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Physiological and Psychological Effects of Heat Stress on Automotive Manufacture Workers

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Abstract

PT XYZ is an automotive parts manufacturer with a press and welding specialty in which workers are easily exposed to heat stress. This study aimed to analyze the effect of heat stress on workers' physiology and psychology. Conducted in May–June 2016 using a cross-sectional approach, this study involved 70 workers. Workers' physiological responses were assessed by measuring their body temperature, heartbeat, and urine specific gravity. Their psychological responses were measured by asking them to complete a questionnaire regarding the heat stress they had experienced. Workers' wet basal globe temperature (WBGT) and thermal work limit (TWL) were the indexes of heat stress used to perform a risk assessment in the work place. Although the WGBT heat stress index exceeded the threshold value, the TWL resulted in an unrestricted area. Inner body temperature,heartbeat, and urine specific gravity values after shift work were increased, and a psychological response was shown by welding workers; the specific symptoms that emerged were excessive thirst and sweating, heat prickle, muscle cramps, and increased pulse rate, temperature, and urine specific gravity. In conclusion, heat stress exposure from press and welding activities affected workers' physiology and psychology.

Keywords: heat stress; manufacture automotive; physiological & psychological response

1. INTRODUCTION

One of thenatural health hazardsin the automotive manufacturing industry is the thermal stress provided by mass engines. Working ina hot environment could lead to heat stress, as thermoregulation fails or is simply inadequate, causing heat-related illness (HRI). HRI can lead to hyperthermia, hyponatremia, heat cramps, heat rash, heat exhaustion, heat stroke, and even death. The symptoms of HRIare thirst, nausea, vomiting, dizziness, excessive sweating, sweat rashes, weakness, elevated body temperature, pain, spasms, and muscle cramps [1, 2].

Heat stress occurs when the environment (air temperature, radiant temperature, humidity, and air velocity), clothing, and activity produce a tendency for elevated body temperature. Other factors, such as an individual's workload, work rate, acclimatization, clothing, hydration, medical conditions, and the environment/climate of the workplace can trigger heat stress.

A measurement used to assess the heat stress index is the wet basal globe temperature (WBGT), an empirical, simple, and practical index used in manufacturing industries. Its weakness isthat it cannot accommodate adirect measure of air velocity, which is an important factor in evaporation/sweating. In addition, the WGBT also requires the estimation of metabolic rates, which could have a margin of error up to 50% [3]. The thermal work limit (TWL) uses five environmental parameters (dry bulb, wet bulb, globe temperatures, wind speed, and atmospheric pressure) and accounts for clothing factors to arrive at predictions of a safe, maximum, continuously sustainable metabolic rate (W m^2) for the conditions [4].

As a premier vendor automotive manufacturer in Indonesia and Asia, PT. XZY'score businesses are the press and welding processes. The flow of process products,such as cutting/stamping raw material, pressing, and welding to deliver parts of automotive components, are conducted in asemi-closed area with a hot environment. This condition causes heat stress among the workers. This study is an attempt to reveal the effect of heat stress exposure onworkers' physiology (increased body temperature, heart rate, and urine specific gravity) and psychology at PT. XYZ.

2. METHODS

The study was conducted in May–June 2016 using a cross-sectional approach to assess exposed and non-exposed workers. Respondents were morning-shift workers who were divided into groups of 35 people. The workers involved needed to meet the study's requirements, such as having worked for 12 months and being free from several illnesses, such as heart, lung, and kidney diseases and diabetes mellitus. The thermal environment was measured by monitor Quest Temp 340, ananemometer for air velocity, which observed workers' metabolic rate and clothing. Physiological monitoring was conducted by measuring workers'body temperature, pulse, and urine specific gravity. Adigital thermometer was used to measure sublingual body temperature, and

Table 1: Results of Temperature, Heartbeat, and Urine Specific Gravity Measurements

	Minimum	Maximum	Mean	p-value
Body temperature(°C) Before shift	36.1	36.8	36.23±0.2	0.0001
After shift	36.3	37.7	36.71±0.3	
Heartbeat, x/min Before shift	80	88	84.40±2.3	0.0001
After shift	83	96	88.29±2.7	
Urine specific gravity after shift Control	1.005	1.030	1.017.71±8.52	0.001
Exposed	1.010	1.030	1.023.86±5.44	

0.5°C was added as a conversion for deep body temperature. Pulse was measured by counting the number of beats for one minute from workers' wrists. Body temperature and pulse measurements were conducted twice, before and after working themorning shift. Urine specific gravity was assessedusing are fractometer after the morning shift. The category of urine specific gravity was divided into well-hydrated <1.010; minimal dehydration 1.010__1.020; significant dehydration 1.021–1.030, and severe dehydration >1.030 [5] Workers' psychological response was assessed by a questionnaire asking workers to describe the effects of heat stress exposure and their symptoms.

