. This can affect physiological functions, such as metabolism, body temperature, heart rate, and blood pressure, ultimately causing heat strain [5, 6].

Thermal stress in the workplace can directly or indirectly affect cognitive performance and cause disorders and diseases. It also reduces working memory, information storage, and processing, increases the rate of work errors, and ultimately leads to accidents. One of the negative impacts of heat stress on the workforce is a decline in work productivity [6, 7]. Dunne et al estimated that over the past decades, heat stress could reduce employees' work capacity to 90% during the hottest working conditions [8]. From this perspective, there is a direct correlation between occupational heat exposure and health and safety hazards for workers, as numerous occupational studies have demonstrated a significant association between work-related injuries and occupational heat exposure [4, 9].

A person's cognitive capabilities are altered by a combination of various individual and occupational factors; however, the fundamental mechanism linking occupational heat exposure to cognitive dysfunction has not been definitively recognized. Thus, one of the potential cognitive effects of occupational heat exposure could be a lack of attention. This factor can reduce job performance and create conditions for unsafe work behaviors by causing slow and incorrect responses in occupational situations [7, 10, 11].

Therefore, it is necessary to examine the conducted studies to better understand the cognitive dysfunction associated with heat exposure in order to reduce the extent of individual and organizational damages [11, 12]. In this context, some studies have reported a decline in cognitive performance related to heat exposure, while others have reported no effect, or even an improvement in cognitive performance under thermal stress [13, 14]. On the other hand, most studies on heat stress were conducted indoors and in simulated environments, with fewer studies taking place in outdoor occupational settings [15, 16]. A review of the results from both types of studies has yielded different findings. Upon examining the literature, it can be concluded that although numerous studies have demonstrated a relationship between cognitive performance and occupational exposure to heat, the results are contradictory due to differences in the studies. Therefore, a systematic approach for evaluating the cognitive effects of heat stress has not been established [7]. For this reason, a better understanding of the cognitive dysfunction associated with heat is needed to reduce the extent of damage related to heat exposure. Given the explanations provided, this study was conducted to investigate occupational heat stress and its effects on physiologic and cognitive performance in operational field workers.

Methods

This study was conducted during the summer of 2023 in the research environment of a power plant. The study included 150 power plant workers (75 operational field workers selected using a census method as the exposure group and 75 workers with the same occupational tasks as the non-exposure group). Two conditions were established to investigate the effect of occupational heat exposure on the physiological and cognitive functions of operational personnel. The conditions for the exposure group were such that only operational personnel who were exposed to occupational heat were examined (n=75), while the non-exposure was selected from the same occupational category without exposure (n=75). The relevant criteria for matching the two groups were examined with examined concerning occupational and demographic variables. Inclusion criteria included good general health, absence of systemic diseases, clinical disorders or complaints of illness, and at least one year of operational experience. This information was collected by physical monitoring and medical records (occupational medical examinations). Furthermore, participants were advised to have sufficient sleep the night before testing and to abstain from consuming tea, coffee, Nescafe, chocolate, and any caffeinated beverages hours prior to the test. For screening auditory and visual statuses, audiometry and the E chart were utilized.

Measurement of physiological response

Physiological parameters were measured at two stages based on occupational exposure conditions according to International Organization for Standardization (ISO) 9886-2001 [17]. In the first stage, before starting the work shift, physiological parameters, such as heart rate, core temperature (measured via tympanic membrane), and blood pressure were measured and their means were recorded as baseline data. In the second stage, participants were asked to return to their workplace and commence their tasks. After working and being exposed to occupational heat for one hour, physiological parameters were measured again. The reason for considering a one-hour post-exposure time was to eliminate the effects of fatigue on the measured responses. Prolonged exposure to a hot environment may lead to dehydration, which naturally could affect the body's responses, especially cognitive functions. Measuring body responses one hour after exposure can help ensure the absence of fatigue and dehydration. In this research, the tympanic membrane temperature of the individuals' right ears was measured using a digital thermometer, model FT70-Beurer (made in Germany), with an accuracy of ±0.2 degrees Celsius and a measurement range of 34 to 43 °C. Heart rate and blood pressure were measured using an Emsig digital sphygmomanometer, model BO26 (made in Taiwan). This device measures both blood pressure and heart rate by applying a cuff around the individual's arm.

