

The Impact of Heat on the Accuracy and Pace of Working by Tests of Job Skill Assessment

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ABSTRACT

Harmful physical factors in workplace including temperature may affect the cognitive performance of human. This study was conducted to determine the impact of the intervention of heat on the accuracy and pace of working in men. This interventional study was conducted on 56 participants of the male students in the climatic chamber. After gathering the demographic information, the participants were divided into 2 groups including “case group” (under the condition of 30% relative humidity and dry bulb temperature of 35 °C) and “control group” (under the condition of 40% relative humidity and dry bulb temperature of 20 °C). After taking a rest for 10 to 15 min, the participants carried out all tests of job skill assessment (BATTERY method) including clockwise and counter-clockwise two-arm coordination test, V Pieron test, and test of targeting accuracy thermometer, in 0, 40, 80 and 120 min after commencing the test. The number of errors (accuracy assessment) and the duration of performing the test (pace assessment) were recorded. There was a significant difference in the mean values of working accuracy when the participants performed the tests of job skill assessment ($P < 0.001$). The differences between the mean values of the pace of working when the participants performed the tests of job skill assessment were not significant except for targeting accuracy thermometer measurement ($P > 0.09$). High temperature may cause a decrease in people’s performance and an increase in harmful behaviors, because of decreasing the accuracy.

KEYWORDS: *Heat, Working accuracy, Working pace, Battery*

INTRODUCTION

Work-related accidents are one of the main causes of disability and mortality around the world. Based on the International Labour Organization report in 2011, about 337 million occupational accidents occur every year in the world, because of which 6300 people are killed every day and more than 2.3 million people, every year. Economically, the human cost of accidents and illnesses amounts are over 4% of the world

GDP [1].

The analysis of enormous accidents such as Three Mile Island in America, Bhopal in India, Chernobyl in the former Soviet Union, and thousands of other examples shows that in more than 70% of cases, unsafe behaviors and human errors are considered the major factors of accidents [2-4]. On the other hand, occupational stress factors may cause unsafe behaviors among the employers because affect negatively their concentration and cause distraction and memory disorder [5]. The study on unsafe behaviors in automotive industry

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indicated that the physical conditions of the workplace including harmful physical and ergonomic factors play the most important role in causing stress [6]. On the other hand, harmful physical factors of workplace may affect staff efficiency, work efficiency and productivity by decreasing the accuracy, pace and the ability to apply the skills [7-8]. For example, the study of habibi and et al showed that a decrease in the intensity of lighting can reduce subject's performance and enhance unsafe behaviors [9].

High temperature is considered as one of the harmful physical factors. High temperature could either be caused by some processes or be the result of environmental factors such as in Iran's southern regions. In addition to causing physiological disorders and diseases, high temperature may cause the cognitive responses and affect performance in human [10]. Mackworth was the first researcher in 1950 who studied the impact of heat stress on human's performance and concluded that if people perform a tiring task in a warm environment, their performance will gradually decrease [11]. The impact of thermal comfort and environmental temperature was studied on the efficiency of 16 clerks during 18 months. The average temperature of 20 °C compared to the average temperature of 26 °C, leads to a 6% increase in the efficiency of workers [12]. Also, the study of monazzam and et al showed with increasing the value of WBGT index in the different regions of Iran, the level of productivity loss greatly increased [13].

The tests of job skill assessment (BATTERY method) are used to measure different people's rehabilitation and their ability to get back to work. This set of tests is used to measure the workers' hand-eye coordination, accuracy, pace of working, motor skills, perception, mental consciousness, two-hand coordination, agility, hand skills and so on [14]. Therefore, the impact of the heat on people's performance and efficiency, and the impact of the heat on people's function had not been studied in Iran by applying the tests of job skill assessment (BATTERY).

This survey was conducted in climatic chamber based on BATTERY method with the aim of determining the impact of the heat on men's accuracy and pace of working.

