Conference Paper

Effect of Heat Stress on Body Weight, Blood Pressure, and Urine Specific Gravity among Underground Miners in PT X 2015

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Abstract

Underground miners are often exposed to thermal stress hazards in the workplace. The closed conditions, heavy workload, and limited ventilation are common causes of high environmental temperatures. Thermal stress can influence the metabolism and physiological function of human body. The objective of this study was to investigate underground mine workers' thermal stress levels and to assess its effect on their physiology (blood pressure, urine specific gravity, body weight, and heart rate). This study was an observational cross-sectional study of a sample of 42 underground miners. The heat stress level in the study location was 147.14 Wm2 and categorized as an unrestricted zone. This study showed that urine specific gravity, systolic and diastolic blood pressure, and heart rates among underground miners change after shift work, while no transformation of body weight was observed. In summary, heat stress exposure affects urine specific gravity, blood pressure, and heart rate.

Keywords: Heat Stress, Body Weight, Blood Pressure, Systole, Diastole, Urine Specific Gravity, Underground Miners

1. INTRODUCTION

As is the case with many industries, workers in the mining, construction, manufacturing, and agricultural industries are exposed to health hazards. In the mining environment, underground mine workers are at risk of exposure heat stress. The conditions are high-risk and caused by a closed environment, the activity of the work, geothermal resources, and a lack of ventilation or air conditioning, resulting in high ambient temperatures and heat stress [5].

The heat sources in the mines are largely the result of environmental factors, such auto-compression. Due to auto-compression, the air temperature can increased by about 10° C in every depth underground because of the poor thermal conductivity of the rock, which blocks heat transfer. Low air movement and high humidity reduce the body's ability to dissipate heat through natural evaporation processes.

The underground environment has high temperatures and is marked by strenuous work activities that can lead to health problems such as heat-related Illnesses like dehydration Research among Australian underground miners working at an ambient temperature of 36.2°C showed that 60% of workers were in some state of dehydration [3]. Exposure to heat stress can influence metabolism and physiological condition through the adaptation of the body, such as changes in blood pressure, urine specific gravity, body weight, and heart rate. In addition, heat stress conditions have an influence on other factors, such as stress levels, workers' health conditions, alcohol consumption, and the adequacy of rest [6].

Heat stress can be brought on by a combination of environment (air temperature, radiant temperature, humidity, and wind speed), clothing, and labor activity, all of which interact to produce heat that increases body temperature. Heat stress occurs when workers are engaged in physical activity continuously in a hot environment [8]. Heat stress can also cause the body to become fatigued and distressed, and extreme heat conditions can decrease work productivity, increasing the risk of accidents and heat-related disorders.

Managing and controlling for exposure to heat stress involves the identification of hazards using the Thermal Work Limit (TWL) measurement method. The TWL is one of several heat stress index assessments currently being developed for workplace settings, and especially for underground mines. The TWL provides for maximum levels of heat stress in the workplace, as it is a valid index of heat stress and be applied as a strategy for controlling heat stress [6].

With the above in mind, we studied heat stress in an underground mine at PT 'X' to determine the level of TWL in miners underground and to measure the physiological effects (blood pressure, urine specific gravity, body weight, and heart rate) on miners working underground and exposed to heat stress.

2. METHODS

2.1. Subjects

The subjects of this study were 42 underground mine workers at PT X (mean age: 35.67 ± 4.89; length of career: 3.68 ± 0.84 years). The research subjects were also evaluated by education level, smoking status, and fluid consumption. This study was conducted at underground mine "T" PT.X for two months, from April through June 2015.

2.2. Measurement

Heat stress index measurements were taken using WBGT Quest Temp 34°C (wet-bulb temperature, dry bulb temperature, globe temperature, RH, and the humidity). Wind speed measurements were made using a thermal anemometer. TWL measurements were made using the Kestrel 4400 Heat Stress Meter and calculated using an online TWL calculator (http://www.haad.ae/Safety-in-Heat/Default.aspx?tabid=63). Blood pressure measurements were taken using a sphygmomanometer. Body weight was measured with a digital scale, and measurement of urine specific gravity was accomplished with a refractometer pen.

2.3. Data Analysis

Statistical analysis was performed to determine the effect of heat stress exposure to changes in blood pressure, pulse, urine specific gravity, and body weight before and after work using two different test means (paired sample t-tests) with $p < 0.05$.

3. RESULTS

3.1. Workers' Characteristics

Table 1 explains the characteristics of the underground mine workers based on age, education, length of career, smoking status, and fluid consumption.

3.2. Distribution of Mine Workers' Underground-Based TWL

The average TWL in the underground mine area was 147.14 (SD: 6.31) and categorized as low risk (unrestricted zone). In Table 2, we can see the categories of work zones. The results show 42 locations' TWL for underground mine workers; the low-risk category (unrestricted zone) has the most, with 28 locations (66.7%).

Table 1: Characteristics of Underground Mine Workers.

Characteristic	Classification	Number (n)	%
Age	< 31 year	8	19.0
	>31 year	34	81.0
Education level	University	3	7.1
	High school	39	92.9
Length of career	3 years	23	54.8
	4 years	9	21.4
	5 years	10	23.8
Smoking status	Non-smoker	9	21.4
	Smoker	33	78.6
Daily water consumption	< 3000 mL	5	11.9
	3000 – 6000 mL	34	81.0
	> 6000 mL	3	7.1

Table 2: Distribution of TWL Scores among Underground Mine Workers.

