UNIVERSITI PUTRA MALAYSIA

ASSOCIATION BETWEEN EXTREME HEAT EXPOSURE AND ACUTE PHYSIOLOGICAL CHANGE AMONG STEEL MILL WORKERS IN TERENGGANU, MALAYSIA

NURUL ATIKAH BINTI CHE HASAN

FPSK(m) 2015 47

ASSOCIATION BETWEEN EXTREME HEAT EXPOSURE AND ACUTE PHYSIOLOGICAL CHANGE AMONG STEEL MILL WORKERS IN TERENGGANU, MALAYSIA

By

NURUL ATIKAH BINTI CHE HASAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fullfiment of the Requirements for the Degree of Master of Science

April 2015

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

ASSOCIATION BETWEEN EXTREME HEAT EXPOSURE AND ACUTE PHYSIOLOGICAL CHANGE AMONG STEEL MILL WORKERS IN TERENGGANU, MALAYSIA

By

NURUL ATIKAH BINTI CHE HASAN

April 2015

Chair : Assoc. Prof. Shamsul Bahri Mohd Tamrin, PhD
Faculty: Medicine and Health Science

A heat stress problem is one of the physical hazards that encountered tropical countries such as Malaysia. Most of steel mill workers were exposed to hot working condition in a different work process. The aim of present study was to identify the predicting factors of Acute Health Score (AHS). About 220 confirmed male workers were participating in this study. The WBGT index during work varied from 27.6°C to 36.2°C. All of the work stations monitored had temperatures regularly exceeded the Threshold Limit Values (TLV) of heat stress recommended by ACGIH. The most common acute health effect among the workers included heat fatigue (96.8%), lethargic (90%), dizziness (82.3%), heat cramp (58.6%), unstable movement (48.2%), and heat rashes (44.5%). The respondents were classified in a heavy metabolic workload based on their work task analysis. The physiological changes shows the significant differences of body core temperature ($p<0.001$), systolic blood pressure ($p<0.05$) and heart rate ($p<0.05$) before the shift starts, 2 hour of shift and at the end of the shift. The results from the study shows there was no significant correlation between WBGT Index and physiological changes of body core temperature ($r=-0.23$, $p=0.34$), systolic blood pressure ($r=0.09$, $p=0.71$), diastolic blood pressure ($r=0.17$, $p=0.5$) and heart rate ($r=0.23$, $p=0.36$). The results from the study also shows there was no significant correlation between WBGT Index and acute health score ($r=-0.5$, $p=0.86$).The regression analysis suggested sweating ($p<0.05$), age ($p<0.05$), duration of heat exposure (hours) ($p<0.001$) and rating of perceived exertion (RPE) ($p<0.001$) are the predictors factors of acute health score (AHS). The finding in this study concluded that steel mill plant considered as a hot workplace area since most of their workplaces were exceed the acceptable temperatures, 28.2°C according to (ACGIH) Threshold Limit Value (TLV). The high prevalence of acute health symptoms among the steel mill workers were heat fatigue, lethargic, dizziness, heat rashes, heat cramp and unstable movement.

Keywords: heat stress, acute health score, physiological changes, steel mill

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PERHUBUNGAN ANTARA PENDEDAHAN HABA EKSTRIM DAN PERUBAHAN AKUT FISIOLOGIKAL DI KALANGAN PEKERJA KILANG BESI KELULI DI TERENGGANU, MALAYSIA

Oleh

NURUL ATIKAH BINTI CHE HASAN

April 2015

Pengerusi: Professor Madya Shamsul Bahri Mohd Tamrin, PhD
Fakulti : Perubatan dan Sains Kesihatan

Masalah tegasan haba merupakan salah satu daripada bahaya fizikal yang dihadapi oleh Negara tropika seperti Malaysia. Kebanyakan pekerja kilang besi dan keluli terdedah kepada kepada keadaan panas yang ekstrim dalam proses kerja yang berbeza. Tujuan kajian ini adalah untuk mengenalpasti faktor-faktor yang menyumbang kepada skor kesan akut kesihatan (AHS). Kira-kira 220 pekerja lelaki mengambil bahagian dalam kajian ini. Hasil kajian mendapati indeks dalaman WBGT semasa kerja berada dalam kadar 27.6°C hingga 36.2°C. kesemua stesen mempunyai nilai WBGT index melebihi nilai ambang had (TLV) yang disyorkan oleh ACGIH. Kesan kesihatan akut paling ketara termasuklah keletihan haba (96.8%), lesu (90%), pening (82.3%) kekejangan haba (58.6%), pergerakan yang tidak stabil (48.2%) dan juga ruam haba (44.5%). Responden telah dikelaskan dalam beban kerja yang sangat berat berdasarkan beban kerja mereka. Hasil kajian menunjukkan perbezaan yang signifikan terhadap perubahan fisiologikal suhu badan teras ($p<0.001$), tekanan darah sistolik ($p<0.05$) dan degupan jantung ($p<0.05$) sebelum shif bermula, 2 jam selepas shift bermula dan selepas tamat syif. Hasil kajian juga mendapati tiada perkaitan yang signifikan antara Indeks WBGT dan perubahan fisiologikal suhu badan teras ($r=-0.23$, $p=0.34$), tekanan darah sistolik ($r=0.09$, $p=0.71$), tekanan darah diastolic ($r=0.17$, $p=0.5$) dan degupan jantung ($r=0.23$, $p=0.36$). Hasil kajian juga mendapati terdapat Indeks WBGT tidak mempunyai perkaitan dengan skor akut kesihatan ($r=-0.5$, $p=0.86$). Analisis regresi mendapati umur ($p<0.05$), berpeluh ($p<0.05$), tempoh terdedah kepada haba panas (jam) ($p<0.001$) dan rating pengerahan tenaga (RPE) ($p<0.001$) merupakan faktor-faktor yang menyumbang kepada skor akut kesihatan. Hasil kajian ini merumuskan bahawa kilang besi dan keluli dianggap sebagai kawasan tempat kerja yang panas kerana kebanyakan stesyen kerja mereka melebihi suhu yang telah ditetapkan oleh ACGIH (28.2°C). Gejala Kesihatan akut yang di kalangan pekerja yang dicatatkan adalah termasuk keletihan haba, lesu, pening, ruam haba, kekejangan haba dan pergerakan tidak stabil.

Kata kunci: tegasan haba, skor akut kesihatan, perubahan fisiologi, kilang besi keluli

ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious and the Most Merciful. Alhamdulillah all praises to Allah for the strengths and His blessing in completing this thesis. Secondly, I would like to thank to my dedicated supervisor, Associate Professor Dr Shamsul Bahri B. Hj Mohd Tamrin for his supervision and constant support. His invaluable help of comments and suggestions throughout the thesis works have contributed to the success of this research.

Not forgotten, a very big thank you also to my supervisory committee, Associate Professor Dr Ahmad Makmom B. Abdullah and Dr Sharifah Norkhadijah Bt Syed Ismail for their time and valuable feedback on my thesis.

I owe a great debt of gratitude to Ministry of Education (MyBrain Master), UPM Graduate Research Fellowship Scheme (GRF) and UPM Research University Grant Scheme (RUGS) for providing financial assistance and research grant which buttressed me to perform my work comfortably.

I am deeply thankful to my family especially to my beloved parents, Hj Che Hasan and Hjh Puan Zahrah and also to my siblings for their continuous support, prayers and encouragement. Special thanks go to my beloved husband Mohd Zul Fareez for his patience, love, and understanding through the good and bad times. Without them, this thesis would never have been written.

Last but not least, it is a pleasant task to express my thanks to all those who contributed in many ways to the success of this study and made it an unforgettable experience for me.