MATERIALS AND METHODS

Subjects: This interventional study was conducted on 56 participants of male students of Isfahan University of Medical Science, Isfahan, Iran in the laboratory of the School of Public Health. Overall, 29 participants were included in the "control group" and 27 participants were included in the "case group". Samples of this study were selected randomly. The inclusion criteria were as follows: the absence of musculoskeletal diseases, the absence of

uncorrected poor vision, taking no medication, the absence of infectious diseases and tiredness. Exclusion criteria include tiredness and not participating appropriately in conducting the study.

Test conditions: Controlled variations included controlling the disturbing noises by conducting the experiment in an acoustic room and controlling the impact of lighting by conducting the test under the condition of 500 Lux in the chamber. To ensure that the conditions were the same during the experiment, noise was monitored by a Casella SLM (Sound Level Meter), and illuminance was monitored by a lux meter on the intended surface. For simulating the weather conditions also, an environmental chamber was used. The dry temperature and humidity of this chamber can be set to simulate the intended environmental conditions. To achieve this aim, the walls, ceiling and the floor of the chamber are made of thermal and moisture proof and all of the seams are insulated by special paste. Radiator and electric heaters were used to set the dry temperature, and a steam generator was used to set the humidity of the chamber. A Cassella WBGT made in England was also used to measure the temperature and moisture of the chamber. Inside the chamber, a 70cm high desk and an ergonomic chair were inserted for the participant.

After preparing, the conditions and approving the participants according to the inclusion and exclusion criteria and the procedures of the tests were explained to the participants, and they signed a consent form. Then the demographic information of the participants (including age) was recorded using the demographic information questionnaire. After that, the participants were divided into two groups including a control group and a case group. The included participants in the case group were under the condition of warm and dry weather (30% relative moisture and dry temperature of 35 °C) [15]. In the control group, the participants were under the condition of mild weather (40% relative moisture and dry temperature of 20 °C) [16-17].

Skill test: Tests of job skill assessment (BATTERY method) were used to measure working accuracy and pace. For performing this study, 2 tests were used: the test of steadiness, and two-arm coordination test. The tools used for the test of steadiness include V Pierron thermometer and targeting accuracy thermometer. V Pireron thermometer contains two metal branches with a metal angle graded in several forms. The participant moves a metal pen in this angle in way that it does not touch the sides. The touch of the sides by the pen is considered as an error. The targeting accuracy thermometer contains a metal pen, a flashing light, a timer and a stopwatch. In this method, the participants push the metal pen into the holes from the largest to the smallest one in sequence, and then take it out. In this test, also the collision with the sides of the holes by the pen is considered as an error

[14, 18]. The other test was the two-hand coordination test which contains a star pattern, a pen attached to two arms, an error detector device, a flash lighting, a buzzer and patch cords for connection [19-20]. In this test, the participant uses the pen and arms to draw another star between two lines of the given star. They should continuously go through this direction clockwise and counter-clockwise. Any contact with the sides of the star or coming out of that is also an error. After entering the examination chamber, the participants took a rest for 10 to 15 min so that they could recover their physiologic parameters. This process was associated with asking the participants to consume some sweet food. During each test, the participants started to accomplish the task by the order of the researcher while the researcher recorded their errors (accuracy measurement) and the time duration of the test (pace measurement). During this time, the participants carried out the job skill assessment test in 4 sessions: at the beginning, 40 min after the beginning, 80 min after the beginning and 120 min after the beginning.

Analysis: SPSS 20 software (Chicago, IL, USA) was used to describe and analyze the data. Dispersion and central indices were used to describe the data. The relationship between the exposure to the heat with the time of the performances and the recorded errors were evaluated using two-way ANOVA test and independent t-test.

