



UNIVERSITI PUTRA MALAYSIA

***HEAT EXPOSURE AND THE EFFECTS ON PHYSIOLOGY AMONG
WORKERS IN ELECTRONIC PARTS INDUSTRY, BANGI, SELANGOR***

**BY
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ABSTRACT

HEAT EXPOSURE AND THE EFFECTS ON PHYSIOLOGY AMONG
WORKERS IN ELECTRONIC PARTS INDUSTRY, BANGI, SELANGOR.

AHMAD AL-BAIHAQY BIN ARIFFIN BILLAH

Introduction: Exposure of extreme heat is one of occupational hazard that present in the workplace. Hot conditions will put the body under stress which may lead to physiological parameter changes. **Objective:** The main objective of this paper is to determine the heat exposure in the workplace and its effects on the physiological parameters (body core temperature, heart rate, systolic and diastolic blood pressure). **Methodology:** A total of 100 respondents from both exposed and comparative group were participated in this study. Interviews based on questionnaires were used to determine respondent's socioeconomic background, medical history and job description. Pre and post measurements were taken before and after work shift for both groups. Environment temperature ($WBGT_{indoor}$) was measured by QUESTEMP[®]34 Thermal Environment Monitor[®] while the body core temperature was measured by Omron MC-510 Gentle Temperature Ear Thermometer. Omron T3 Automatic Blood Pressure Monitor[®] was used to measure respondent's blood pressure (systolic and diastolic) and heart rate. Interviews based on questionnaires were used to determine respondent's socioeconomic background, medical history and job description. **Result:** The heat exposure ($WBGT_{indoor}$) was higher in the workplace of exposed group (29.8 °C) compared to the comparative group (26.0 °C). Prevalence of heat stress disorders based on health complaint was higher in exposed group compared to comparative group. Significant difference of physiological parameters between exposed and comparative group were determined in this study ($p < 0.05$). However, only body core temperature and systolic blood pressure in exposed group showed significant increase after work shift ($p < 0.05$). **Conclusion:** Study highlighted a significant increase of body core temperature and systolic blood pressure with 8 hours work duration for the workers that exposed to heat.

Keywords: Heat Stress, Environmental Temperatures, Physiological Parameters

ABSTRAK

PENDEDAHAN TERHADAP HABA DAN PERUBAHAN KE ATAS FISIOLOGI DI KALANGAN PEKERJA DALAM INDUSTRI ELEKTRONIK, BANGI, SELANGOR.

AHMAD AL-BAIHAQY BIN ARIFFIN BILLAH

Pengenalan : Pendedahan haba yang berlebihan merupakan salah satu hazard pekerjaan yang terdapat di tempat kerja. Keadaan yang panas akan meletakkan tubuh badan di bawah satu tekanan di mana ia berkemungkinan menyebabkan berlaku perubahan fisiologi badan. **Tujuan :** Tujuan utama kajian ini adalah untuk menentukan tahap pendedahan haba di tempat kerja dan kesannya ke atas beberapa parameter fisiologi manusia (suhu badan, kadar denyutan jantung, tekanan sistolik dan tekanan diastolik jantung). **Metodologi :** Seramai 100 responden keseluruhan yang terdiri daripada kumpulan terdedah dan kumpulan perbandingan telah menyertai kajian ini. Temubual berdasarkan borang soal selidik telah digunakan untuk mengetahui latar belakang responden, sejarah perubatan dan maklumat tentang pekerjaan. Ukuran awal dan akhir telah diambil iaitu sebelum dan selepas bekerja untuk kedua-dua kumpulan. Suhu persekitaran dalaman ($WBGT_{indoor}$) telah diukur menggunakan *QUESTEMP³⁴ Thermal Environment Monitor*® manakala suhu teras badan telah diukur menggunakan *Omron MC-510 Gentle Temperature Ear Thermometer*. *Omron T3 Automatic Blood Pressure Monitor*® telah digunakan untuk mengukur tekanan darah (sistolik dan diastolik) dan kadar denyutan jantung. **Keputusan :** Tahap pendedahan suhu persekitaran dalaman ($WBGT_{indoor}$) di kawasan kerja bagi kumpulan terdedah (29.8°C) didapati lebih tinggi berbanding kawasan kerja kumpulan perbandingan (26.0°C). Kelaziman penyakit tegasan haba berdasarkan aduan kesihatan menunjukkan ia lebih tinggi di kalangan kumpulan terdedah berbanding kumpulan perbandingan. Semua parameter fisiologi menunjukkan perbezaan signifikasi antara kedua-dua kumpulan ($p < 0.05$). Namun begitu, hanya suhu teras badan dan tekanan sistolik darah sahaja yang menunjukkan peningkatan signifikasi ($p < 0.05$) sebelum dan selepas shift bekerja dalam kumpulan terdedah. **Kesimpulan :** Kajian menegaskan kadar peningkatan signifikasi suhu teras badan dan tekanan sistolik darah dengan jangkamasa 8 jam bekerja bagi pekerja yang terdedah kepada haba.

Kata Kunci : Tegasan Haba, Suhu Persekitaran, Parameter Fisiologi

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LIST OF ABBREVIATIONS

%	Percent
<	Less than
=	The same as
°C	Degree celcius
ACGIH	American Conference of Industrial Hygienists
BMI	Body Mass Index
bpm	Beats per minute
mmhg	Millimetres of mercury
N	Number of sample
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
<i>p</i>	Significance
SPSS	Statistical Package for Social Science
TLV	Treshold Limit Value
WBGT _(in)	Wet Bulb Globe Temperature Indoor

CHAPTER 1

INTRODUCTION

1.1 Background

The temperature of a workplace may significantly affect performance and the well being of workers. Added heat and humidity beyond the heat generated by the body during physical work may lead to notable performance decrement and may place the health of workers at risk (Pulat, 1997). Pulat also stated that the high temperature of a workplace can also cause physiological changes such as increase body temperature, blood pressure, heart rate and increased sweat rate that contribute to heat loss from the body. The American Conference of Governmental Industrial Hygienist (ACGIH) in 2001 stated the workers should not permit to work when their deep body temperature exceeds 38°C. In addition, World Health Organization (WHO, 2008) also recommended that deep body temperature should not, under circumstances of prolonged daily work and heat be permitted to exceed 38°C (rectal) or 37.5°C (oral).

2.2 Problem Statement

Heat stress is the aggregate of environmental and physiological work factors that constitute the total heat load imposed on the body (Alpaugh, 2001). Heat stress usually caused by high temperatures, has not been widely regarded as a major risk to worker's health as its negative impact goes largely unnoticed. According to the US Department of Labor (2002), operations involve high air temperatures, radiant heat sources, high humidity, direct physical contact with hot object or strenuous physical activities have high potential for inducing heat stress among employees.

