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EFFECT OF THERMAL STRESS ON URINE SPECIFIC GRAVITY, BLOOD PRESSURE, AND HEARTBEAT AMONG UNDERGROUND MINERS

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Abstract

Underground miners highly exposed to thermal stress hazard. Closed condition, heavy work load, and limited ventilation are the common cause of high environment temperature in underground mining. Thermal stress can influence metabolism and physiological function of human body. The objective of these study is to investigate the effect of thermal stress to physiological (bodyweight, blood pressure, urine specific gravity, and heartbeat) of underground miners. This study is observational cross sectional study with 42 underground miners. Thermal stress level is 147.14 Wm^2 and categorized as unrestricted zone. These study showed that urine specific gravity, blood pressure, and heart beat on underground miners were change after shift work, while the body weight changes were not observed. The relation among TWL with blood pressure, urine specific gravity, and heartbeat is low category.

Introduction

In various industry, groups of worker in mining, construction, manufacture and farming are exposed to occupational health hazard. On mining environment, one of work that risked to be exposed by thermal stress is underground miners. The high risk is caused by convined environment condition, heavy work activity, geothermal source, lack of ventilation or air conditioning thus causing high ambient temperature and thermal stress (Donoghue, 2007).

Heat source on mining come from environment factor, like auto-compression which has been a main heat source, for every depth underground, temperature could increase around 10^{o}C. This is caused by bad heat conductor from the rocks so that the heat transfer is hampered. Low air transfer and high humidity reduce body ability to release body heat through evaporation.

Underground environment having high ambient temperature and heavy work activity could result a health disorder called Heat Related Ilness (HRI), such as dehydration. The research in Australia on underground miners with ambient temperature 36.2°C indicates that 60% miners begin to work in dehydrated condition already. The hazardous exposure of thermal stress could also affect metabolism and physiologic as body adaptation form, like the change of blood pressure, urine specific gravity, body weight and heart beat. Beside, the condition where the thermal stress emerge

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is affected by other factors like stress level, health condition, alcohol consumption and rest sufficiency (Bates, 2007).

Thermal stress or heat stress is a combination of environment (temperature, radiant temperature, humidity and wind velocity), apparel and worker's activity, which interact each other to generate heat that will increase body temperature. Thermal stress is emerged when the worker is performing consecutive physical activity in high temperature working environment (Pancardo, 2015). Thermal stress could also ignite body's fatigue and distressed. Where in extreme high temperature environment condition could decrease productivity, increase risk of accident and increase risk of heat-related disorders (Wu, 2017).

The early management of heat stress exposure management is hazard identification with Thermal Work Limit (TWL) measurement method that currently developed for measurement of work environment heat sress index particularly on underground mine. TWL is a valid thermal stress index and become an applicable strategy on work place to control heat stress (Bates, 2007). TWL, which is also a thermal stress reference standard for underground mine in Australia, can describe and more proper as heat stress indicator (Brake, 2004). Therefore, a research is conducted on one of "X" Ltd. Underground mine to find out effect of TWL level to physiological change (bodyweight, blood pressure, urine specific gravity, and heartbeat) on underground miner due to thermal stress exposure while working (Afify, 2016; Chen, 2017).

Method

Subjects of this research were 42 underground miners on "X" Ltd. The research subjects were also considered based on education, smoking habit, rest duration while working and amount of liquid consumed. This research was conducted for two months from April to June 2015.

The measurement of thermal stress index is conducted in the work environment by WBGT Quest Temp 34° which mean *wet-bulb temperature, dry bulb temperature*, *globe temperature, RH,* and *humidity.*Then the TWL is calculated using Kestrel 4400 Heat Stress Meter and by calculator on web http://www.haad.ae/Safety-in-Heat/Default.aspx?tabid=63. TWL uses five environment parameters (*dry bulb, wet bulb, globe temperature*, wind velocity and atmosphere pressure) and acomodate apparel factor to determine maximumg safety prediction and advanced metabolism level. The wind velocity is measured by thermo anemometer device. Blood pressure is measured by *Sphygmomanometer* (Tensionmeter)**.** Body weight scaling by digital scale and urine specific grafity is measured by pen refractometer.

Statistic analysis is conducted to find out the effect of termal heat esposure to blood pressure, heart beat and urine specific gravity before and after work by *paired sample* T-test with $p<0.05$, and also correlation test between TWL with blood pressure, heart beat and urine specific gravity by using linear regression.