3. RESULTS

The TWL index assessed the environmental conditions in the welding and non-welding areas as shown at unrestricted area (TWL > 220 W/m^2). Another study using theTWL index on Iranian construction workers showed 215.8±5.2 W/m^2 for the control group and 144±9.8 W/m2 for the exposed group (Montazer et al. 2013). Interestingly, the WBGT index results from the welding area had excessive values, of 29.22°C, air humidity of 64.83%, and an air velocity of 2.67 m/s, while the non-welding/office area did not exceed the threshold value of 24.6°C and had an air velocity of 0.8 m/s.

Table 1 shows the physiological effects of exposed workers, i.e., body temperature, pulse, and urine specific gravity.

In theexposed group, the occurrence of symptoms was as follows: 29 workers (82.8%) reported suffering from thirst, 18 workers (51.4%) from excessive sweating,11 workers (31.4%) from muscle cramps 12 workers (34.3%) from a heat rash, and 13 workers (37.1%) experienced headaches and dizziness. The symptoms emerging in the non-exposed area were thirst (10 workers, 28.6%), excessive sweating (4 workers, 11.4%), and frequent urination (18 workers, 51.4%). The results are shown in Figure 1.

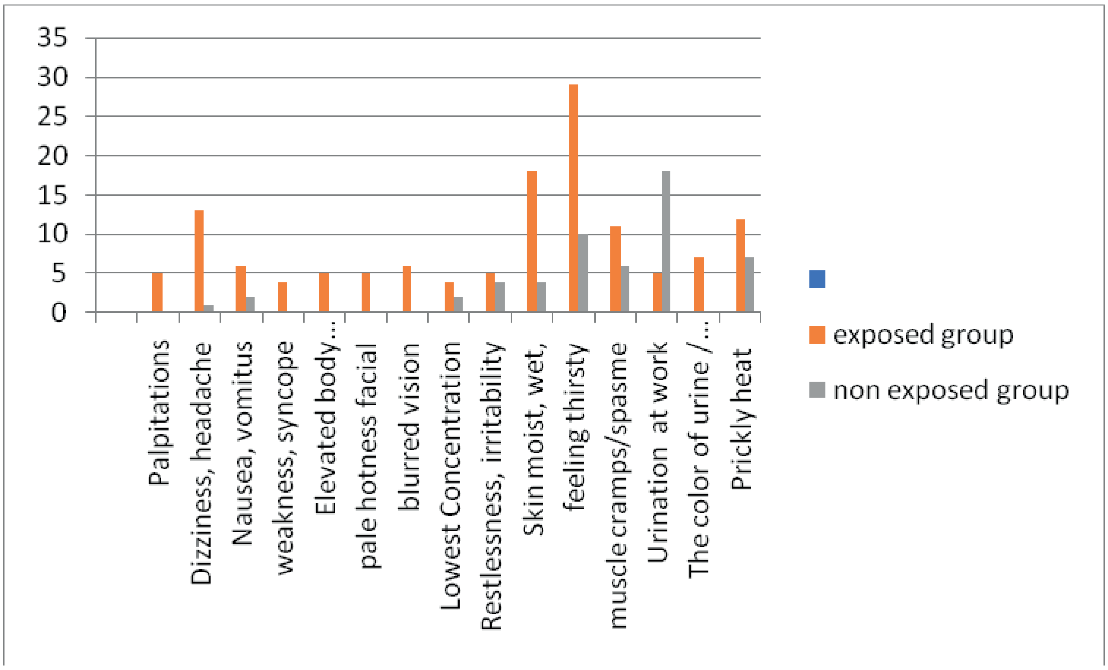

Figure 1: Percentage of subjective complaints among the exposed and non-exposed groups.

4. DISCUSSION

The source of heat exposure leadingto heat stress among workers at PT. XYZ was 200 welding machines in a 400 m^2 semi-closed area. Using the available information on WBGT in the environment and workload, work rate exposed area index exceeded the threshold value.TLV ACGIH permitted allocations of work in a cycle of work and recovery 75–100%, moderate work load for acclimated workers 28°C, and their action limit for unacclimated workers, moderate work load was 25°C.