Work Zones	TWL	Number	
		n	%
Low Risk	140– 220	28	66.7
Medium Risk	115–140	14	33.3

3.3. Physiological Effects

Table 3 shows the average of miners' urine specific gravity, blood pressure, heart rate, and body weight before and after working. The average number of urine specific gravity is 1008.81 ± 5.23, with no significant differences after working, though the average number after work did increase. The average systolic and diastolic blood pressure after working showed a decrease, compared to before-work levels. The average workers' weight did not change before or after work.

Table 3: Distribution of Urine Specific Gravity, Blood Pressure, Heart Rate, and Body Weight Before and After Work among Underground Mine Workers.

	Before		After	
Variable	(*Mean* ± SD)	Min–Max	(*Mean* ± SD)	Min–Max
Specific Gravity Urine	1008.81 ± 5.23	1001–1019	1012.76 ± 5.01*	1005–1023
TD systolic	109.76 ± 12.4	90–140	91.67 ± 11.02*	70–120
TD diastolic	74.05 ± 6.65	60–90	65.95 ± 6.27*	60–80
Heart rate	77.76 ± 8.34	64–96	92.14 ± 9.15*	76–112
Body weight	69.12 ± 8.61	56–95.9	68.86 ± 8.45	55.4–95.1
* p<0.01				

There was a significant change in urine specific gravity, systolic and diastolic blood pressure, and heart rate before and after workers were exposed to heat stress.

3.4. Relationship of TWL with Urine Specific Gravity, Blood Pressure, Heart Breath, and Weight Loss on Mine Workers Underground

Relation of TWL with urine specific gravity, blood pressure, heart breath and body weight on the underground mine workers using linear regression were shown in table 4.

Table 4: Relationship between TWL and Urine Specific Gravity, Blood Pressure, Heart Rate, and Body Weight in Underground Mine Workers.

Variable	Correlation coefficient *R*
Specific Gravity Urine	0.012
BP systolic	0.186
BP diastolic	0.032
Heart rate	0.036
Body weight	0.237

As Table 4 indicates, the value of the correlation coefficient (R) of each variable is weak, so we can conclude that the relationship between TWL and urine specific gravity, systolic, diastolic blood pressure, heart rate, and body weight are in the weak category.

4. DISCUSSION

The results of TWL measurements in underground mine workers shows the low-risk category (the unrestricted zone) to be the most prevalent, with 28 locations (66.7%), and the rest in the medium-risk category (the cautionary zone). The average TWL for underground mine sites is in the low-risk category, where workers are safe to engage in all types of work, whether light or heavy.

In regard to the average weight of the urine specific gravity, according to before and after work measurements, the statistical test showed that there was a significant change between the two samples. However, both the before and after work levels were still within safe limits. The safe limit for the specific gravity of urine before the start of the work is no more than 1.015, and at the end of the shift or after work, it is no more than 1.029.

These results indicate that the specific gravity of urine after work is greater than the specific gravity of urine before work. This is in accordance with study on lumberjacks, which examined the amount of urine specific gravity when temperatures increased [1]. That study also determined the specific gravity of urine to be a good marker for assessing workers' levels of dehydration.

Statistical test results showed that there is a significant relationship between workers' blood pressure changes before and after work. However, the results of the present study showed that the average blood pressure was higher during and after work. This is not in accordance with the study which indicated a strong relationship between heat stress with blood pressure, where the higher the pressure, the greater the heat and higher the systolic and diastolic levels [2, 4, 9].

Exposure to high heat stress can also cause additional load on the circulation of the blood, since the blood has to carry oxygen to the working muscles. Blood must also carry heat from the body to the skin's surface. This can be an additional burden for the heart to pump more blood, so blood pressure will be increased.

Statistical tests showed a significant difference between pulse pressure (heart rate) among workers before and after working. It is known that, on average, a higher pulse during and after work, or after working, is the result of exposure to heat stress in the underground mines, as compared to the time before starting work. These results are consistent with the research which shows that a person's heart rate will continue to increase if his or her body temperature rises. Increased body temperature is one result of heavy physical work in a hot environment [7].

Our statistical tests revealed no significant difference between workers' weight before and after working. Some small differences were observed; with the average weight of workers during and after work being lower than their average weight before work. Weight loss caused by a loss of body fluids after exposure to heat stress may explain this.

5. CONCLUSION

Based on this research, we can conclude that heat stress in the underground mine "T" PT X is relatively low risk (making it an unrestricted zone), so that workers can safely perform light or heavy work activities. Only a few locations ere classified as medium risk. Further, we observed significant physiological changes in the underground mine workers after working or being exposed to the dangers of heat stress. These physiological changes, among others, included increased urine specific gravity, weight loss, and increased heart rate.

Though the working conditions of this underground mine were classified as low and medium risk, a control study remains to be done. A control can be used to educate workers or the promotion of health and safety, and improving engineering, such as improving underground ventilation, monitoring heat stress in the work environment, and to continuing to ensure that workers have adequate fluid intake before starting work each day.

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