Work in heat produced a phenomenon called acclimatization (Alpaugh, 2001). In addition, Gullickson (2000) stated that heat acclimatization occurs over 5-14 days with daily exercise in hot ambient condition of sufficient duration and of exertion to raise body temperature. Gullickson also stated although a worker can be acclimatized, excessive exposure to hot environment can bring about a variety of heat-induced disorders such as heat stroke, heat exhaustion, heat cramps, heat rash and heat fatigue.

1.2 Problem Statement

There are many industries that can cause heat stress to its employees such as iron and steel foundries, non-ferrous foundries, brick firing foundries and ceramic plant, glass product facilities, rubber product factories, smelters and steam tunnel. According to OSHA (1999), the employees have high potential of getting heat stress when performing task involving radiant heat sources, high humidity, and direct physical contact with hot objects or strenuous physical activities. Workers at risk of heat stress include outdoor workers and workers in hot environments such as firefighters, bakery workers, and others (NIOSH 2009).

Electronic parts industry is the one of the industries that can also cause heat stress among employees. Die-casting section is the one of electronic parts industry operations which is generally closely related to high temperatures during the work shift. According to Singh *et al.*, (2010), casting workers are continuously exposed to heat and the level of exposure is mainly depends on the level of occupational hygiene and control methods being implemented. Balakrishnan *et al.*, (2010) noted that the workers at casting area were exposed to 35.3 °C which above the recommended exposure value. The high temperature can influence the productivity of the workers.

Previous studies done by Muznita (2003) and Nor Hidayah (2004) stated that ultimate temperatures can reduce the quality of work, mental and physical ability. According to Goestch (2000), another symptom that heat stress occurs among workers are increasing of heart rate 180 minus with age of the worker, increasing of body core temperature over than 38.5°C , fatigue, vomiting and headache.

Holmes Safety Association (2000) stated when one's ability to respond to heat stress is exceeded, it can lead to reduce ability to perform good quality work, increasing accidents on the job or heat related illness. Besides, heat stress also has a direct impact on production by causing poor task performance and it increases the possibility of work-related morbidity and injuries (Cortez, 2009).

1.3 Study Justification

In Malaysia, limited numbers of studies were conducted regarding to high temperature and its effect on physiological changes among workers. Thus, this study can help to strengthen the previous study.

The purpose of this study is to study the effect of heat stress on physiology changes (body core temperature, blood pressure and heart rate) in electronic manufacturing industry. This study can help the respondents to know if there are some abnormalities arise from these three parameters and thus the respondents are able to take immediate action by seeking the physicians. Besides, it is also to encourage the workers to be aware of their health during working in high temperature.

This study also can provide interventions to reduce the risk of heat-related disorders in order to enhance the efficiency of the workers resulting in reduced reject quantity, improved production and hence increased profits.

Finally, this study can also serve as a guideline for the administration for the factory in terms to provide a solution and efficient control measure such as administrative and engineering control in terms of reducing heat stress exposure in the workplace.

1.4 Conceptual Framework

There are some physical hazards in the electronic parts factory such as noise, particulate and heat stress. In this factory, heat stress becomes the major physical hazards and it caused by environmental and individual factors. Therefore from the conceptual framework, the variables determined in this study were environmental factor consist of ambient temperature, radiant heat, cooling effect and air velocity , while the personal factors consist of age, body mass index, work load, gender and clothing.

The workers who were exposed to high temperature at a workplace can have physiological effects on body core temperature, blood pressure and heart rate. Other than that, high temperature in workplace can increased the sweating rate and body weight loss. High temperatures can affect the normal function of the body and show symptoms of heat induced disorders such as heat stroke, heat exhaustion, heat cramps, heat collapse, heat rash and heat fatigue (Figure 1).

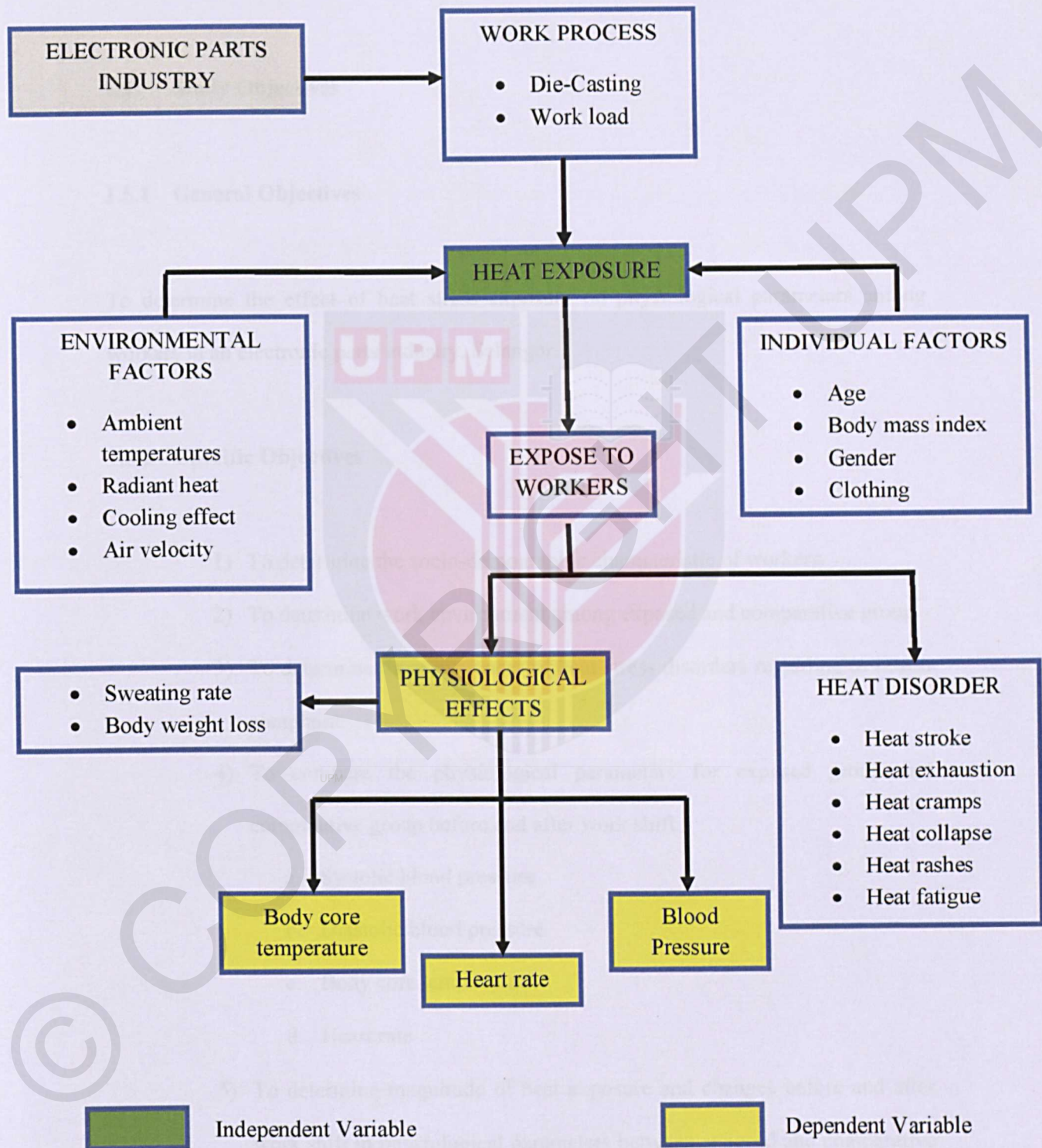


Figure 1.1: Conceptual Framework

1.5 Study Objectives

1.5.1 General Objectives

To determine the effect of heat stress exposure on physiological parameters among workers in an electronic parts industry, Selangor.