Humidity, the amount of water vapor within a given space, was relatively humid. Humidity was important as a temperature-dependent expression of the actual water vapor pressure, which is the key factor affecting the heat exchange between the body and the environment by evaporation.The higher the water vapor pressure, the lower the evaporative heat loss will be (2). The wind speed produced air velocity, which decreased workers' body temperature. There were blowers and exhaust fans in the welding area to control heat stress exposure. Masks, helmets, shielding clothing, and safety glasses, were used to reduce radiant heat. The TWLwas designed for self-paced, hydrated, and acclimatized workers. The TWLwas an integrated measure of the dry bulb, wet bulb, wind speed, and radiant heat. From this variable, type of clothing worn, and acclimatization state of the worker, the TWL predicted the maximum level of work that could be carried out in a given environment, without workers exceeding a safe core body temperature and sweat rate.In excessively hot conditions, the index could also determine the safe work duration, thus providing guidelines for work/rest cycling. Sweat rates were also calculated so that the level of fluid replacement necessary to avoid dehydration could be established. The TWL could usean online calculator by inserting specific measurement results that would present the TWL values. The higher the number, the higher the sustainable work rate in terms of thermal.Remarkably, the TWL results in exposed and non-exposed areas were in the unrestricted zone that had no limit on work due to thermal stress. The wind speed in the welding area was 2.67 m/sec and presented air movement indicating aheavy breeze (e.g., located close to a fan; air causing marked movement of clothing).

When a human body is exposed to thermal stress, either external environmental stress or internal metabolic stress, it will attempt to maintain heat balance using a number of thermoregulatory mechanisms. It will use every option available to transfer the internal energy to the outside environment. These transfer methods are a body's thermoregulatory response [3]. When analyzing the physiological effects of heat stress, under conditions of heat stress the body absorbs and/or produces more heat than it can dissipate, which meansworkers experience negative health effects. Acclimatization to heat stress increases workers' tolerance to work in heat and lowers their risk of developing heat illness. When workers' acclimatization increases, it results in a more efficient sweating mechanism, greater sweat production, lower electrolyte concentration, and a concomitant stabilization of the circulation, with a much lower core temperature and heart rate. All respondents in this study have acclimatized.

The body temperature measurement results were not higher than 38°C, which is under the threshold value according to TLV ACGIH 2016. Elevated core temperature is one of thermoregulatory mechanisms through sweating and heat loss via evaporation.

The heart rate can be estimated by palpitation of theartery near the surface so that the pulse can be felt by the fingertips. Workers could measure their own heart rate using this method prior toand after ashift. One method of the recovery of the heart rate proposes that one minute after sitting down, the heart rate be at or below 110 beats per minute (bpm). Another method recommends that the heart rate at three minutes be below 90 bpm. The workers' pulse at PT. XYZ was below the threshold value, indicating their physiological regulatory mechanism to heat stress exposure. When the body temperature is elevated, the hypothalamus responds by setting point autonomic nervous system's equilibrium system. The pulse measurement results in PT. XYZ workers did not exceed the threshold value limit, in which acclimatized workers could adapt physiologically to exposed heat stress.

In urine specific gravity measurement, 12 workers were in the significant dehydration category (1.021–1.030), which means they would need to consume a minimum of 1.5 liters of water to prevent dehydration.

The exposed groups experienced more heat stress exposure than the non-exposed groups. The symptoms that emerged due to the exposure were excessive sweating, dizziness, muscle cramps, palpitations, and excessive thirst.The results also indicate a increase in the body temperature, heart rate, and urine specific gravity [2, 6]. Previous study stated that experiencing symptoms of heat illness may not indicate actual cases of heat illness, as it may suggest a high degree of heat strain [7]. Physiologically, the systems of the body are struggling to meet the demands of thermoregulation. Heat stress can be managed by providing education and health promotion related to heat-related illnesses.

5. CONCLUSIONS

Heat stress exposed affected the physiological and psychological condition of PT. XYZ's workers. WBGT index result show exceeds the threshold value. Using TWL is greatly recommended for later research to measure heat stress index and monitor workers' physiological condition.

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References

[1] Brake DJ. The Deep Body Core Temperatures, Physical Fatigue and Fluid Status of Thermally Stressed Workers and the Development of Thermal Work Limit as an Index of Heat Stress Derrick John Brake. 2002;

[2] Jacklitsch B, Williams J, Musolin K, Coca A, Kim J-H, Turner N. Criteria for a Recommended Standad: Occupational Exposure to Heat and Hot Environments. NIOSH Publ. 2016;

[3] Brown EN. Evaluation of Heat Stress and Strain in Electric Utility Workers [Internet]. University of California, Los Angeles; 2013. Available from: http://escholarship.org/uc/item/3pj937jm

[4] Bates GP, Schneider J. Hydration status and physiological workload of UAE construction workers: A prospective longitudinal observational study. Vol. 3, Journal of Occupational Medicine and Toxicology (London, England). 2008. p. 21.

[5] Armstrong LE. Assessing hydration status: the elusive gold standard. J Am Coll Nutr. 2007 Oct;26(5 Suppl):575S–584S.

[6] Brake DJ, Bates GP. Limiting metabolic rate (thermal work limit) as an index of thermal stress. Appl Occup Environ Hyg. 2002 Mar;17(3):176–86.

[7] Hunt A, Stewart I, Parker T. Dehydration is a Health and Safety Concern for Surface Mine Workers. 2017;