Measurement of cognitive response

The study used the continuous performance test (CPT) to assess cognitive performance at rest and during work. CPT is a valid test for assessing vigilance and alertness by detecting impairments in sustained attention performance. In this test, 150 numbers appear at certain intervals, and one stimulus is designated as the target. Participants should press the corresponding key as quickly as possible when they see the designated numbers. After completing the measurements in a resting state, individuals were instructed to return to their workstations and begin their tasks. Cognitive performance was measured again after one hour of working in a hot environment. The variables assessed in this study included omission error, commission error, and reaction time (in milliseconds) [12]. External reliability of this test was obtained for a healthy sample, with an intergroup correlation coefficient of 0.89 [17].

Time-weighted Average of Wet Bulb Globe Temperature (WBGT) Index

To calculate the eight-hour average WBGT index and compare it with the standard, environmental variable measurements were conducted [12]. Seventy measurement stations were set up near workers to record environmental variables at rest and during work, along with physiological and cognitive performance parameters. The environmental variables were measured using a digital WBGT meter and a rotating hygrometer, both manufactured by Casella. Additionally, to assess the airflow velocity, a silver-coated kata thermometer with a kata factor of 420 and a cooling strip range of 52-55 °C was employed. This instrument is designed for measuring airflow velocity in hot environments. Based on the ISO 7243 standard, measurements were taken only at the waist level of workers (1.1 m) since their work environment was thermally homogeneous during the pre-test. The WBGT index was calculated using the following equation. The calculation considered that workers were wearing standard work clothes and overalls while working. After estimating the WBGT index, a correction coefficient equivalent to 0.6 clo was applied for standard work clothes, and a correction coefficient equivalent to 1 clo was applied for overalls (Equation 1).

1.

$$WBGT = 0.7 \times t_{nw} + 0.2 \times t_g + 0.1t_a$$

For the calculation of the time-weighted average of the WBGT index, the Equation 2 was utilized:

2.

$$WBGT_{TWA} = \frac{(WBGT_1 \times T_1) + (WBGT_2 \times T_2) + \cdots + (WBGT_n \times T_n)}{T_1 + T_2 + \cdots + T_n}$$

In this equation, $WBGT_n$ represents the wet bulb globe temperature index at different hours of the work shift, and T_n represents the duration of each measurement.

Consideration

In this research, the clothing insulation value (clo) was estimated based on ISO 9920, and the metabolic rate of individuals during the work shift was determined using the standard ISO 8996 table [12]. Subsequently, the mean working metabolism over the work shift for each individual was calculated using the Equation 3:

$$3.\ \bar{M} = \frac{1}{T}\sum_{i=1}^{n} M_i \times T_i$$

In this equation, M_i represents the metabolic rate of each activity, T_i is the duration of each activity, and T is the total duration of work in a work shift. To eliminate the effects of shift work on the results related to physiological functions, cognitive performance, and work capacity, individuals with a fixed work shift (07:00 to 17:00) were examined. Additionally, the day before measurements, participants were reminded of the study's purpose and the importance of adhering to guidelines, such as adequate rest at night. During the measurement, efforts were made to ensure that individuals were placed under similar conditions, and care was taken to ensure that the subjects were not affected by fatigue or dehydration during the measurements.

Statistical analysis

Before data collection, careful matching between the exposed and non-exposed groups was conducted by considering the demographic characteristics to ensure an appropriate comparison. After data collection, the data were analyzed using SPSS software, version 18. Statistical parameters were used to present the demographic characteristics of the participants and study variables. The Kolmogorov-Smirnov test was employed to assess the normality of variables. The paired samples t-test was utilized to compare the results. Moreover, a significance level of <0.05 was considered.

Results

The mean age of participants was 41.34±2.91 years. Additionally, the mean body mass index (BMI) and work experience were reported as 25.09±1.08 and 11.57±2.94, respectively. Environmental monitoring and the recording of WBGT at 70 workstations are presented in Table 1. Accordingly, individuals' occupational exposure places them in a condition of heat stress, with the average WBGT index at workstations determined to be 31.50±0.31.

Table 2 depicts the physiological variables measured among participant groups in the study. Based on these measurements, all physiological indices of the exposure group significantly increased in comparison to the control group ($P<0.05$).