1.5.2 Specific Objectives

- 1) To determine the socio-demographic characteristic of workers.
- 2) To determine work environment among exposed and comparative group.
- 3) To determine the prevalences of heat stress disorders regarding to health complaint.
- 4) To compare the physiological parameters for exposed group and comparative group before and after work shift.
 - a. Systolic blood pressure
 - b. Diastolic blood pressure
 - c. Body core temperature
 - d. Heart rate
- 5) To determine magnitude of heat exposure and changes before and after work shift in physiological parameters between exposed and comparative group.

1.5.3 Study Hypothesis

- 1) There is significant difference between physiological parameters for exposed group and comparative group before and after work shift.
 - a. Systolic blood pressure
 - b. Diastolic blood pressure
 - c. Body core temperature
 - d. Heart rate

- 2) There is significant difference between magnitude of heat exposure and changes rate before and after work shift in physiological parameters between exposed and comparative group.
 - a. Systolic blood pressure
 - b. Diastolic blood pressure
 - c. Body core temperature
 - d. Heart rate

1.6 Definition of Terms

1.6.1 Conceptual Definitions

a) Heat Stress

Heat stress is the aggregate of environmental and physical work factors that constitute the total heat load imposed on the body (Alpaugh, 2001).

b) Dry Bulb Temperature (db)

Dry Bulb Temperature (db) is measured by using a thermal sensor i.e. mercury-in-glass thermometer that is shielded from direct radiant energy sources (OSHA, 1996).

c) Natural Wet Bulb Temperature (t_{nwb})

Natural Wet Bulb Temperature (t_{nwb}) is the temperature measured using a thermometer with the sensor covered by wetted cotton wick and exposed only to the natural air movement (NIOSH, 1986).

d) Globe Bulb Temperature (gb)

Globe Bulb Temperature (gb) is the temperature measured by a sensor attached inside a black, hollow, thin copper globe (OSHA, 2007).

e) Humidity

Humidity is the amount of water vapour within a given space and measured as relative humidity (Alpaugh, 2001).

f) Body Core Temperature

The body core temperature is defined as the temperature of the tissues at 2.5 cm beneath the surface of the skin (Green et al., 1996).

g) Blood Pressure

Blood pressure is the pressure or push of blood. It exists in all blood vessels, but is highest in the arteries and lowest in veins (Thibodeau & Patton, 1997). A single blood pressure reading consists of two separate figures that represent the pressure of blood during two different times. During heartbeats blood pressure oscillates between maximum which is systolic and minimum which is diastolic (Brown et al, 2006).

h) Heart Rate

Heart rate can be defined as rate of heartbeat. This rate has an effect on blood pressure. Each complete heart beat is called a cardiac cycle. A cardiac cycle includes contraction (systole) and relaxation (diastole) of atria and ventricles (Thibodeau & Patton, 1997).

1.6.2 Operational Definitions

a) Heat Stress

Heat stress was determined by measuring five parameters : WBGT (t_{in}), Natural Wet Bulb Temperature (t_{nwb}), Dry Bulb Temperature (db), Globe Bulb Temperature (gb) and relative humidity and measurement of worker's work load and exposure time.

b) Dry Bulb Temperature (db)

The dry bulb thermometer (db) measures the ambient temperature. This thermometer is exposed to the air just as any thermometer is used to measure air temperature. A dry bulb thermometer consist of a hollow glass tube with a bottom reservoir of mercury. The range of the thermometer should be -5 to $+50^{\circ}\text{C}$ and accurate to $\pm 0.5^{\circ}\text{C}$. The reading was taken in degree Celsius ($^{\circ}\text{C}$) automatically.

c) Natural Wet Bulb Temperature

QUESTemp°34 Thermal Environment Monitor was placed at the workplace exposed to heat. The instrument records reading for eight hour per shift and calculates the WBGT_(in) index in degree Celsius (°C) automatically.

d) Globe Bulb Temperature (gb)

The Globe Bulb Temperature (gb) gives an indication of the radiant heat exposure in an individual. A sensor is positioned inside a blackened copper sphere and the temperature rise in measurement. The information was used in calculating in WBGT_(in) and the reading was taken in degree Celsius (°C) automatically.

e) Humidity

The Natural Wet Bulb Thermometer gives an indication of the effects of humidity on an individual. Measurements were taken using a thermometer covered by moistened cotton wick immersed into a reservoir containing distilled water. The information was used in calculating in WBGT_(in).

f) Body Core Temperature

Body core temperature was measured in degree Celsius (°C) by using Omron MC-510 Gentle Temperature Ear Thermometer. This instrument measures the temperature by inserting the sensor into the right ear.

g) Blood Pressure

Omron T3 Automatic Blood Pressure Monitor was used to measure blood pressure. The cuff was fastened onto the left arm and it was ensured the respondents were remained seated while the measurement was taken. Reading was taken before work and after 8 hours of work. Three measurements were taken per session.

h) Heart Rate

Heart rate was measured by using Omron T3 Automatic Blood Pressure Monitor. The cuff was fastened onto the left arm and it was ensured the respondents were remained seated while the measurement was taken. Three measurements were taken per session and respondents were asked not to eat and drink at least 15 minutes before the measurement.

CHAPTER 2

LITERATURE REVIEW

2.1 Heat at the Workplace

Heat is an occupational health issue (Shanks and Papworth, 2001). With high heat stress level, mental confusion can develop and predispose workers to perform unsafe acts: the risk of accidents increases with extreme temperature (Shanks and Papworth, 2001).

Intense hot environments are prevalent in the iron, steel, glass and ceramic units, rubber, foundries, coke ovens, mines and many other industries (Srivastava *et al.*, 2000). In these industries where workers are constantly exposed to hot environments, the workers are at risk of experiencing heat stress. It affects range from changes in worker behaviors to heat-related disorders (Bernard *et al.*, 1999).