This thesis was submitted to the senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of Supervisory Committee were as follows:

Shamsul Bahri Mohd Tamrin, PhD
Associate Professor
Faculty of Medicine and Health Science
Universiti Putra Malaysia
(Chairman)

Ahmad Makmom Abdullah, PhD
Associate Professor
Faculty of Environmental Studies
Universiti Putra Malaysia
(Member)

Sharifah Norkhadijah binti Syed Ismail, PhD
Senior Lecturer
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Member)

____

BUJANG KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:
This thesis is my original work;

- quotations, illustrations and citations have been duly referenced;
- This thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by University Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: ________________________ Date: ____________

Name and Matric No: Nurul Atikah Binti Che Hasan (GS31137)

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature : ___________________________________
Name of Chairman
Supervisory Committee : Assoc. Prof. Dr Shamsul Bahri Mohd Tamrin

Signature : ___________________________________
Name of Member
Supervisory Committee : Assoc. Prof. Dr Ahmad Makmom Abdullah

Signature : ___________________________________
Name of Member
Supervisory Committee : Dr. Sharifah Norkhadijah Syed Ismail

TABLES OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AHS	Acute Health Score
ACGIH	American Conference of Governmental Industrial Hygienist
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
TLV	Threshold Limit Value
WBGTin	Wet Bulb Globe Temperature Index
RPE	Rating of Perceived Exertion

CHAPTER 1

INTRODUCTION

1.1 Introduction

Occupational heat exposure threatens the health of workers not only when heat illness occurs but also impairs the productivity and worker's performance as well. It is involved hot and humid climatic conditions, heavy physical workloads or protective clothing that creates a potentially dangerous thermal load for a worker (Lucas *et al.*, 2014).

Heat is a form of energy. It can be generated either endogenous or exogenous process (Simon, 1994). Heat stress from safety and health point of view is physical hazards which can cause health effect direct or indirect into certain industrial workers. Workers are potentially exposed to heat will facing heat stress symptoms if they are not properly protected.

The frequent heat stress problems are prevalent in the iron, steel, glass and ceramic manufacturing industry, construction, aluminum, rubber, foundries, coke ovens and mining (Andrew, 2011; Chan and Yam, 2012, Kishor, Ashok and Sanjay et al., 2012 and Tawatsupa *et al.*, 2012). It is well known that prolonged exposure to excessively heat exposure is a serious hazard to health of an individual. They are may be at risk of heat stress.

International Labor Organization, 2005 has listed heat stress is one of the most common cause of physical hazards in the iron steel industry together with noise, vibration and ionizing and non-ionizing radiation. Steel mill plant is the type of environment where the workers are exposed to high temperature for continuously during shift hour. They are exposed to a high heat exposure during the various processes such as extraction, tapping, burning a scrap, casting, charging and molten steel production.

There are many causal factors reported that can contribute to heat stress. These include age, weight, degree of physical fitness, acclimatization, metabolism, alcohol or drug intake, medical condition as well as clothing worn (Stellman, 1998; Bernard and Cross, 1999; Logan and Bernard, 1999 and Ramphal, 2000). The climatic factors of environmental heat load that can affect heat stress are air temperature, humidity, wind speed as well as mean radiant temperature. Apart from that, environmental factors that can contribute to heat stress are low convection currents, high humidity, low evaporative loss, and high insulation levels around the body (Ramphal, 2000).

The physical changes of the workers include increased heart rate, sweating, an imbalance of water and salt level in the body and changes in skin blood flow. Studies on workers experiencing heat stress and physiological strain in aluminum smelter shows that recovery heart rate is the indication of physiological strain (Logan and Bernard, 1999).

Many studies have investigated heat stress and its effects on workers. As reported by Chen *et al.*, (2003), the workers who are continuously exposed to heat condition resulted in the fatigue related health symptoms. Exposure to prolonged hot condition also resulted in cognitive reduction and unsafe behavior (Enander, 1989; Hancock and Vasmatzidis, 1998). Working with heat also can affect the workers mentally mental and physical of the workers. Prolonged heat stress may lead to loss of body fluid or hypohydration which resulted on performance, especially endurance (Rodahl, 2003).

Heat strain is the physiological response of the body to an increase in heat storage in the deep tissue (Brake and Bates, 2002). Heat strain is refers to the acute (short term) and chronic (long-term) consequences of exposure to environmental heat stress on worker's physical and mental state. The rise of heat strain level can lead to a variety of heat related illnesses.

Physiological strain evoked during initial exposures to hot climates reduces the reserves of physical capacity and may cause a health hazard in the case of strenuous muscular work. Heat stress that result from heat strain usually are marked by increasing of body temperature, heart rate and sweating (Logan and Bernard, 1999).

Body core temperature is the most obvious indicators for the physiological response in the body. According to Havenith and Middendorp (1990), body core temperature, heart rate and body heat storage are the three most interesting variables that can be related to heat strain prediction. Change in body core temperature is a basic physiological measure of heat strain. Core body temperature that exceeds it optimal temperature of 37°C when heat exchange with the environment by convection and evaporation are not enough to dissipate the heat produced within the body (John, 1999).

The effect of this physical hazard varies from acute health problems, decreased efficiency, increased fatigue, and has triggered more accident rates (Enviniosh, 2013). Physical work under hot conditions can be very stressful and impairs the health and efficiency of the workers. For gainful work involving sustained and repeated effort, a reasonable temperature must be maintained in each work room.

Heat related disorder range from mild such as heat exhaustion and heat cramp to severe heat related condition like heat stroke. Heat related health effects such as fatigue, lethargy, dizziness, heat rashes, unstable movement, and heat collapse contribute to the excessive heat exposure of the workers (OSHA, 1999; Noordin and Hashim, 2009).

Wet Bulb Globe Temperature (WBGT) index is the common heat stress indices widely used which contains important environmental factors such as dry bulb, natural wet bulb and globe temperature. WBGT index also recommended adjusted exposure criteria for the contributions of work demand by measuring the metabolic work load of the workers (Budd, 2008).

To address this issue, the ACGIH have set the guidelines for a safe thermal environment. The Threshold Limit Values (TLVs) for work according to WBGT index and metabolic work load was established to determine how long the workers can safely work or remain in a particular hot environment (ACGIH, 2008). This study is going to determine the significant predictor factors of heat stress in steel mill industry.

1.2 Problem Statement

Heat stress is considered a major problem among steel mill workers not only in Malaysia but also worldwide. Heat stress condition arise in special conditions includes; extreme high of temperature and humidity, exposure to high radiant heat, high temperature or humidity occur in combination with heavy protective clothing or higher work rate (Aziah et al., 2012). The steel industry has local hot spots such as ovens and furnaces, which radiate heat. Physical work under such conditions is very stressful and impairs the health and efficiency of the workers.

Study done by Chan and Yam, (2012) among construction workers in Hong Kong revealed that factors includes drinking habit, age and work duration are the most significant predictors of heat stress. The higher prevalence of acute health effect problems such as lethargy, muscle cramp, giddiness, headache, nausea and unstable movement had been reported among steel plant workers in Selangor (Noordin and Hashim, 2006).

Previous researchers also recorded frequently health related disorders in steel mill industry workers. Motamedzade and Azari (2006) revealed 23.5% of the exposed workers in his study experienced heat related illness in steel factory. Chen et al., 2003 reported the steel workers experienced the fatigue symptoms. . A study conducted by Gomes et al., (2002), found that about 30% of steel foundry workers experienced heat cramps. A study conducted by Logan and Bernard (1999), found that workers who expose to heat stress in steel plant were subjected to fatigue symptoms and had low resting heart rate and low systolic blood pressure as well.

The environmental heat stress and the combination of physical work cause heat strain among steel workers. Environmental heat stress increases the sweat rate, core body temperature and pulse rate among the employees exposed to heat (Parameswarappa and Narayana, 2014). A study done by Dehghan et al., (2012) found that ear canal temperature was found to be significant with heat stress.

The main purpose of this study is to investigate the heat stress problem and determine the significant factors that can contribute to acute health symptoms of heat stress in steel mill industry. The concern of this study is to give some awareness to the exposed workers and people outside about the risk of heat stress.