Based on Table 3, the mean commission error and omission error showed a significant difference between the control and exposure groups, with the mean of this factor being lower in the control group. Additionally, exposure to occupational heat stress resulted in significantly different reaction times compared to non-exposure conditions ($P<0.05$). On the other hand, the number of correct responses was also affected by heat exposure, showing a marked decrease. In this study, regression analyses were used to compare groups in terms of physiological functions, psychological performance, and work capacity index, while controlling for confounding factors.

Discussion

Given the numerous changes in technology and workplace processes, the execution of tasks by operators in major industries (including oil and gas, petrochemicals, nuclear industries, and power plants) is heavily dependent on the physiological and cognitive performance of these employees. Capabilities such as comprehension, analysis, and responsiveness are essential for achieving desired outcomes and mitigating human errors [18].

According to the results, there was a significant correlation between occupational heat exposure and changes in blood pressure levels. The systolic and diastolic blood pressure of individuals exposed to heat stress was higher than that of those not exposed. In this context, Gaoua et al. conducted a study to investigate the impact of heat exposure on blood pressure. They found that there is a direct and significant correlation between heat exposure and systolic blood pressure [19]. Similarly, the study by

Table 1. Measurement values of exposure to harmful factors in the work environment

Variable		No Exposure	Heat Exposure
WBGT	Minimum	23.08	30.48
	Maximum	24.01	31.40
	Mean	23.54±0.31	31.50±0.29

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Table 2. Information and comparison of physiological factors in groups

Variables	Mean±SD		P+
	No Exposure (n=75)	Heat Exposure (n=75)	
Systolic pressure	118.09±8.98	122.66±8.88	<0.001
Diastolic pressure	79.09±5.97	83.80±7.38	<0.001
Heart rate	69.91±4.22	72.29±3.6	<0.001
Core temperature	36.25±0.39	36.50±0.68	0.014

+Paired samples t-test.

Binder et al. also confirmed the increase in mean systolic blood pressure under heat stress conditions [20]. Research has shown that during exposure to heat stress, peripheral vascular resistance decreases and blood volume shifts from central body regions to peripheral areas to facilitate heat exchange.

The current study's findings indicate that as heat stress rises, individuals' heart rate also increases significantly. These results support the previous findings of Iguchi et al., further strengthening the connection between heat stress and cardiovascular condition [21]. Additionally, Zamanian et al. conducted a study on the connection between heat indices and specific physiological parameters. Their findings revealed a direct correlation between heat indices and heart rate, indicating that higher heat stress levels result in an increased heart rate [22]. When the body is exposed to heat, the thermoregulatory center located in the hypothalamus becomes active. This activation triggers various heat release mechanisms, including sweat glands, endocrine glands, the cardiovascular system, and blood vessels. These mechanisms work together to regulate heat production and dissipation in the body [23]. The blood flow to the skin surface increases in response to heat. This increased blood flow helps dissipate the heat through thermal exchanges. As a result, there is an accompanying rise in cardiac output, leading to an increased heart rate [24]. The results of the study revealed a significant difference in the mean core temperature among the groups. Heat stress had a pronounced impact on altering the core temperature of employees who were exposed to it. Dehghan et al. conducted a study to explore the integration of the WBGT index with physiological cardiac indices in hot weather conditions. They measured the ear core temperature and found that exposure to heat in the workplace led to an increase in core temperature [25]. Heat stress induces an increase in sympathetic nerve activity and raises the temperature of the tympanic membrane. Furthermore, heat exposure leads to increased levels of noradrenaline (NA) and arginine vasopressin (AVP), which consequently result in elevated skin blood flow and heart rate [25, 26].

Based on the results obtained from cognitive function tests, a difference in outcomes before and after exposure to occupational heat was reported, with commission errors, omission errors, and mean reaction time significantly increasing as a result of heat exposure. Furthermore, studies by Zamanian et al. and Amiri et al., which examined the impact of temperature on memory, concluded that heat exposure weakens data storage capacity and reduces the ability to retain information compared

Table 3. Information and comparison of CPT factors in groups

Variable		Mean±SD		P
		Control	Heat Exposure	
CPT	Commission error	0.17±0.38	0.51±0.82	<0.001
	Omission error	0.14±0.36	0.26±0.51	<0.001
	Correct answer	149.69±0.47	137.23±1.08	<0.001
	Reaction time	505.77±43.48	527.91±33.66	0.032

+Paired sample t-test

to comfortable thermal conditions [22, 27]. Karami et al. also reported a significant statistical relationship between the WBGT index and the omission error variable [28]. On the other hand, Hemmatjo et al. demonstrated that improving heat stress conditions and adopting cooling strategies in the firefighter occupational group could enhance reaction time and the number of correct responses (accuracy) [29]. In relation to heat stress, Qian et al. found that blood flow increases to the brainstem, consequently leading to an extended reaction time [5]. Patterson et al. discovered that under heat stress conditions, workers' reaction time varies based on task complexity. Furthermore, as the temperature rises from 21°C to 35 °C, reaction time also increases [30].