National Institute of Occupational Safety and Health (1986) developed the first criteria document for recommended standards related to occupational exposure to hot environment. It suggested that work practices should be instituted when exposure of an

employee was continuous for one hour or intermittent for two hours at a time-weighted average wet bulb globe temperature (WBGT) that exceeds 26 °C (79 °F) for men or 24 °C (76 °F) for women. The WBGT is the most commonly used index for limiting thermal exposure levels in occupational environments (OSHA, 2007).

2.2 Heat Stress

Heat stress can be described as the situation where the human body experiences problems in dissipating excess heat to the environment. It is the difference between internal or metabolic heat production and the heat lost to the actual environment (Rabiul *et al.*, 2002).

Heat stress occurs when the body produces or gains more heat than it is capable of giving off or losing. The heat stress on the workers depends on four environmental factors, namely the air temperature, humidity, mean temperature of the surrounding area and air movement (Srivastava *et al.*, 2000).

2.3 Heat Strain

Heat strain is the overall physiological response resulting from heat stress. Heat strain occurs when environmental factors (temperature, humidity, air movement) combine with metabolic heat production to place an uncompensable heat stress on the body (Armstrong, 2006). The physiological adjustments are dedicated to dissipating excess heat from the body (ACGIH 2001). Heat strain reflects the extent to which the individual has to marshal defenses to keep total body heat content and deep body temperature in a workable and livable range (ACGIH 2001).

2.4 Physiological Changes

2.4.1 Body Core Temperature

The normal human body temperature is between 36.2°C and 37.6 (Thibodeau and Patton, 1997). According to Green *et al.* (1996), the body temperature is defined as the temperature of the tissues 2.5 cm beneath the surface of the skin. When engaged in heavy physical activity, the body produces excess heat thus elevating the body core temperature (Vigil, 2002).

There are number of sites where body temperature can be measured, such as oral, oesophageal, tympanic, rectal and skin. The tympanic membrane has been noted for

its accuracy as the eardrum shares the same blood vessels as the hypothalamus, which is the centre of thermoregulation in the body. This reading is not affected by such activities as talking, eating, drinking or smoking. Kenny (2000) has reported that local ear canal and ambient temperatures affect the tympanic temperature.

2.4.2 Blood Pressure

Blood pressure is the force caused by blood pushing up against the walls of the blood vessels (Green et al., 1996). According to Tortora and Grabowski (2003), systolic blood pressure is the highest pressure attained in arteries during systolic and diastolic blood pressure is the lowest arterial pressure during diastole.

In acute heat exposure, there is an increase in blood circulation at the skin and exercising muscle areas, and this is met by a decrease of blood circulation at the renal, splanchnic and non-exercising muscles. When the body is overheated, blood flow to the skin increases to lose the excess heat and to maintain the stability of the internal environment. Warm blood from the body core can then be cooled from the skin, which acts as a radiator (Thibodeau and Patton, 1997).

The increase of blood pressure is closely related with the increase of heart rate. This is because the heart has to work harder to pump blood to all the body parts so that the body temperature can be reduced (Alpaugh, 1998).

2.4.3 Heart Rate

Heart rate is the rate of heartbeat. Heart rate is a general indicator of stress in the body (Lu and Zhu, 2007). The WHO recommended that an average heart rate over the duration of a working shift should not exceed 110 beats per minute (Bates and Schneider, 2008).

According to Rodahl (2003), in case of heat stress, our circulating blood volume need to transport oxygen and also has to serve as a cooling fluid. It therefore transports heat from the interior of the body to the skin where it is dissipated to the surrounding environment by conduction, convection, radiation or sweat evaporation. This requires an increase in speed of the blood circulating by increasing the heart rate. Thus, the heart rate becomes an expression of the degree of the additional load exerted on the cardiovascular system when the body exposed to certain heat.

2.4.4 Thermal Balance

Thermal balance is achieved by an interaction of behavioral and automatic responses, which results in total thermoregulatory response (Khogali, 1992). Thermoregulation response occur when receptors, sensitive to change, send messages via the Central Nervous System to the hyphothalamus, from where the regulation of body temperature is controlled. The ultimate control and coordination of

thermoregulation in humans is controlled by the autonomic system (Bethea and Parsons, 2002).

Autonomic system is the neural system within the human body that controls those bodily functions which are not usually under voluntary control. When set point is exceeded, blood vessels widen (vasodilation) and blood is pumped to the skin, thereby losing heat from the blood to the skin. This turn reduces the gradient between skin temperature, reducing the gain of heat through convection and conduction. Through this process of thermoregulation, human maintain their deep temperature at or about 37 °C and any deviation of a degree or more (plus or minus) from 37 °C can have serious consequences (Bethea and Parsons, 2002).

Based on Kamijo et al., (2006), there are two physiological mechanisms involved in heat dissipation in humans which are skin blood flow and sweating. Skin blood flow transfer the heat generated by the contracting muscles to the skin surface according temperature gradient between skin and the air (non-evaporative heat loss). On the other hand, sweat transfers heat from the skin surface to the air when sweat evaporates (evaporative heat loss) Thus, the core temperature is controlled within a narrow range when heat balance is attained, but is increases rapidly when heat production overcomes heat dissipation such as during heavy labor in hot and humid environment.

2.5 Heat Related Disorders

Heat related disorders are physical manifestations of untoward outcomes of heat stress exposures (ACGIH, 2001). Heat disorders (in order of increasing severity) are heat rash, heat syncope, heat cramps, heat exhaustion and heat stroke (Cohen *et al.*, 2004).

2.5.1 Heat Fatigue

Heat fatigue is usually first indication of more serious heat illness (Vigil, 2002). A factor that predisposes an individual to heat fatigue is lack of acclimatization (OSHA Technical Manual, 2002). The sign and symptoms of heat fatigue include impaired performance of skilled sensor motor, mental or vigilance jobs. The immediate treatment such as remove the heat stress exposure to the workers before more serious heat-related conditions develops.

2.5.2 Heat Rashes

According to OSHA Technical Manual (2002), heat rashes are the most common problem in hot work environments. Prickly heat is manifested as red papules and usually appears in areas where the clothing is restrictive. As sweating increases, these papules give rise to a prickling sensation. Prickly heat occurs in skin that is persistently wetted

by unevaporated sweat, and heat rash papules may become infected if they are not treated. In most cases, heat rashes will disappear when the affected individual returns to a cool environment.

2.5.3 Heat Collapse

Heat collapse occurs when the brain does not receive enough oxygen because blood pools in the extremities (OSHA Technical Manual, 2002). As a result, the exposed individual may lose consciousness. This reaction is similar to that of heat exhaustion and does not affect the body's heat balance. However, the onset of heat collapse is rapid and unpredictable. To prevent heat collapse, the workers should gradually become acclimatized to the hot environment (NIOSH, 2009)

2.5.4 Heat Cramps

Gullickson (2000) stated, heat cramps are painful muscle spasms that occur during or following intense physical exercise in hot environments. The cramps are caused by excessive sweating and loss of salts from the blood and tissues (Vigil, 2002). These cramps have been attributed to an electrolyte imbalance caused by sweating. It is important to understand that cramps can be caused by both too much and too little salt. Cramps appear to be caused by the lack of water replenishment. Recent studies have shown that drinking commercially available carbohydrate-electrolyte replacement

liquids is effective in minimizing physiological disturbances during recovery. According to (Vigil, 2002), the best treat for heat cramps by drinking a salty liquid.