1.3 Research Justification

This study is important to improve and support the current database of heat stress among those working in extreme heat temperature especially in steel mill industry. It has been acknowledge that there are many physical hazards in the steel industry, but heat stress related problems and its effects to health and physiological changes has not been highlighted. It will also help to recognize the contribution factors of heat stress especially in steel mill industry. This study can assist the factory’s administration especially the safety and health division to help acquire for base line data. The study may improve the safety and health of the workers, as it allows the detection of problems at an early stage.

Therefore this study will benefit the government sector especially the Department of Occupational Safety and Health (DOSH) and Social Security Organization (SOCSO) in order to reduce the occupational health hazards in the workplace. In addition, this current study also assists the Department of Occupational Safety and Health (DOSH) for proposing a new standard of temperature that can be used as a guideline in determining the heat stress level in tropical country such as Malaysia.

The Factory and Machinery Act (FMA) 1967 had specified the regulation of high temperature in Factory and Machinery (Safety, Health and Welfare) Regulation 1970 Regulation No 28 (Temperature). This regulation emphasize that in any operation of machinery or any process that can contribute to high heat exposure, the inspector will require proper provision to reduce the effect thereof on any person employed to such extent as he may consider reasonable and practicable.

In addition, the data obtained from this study can be used by the Department of Occupational Safety and Health (DOSH) Malaysia in order to plan and implement a safe threshold limit value of heat stress in the steel plant organization. Next, this study can be used as a guideline for the factory in order to provide a workplace precaution for reducing the heat stress level such as administration control and engineering control. This effort is needed to fulfill the Department of Occupational Safety and Health (DOSH) requirement for reducing the workplace accident rate.

This study is also going to increase the awareness level among steel workers in term of health and safety and remind them how important to have the safe workplace by reducing any hazards especially exposure to the heat hazards. Therefore, this study aims to determine the effect of heat stress on health effect, physiological effect and rating of perceived exertion among the steel mill workers.

1.4 Conceptual Framework

Figure 1.1 shows the conceptual framework of the study. Hazards in the steel making operation are divided into three main sections which are included biological, chemical, physical and also ergonomic. The factors that contributed to the heat stress physical hazard are individual factors, occupational and environmental factors. Individual factors that contribute to heat stress are acclimatization, age, degree of acclimatization, body mass index, percentages of body fat, monthly income and marital status. For the occupational factors, the years of employment, duration of heat exposure, rating of perceived exertion (RPE), work shift, metabolic workload, work unit and water consumption are the contributing factors to heat stress. Environmental factors that are related to heat stress are based on the Wet Bulb Globe Temperature (WBGT) index, wert bulb temperature, dry bulb temperature, globe temperature, relative humidity and air velocity. There are four main effects of heat stress which are heat related disorder, physiological strain, performance and productivity (Thomas, 1971; Enander, 1989, Noordin and Hashim 2006, and Kjellstrom 2006). Physiological changes that have been identified that effects heat stress are as follows; body core temperature, heart rate, blood pressure, sweating rate and dehydration. Health effects are divided into two part which are acute and chronic health effect. Acute health problems that may occur are like heat fatigue, lethargy, dizziness, heat rashes, heat cramp, unstable movement, heat collapse and heat stroke.

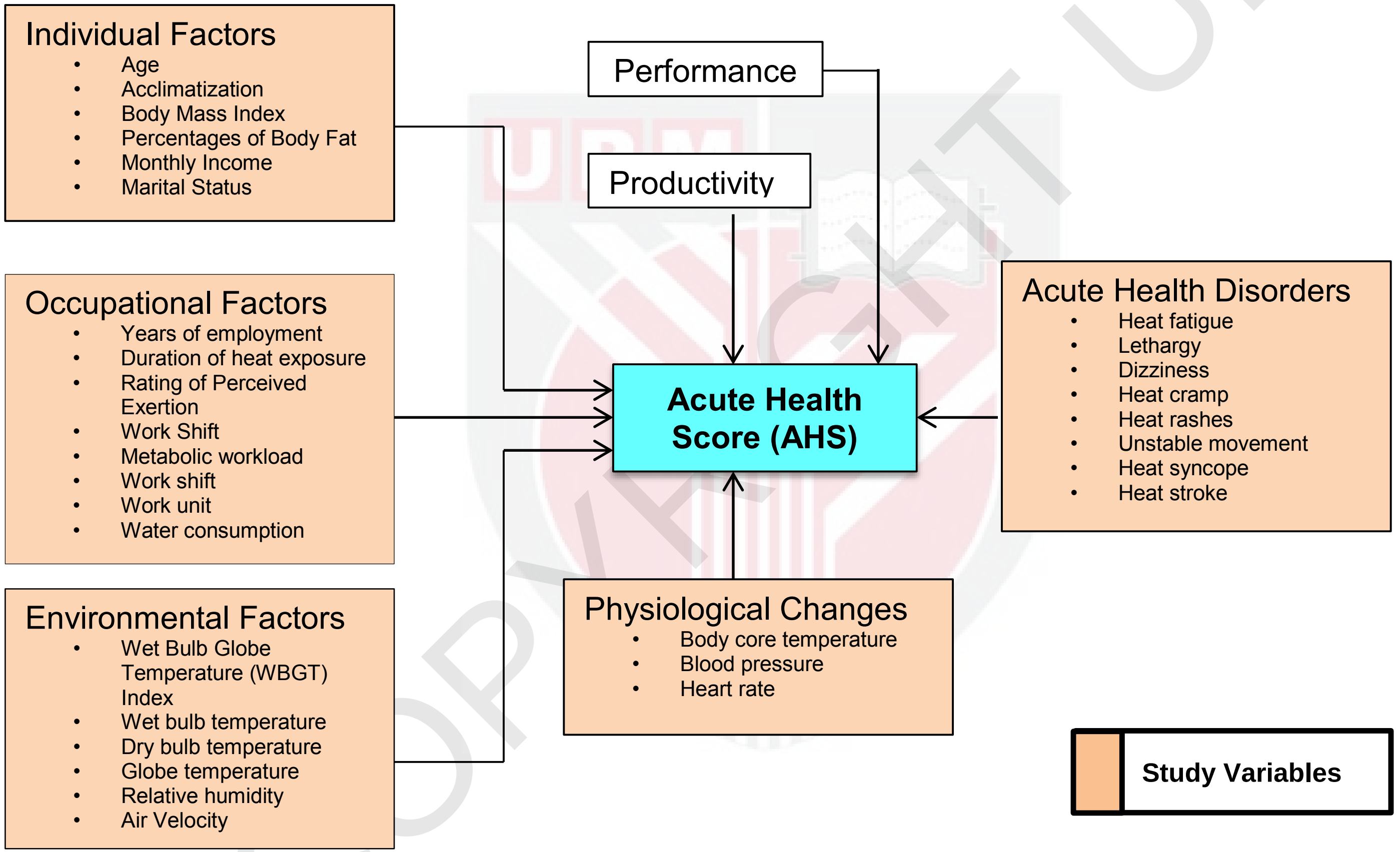

Figure 1.1: Conceptual Framework of the Study

1.5 Research Objective

1.5.1 General Objective

To determine the association between heat exposure and acute health score (AHS)

1.5.2 Specific Objectives

1. To identify the individual factors, occupational factors and environmental factors of the steel mill workers

2. To calculate the acute health score (AHS) of the steel mill workers

3. To compare the physiological changes of body core temperature, blood pressure and heart rate before shift, after 2 hour shift and after at the end of shift

4. To determine the correlation between WBGT index and physiological changes of body core temperature, blood pressure and heart rate of the steel mill workers

5. To determine the correlation between WBGT index and acute health score (AHS) of the steel mill workers

6. To develop the relationship between acute health score (AHS) and predicting factors in steel mill plant

1.6 Research Hypothesis

1. There is no significant difference in body core temperature, blood pressure, and heart rate before shift, after 2 hours shift and at the end of work shift.