Despite thermal pressure, the human brain utilizes neural resources to safeguard cognitive and mental functioning when confronted with heat stress conditions. However, with increased exposure and the occurrence of hyperthermia, the performance of complex tasks may become impaired, and cognitive functions may decline. Individuals who perform important tasks based on motor accuracy, such as surgical procedures, are highly susceptible to the effects of heat exposure. In such circumstances, being exposed to moderate heat can significantly reduce an individual's cognitive performance [31, 32]. Furthermore, it should be noted that as the complexity of tasks increases, a higher level of individual performance is required, and consequently, higher levels of cognitive functioning are necessary. In such situations, the impact of factors on individuals' cognitive performance should be considered, as heat stress can act as a significant environmental risk factor that may negatively affect a wide range of cognitive functions, from attention-related tasks to more complex psychomotor functions [33, 34].

This study, similar to others, had both advantages and limitations. One notable advantage of this study was that it was conducted in real workplace conditions, unlike previous studies that used simulated environments. This aspect is advantageous as it allows the results to be directly applicable in real occupational settings. However, a limitation of this study was the challenge of conducting research in actual workplace conditions. In industrial environments, various intervening factors, such as harmful occupational factors and psychosocial factors can influence the study's outcomes. To address these limitations, it is recommended to consider combining multiple factors to enhance the study's validity.

Conclusion

The physiological responses of individuals exposed to occupational heat undergo significant alterations. Additionally, cognitive aspects studied, such as the number of correct responses, the number of errors, mean reaction time, accuracy (percentage of correct responses), and mean response time, experience significant changes when exposed to heat. Given the importance of the power generation industry and the exposure of its employees to harmful factors, the disruption of physiological and cognitive functions can have great significance in terms of health and safety consequences. Therefore, attention to occupational exposures, the functional status of employees, and factors influencing them is essential. Consequently, the findings of this research can be useful and practical for safety and health managers.

Ethical Considerations

Compliance with ethical guidelines

This paper was approved by the Ethics Committee for Experimental Medicine of Mazandaran University of Medical Sciences, Sari, Iran (Code: IR.MAZUMS.REC.1401.193).

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Authors' contributions

Conceptualization and supervision: Seyed Ehsan Samaei; Methodology and data collection: Hadi Ehsani, Zahra Musavi and Seyed Ehsan Samaei; Data analysis: Abolfazl Hossein Nataj; Writing the original draft: Zahra Musavi and Seyed Ehsan Samaei; Review and editing: Siavash Etemadinezhad and Hesam Elahi.

Conflict of interest

The authors declared no conflict of interest.

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References

[1] Abikenova S, Issamadiyeva G, Kulmagambetova E, Daumova G, Abdrakhmanova N. Assessing occupational risk: a classification of harmful factors in the production environment and labor process. International Journal of Safety & Security Engineering. 2023; 13(5):1-11. [DOI:10.18280/ijsse.130511]

[2] Benson C, Dimopoulos C, Argyropoulos CD, Mikellidou CV, Boustras G. Assessing the common occupational health hazards and their health risks among oil and gas workers. Safety Science. 2021; 140:105284. [DOI:10.1016/j.ssci.2021.105284]

[3] Xiang J, Bi P, Pisaniello D, Hansen A. Health impacts of workplace heat exposure: an epidemiological review. Industrial Health. 2014; 52(2):91-101. [DOI:10.2486/indhealth.2012-0145] [PMID] [PMCID]

[4] Spector JT, Masuda YJ, Wolff NH, Calkins M, Seixas N. Heat exposure and occupational injuries: Review of the literature and implications. Current Environmental Health Reports. 2019; 6(4):286-96. [DOI:10.1007/s40572-019-00250-8] [PMID] [PMCID]