RESULTS

The mean and the standard deviation of the participant's age were 24.33 ± 2.12 , and for the participant's weight and BMI were 72.08 ± 11.14 and 23.35 ± 3.38 , respectively. The results of the independent t-test indicated that the difference between the mean of age, weight, and BMI of the participants in the case group and the control group was not significant ($P > 0.11$). In addition, the mean

and the standard deviation of relative humidity and dry temperature were 31.4 ± 2.1 and 35.8 ± 0.9 , respectively in case group; and 40.7 ± 1.8 and 21.3 ± 1.1 respectively, in the control group. The mean and the standard deviation of the number of errors made by participants in the control group and the case group were indicated in Table 1. In order to represent the amount of working accuracy while carrying out the tests of job skill assessment including clockwise and counter-clockwise two arm coordination, V pieron test and test of targeting accuracy thermometer after 0, 4, 80, and 120 min. The results of the two-way ANOVA also indicated that there was a significant difference in the amounts of Mean of working accuracy when the participants performed the tests of job skill assessment including clockwise and counter-clockwise two arm coordination, V pieron test and test of targeting accuracy thermometer ($P < 0.001$).

Table 2 represents the amounts of mean and standard deviation of the time taken by the participants to carry out the tests. In order to indicate the pace of working when the participants performed the tests of job skill assessment including clockwise and counter-clockwise two arm coordination, V pieron test and test of targeting accuracy thermometer in the control group and the case group after 0, 40, 80, and 120 min. Moreover, there was no significant difference between the amounts of the mean of pace of working when the participants performed the tests of job skill assessment including clockwise and counter-clockwise two arm coordination and V pieron test ($P > 0.09$). However, there was a significant difference between the amounts of the Mean of working when the participants performed the tests of targeting accuracy thermometer in the control group and the case group.

Table 1. The mean and the standard deviation of the participants' errors in the case group and the control group as an indicator of working accuracy when the participants performed the tests of job skill assessment

Parameters	Groups	Elapsed time (min)					P-value	
		0	40	80	120	Total		
		Mean± Standard Deviation	Mean± Standard Deviation	Mean± Standard Deviation	Mean± Standard Deviation	Mean± Standard Deviation		
The type of the test	Clockwise two arm coordination	Control	0.13±0.35	0.34±0.55	0.41±0.62	0.75±0.43	0.41±0.54	<0.001
		Case	0.37±0.49	0.62±0.68	0.66±0.62	1.03±0.64	0.67±0.65	
	Counter- clockwise two arm coordination	Control	0.20±0.49	0.24±0.43	0.51±0.5	0.37±0.49	0.33±0.49	<0.001
		Case	0.51±0.57	0.59±0.63	0.81±0.48	0.96±0.58	0.72±0.63	
	V pieron test	Control	11.10±3.13	10.93±2.60	10.93±2.26	12.1±2.80	11.26±2.71	<0.001
		Case	14.70±33.39	14.92±3.24	16.11±3.96	16.4±3.55	15.53±3.57	
	Test of targeting accuracy tremometer	Control	9.65±2.17	6.68±2.28	10.06±2.75	10.96±2.55	10.09±2.47	<0.001
		Case	2.24±13.18	2.91±13.25	2.66±13.77	2.84±14.92	30.09±13.78	

Table 2. The Mean and the Standard Deviation of working time (seconds) in two groups of case and control as an indicator of working accuracy when the participants performed the tests of job skill assessment

The type of the test	Parametes	Groups	Elapsed time (min)					P-value
			0	40	80	120	Total	
			Mean± standard deviation	Mean± standard deviation	Mean± standard deviation	Mean± standard deviation	Mean± standard deviation	
Clockwise two arm coordination	Control	38.96±12.81	38.09±14.18	34.97±11.38	33.55±110.3	36.4±12.45	0.572	
	Case	40.25±14.40	38.04±15.04	33.54±9.62	30.09±6.75	35.48±12.35		
Counter-clockwise two arm coordination	Control	38.57±13.39	35.54±11.65	34.27±11.56	33.49±10.73	35.46±11.88	0.182	
	Case	37.86±12.93	34.66±9.48	32.45±8.15	28.97±9.11	33.49±10.46		
V pieron test	Control	19.21±4.64	19.17±4.47	18.95±3.90	19.75±4.61	19.27±4.37	0.96	
	Case	21.06±15.16	20.81±6.09	20.48±5.29	19.08±4.54	20.36±5.28		
Test of targeting accuracy thermometer	Control	33.36±7.12	31.40±6.92	32.27±5.63	31.66±6.24	32.17±6.46	0.024	
	Case	36.74±11.99	33.78±7.66	35.54±8.14	32.01±7.71	34.52±8.86		