2. There is no significant correlation between WBGT index and physiological changes of body core temperature, blood pressure and heart rate of the steel mill workers

3. There is no significant correlation between WBGT index and acute health score (AHS) of the steel mill workers

4. There is no significant relationship between acute health score (AHS) and predicting factors.

1.7 Definition of Term

1.7.1 Conceptual definition

1. Heat Stress

Heat stress is defined as the sum of the heat generated in the body (metabolic heat) plus the heat gained from the environment (environmental heat) minus the heat lost from the body to the environment (NIOSH, 1986).

2. Wet Bulb Globe Temperature (WBGT) index

WBGT index (WBGTin) is one of the indexes of heat stress that calculates the reading of the three thermometers which are natural wet-bulb (NWB), globe bulb (GT) and dry-bulb (DB) (Budd, 2008).

3. Globe temperature (GT)

Globe temperature is measures the combined effect of radiant heat, air temperature and wind speed (Budd, 2008).

4. Dry bulb temperature (DB)

Dry bulb is the measures of the standard ambient temperature. It is the temperature of workplace when a high solar heat load is present.

5. Wet Bulb Temperature (NWB)

Wet bulb temperature is measures the amount air of moisture air in the air.

6. Body Mass Index (BMI)

Body mass index (BMI) is the value that explained the obesity of an individual without showing the body weight (WHO, 2000)

7. Percentage of body fat

Percentage of body fat is the value of an individual's body fat that includes essential body fat and storage body fat.

8. Body core temperature

The body core temperature is the human body temperature that is measured to obtain an instant evaluation of a human's health.

9. Blood pressure

Blood pressure is the pressure of the blood in the circulatory system within the major arterial system of the body that is separated into systolic and diastolic determination. Systolic blood pressure is the maximum blood pressure during contraction of the ventricles and diastolic blood pressure is the minimum blood pressure recorded just prior to the next contraction (Walker et al., 1990).

10. Heart rate

Heart rate is a value that refers to the speed of heartbeat based on the number of contractions of the ventricles (the lower chambers of the heart).

11. Air velocity

Air velocity is the value of the distance an air molecule is moving during certain of period time.

12. Rating of perceived exertion (RPE)

RPE is the measure of physical activity intensity level at work.

1.7.2 Operational Definition

1. Heat stress

Heat stress can be determined by measuring four parameters: Globe Temperature, Natural Wet Bulb, Relative Humidity and Dry Bulb Temperature as well as collecting other information such as workers' work load and exposure time (Angus, 1968).

2. Wet bulb globe temperature (WBGT) Index

WBGT index (WBGTin) is measured by Questemp°34 Thermal Environment Monitor and is placed at the workplace that exposed is to heat.

The calculation of WBGTin for outdoor conditions with solar load is as following:

$$WBGT = 0.7\ NWB + 0.2\ GT + 0.1\ DB \quad (1)$$

The calculation of WBGTin for indoor conditions with no solar load is as following:

$$WBGT = 0.7\ NWB + 0.3\ GT \quad (2)$$

3. Globe temperature (GT)

The globe temperature is measured as an indication of the radiant heat exposure from in an individual. A sensor is positioned inside a blackened copper sphere and the temperature rise is measured. The information will be used in calculating the WBGTin.

4. Dry bulb temperature (DB)

Dry bulb temperature is measured by thermometer to indicate the amount of heat in the air and is directly proportional to the mean kinetic energy of the air molecules. This calculation is used in outdoor WBGT calculation when high solar radiant heat load may be present. The series of white plates surrounding the sensor shield it from radiant heat. This information will be used in calculating the WBGTin.

5. Wet bulb temperature (NWB)

The wet bulb thermometer gives an indication of the effects of humidity on an individual. Measurements are taken using a thermometer covered by a moistened cotton wick immersed into a reservoir containing distilled water. The information will be used in calculating the WBGTin.

6. Body Mass Index

Classification of body weight and the height of a person is done using the following formula:

$$\text{BMI} = \frac{\text{Weight (kg)}}{\text{Height m}^2}$$

The indicators of BMI are:

BMI (< 18.5)	= under weight
BMI (18.5 – 24.9)	= Normal range
BMI (25.0-29.9)	= over weight
BMI (30.0-34.9)	= class I obesity
BMI (35.0-39.9)	= class II obesity
BMI (≥40.0)	= class III obesity

7. Percentages of Body Fat

Percentage of body fat (PBF) is the total body fat divided by the total body mass. It is measured by using Body Composition Monitor OMRON HBF 212.
The indicators of percentages of body fat for male are as following:

PBF (5.0 – 9.9)	= Low
PBF (10.0 – 19.9)	= Normal range
PBF (20.0 – 24.9)	= High
PBF (25.0 – 50.0)	= Very high

8. Body core temperature

An ear (tympanic) temperature is measured by using OMRON MC510 Gentle Temperature Ear Thermometer in degree Celsius (°C). A normal body temperature for human is approximately 98.6°F or 37.0°C. The body temperatures that recorded greater than 37.5°C is considered as in hyperthermia condition which is occurs when body has produces or absorb more heat (Kelly, 2006).

9. Blood pressure

Blood pressure is measured in millimeters of mercury (mmHg) and the classification blood pressure is as following:

Table 1.1: The classification of Blood Pressure Level

Category	Blood Pressure Level (mmHg)	
	Systolic	**Diastolic**
Normal	<120	<80
Pre-hypertension	120-139	80-89
Stage 1 hypertension	140-159	90-99
Stage 2 hypertension	≥160	≥100

10. Heart rate

Heart rate (HR) is defined as the number of heart beats per unit of time, usually per minute (bpm). The classification of heart rate in healthy male is as following:

Normal human heart rate = 60 -110 bpm
Excessive human heart rate = >110 bpm

11. Air velocity

Air velocity is measured using Velocicalc Multi-Function Ventilation Meter 9565 and unit in meter per second (ms^{-1}). A reading was taken three times in 8 hour total work duration and the average was obtained to get an accurate reading. The reading was taken during the start of work, in the middle of work and at the end of the work shift.

12. Relative humidity

Relative humidity is expressed in percentages that is calculated by using the following equation

$$= \frac{\text{Vapor pressure of dewpoint temperature}}{\text{Vapor pressure of dry} - \text{bulb (air)temperatue}} \text{ X } 100$$

13. Rating of Perceived Exertion (RPE)

The RPE is measure by using a rating scale from 6 to 20 with every odd number anchored by verbal expressions ranging from very-very light at 7 to maximal exertion at 20. The workers need to report their exertion during when they are performing their work task.

REFERENCES

ACGIH (1992). *Threshold limit values for chemical substances and physical agents and biological exposure indices, 1992-1993*. Cincinnati: American Conference of Governmental Industrial Hygienist

ACGIH (1995). Threshold Limit Values and Biological Exposure Indices for 1995-1996. Cincinnati: American Conference of Governmental Industrial Hygienist

ACGIH (2006). *TLVs and BEIs: Threshold limit values for chemical substances and chemical agents*. Cincinnati: American Conference of Governmental Industrial Hygienists

ACGIH (2006). *TLVs and BEIs: Threshold limit values for chemical substances and chemical agents*. Cincinnati: American Conference of Governmental Industrial Hygienists

ACGIH (2008). *2008 TLVs and BEIs - Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*. Cincinnati: American Conference of Governmental Industrial Hygienists

Ahasan, R., Mohiuddin, G., & Faruquee, S. M. (2002). Strenuous tasks in a hot climate – a case study. *51*(4), 175-181.

American College of Sport Medicine (1987). American College of Sports Medicine position stand on the prevention of thermal injuries during distance running. *Med Sci Sports Exerc*, 19. 529-533

Andrew, P.H. (2011). Heat stress, hydration status and symptoms of heat illness in surface mine workers. Unpublished Thesis, Queensland University of Technology, Queensland.