[5] Qian S, Li M, Li G, Liu K, Li B, Jiang Q, et al. Environmental heat stress enhances mental fatigue during sustained attention task performing: Evidence from an ASL perfusion study. Behavioural Brain Research. 2015; 280:6-15. [DOI:10.1016/j.bbr.2014.11.036] [PMID]

[6] Negahban SA, Aliabadi M, Babayi Mesdaraghi Y, Farhadian M, Jalali M, Kalantari B, et al. [Investigating the association between heat stress and its psychological response to determine the optimal index of heat strain (Persian)]. Journal of Occupational Hygiene Engineering. 2014; 1(1):8-15. [Link]

[7] Yeoman K, Weakley A, DuBose W, Honn K, McMurry T, Eiter B, et al. Effects of heat strain on cognitive function among a sample of miners. Applied Ergonomics. 2022; 102:103743. [DOI:10.1016/j.apergo.2022.103743] [PMID] [PMCID]

[8] Dunne JP, Stouffer RJ, John JG. Reductions in labour capacity from heat stress under climate warming. Nature Climate Change. 2013; 3(6):563-6. [DOI:10.1038/nclimate1827]

[9] Levy BS, Roelofs C. Impacts of climate change on workers' health and safety. Oxford Research Encyclopedia of Global Public Health. 2019; 1(1):1-15. [DOI:10.1093/acrefore/9780190632366.013.39]

[10] Varghese BM, Hansen A, Nitschke M, Nairn J, Hanson-Easey S, Bi P, Pisaniello D. Heatwave and work-related injuries and illnesses in Adelaide, Australia: A case-crossover analysis using the Excess Heat Factor (EHF) as a universal heatwave index. International Archives of Occupational and Environmental Health. 2019; 92(2):263-72. [DOI:10.1007/s00420-018-1376-6] [PMID]

[11] Varghese BM, Hansen A, Bi P, Pisaniello D. Are workers at risk of occupational injuries due to heat exposure? A comprehensive literature review. Safety Science. 2018; 110:380-92. [DOI:10.1016/j.ssci.2018.04.027]

[12] Rastegar Z, Ghotbi Ravandi MR, Zare S, Khanjani N, Esmaeili R. Evaluating the effect of heat stress on cognitive performance of petrochemical workers: A field study. Heliyon. 2021; 8(1):e08698. [DOI:10.1016/j.heliyon.2021.e08698] [PMID]

[13] MacLeod H, Cooper S, Bandelow S, Malcolm R, Sunderland C. Effects of heat stress and dehydration on cognitive function in elite female field hockey players. BMC Sports Science, Medicine & Rehabilitation. 2018; 10:12. [DOI:10.1186/s13102-018-0101-9] [PMID] [PMCID]

[14] Schlader ZJ, Gagnon D, Adams A, Rivas E, Cullum CM, Crandall CG. Cognitive and perceptual responses during passive heat stress in younger and older adults. American Journal of Physiology. 2015; 308(10):R847-54. [DOI:10.1152/ajpregu.00010.2015] [PMID] [PMCID]

[15] Mazloumi A, Golbabaei F, Mahmood Khani S, Kazemi Z, Hosseini M, Abbasinia M, et al. Evaluating effects of heat stress on cognitive function among workers in a hot industry. Health Promotion Perspectives. 2014; 4(2):240-6. [DOI:10.5681/hpp.2014.031] [PMID]

[16] Spector JT, Krenz J, Calkins M, Ryan D, Carmona J, Pan M, et al. Associations between heat exposure, vigilance, and balance performance in summer tree fruit harvesters. Applied Ergonomics. 2018; 67:1-8. [DOI:10.1016/j.apergo.2017.09.002] [PMID]

[17] Narimani M, Soleymani E, Tabrizchi N. [The effect of cognitive rehabilitation on attention maintenance and math achievement in ADHD students (Persian)]. Journal of school psychology. 2015; 4(2):118-34. [Link]

[18] Zhang F, de Dear R, Hancock P. Effects of moderate thermal environments on cognitive performance: A multidisciplinary review. Applied Energy. 2019; 236(1):760-77. [DOI:10.1016/j.apenergy.2018.12.005]

[19] Gaoua N. Cognitive function in hot environments: A question of methodology. Scandinavian Journal of Medicine & Science in Sports. 2010; 20(Suppl 3):60-70. [DOI:10.1111/j.1600-0838.2010.01210.x] [PMID]