2.5.5 Heat Exhaustion

Heat exhaustion is a type of heat stress that occurs as a result of water and salt depletion (Goetsch, 2000). In this case, the body comes dehydrated. The signs and symptoms of heat exhaustion are headache, nausea, weakness, thirst and giddiness (OSHA Technical Manual, 2002). Workers suffering from heat exhaustion should be removed from the heat environment and given fluid replacement. They should also be encouraged to get adequate rest.

2.5.6 Heat Stroke

Heat stroke occurs when the body's system of temperature regulation fails and body temperature rises to critical levels. This condition is caused by a combination of highly variable factors and its occurrence is difficult to predict. Heat stroke is a medical emergency. The primary symptoms of heat stroke are the workers become confused, stagger and may collapse (Vigil, 2002). It can also cause skin to be dry, hot and also contribute to abnormally high body temperature, where a rectal temperature is 41°C. If body temperature is too high, it causes death. The medical outcome of an episode of heat

stroke depends on the victim's physical fitness and the timing and effectiveness of first aid treatment.

2.6 Heat Stress Symptoms

According to Goestch (2000), the symptoms for heat stress are:

- Increase in heart rate
- Body core temperature exceed 38.5°C
- Tired, nausea, dizziness and headache
- Heart rate recovery more than 110 after 2.5 minutes after rest

Above symptoms can be measured at the same time while other method use in measuring for long term. The symptoms that indicate heat stress after long term measurement are:

- Excessive sweating rate
- Loss of body weight exceed 1.5% of body weight during working
- Excretion of urine and natrium less than 50 mol (24 hours)

2.7 Heat Transfer

Heat can be transferred to and from the body by conduction, convection, radiation and evaporation. Heat from the body core is transferred to the surface through conduction and convection, while warmed blood is shunted to the skin for evaporative cooling. Evaporation is the mechanism that is most effective in releasing heat from the body during exercise in a hot environment (Brown *et al.*, 2006).

2.8 Personal Factor

Personal risk factors are those elements that may reduce an individual's tolerance for heat stress. (ACGIH, 2001).

2.8.1 Age

Age itself may not be the most important criterion. Physical condition and debilitations commonly associated with age are more significant. Some physical disabilities associated with aging seriously weaken response to heat stress. Similarly, chronic illnesses that weaken cardiac output or reduce circulating blood volume reduce safety in heat stress (ACGIH, 2001).

2.8.2 Gender

Gender differences were difficult to demonstrate between men and women in the adult years. Whatever differences there may be are overshadowed by factors of physical fitness and levels of heat acclimatization. Temporary infertility in both females and males has been observed when core temperature was above 38°C (100.4°F). During the first trimester of pregnancy, there is an increased risk of malformation of the unborn fetus if the mother's core temperature exceeds 39°C (102.2°F) for extended periods (ACGIH, 2001).

2.8.3 Clothing

Clothing, by its very nature, interferes with our ability to lose heat to the environment. Wearing too much clothing or personal protective equipment (PPE) may be a primary cause of heat stress even if the environment is not considered warm or hot. Clothing is both a potential cause of thermal discomfort as well as a control for it as we adapt to the climate in which we live and play (HSE, 2007)

2.8.4 Alcohol

Alcohol in high doses induces many physiological and perceptual disorders. Not only is it a central nervous system depressant, but alcohol also produces peripheral vasodilation and diuresis. Aside from affecting perception and judgement, demonstrating that low doses of alcohol seriously reduce thermoregulatory response, including vasomotor and sweating reflexes or that it may serve as a diuretic is difficult. Alcohol use will adversely affect cardiovascular regulation of blood pressure, leaving some people more susceptible to a fall in arterial pressure during heat stress (ACGIH, 2001).

2.8.5 Smoking

Smoke from cigarettes reduces immune system function, influences the response to other agents and increases the risk of heart disease. Tobacco in cigarettes contains nicotine which constricts the walls of the blood vessels. Constriction means the vessel is narrower, requiring the heart to pump harder to push the blood through the narrower vessel, throughout the body, and back to the heart (Tortora & Grabowski, 2003).

2.8.6 Drug

Many prescription drugs and some over-the counter medications need to be used with extra caution in heat stress. Some anticholinergic medications for example, inhibit sweating, especially for the elderly. In addition, some sedatives affect thirst thresholds, some behavioral modifying drugs increase metabolic heat production and reduce heat distribution by seriously affecting the peripheral circulation. Prozac and lithium-based antidepressants reduce the ability for those working in the heat for thermoregulation. Amphetamine-like drugs, for example, characteristically increase body heat loading and produce hyperthermia (ACGIH, 2001).

2.8.7 Obesity

Body fat is an especially good thermal insulator. Skin has a thermal conductivity about 95% and muscle about 86% that of water, whereas fat conducts heat only about 36% as well. Fat is also heavy and requires a greater expenditure of energy for the obese person to move around. Those people who are obese are commonly not in the best of physical condition. Many show comparatively higher heart rates during exercise and physical exertion. On the face of it, the obese person faces several potential disadvantages in heat stress, based on the greater thermal insulation and possibly diminished cardiovascular and exercise potentials (ACGIH, 2001).

2.8.8 Hypertension

Hypertension affects the body's ability to keep itself cool. It also places greater stress on the heart, making it harder for the heart to pump blood throughout the body. In addition, many people with hypertension are on low-salt diets. Not having enough salt in the system can lower the threshold to heat stroke (Thibodeau & Patton, 1997).

2.8.9 Hydration

The important job of distributing heat in the body falls almost completely to the cardiovascular system. Virtually all heat is transferred within the body by forced convection mediated by blood flow. Keeping a large circulating blood volume is essential for safe human heat exposures. Water accounts for much of blood and tissue volume. While body water is lost by diffusion across the skin and from the nasopharyngeal, lingual, and buccal surfaces with each breath, most water losses during heat stress is from sweating (ACGIH, 2001).

2.8.10 Acclimatization

Acclimatization is the gradual process where your body is made used to higher work and heat levels. Through acclimatization, our body benefits from smaller increases in body temperature and heart rate, and increased sweat production, while working in heat. It takes about 7 days, working in a warm or hot environment for at least 100 minutes a day, to approach full acclimatization to the environment about 2 weeks. Full-time workers usually become naturally acclimatized as weather warms, and do not need a formal acclimatization period unless there is a sudden increase in workload, temperature, humidity, or PPE that restricts body cooling (HSE, 2007).