Anna, M., Juhani, S., & Krzysztof, S. (2004). Age-related thermal strain in men while wearing radiation protective clothing during short-term exercise in the heat *International Journal of Occupational Safety and Ergonomics 10*(4), 361-367.

ANSI/ASHRAE, 2013. Thermal Environmental Conditions for Human Occupancy. Standard 55-2013.

Armstrong (1998). *Heat Acclimatization*. Storrs: Encyclopedia of Sports Medicine and Science.

Armstrong, C. G., & Kenney, W. L. (1993). Effects of age and acclimation on responses to passive heat exposure. *J Appl Physiol (1985), 75*(5), 2162-2167.

Armstrong, L. E., Johnson, E. C., Casa, D. J., Ganio, M. S., McDermott, B. P., Yamamoto, L. M., et al. (2010). The American football uniform: uncompensable heat stress and hyperthermic exhaustion. *J Athl Train, 45*(2), 117-127.

Armstrong, L. E., Maresh, C. M., Gabaree, C. V., Hoffman, J. R., Kavouras, S. A., Kenefick, R. W., et al. (1997). Thermal and circulatory responses during exercise:

effects of hypohydration, dehydration, and water intake. *J Appl Physiol (1985), 82*(6), 2028-2035.

Aziah, D., Edimansyah, A., Azwan, A., Lin, N., & Rusli, N. (2012). Assessment of indoor air quality and heat stress exposure in an automotive assembly plant. Retrieved on July 1, 2015 from http://www.intechopen.com/

Azwan, A., & Rampal, K. G. (2001). *Heat stress among workers in two steel plants in Peninsular Malaysia.* Paper presented at the Second National Public Health Medicine Conference Summit Hotel, Subang Jaya.

Azwan, A., & Rampal, K. G. (2001). *Heat stress among workers in two steel plants in Peninsular Malaysia.* Paper presented at the Second National Public Health Medicine Conference Summit Hotel, Subang Jaya.

Baker, M. A. (1982). Brain cooling in endotherms in heat and exercise. *Annu Rev Physiol, 44*, 85-96.

Banaee, S. (2005). *The association between thermal conditions & and cardiovascular diseases, among Iron & steel industry workers.* Paper presented at the The 4th International Conference on Work Environment and Cardiovascular Diseases, 2005, Newport Beach, California.

Bates, G. P., & Schneider, J. (2008). Hydration status and physiological workload of UAE construction workers: A prospective longitudinal observational study. *J Occup Med Toxicol, 3*(21), 1-10.

Beaird, J. S., Bauman, T. R., & Leeper, J. D. (1996). Oral and tympanic temperatures as heat strain indicators for workers wearing chemical protective clothing. *Am Ind Hyg Assoc J, 57*(4), 344-347.

Bernard (1988). Thermal Stress. In B. A. Plog (Ed.), *Fundamentals of Industrial Hygiene* (5th ed.). United States National Safety Council

Bernard, & Cross, R. R. (1999). Heat stress management: Case study in and aluminum smelter. *International Journal of Industrial Ergonomics, 23*(5-6), 609-620.

Borg, G. (1998). *Borg's Perceived Exertion and Pain Less* (1st Edition ed.). Champaign, IL: Human Kinetics.

Bouchama, A., & Knochel, J. P. (2002). Heat stroke. *N Engl J Med, 346*(25), 1978-1988.

Brake, D. J., & Bates, G. P. (2001). Fatigue in industrial workers under thermal stress on extended shift lengths. *Occup Med (Lond), 51*(7), 456-463.

Brake, D. J., & Bates, G. P. (2002). Deep body core temperatures in industrial workers under thermal stress. *J Occup Environ Med, 44*(2), 125-135.

Brennan, P. J., Greenberg, G., Miall, W. E., & Thompson, S. G. (1982). Seasonal variation in arterial blood pressure. *Br Med J (Clin Res Ed), 285*(6346), 919-923.

Brothers, R. M., Wingo, J. E., Hubing, K. A., & Crandall, C. G. (2009). The effects of reduced end-tidal carbon dioxide tension on cerebral blood flow during heat stress. *J Physiol, 587*, 3921-3927.

Budd, G. M. (2008). Wet-bulb globe temperature (WBGT)--its history and its limitations. *J Sci Med Sport, 11*(1), 20-32.

Budd, G. M. (2008). Wet-bulb globe temperature (WBGT)--its history and its limitations. *J Sci Med Sport, 11*(1), 20-32.

Burse, R. L. (1979). Sex differences in human thermoregulatory response to heat and cold stress. *Hum Factors, 21*(6), 687-699.

Canadian Centre for Occupational Safety and Health, CCOHS (2008). Hot Environments - Health Effects Retrieved 14th January, 2014.

CDC (2011). Physical Activity. *Perceived Exertion (Borg Rating of Perceived Exertion Scale)*

Chan, A.P. and Yam, M.C.H. (2012). Developing a heat stress model for construction workers. *Journal of Facilities Management* 10(1), 59-74.

Chen, M. L., Chen, C. J., Yeh, W. Y., Huang, J. W., & Mao, I. F. (2003). Heat stress evaluation and worker fatigue in a steel plant. *AIHA J (Fairfax, Va), 64*(3), 352-359.

Cheung, S. S., & McLellan, T. M. (1998). Influence of hydration status and fluid replacement on heat tolerance while wearing NBC protective clothing. *Eur J Appl Physiol Occup Physiol, 77*(1-2), 139-148.

Cheung, S. S., McLellan, T. M., & Tenaglia, S. (2000). The thermophysiology of uncompensable heat stress. Physiological manipulations and individual characteristics. *Sports Med, 29*(5), 329-359.

Christensen, E. H. (1990). Physical working capacity of old workers and physiological background for work tests and work evaluations. *Bull World Health Organ, 13*(4), 587-593.

Chung, N. K., & Pin, C. H. (1996). Obesity and the occurrence of heat disorders. *Mil Med, 161*(12), 739-742.

Cian, C., Barraud, P. A., Melin, B., & Raphel, C. (2001). Effects of fluid ingestion on cognitive function after heat stress or exercise-induced dehydration. *Int J Psychophysiol, 42*(3), 243-251.

Crandall, C. G. (2008). Heat Stress and Baroreflex Regulation of Blood Pressure. *Med Sci Sports Exerc, 40*(12), 2063.

Crewe, H., Tucker, R., & Noakes, T. D. (2008). The rate of increase in rating of perceived exertion predicts the duration of exercise to fatigue at a fixed power output in different environmental conditions. *Eur J Appl Physiol, 103*(5), 569-577.

Crowe, J., van Wendel de Joode, B., & Wesseling, C. (2009). A pilot field evaluation on heat stress in sugarcane workers in Costa Rica: What to do next? *Glob Health Action, 2*.

Cuddy, M. L. (2004). The effects of drugs on thermoregulation. *AACN Clin Issues, 15*(2), 238-253.

Dang, B. N., & Dowell, C. H. (2014). Factors associated with heat strain among workers at an aluminum smelter in Texas. *J Occup Environ Med, 56*(3), 313-318.

Dehghan, H., Mortazavi, S. B., Jafari, M. J., & Maracy, M. R. (2012). Evaluation of wet bulb globe temperature index for estimation of heat strain in hot/humid conditions in the Persian Gulf. *J Res Med Sci, 17*(12), 1108-1113.

Donoghue, A. M., & Bates, G. P. (2000). The risk of heat exhaustion at a deep underground metalliferous mine in relation to body-mass index and predicted VO2 max. *Occup Med, 50*(4), 259-263.

Economy Plan Unit, 2001. Angka Jangka Panjang Ketiga 2001-2010. Kuala Lumpur:Jabatan Perdana menteri. Page 96

Eijsvogels, T. M., Veltmeijer, M. T., Schreuder, T. H., Poelkens, F., Thijssen, D. H., & Hopman, M. T. (2011). The impact of obesity on physiological responses during prolonged exercise. *Int J Obes (Lond), 35*(11), 1404-1412.