Result and Discussion

Table 1 describes of miners by age, education, working period, smoking habit, rest time while working and amount of liquid consumed.

From table 1 can be seen that most of the underground miner age more than 31 years old (81%) with last education high school graduate (92.9%). Working period mostly less than 3 years (54.8%). Most of the workers smoke (78.6%) and daily liquid consumption 3000-6000mL (81%).

Age factor is related with dehydration, this is aligned with Agus Burhan research on RBH Ltd. Mentioning body resistance will adapt the heat environment and workers ages >31 years old will have a decrease in body hidration quality. Worker's education influence the knowledge level considering the hazard on working environment particularly physical hazard which is thermal stress. Working period indicate exposure period on work place. The longer working in one place then the more risk of environment exposure whether physically, chemically, biologically, etc. One with 5 years working periods will have more risk to be infected by a disease causing by working in heat environment compare to one with 3 year working periods. Amount of liquid consumed should be consider while working in heat environment, more intense drink frequence is highly recommended. According to Bates

Table 1. Characteristics Distribution of Underground Miner

Characteristics (Mean ± SD)	Classification	Numbers (n)	Percentage (%)
Age (35.67 ± 4.897)	< 31 years	8	19
	> 31 years	34	81
Education	University	3	7.1
	High School	39	92.9
Working Period (3.68 ± 0.841	3 years	23	54.8
	4 years	9	21.4
	5 years	10	23.8
Smoking Habit	No Smoker	9	21.4
	Smoking	33	78.6
Amount of Liquid Consumed	< 3000 mL	5	11.9
	3000-6000 mL	34	81
	> 6000 mL	3	7.1

Source : Primary Data

related with heat stress arrangement and victim management, worker exposed to thermal stress more than 30°C and average work activity should get liquid intake as much as 700 mL per hour. The sufficient liquid intake will stabilize blood pressure condition and hear beat of the worker.

The thermal stress index is stated in *Thermal Work Limit (TWL)*, it is noted that average TWL in underground mine area is 147,14 ± 6,31. It is cathegorized as *low risk* (*unrestricted zone*). On table 2, can be seen the TWL based on working zones cathegory. From the measurement of TWL for 42 location of underground miner, indicate that mostly is in *low risk* (*unrestricted zone*) with 28 location (66,7%) and the rest is *medium risk (cautionary zone)*. On *low risk* (*unrestricted zone*) condition there is no limitation for miner on the areas since they still cathegorized as safe condition, the miner work with light work load (sit or stand with lower arm work and light) is recommended to consume 600-1000 mL liquid per hour, miner is recommended to take a break while uncomfortable feeling occured. This is to keep the miner safe and comfort on the work area every day.

Table 2. Distribution of Underground Miner Based on TWL

Working Zones	TWL	Numbers	
		n	%
Low Risk	140-220	28	66.7
Medium Risk	115-140	14	33.3
Total		42	100

Source : Primary Data

On Table 3 indicates point of urine specific gravity, blood pressure, heart beat and body weight of underground miner before and after work. The average of urine specific gravity after work showed significant difference. It is increased compare to before work. The average of sistolic and diastolic blood pressure after work indicate a decrease compare to before work. However, the average number of body weight does not change before and after work.

Based on average urine specific gravity before and after work on underground miner, statistic test result indicate there is significant relation between worker's urine specific gravity before and after work. Yet, the urine specific gravity whether before and after work still in safety margin. Based on Abu Dhabi EHSMS Regulatory (2013), safety limit for urine specific gravity before the work shift start is not more than 1.015 and by end of work shift or after work is no more than 1.029.

This research result shows that urine specific gravity after work is higher than

Table 3. Distribution of Underground Miner Based on Urine Specific Gravity, Blood Pressure, Heart Beat and Body Weight Before And After Work

	Before		After	
Variable	**(*Mean* ± SD)**	**Min - max**	**(*Mean* ± SD)**	**Min - max**
Urine Specific Gravity	1008.81 ± 5.23	1001 - 1019	1012.76 ± 5.01*	1005 - 1023
Blood Pressure Sistolic	109.76 ± 12.4	90 - 140	91.67 ± 11.02*	70 - 120
Blood Pressure Diastolic	74.05 ± 6.65	60 - 90	65.95 ± 6.27*	60 - 80
Heart Beat	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

* $p<0.05$
Source : Primary Data

before work, as researched by Bates (2001), on lumberjack worker, showed the increase of urine specific gravity during the increase of thermal stress. Bates' (2001) research, also showed that urine specific gravity is a valid indicator for one hydration level. To avoid dehydration, then there should be correction to worker hydration status by providing drinking water on work area to replace lost liquid with drinking water temperature 10-15°C (WorkSafe, BC).