CHAPTER 3

METHODOLOGY

3.1 Study Design

The study design that was used is a cross-sectional study design which exposure and health effects were measured in the same time. The physiological effects of the respondents in exposed and comparative groups were measured in this study.

3.2 Study Location

This study was conducted at one of electronic parts industry in Bangi, Selangor. There were two section covered which die-casting and visual inspection section. Die-casting section produce lot of heat compared to visual inspection section.

3.3 Study Population

The study populations comprise of males and females workers at die-casting and visual inspection section. Workers that working at die-casting section represented as exposed group while workers that working at visual inspection section represented as comparative group.

3.3.1 Background Study Location

The nature of business for this electronic industry is manufacturing of electronic and computers peripherals parts. The work flow process was started with die casting of raw molten aluminium and finished with last process which was visual inspection.

Die casting process is the first phase of work process in electronic parts manufacturing industry. The process started with the raw material, aluminium ingots were undergo melting process which take place in furnace for melting. The temperature in furnace was 650 °C. Then molten aluminium are being transferred to casting machine through robotic arms and later in this process, the liquid metal was injected at high speed and high pressure onto a metal mould. Once the metal was solidified, the die opened and the casted rotor was removed manually or robotically. The die releasing fluid was injected automatically and the next cycle will be restarted. In this section the solidified

metal plate was collected and undergoes trimming process manually. In this section, workers were exposed highly to heat.

After undergoes some process, it will finished at visual inspection section. At his section, the product will undergo final inspection for quality control and quality assurance. The products will be inspected in operator line and if there was abnormality, the products will be rejected. The full work flow process was summarized and can be described in Figure 2 below.

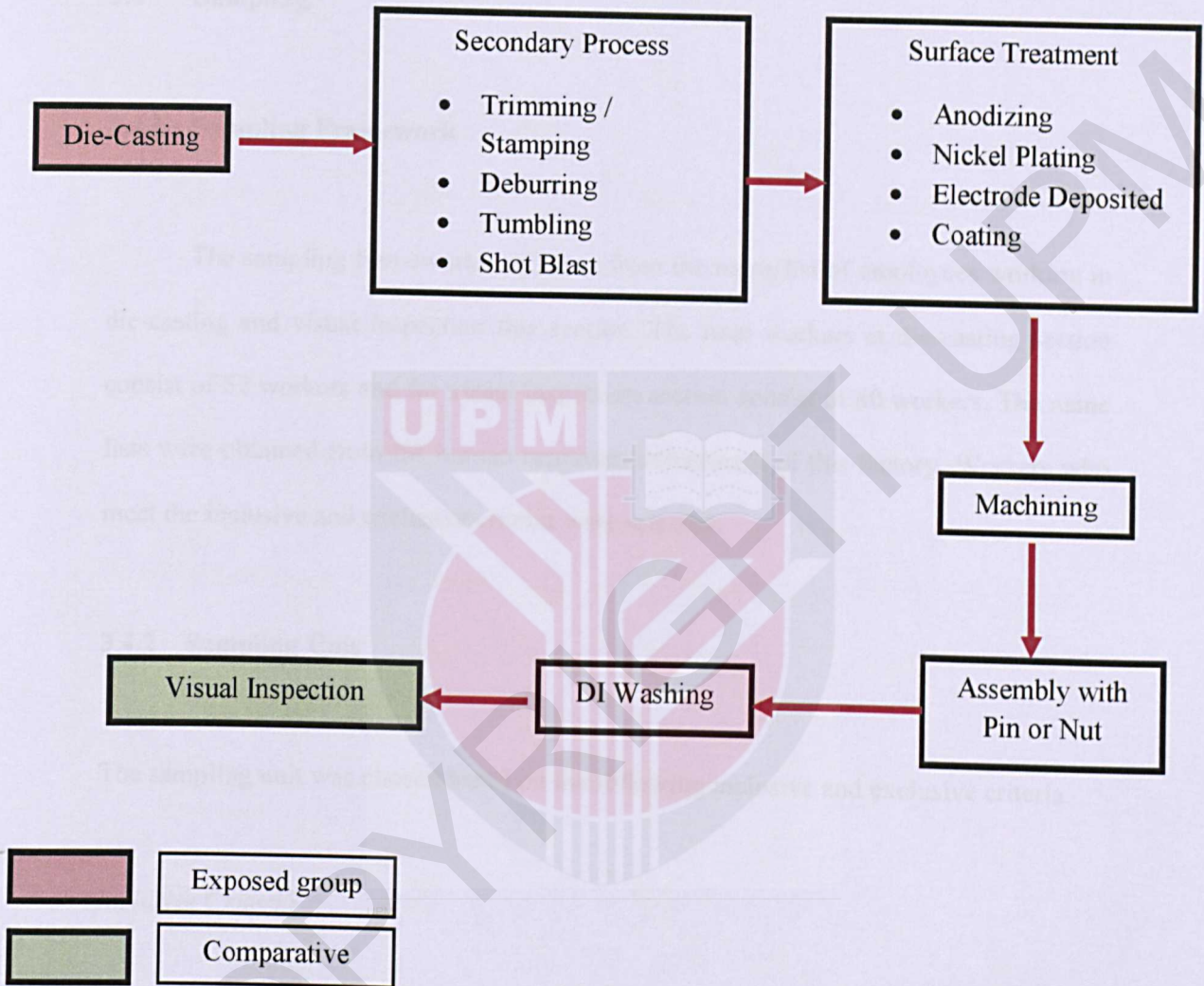


Figure 3.1 : Full work flow process

3.4 Sampling

3.4.1 Sampling Framework

The sampling framework was taken from the name list of employees working in die-casting and visual inspection line section. The total workers at die-casting section consist of 52 workers and for visual inspection section consist of 60 workers. The name lists were obtained from the human resources department of this factory. Workers who meet the inclusive and exclusive criteria were selected.

3.4.2 Sampling Unit

The sampling unit was chosen based on the following inclusive and exclusive criteria.

Inclusive Criteria :

- a) Male and Female workers
- b) Full time workers who have been working for more than a month. Full-heat acclimatization requires up to 3 weeks of continued physical activity under heat stress conditions. (ACGIH 2001).
- c) Workers who are exposed to workplace temperature of more than 28.5°C.

Exclusive Criteria :

- a) Workers who were on leave for more than 4 days. This is because loss to heat acclimatization begins when the activity under those heat stress condition is discontinued, and a noticeable loss occur after 4 days. (ACGIH 2001)
- b) Workers who have been diagnosed with diabetes mellitus, hypertension, asthma, and any heart disease. This is because workers who consume medication such as diuretic drug, anti-hypertension, anti-histamine drugs due to the mentioned medical condition will contribute to the increase in body temperature due to effects on the body fluid balance, vasoconstrictor/ dilator activity and on cardiac function (Havenith, 1995).