Enander, A. E. (1989). Effects of thermal stress on human performance. *Scand J Work Environ Health, 15 Suppl 1*, 27-33.

Factories and Machinery Act, 1967. Act 139 Regulations and Rules. International Law Book Services.

Fawziah, S. N. M. (2002). *Tegasan haba dan perubahan fisiologi pekerja kilang besi (laporan projek tahun akhir).* Universiti Putra Malaysia, Selangor.

Fogleman, M., Fakhrzadeh, L., & Bernard, T. E. (2005). The relationship between outdoor thermal conditions and acute injury in an aluminum smelter. *International Journal of Industrial Ergonomics, 35*(1), 47-55.

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., et al. (2001). A new approach to monitoring exercise training. *J Strength Cond Res, 15*(1), 109-115.

Fujii, R. K., Horie, S., Tsutsui, T., & Nagano, C. (2007). Heat exposure control using non-refrigerated water in Brazilian steel factory workers. *Ind Health, 45*(1), 100-106.

Gaebelein, C. J., Senay, L. C., Jr., & Ladd, C. M. (1985). Changes in blood pressure, heart rate and blood constituents during heat exposure in men with elevated blood pressure. *Eur J Appl Physiol Occup Physiol, 54*(5), 506-510.

Givoni, B., & Goldman, R. F. (1972). Predicting rectal temperature response to work, environment, and clothing. *J Appl Physiol, 32*(6), 812-822.

Glazer, J. L. (2005). Management of heatstroke and heat exhaustion. *Am Fam Physician, 71*(11), 2133-2140.

Gomes, J., Lloyd, O., & Norman, N. (2002). The health of the workers in a rapidly developing country: effects of occupational exposure to noise and heat. *Occup Med (Lond), 52*(3), 121-128.

Gonzalez-Alonso, J., & Calbet, J. A. (2003). Reductions in systemic and skeletal muscle blood flow and oxygen delivery limit maximal aerobic capacity in humans. *Circulation, 107*(6), 824-830.

Gonzalez-Alonso, J., Mora-Rodriguez, R., & Coyle, E. F. (1999). Supine exercise restores arterial blood pressure and skin blood flow despite dehydration and hyperthermia. *Am J Physiol, 277*(2 Pt 2), H576-583.

Hancock, P.A. and Vasmatzidis, I. (1998). Human occupational and performance limits under stress: the thermal environment as a prototypical example. *Ergonomics, 41*(8), 1169-1191.

Hansen, A., Bi, P., Nitschke, M., Ryan, P., Pisaniello, D., & Tucker, G. (2008). The effect of heat waves on mental health in a temperate Australian city. *Environ Health Perspect, 116*(10), 1369-1375.

Hardy, J. D. (1970). thermal comfort; skin temperature and physiological thermoregulation *Physiological and behavioral temperature regulation* (Vol. III). Springfield: Thomas.

Hargreaves, M. (2008). Physiological limits to exercise performance in the heat. *J Sci Med Sport, 11*(1), 66-71.

Harshal, C. P., Nellore, M. R., & Asim, S. (2006). Heat exposure effects among firefighters. *Indian J Occup Environ Med, 10*(3), 121-123.

Havenith, & Middendorp, H. (1990). The relative influence of physical fitness, acclimatization state, anthropometric measures and gender on individual reactions to heat stress. *Eur J Appl Physiol Occup Physiol, 61*(5-6), 419-427.

Havenith, G. (1985). Individual parameters in thermoregulatory control; a review; TNO institute for perception, report IZF. 26

Havenith, G., Coenen, J. M., Kistemaker, L., & Kenney, W. L. (1998). Relevance of individual characteristics for human heat stress response is dependent on exercise intensity and climate type. *Eur J Appl Physiol Occup Physiol, 77*(3), 231-241.

Havenith, G., Inoue, Y., Luttikholt, V., & Kenney, W. L. (1995). Age predicts cardiovascular, but not thermoregulatory, responses to humid heat stress. *European Journal of Applied Physiology and Occupational Physiology, 70*(1), 88-96.

Holmer, I. (1995). Protective clothing and heat stress. *Ergonomics, 38*(1), 166-182.

Horie, S. (2013). Prevetion of heat stress disorders in the workplace *Japan Medical Association Journal, 56*(3), 186-192.

Huang, Y., Zhang, K., Yang, S. and Jin, Y. (2013). A method to measure Humidity based on dry-bulb and wet-bulb temperatures. *Research Journal of Applied Sciences, Engineering and Technology* 6(16), 2986-2987.

Ikemura, T., & Naoyuki, H. (2014). Effect of heat stress on ocular blood flow during exhaustive exercise *J Sports Sci Med. , 13*(1), 172-179.

Inoue, M., Fujimura, T., Morita, H., Inagaki, J., Kan, H., & Harada, N. (2003). A comparison of heart rate during rest and work in shift workers with different work styles. *Ind Health, 41*(4), 343-347.

Inoue, Y., & Shibasaki, M. (1996). Regional differences in age-related decrements of the cutaneous vascular and sweating responses to passive heating. *Eur J Appl Physiol Occup Physiol, 74*(1-2), 78-84.

International Labor Organization (2005). Code of Practice on safety and health in the iron and steel industry (pp. 1-106). Geneva: International Labor Organization.

Izzate, M. S. (2011). *Association Between Occupational Heat Exposure with Physiological Changes among Palm Oil Mill Workers.* Unpublished Thesis, Universiti Putra Malaysia Selangor.

Jackson, L. L., & Rosenberg, H. R. (2010). Preventing heat-related illness among agricultural workers. *J Agromedicine, 15*(3), 200-215.

Jimenez, C., Melin, B., Koulmann, N., Allevard, A. M., Launay, J. C., & Savourey, G. (1999). Plasma volume changes during and after acute variations of body hydration level in humans. *Eur J Appl Physiol Occup Physiol, 80*(1), 1-8.

Jonathan, A. B., & Lynsey, K. S. (2011). Heat related illness. *American Family Physician, 83*(11), 1325-1330.

Karwowski, W., & Marras, W. S. (2003). *Occupational Ergonomics: Design and Management of Work Systems*. Florida: CRC Press.

Kelly, G. (2006). Body temperature variability (Part 1): a review of the history of body temperature and its variability due to site selection, biological rhythms, fitness, and aging. *Altern Med Rev, 11*(4), 278-293.

Kenefick, R. W., Ely, B. R., Cheuvront, S. N., Palombo, L. J., Goodman, D. A., & Sawka, M. N. (2009). Prior heat stress: effect on subsequent 15-min time trial performance in the heat. *Med Sci Sports Exerc, 41*(6), 1311-1316.

Kenney, W. L., & Munce, T. A. (2003). Invited review: aging and human temperature regulation. *J Appl Physiol (1985), 95*(6), 2598-2603.

Kim, Y. M., Kim, S., Cheong, H. K., Ahn, B., & Choi, K. (2012). Effects of heat wave on body temperature and blood pressure in the poor and elderly. *Environ Health Toxicol, 27*, e2012013.

Kishor, P. B., Ashok, G. L., Sanjay, P. Z., Vaishali, K. B., Gautam, M. K., Subhash, B. T., et al. (2012). Heat stress and its effect in glass factory workers of central India. *International Journal of Engineering Research and Technology, 1*(8), 1-13.

Kishor, P.B., Ashok, G.L., Sanjay, P.Z et al., (2012). Heat stress and its effect in glass factory workers in central India. *International Journal of Engineering Research Technology,* 1(8), 1-13.

Kjellstrom (2009). Climate change, direct heat exposure, health and well-being in low and middle-income countries. *Global Health Action, 2*, 1-3.