The statistic test indicate there is significant relation between miner's blood pressure before and after work. Yet, on this research showed that average blood pressure is lower than after work. There is strong relation between thermal stress with blood pressure, where the higher the thermal stress then the higher sistolic and diastolic blood pressure.

Beside, the exposure of high thermal stress can bring additional load to blood circulation, since blood must carry the heat from inside the body to the skin surface, therefore it will be additional load for the heart to pump more blood, so the blood pressure increase (Muflichatun, 2006).

Statistic test indicates that there is significant difference between miner heart beat before and after work. It can be known that average heart beat is higher after work or after the miner exposed by thermal stress in underground mine, compare to before work. This is aligned with research by Muflichatun (2006), showed that one heartbeat will increase if body temperature increase. The increase of body temperature one of the reason is due to perform heavy physical work under heat environment. In this case, underground miner performs a heavy physical work within heat environment.

Statistic test indicates there is no significant difference between miner's body weight before and after work. It can be caused by the small of margin of average body weight before and after work. Where miner average body weight after work is lower than before work. This is due to loss of body liquid caused by thermal stress exposure.

The statistic test between TWL with urine specific grafity, blood pressure, heart beat and body weight of underground miner by linier regression test.

Based on table 4, coefficient correlation value (R) on every variable is weak. This showed that relation between TWL with urine specific gravity, blood pressure sistolic, blood pressure diastolic, heart beat and body weight is in weak cathegory indicating that thermal stress in this

Table 4. Relation between TWL with Urine Specific Gravity, Blood Pressure, Heart Beat and Body Weight of Underground Miner

Variable	R
Urine Specific Gravity	0.012
Blood Pressure Sistolic	0.186
Blood Pressure Diastolic	0.032
Heart Beat	0.036
Body Weight	0.237

Source : Primary Data

case TWL does not significantly affect to the change of urine specific gravity, blood pressure sistolic, blood pressure diastolic, heart beat and body weight. It can be caused by several factors, like:

1. Acclimatization

For miner working in heat stressed underground mine for years, the body will be acclimatized. With working climate (ISBB) 30.08°C and 27.75°C then the body will feel heat. Perspire is body respon to heat condition. Acclimatization is a physiology adaptation process marked by increasing perspire while heart beat, blood pressure and body temperature are decreasing.

2. Drinking Water Consumption

Perspiring or sweating is a natural body mechanism to decrease body temperature. On the process, body liquid lossing. As the result, it become dehydration. Liquid intake that insufficient to the requirement could be caused by drinking habit. Based on the research result, 88.1% miners drink 3000 – 6000 mL of water while 11.9 % still drink less than 3000 mL. The worker in heat environment should consider to drink more frequent. Though having adequate water intake, light dehydration still able to be experienced. So one should consider the requirement of water and mineral as the replacement of liquid coming out from the body. The awarenes of the importance to consume water for worker is very important since it will affect the health of worker it self.

3. Temperature in Underground Mine Working Area

Underground mine working area has a very high temperature reaches between 30 - 34°C. This is one of the obstacles in this research due to the hot water source in underground mine that the temperature relatively change along with production activity and type of the rock that include in heat rock. Temperature regulation on underground working area is assisted by natural and artificial ventilation system and additional fans / chiller which is the low temperature area in underground mine as well as temperature routine inspection.

4. Miner Awareness in Dehydration Test

Work health program for the miner particularly to identify worker hydration status has been applied. This program affect miner to routinly check the urine before and after work. Yet wit not so high awareness make this program oftenly ignored by miner.

Conclusion

Based on the research, can be concluded that thermal or heat stress in underground mine work area is still categorized as *low risk* (*unrestricted zone*), where the miners are safe to perform heavy or light work activity, while only some location is medium risk. Beside, there are significant physiologic changes on underground miner after work and exposed by thermal stress hazard, like the increase of urine specific gravity, decrease of blood pressure and increase of heartbeat.

With underground mine work environment that consider as *low risk* and *medium risk*, still it should be controlled. The control that can be done ia: worker education or work health and safety promotion, engineering design such as underground ventilation improvement, thermal stress monitoring on work environment, and ensuring the worker to have sufficient liquid intake before begin to work.

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