3.4.3 Sampling size

The sampling size for the study was based on Kirkwood & Sterne (1988).

$$\begin{aligned} N &= (P\beta + P\alpha)^2 (SD_1^2 + SD_2^2) / (X_1 - X_2)^2 \\ &= (0.84 + 1.96)^2 (14.08 + 12.67)^2 / (124.98 - 117.51)^2 \\ &= 50 \end{aligned}$$

Where :

$P\beta$ = z-value at beta of 0.2

$P\alpha$ = z-value at alpha of 0.05

SD_1 & SD_2 = standard deviation of systolic BP exposed group (1)* & comparative group (2)*

X_1 & X_2 = mean of systolic BP exposed group (1)* & comparative group (2)*

*Value taken from (Muznita, 2004).

Based on calculation above, Beta value will be set at 0.2 and Alpha value will be set at 0.05 level of significant in statistical analysis. The minimum sample size required is 50 workers for each exposed and comparative group. Thus, the minimum total number of all respondent for expose group and comparative group will be 100.

3.4.4 Sampling Method

There were 52 workers working at die-casting section while 60 workers at visual inspection section. The total of 100 workers that fulfilled inclusive and exclusive criteria were selected which 50 respondents for exposed group and 50 respondents for comparative group. The sampling method in this study was purposive sampling as only individual who satisfying the inclusion and exclusion criteria of this study were selected from work section until the required sample size was reached.

3.5 Instrumentation

3.5.1 Questionnaire

A self-constructed questionnaire was administered. The questionnaire was divided into a few sections. These include respondent's socio-demographic, general health profile, employment health complain and work details. These questionnaires were distributed to the respondent before the measurement of body core temperature, blood pressure and heart rate.

3.5.2 Thermal Environmental Monitor

Questemp[®]34 Thermal Environmental Monitor was used to measure the WBGT_(indoor) and relative humidity for the study area. It was fixed on a tripod at 3.5 feet (1.1m) above the floor and its natural wet bulb thermometer cotton wick was moistened and immersed in a reservoir containing distilled water. The instrument was programmed to record and monitor the WBGT_(in) for eight hours with a logging rate of every 15 minutes (Quest Technologies, 2000).



Figure 3.2 : Wet Bulb Globe Temperature

3.5.3 Tanita Weighing Scale and Seca Body Meter

Tanita Weighing Scale was used to measure the weight, while Seca Body Meter was used to measure the height of the respondent. The height and weight were used to calculate the body mass index (BMI) of the respondent.



Figure 3.3: Tanita Weighing



Figure 3.4: Seca Body

3.5.4 Ear Thermometer

Omron MC-510 Gentle Temperature Ear Thermometer was used to measure the respondent's body core temperature. Measurement of body core temperature was carried out before work and after work shift. The sensor was inserted into the right ear and three measurements were taken per session.



Figure 3.5: Omron MC-510 Gentle Ear Temperature

3.5.5 Blood Pressure monitor

Omron T3 Automatic Blood Pressure Monitor was used to measure blood pressure and heart rate of the respondents. Three measurements were taken per session. The cuff was fastened onto the left arm and it was ensured the respondents were remained seated while the measurement was taken. The respondents were asked not to eat and drink at least 15 minutes before the measurement.



Figure 3.6: Omron T3 Automatic Blood Pressure

3.6 Data Quality Control

3.6.1 Pre-Test

Prior to the actual data collection for this research, a pre-test was conducted on 10% of the sample size at one of manufacturing factory in Bangi, Selangor. The respondents were tested on the self-constructed questionnaires to evaluate their level of understanding or perception of the questionnaires. It is to ensure that the questionnaire should be suitable and can be understood by the workers so that any mistakes can be rectified before the actual data collection.

3.6.2 Calibration

All the instruments used were calibrated before used in the actual data collection. Calibration was carried out to eliminate any measurement error that may result from the condition of the instrument itself. For each of the instruments, calibration was carried out according to the instruction manuals.

3.7 Data Analysis

A statistical analysis of data was performed by using the Statistical Packages for Social Sciences (SPSS) version 17 software. The results were considered statistically significant at ($p \leq 0.05$). The variables were tested using histogram, skewness, kurtosis, Q-Q plot, Kolmogorov-Smirnov and Shapiro-Wilk statistic with Lilliefors significance level for normality. The assumption of normality for significance level was ($p > 0.05$). Since the all data were normally distributed, parametric tests were used.

3.7.1 Descriptive Analysis

Descriptive analyses were performed on all study variables to obtain a general concept concerning the background and demographic data of the subjects. The data was presented in the form of mean and standard deviation for continuous variables, and count or percentage for categorical variables. Chi-Square was performed to determine if standard deviation were equally distributed in both exposed and comparative groups.

3.7.2 Bivariate Analysis

This analysis give focus on the study hypothesis, which involved in testing for statistical significant different.

- 1) There is significant different between physiological parameters for exposed group and non-exposed group before and after work shift. (Paired T-test was used)

- a. Systolic blood pressure
- b. Diastolic blood pressure
- c. Body core temperature
- d. Heart rate

- 2) There is significant different between magnitude of heat exposure and changes rate in physiological parameters between exposed and comparative group. (Independent Sample t-test was used)

- a. Systolic blood pressure
- b. Diastolic blood pressure
- c. Body core temperature
- d. Heart rate

3.8 Study Ethics

In terms of ethical consideration, the study was proposed and sought from ethical community from the Medical Research Ethical Committee of Faculty of Medicine and Health Sciences of Universiti Putra Malaysia. Besides that, the permission from employer and employees was sought before conducting the assessment. In addition, subject was informed the content of the research and the written informed consent that was obtained. Finally, the confidential of all the information about the respondent and the company that was involved in this study are honored at all times.

3.9 Study Limitation

3.9.1 Confounder

a) Noise

Environmental factor such as noise is a limitation in this study. Noise can influence the findings of this study since it also had the same effect on the physiological changes which can increase the blood pressure and heart rate as the workers exposed to high level of noise. Based on baseline data on noise exposure, visual inspection section (comparative group) was higher (95 dBA) compared to die-casting section (exposed group) which was 90 dBA. However the workers at visual inspection section were

provided with ear plug but the effectiveness of usage was unreliable since no enforcement and most of them did not wear it. In order to overcome this problem, workers were provided with new ear plug and its usage was compulsory on that day.

b) Diet

This study does not take account the diet of its respondents, thus the taking of supplements or certain types of food, like coffee or anything high in caffeine, has the ability to influence the readings obtain from the measurement. Certain supplements and types of food can influence a person's heart rate or even increase a person's temperature and rate of sweating. It was difficult to measure diet intake by respondents since most of them were foreigner and there were also variations of diet among them. In addition, it was difficult to conclude the diets factor in one measurement and respondents might be difficult to recall information about their diet intake in specified period. Respondents were asked to do not take any food and drink for 30 minute before measurement taken.

c) Smoking

Smoking is one of the study limitations in this study. It may affect the accuracy of the measurement of body core temperature, blood pressure and heart rate (Willis *et al.*, 2004). Respondent were asked to do not smoking for 1 hour before measurement taken.