Kjellstrom, Gabrysch, S., Lemke, B., Dear, K. (2009). The Hothaps' programme for assessing climate change impacts on occupational health and productivity: an invitation to carry out field studies. *Glob Health Action,* 2, from http://www.globalhealthaction.net/index.php/gha/article/view/2082/2563

Kjellstrom, T., Holmer, I., & Lemke, B. (2009). Workplace heat stress, health and productivity – an increasing challenge for low and middle-income countries during climate change. *Glob Health Action, 2*(10).

Knochel, J. P. (1989). Heat stroke and related heat stress disorders. *Dis Mon, 35*(5), 301-377.

Latzka, W. A., Sawka, M. N., Montain, S. J., Skrinar, G. S., Fielding, R. A., Matott, R. P., et al. (1997). Hyperhydration: thermoregulatory effects during compensable exercise-heat stress. *J Appl Physiol (1985), 83*(3), 860-866.

Latzka, W. A., Sawka, M. N., Montain, S. J., Skrinar, G. S., Fielding, R. A., Matott, R. P., et al. (1998). Hyperhydration: tolerance and cardiovascular effects during uncompensable exercise-heat stress. *J Appl Physiol (1985), 84*(6), 1858-1864.

Lemke, B., & Kjellstrom, T. (2012). Calculating workplace WBGT from meteorological data: a tool for climate yge assessment. *Ind Health, 50*(4), 267-278.

Lieberman, H. R., Bathalon, G. P., Falco, C. M., Kramer, F. M., Morgan, C. A., 3rd, & Niro, P. (2005). Severe decrements in cognition function and mood induced by sleep loss, heat, dehydration, and undernutrition during simulated combat. *Biol Psychiatry, 57*(4), 422-429.

Liljegren, J. C., Carhart, R. A., Lawday, P., Tschopp, S., & Sharp, R. (2008). Modeling the wet bulb globe temperature using standard meteorological measurements. *J Occup Environ Hyg, 5*(10), 645-655.

Lind, A. R., Humphreys, P. W., Collins, K. J., Foster, K., & Sweetland, K. F. (1970). Influence of age and daily duration of exposure on responses of men to work in heat. *J Appl Physiol, 28*(1), 50-56.

Logan, P. W., & Bernard, T. E. (1999). Heat stress and strain in an aluminum smelter. *Am Ind Hyg Assoc J, 60*(5), 659-665.

Lucas, R.A.I., Epstein, Y. and Kjellstrom, T. (2014). Excessive occupational heat exposure: a significant ergonomics challenge and health risk for current and future workers. *Extreme Physiology & Medicine.* 3(14), 1-8.

Lumingu, H. M. M., & Dessureault, P. (2009). Physiological responses to heat strain: A study on personal monitoring for young workers. *Journal of Thermal Biology, 34*(6), 299-305.

Lundgren, K., Kuklane, K., Gao, C., & Ingvar, H. (2013). Effects of heat stress on working populations when facing climate change *Ind Health, 51*, 3-15.

Luscher, T. F. (1996). Heart Rate Variability. *Europian Heart Journal.*17, 354-381.

Lutz, E. A., Reed, R. J., Turner, D., & Littau, S. R. (2014). Occupational heat strain in a hot underground metal mine. *J Occup Environ Med, 56*(4), 388-396.

Mangum, B. W., & Hill, J. E. (1977). *Thermal Analysis-Human Comfort-Indoor Environments*. Maryland: US Department of Commerce

Martinez, M., Devenport, L., Saussy, J., & Martinez, J. (2002). Drug-associated heat stroke. *South Med J., 95*(8), 799-802.

Maw, J. G., Boutcher, S. H., & Taylor, N. A. (1993). Rating of perceived exertion and affect in hot and cool environments. *Eur J Appl Physiol, 67*, 174-179.

Mekjavic, I. B., Banister, E. W., & Morrison, J. B. (1988). *Environmental Ergonomics –Sustaining Human Performance in Harsh Environments.* (1st ed.). London: CRC Press.

Millard, C. E., & Whitey, W. R. (1998). Heat strain in clothed, hypohydrated personnel. Loughborough University.

Miller, V., Bates, G., Schneider, J., & Thomsen, J. (2011). Self-Pacing as a Protective Mechanism against the Effects of Heat Stress. *The Annals of Occupational Hygiene, 55*(5), 548-555.

Minami, J., Ishimitsu, T., Kawano, Y., & Matsuoka, H. (1998). Seasonal variations in office and home blood pressures in hypertensive patients treated with antihypertensive drugs. *Blood Press Monit, 3*(2), 101-106.

Monazzam, M. R., Jafariroodbandi, A., Mohammadi, P., Amirzadeh, F., & Tabatabaee, S. H. R. (2013). A study on heat stress and its risk assessment in a steel factory *Iran Occupational Health Journal, 9*(4), 41-49.

Mongoni, J. M. (1996). Heavy physical work in Kenya. *African Newsletter on Occupational Health and Safety, 6*(2), 105-107.

Montain, S. J., Sawka, M. N., Cadarette, B. S., Quigley, M. D., & McKay, J. M. (1994). Physiological tolerance to uncompensable heat stress: effects of exercise intensity, protective clothing, and climate. *J Appl Physiol (1985), 77*(1), 216-222.

Moran, D. S., Shitzer A Fau - Pandolf, K. B., & Pandolf, K. B. (1998). A physiological strain index to evaluate heat stress. *Am J Physiol*, 275, 129-134.

Motamedzade, M., & Azari, M. R. (2006). Heat Stress Evaluation Using Environmental and Biological Monitoring *Pakistan Journal of Biological Sciences*, *9*(3), 457-459.

Nag, P. K., Dutta, P., & Nag, A. (2013). Critical body temperature profile as indicator of heat stress vulnerability. *Ind Health*, *51*(1), 113-122.

Nielsen, Hales, J. R., Strange, S., Christensen, N. J., Warberg, J., & Saltin, B. (1993). Human circulatory and thermoregulatory adaptations with heat acclimation and exercise in a hot, dry environment. *J Physiol*, *460*, 467-485.

Nielsen, R. (1986). Clothing and thermal environments: Field studies on industrial work in cool conditions. *Applied Ergonomics*, *17*(1), 47-57.

NIOSH (1986). Criteria for a recommended standard. Occupational exposure to hot environments. Revised criteria 1986. *National Institute for Occupational Safety and Health*, 140.

NIOSH (1986). Criteria for a recommended standard. Occupational exposure to hot environments. Revised criteria 1986. *National Institute for Occupational Safety and Health*, 140.

Noordin, S., & Hashim, J. H. (2006). A prevalence study on the effect of heat stress among a steel plant employees in Selangor Darul Ehsan, 1997. *Jurnal Kesihatan Masyarakat, 12*(1), 1663-1675.

Nunneley, S. A. (1989). Heat stress in protective clothing. Interactions among physical and physiological factors. *Scand J Work Environ Health, 15 Suppl 1*, 52-57.

Ono, M. 2012. Heat stroke and the thermal environment. *Journal of the Japan Medical Association.* 141(2):305-309.

OSHA (1999). OSHA Technical Manual (OTM), *Heat Stress*. Washington, DC: Department of Labor.

OSHA (1999). OSHA Technical Manual (OTM), *Heat Stress*. Washington, DC: Department of Labor.

OSHA (2013). Heal Ilnesses, *Monitoring Workers at Risk of Heat-related Illness*. Washington D.C: Department of Labor, U.S.

Pandolf, K. B. (1988). Perceived exertion during exercise in the heat, cold or at high altitude. U.S Army Research Institute of Environmental Medicine (USARIEM)

Parameswarappa, S. B., & Narayana, J.. (2014). Assessment of heat strain among workers in steel industry - a study. *Int. J. Curr. Microbiol. App. Sci, 3*(9), 861-870.

Parsons, K. (2002). *Human Thermal Environments: The Effects of Hot, Moderate, and Cold Environments on Human Health, Comfort, and Performance* (2nd ed.). London: Taylor & Francis Ltd.