[20] Binder K, Gagnon D, Lynn AG, Kondo N, Kenny GP. Heat stress attenuates the increase in arterial blood pressure during isometric handgrip exercise. European Journal of Applied Physiology. 2013; 113(1):183-90. [DOI:10.1007/s00421-012-2428-3] [PMID]

[21] Iguchi M, Littmann AE, Chang SH, Wester LA, Knipper JS, Shields RK. Heat stress and cardiovascular, hormonal, and heat shock proteins in humans. Journal of Athletic Training. 2012; 47(2):184-90. [DOI:10.4085/1062-6050-47.2.184] [PMID] [PMCID]

[22] Zamanian Z, Sedaghat Z, Hemehrezaee M, Khajehnasiri F. Evaluation of environmental heat stress on physiological parameters. Journal of Environmental Health Science & Engineering. 2017; 15:24. [DOI:10.1186/s40201-017-0286-y] [PMID] [PMCID]

[23] Habib E, Dehqana H, Lotfi S, Hassanzadeh A. [The effect of heat on the precision and speed of the work in men by the battery method under experimental condition (Persian)]. Journal of Preventive Medicine. 2016; 3(1):28-36. [Link]

[24] Logan PW, Bernard TE. Heat stress and strain in an aluminum smelter. American Industrial Hygiene Association Journal. 1999; 60(5):659-65. [DOI:10.1080/00028899908984488] [PMID]

[25] Dehghan H, Mortazavi SB, Jafari MJ, Maracy MR. Combination of wet bulb globe temperature and heart rate in hot climatic conditions: The practical guidance for a better estimation of the heat strain. International Journal of Environmental Health Engineering. 2012; 1(1):18. [DOI:10.4103/2277-9183.96006]

[26] Gravel H, Chaseling GK, Barry H, Debray A, Gagnon D. Cardiovascular control during heat stress in older adults: Time for an update. American Journal of Physiology. 2021; 320(1):H411-6. [DOI:10.1152/ajpheart.00536.2020] [PMID]

[27] Amiri F, Zamanian Z, Mani A, Hasanzadeh J. Effects of combined exposure to noise, heat and lighting on cognitive performance. Iran Occupational Health. 2015; 12(5):10-20. [Link]

[28] Karami M, Mehrparvar AH, Dehghani Tafati A, Mozaffari A, Sahranavard Y. [The relationship between heat stress on the vital factors and cognitive function Sarcheshmeh copper smelter workers in 2018 (Persian)]. Occupational Medicine Quarterly Journal. 2018; 10(2):10-21. [Link]

[29] Hemmatjo R, Hajaghazadeh M, Allahyari T, Zare S, Kazemi R. The effects of live-fire drills on visual and auditory cognitive performance among firefighters. Annals of Global Health. 2020; 86(1):144. [DOI:10.5334/aogh.2626] [PMID] [PMCID]

[30] Patterson MJ, Taylor NA, Amos D. Tests of cognitive, perceptual and sustained attention functions in hot environments. Melbourne: DSTO Aeronautical and Maritime Research Laboratory; 1998. [Link]

[31] Mazlomi A, Golbabaei F, Farhang Dehghan S, Abbasinia M, Mahmoud Khani S, Ansari M, et al. The influence of occupational heat exposure on cognitive performance and blood level of stress hormones: A field study report. International Journal of Occupational Safety and Ergonomics. 2017; 23(3):431-9. [DOI:10.1080/10803548.2016.1251137] [PMID]

[32] Byrne J, Ludington-Hoe SM, Voss JG. Occupational heat stress, thermal comfort, and cognitive performance in the OR: An integrative review. AORN Journal. 2020; 111(5):536-45. [DOI:10.1002/aorn.13009] [PMID]

[33] Piil JF, Lundbye-Jensen J, Trangmar SJ, Nybo L. Performance in complex motor tasks deteriorates in hyperthermic humans. Temperature. 2017 4(4):420-8. [DOI:10.1080/23328940.2017.1368877] [PMID] [PMCID]

[34] Berg RJ, Inaba K, Sullivan M, Okoye O, Siboni S, Minneti M, et al. The impact of heat stress on operative performance and cognitive function during simulated laparoscopic operative tasks. Surgery. 2015; 157(1):87-95. [DOI:10.1016/j.surg.2014.06.012] [PMID]