DISCUSSION

The obtained results from this study indicate that although high temperature decreases the workers' accuracy has no effect on the pace of working. The differences of working pace in the control group and the case group were not significant. The Mean of parameters including age, weight, and BMI known as heat strain risk factors [21], had no significant difference in the control group and the case group and were almost the same. Therefore, the accuracy of participants when performing the tests was affected by heat. The results of all 4 tests of job skill assessment verify this claim.

Heat is one of the main factors that affect the workers' cognitive performance by causing thermal discomfort [22]. Too high or too low temperature affects the workers' performance was concluded. These unfavorable temperatures had a negative effect on a variety of cognitive tasks. In cold conditions (10 °C), the workers' performance had an average decrease of 13.91 percent. In too warm conditions, also the workers' performance had an average decrease of 14.88 percent [23]. The obtained results of another survey using the continuous performance test examined the cognitive performance of 33 students in exposure to four WBGT degrees of temperature including 22, 18, 29 and 33 °C indicated that exposure to thermal discomfort decreases people's cognitive performance [24]. The effects of thermal discomfort were examined on working memory, reaction time and temperament changes. Thermal discomfort (dry temperature of 36 °C and 75% relative humidity) decreases the workers' ability to perform their tasks [25]. The performance of the telephone center's staff was decreased of 5 to 7% when the temperature is more than 25 °C. There

was a 2.4% decrease in the performance of workers per each degree of centigrade of temperature to rise in the range of 21.9 to 28.5 °C [26].

In most of the completed tests, there was more increase in the number of the occurred errors in the group exposed to high temperature compared to the control group (Table 1). Because of the accuracy of people decreases in exposure to high temperature, the number of their errors increases. This increase in the number of errors increases the needed time for completing a task correctly and affects the overall efficiency negatively. The results of the present study indicated that the duration of taking the tests as an indicator of working pace was almost the same in the case group and the control group. Nevertheless, completing the tasks in this duration includes errors and probably the act of working with no error takes more time in the group exposed to high temperature compared to the group exposed to mild temperature; however, this claim needs more study and examination.

In addition, the effect of thermal discomfort was examined on the selective attention and the reaction time of 70 casting workers in an automobile factory indicated that in carrying out simple tasks. There is no significant relationship between the duration of the test, reaction time and a number of errors with temperature. However, there is a significant relationship between the mentioned variations and temperature while carrying out complicated tasks [27]. Temperature has different effects on the cognitive performance of people with different tasks. The effect of thermal discomfort on the cognitive performance was less in the tasks that needed less attention. However, the effect of thermal discomfort was more noticeable in complicated tasks that needed more attention [10]. In the present study, the selected tasks needed more

cognitive performance so the effect of high temperature was examined on the tasks with high cognitive performance. Moreover, a number of harmful behaviours and industrial accidents increases in exposure to WBGT of more than 24 °C and deep temperature of more than 28 °C [28]. Accordingly, this decrease in people's accuracy caused by exposure to high temperature not only affects the efficiency and performance of people negatively but also may endanger the health of people due to the lack of attention.

CONCLUSION

Heat decreases the accuracy of people when participants performed the mentioned cognitive tasks. The actions which need cognitive performance should be prevented in warm working environments or the environmental temperature should be controlled by applying appropriate solutions in order to increase the safety of workplaces prevent disasters and increase people's efficiency. The tests of job skill assessment (BATTERY) could also be used to select people who commit fewer errors in exposure to unfavorable environmental conditions.

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