Pedisius, A., Janusas, V. and Bertasiane, A. (2009). *International Journal of Mechanical, Industry and Aerospace Engineering,* 3(1), 25-29

Pilcher, J. J., & Huffcutt, A. I. (1996). Effects of sleep deprivation on performance: a meta-analysis. (0161-8105 (Print)).

Pilcher, J. J., Nadler, E., & Busch, C. (2002). Effects of hot and cold temperature exposure on performance: a meta-analytic review. *Ergonomics, 45*(10), 682-698.

Pitts, G. C., Johnson, R. E., & Consolazio, F. C. (1944). Work in the heat as affected by intake of water, salt and glucose. *J Physiol, 142*(2), 253-259.

Plog, B. A. (1988). *Fundamentals of Industrial Hygiene* (third ed.). Chicago: National Safety Council.

Ramalingam, A., Sambandam, S., Paramasivan, R., & Kalpana, B. (2009). Work-related heat stress concerns in automotive industries: a case study from Chennai, India. *Global Health Action*. 2, 1-9.

Ramphal, L. (2000). *Heat stress in the workplace.* Paper presented at the Baylor University Medical Center Proceedings, Texas.

Rastogi, S. K., Gupta, B. N., & Hussain, T. (1992). Wet-bulb globe temperature index: a predictor of physiological strain in hot environments. *Occup Med (Lond), 42*(2), 93-97.

Rathod, R. A., Bhagia, L. J., Pandya, G. L., Katagade, V. L., Parikh, D. J., & Chatterjee, B. B. (1987). Thermal stress and physiological strain in the glass bangle industry. *Eur J Appl Physiol, 56*, 58-63.

Redmond, C. K., Emes, J. J., Mazumdar, S., Magee, P. C., & Kamon, E. (1979). Mortality of steelworkers employed in hot jobs. *J Environ Pathol Toxicol, 2*(5), 75-96.

Reneau, P. D., & Bishop, P. A. (2010). Validation of a Personal Heat Stress Monitor. *Am Ind Hyg Assoc J, 57*(7), 650-657.

Rich B. 1997. Environmental concerns: heat. In: Sallis E R, Massimino F, editors. Essentials of Sports Medicine. Mosby Year Book; St Louis. pp. 129–133.

Robert, J. R. (2004). *Perceived Exertion for Practitioners: rating efforts with OMNI pictures system* Champaign, IL: Human Kinetics

Rodahl, L. (2002). Occupational health conditions in extreme environments. *The Annals of Occupational Hygiene, 47*(3), 241-252.

Sahu, S., Sett, M., & Kjellstrom, T. (2013). Heat exposure, cardiovascular stress and work productivity in rice harvesters in India: implications for a climate change future. *Ind Health, 51*(4), 424-431.

Sawka, M. N., Young, A. J., Latzka, W. A., Neufer, P. D., Quigley, M. D., & Pandolf, K. B. (1992). Human tolerance to heat strain during exercise: influence of hydration. *J Appl Physiol (1985), 73*(1), 368-375.

Schlader, Z. J., Stannard, S. R., & Mundel, T. (2009). Exercise and heat stress: performance, fatigue and exhaustion--a hot topic. *Br J Sports Med, 45*(1), 3-5.

Schroter, R. C., Marlin, D. J. and Jeffcott, L. B. (1996). Use of the wet bulb globe temperature (WBGT) Index to quantify environment heat loads during Three-day-event competitions. *Equine Veterinary Journal*, 22, 3-6

Sharma, M. A. (2000). Role of Dehydration in Heat Stress-Induced Variations in Mental Performance.

Shephard, R. J. (1999). Age and physical work capacity. *Exp Aging Res, 25*(4), 331-343.

Shvartz, E., & Reibold, R. C. (1990). Aerobic fitness norms for males and females aged 6 to 75 years: a review. *Aviat Space Environ Med, 61*(1), 3-11.

Shvartz, E., Shibolet, S., Meroz, A., Magazanik, A., & Shapiro, Y. (1977). Prediction of heat tolerance from heart rate and rectal temperature in a temperate environment. *J Appl Physiol Respir Environ Exerc Physiol, 43*(4), 684-688.

Simon, H.B. (1994). Hyperthermia and heatstroke. *Hosp Prac.* 29(8): 65-8, 73, 78-80.

Stellman, J. M. (1998). *Encyclopeadia of Occupational Health and Safety* (4th ed. Vol. 2). Geneva: International Labor Organization (ILO).

Tanaka, M. (1999). Health problems and working in cold and hot environment. *Occup Med Rev, 11*, 171-185.

Tanaka, M. (2007). Heat stress standard for hot work environments in Japan. *Ind Health, 45*(1), 85-90.

Tawatsupa, B., Lim, L.L., Kjellstrom., Seubssman, S. et al., (2012). Association between occupational heat stress and kidney disease among 37 816 workers in the Thai cohort study (TCS). *J Epidemiol,* 22(3), 251-260.

Tawatsupa, B., Yiengprugsawan, V., Kjellstrom, T., Berecki-Gisolf, J., Seubsman, S. A., & Sleigh, A. (2013). Association between heat stress and occupational injury among Thai workers: findings of the Thai Cohort Study. *Ind Health, 51*(1), 34-46.

Thibodeau, G. A. (1997). *The Human Body in Health Disease*. St Louis: Mosby.

Thomas, E. B. (1971). Thermal Stress. In A. P. Barbara (Ed.), *Fundamental of Industrial Hygiene* (Vol. 5th edition, pp. 1080). United States: National Safety Council.

Thomas, E. B. (1971). Thermal Stress. In A. P. Barbara (Ed.), *Fundamental of Industrial Hygiene* (Vol. 5th edition, pp. 1080). United States: National Safety Council.

Tucker, R., Rauch, L., Harley, Y. X., & Noakes, T. D. (2004). Impaired exercise performance in the heat is associated with an anticipatory reduction in skeletal muscle recruitment. *Pflugers Arch, 448*(4), 422-430.

Varley, F. (2004). *A study of heat stress exposures and interventions for mine rescue workers.* Paper presented at the SME Annual Meeting Preprints.

Vasmatzidis, I., Schlegel, R. E., & Hancock, P. A. (2002). An investigation of heat stress effects on time-sharing performance. *Ergonomics*, *45*(3), 218-239.

Wagner, J. A., Robinson, S., Tzankoff, S. P., & Marino, R. P. (1972). Heat tolerance and acclimatization to work in the heat in relation to age. *J Appl Physiol, 33*(5), 616-622.

Wakui, T. (2000). Study on work load of matrons under shift work in a special nursing home for the elderly. *Ind Health, 38*(3), 280-288.

Walker, H. K., Hall, W. D., & Hurst, J. W. (1990). *The History, Physical, and Laboratory Examinations*. Atlanta, Georgia Emory University School of Medicine.

WHO (1969). *Health factors involved in working under condition of heat stress* Geneva: World Health Organization (WHO).

WHO (1969). *Health factors involved in working under condition of heat stress* Geneva: World Health Organization (WHO).

WHO (2000). *Obesity: Preventing and Managing the Global Epidemic*. Geneva.

Wilson, T. E., & Crandall, C. G. (2012). Effect of Thermal Stress on Cardiac Function. *Exerc Sport Sci Rev., 39*(1), 12-17.

Winkley, H. M., Beckett, J., Casa, D. J., Kleiner, D. M and Plummer, P. E. 2002. National athletic trainers' association position statement: Exertional Heat Ilnesses. *J Athl Train*, 37(3), 329-343

Yale (2009). Extreme Temperature Retrieved 22nd, january, 2014, from http://www.yale.edu/ergo/extremetemp.html

Yoshitake, H. (1978). Three Characteristic Patterns of Subjective Fatigue Symptoms. *Ergonomics*, *21*(3), 231-233.