3.9.2 Information Bias

This situation arises when the answers given by the respondents does not reflect the true situation or the respondents tend to forget certain information that might seem trivial but in fact, it can affect the outcome of readings and result. It has been observed that respondents might not be aware of certain factors, like being unaware of suffering from high blood pressure, thus are not able to give answers that reflect their current physiological state.

3.9.3 External Validity

This data cannot be interpreted for chronic effect since the changes of physiological parameters is acute effect. The results also might not be applicable to others industries.

CHAPTER 4

RESULT

4.1 Respondent's Social Demographic Data

All respondents in exposed group consist of male workers but for comparative group, there were 58% males and 42% females. There was significant different ($\chi^2=26.58$, $p<0.001$) across gender between exposed and comparative group approximately 50% of respondents ages between 18 to 27 years old for both groups. The BMI of respondents in both groups also showed that almost 60% of them have normal BMI but there were also reported on underweight which 14% for exposed group and 16% for comparative group. In overweight category for BMI, there was 18% and 22% of workers respectively for exposed and comparative group. There were no obesity category reported in exposed group but there were 2% reported in comparative group.

The majority of workers at work section for exposed and comparative group were non-Malays which were 78% and 76% respectively. Most of respondents were Muslim for both groups which is exposed group (94%) and comparative group (82%) respectively. The workers status showed that most of respondents in exposed group were married (52%) but for comparative group, most of them reported still single (56%). The Table 4.1 presents the socio-demographic background of respondents.

In terms of education level, most of the respondents from both groups were in secondary school level (78% for exposed and 76% for comparative group. Lastly, most of the workers from both groups have income between RM500 – RM1000 and recorded as active smoker (58% for exposed and 90.2% for comparative group. None of them consumed alcohol.

Table 4.1: Socio-demographic of respondents

Characteristic	Exposed group, n=50 N (%)	Non-exposed group, n=50 N (%)	χ^2	p-value
Gender				
Male	50 (100)	29 (58)	26.58	<0.001*
Female	-	21 (42)		
Age				
18-27	23 (46.0)	26 (52.0)	0.94	0.816
28-37	21 (42.0)	17 (34.0)		
38-47	5 (10.0)	5 (10.0)		
48-57	1 (2.0)	2 (4.0)		
BMI				
<18.5 (underweight)	7 (14.0)	8 (16.0)	1.26	0.739
18.5-24.9 (normal)	34 (68.0)	31 (62.0)		
25-29.9 (overweight)	9 (18.0)	10 (20.0)		
>30 (obesity)	-	1 (2.0)		
Race				
Malay	11 (22.0)	12 (24.0)	0.06	0.812
Non-Malay	39 (78.0)	38 (76.0)		
Religion				
Muslim	47 (94.0)	41 (82.0)	3.41	0.065
Non-muslim	3 (6.0)	9 (18.0)		
Education				
None	-	2 (4.0)	6.35	0.096
Primary school	10 (20.0)	5 (10.0)		
Secondary school	39 (78.0)	38 (76.0)		
Above secondary school	1 (2.0)	5 (10.0)		
Current Smoker				
Yes	21 (58.0)	46 (90.2)	3.66	0.056
No	19 (42.0)	5 (9.8)		

*Significant at $p<0.05$

4.2 Environment parameter and Workload Category

Table 4.2 showed the workload category and work regime of the exposed and comparative groups. The exposed and comparative group were having heavy workload category based on assessment of work but there are different environment temperature for both work section. The work regime for both exposed and comparative groups are 75% work and 25% rest.

Table 4.2: Workload categories and work regime of exposed and comparative groups

Work Area	Work Unit	Measured WBGT _{in} (°C)	Relative Humidity (%)	Workload Category	Work Regime
Exposed	Die-Casting	29.8	81	Heavy*	75% work,*
Comparative	Visual inspection	26.0	78		25% rest

*Classification based on ACGIH (2001)

4.3 **Prevalence of Heat Stress Disorders**

The third objective of this study was to determine the prevalence of heat stress disorder from health complaint among workers in both exposed and comparative group during working. Table 4.3 showed the acute symptoms that occur among the workers regarding work environment.

Based on the table showed the symptoms that occur among exposed and comparative group when expose to different heat temperature in their work section. Majority of the respondents in both exposed and comparative group reported having fatigue which 100% and 98% respectively. The symptom of headache showed slightly higher in exposed group (72%) compared to comparative group (68%). Based on nausea symptom, the comparative group showed higher prevalence which was 34% compared to exposed group (16%). The health complaint about muscle cramp symptom was reported in exposed group (22%) while there was no incident reported in comparative group.

Table 4.3: Prevalence of heat stress disorders from health complaints among exposed and comparative group.

Symptoms	Exposed group (N=50)		Comparative group (N=50)	
	Yes (%)	No (%)	Yes (%)	No (%)
Fatigue	50 (100)	-	49 (98)	1 (2)
Headache	36 (72)	14 (28)	34 (68)	16 (32)
Nausea	17 (34)	33 (66)	8 (16)	42 (84)
Muscle cramp	11 (22)	39 (78)	-	50 (100)

4.4 Physiological Parameters Before and After Work Shift

The fourth objective for this study is to compare the physiological parameters for exposed group and comparative group before and after work shift. Body core temperature, blood pressure (systolic and diastolic) and heart rate are four parameters that can show and contribute to physiological changes among the respondents when exposed to heat. Table 4.3 below showed the differences in physiological parameters before work and after work shift among exposed and comparative groups.

The body core temperature before work and after work shift for both exposed and comparative group was showed significantly different which is ($p<0.05$) for exposed and comparative group.

Variable	Study Group	Before work	After work	t-value	p-value
		Mean $\pm$ S.D	Mean $\pm$ S.D	(t)	

The heart rate before work and after work shift showed significantly different in comparative group ($p<0.05$) but there is no significant different among exposed group ($p>0.05$).

The systolic blood pressure before work and after work shift for both exposed and comparative showed significant different which is ($p<0.05$) for exposed and comparative group.

The diastolic blood pressure before work and after work shift showed significant different in comparative group ($p<0.05$) but not significantly different in exposed group ($p>0.05$).

Table 4.4: The comparison of physiological parameters for exposed group and comparative group before and after work shift.

Variables	Study group	Before work	After work	t-value (df)	N	p-value
		Mean ± S.D	Mean ± S.D			
Body core temperature (Celcius)	Exposed	35.77 ± 0.55	36.58 ± 0.60	9.70 (49)	50	< 0.001*
	Comparative	36.55 ± 0.46	36.73 ± 0.31	2.65 (49)	50	0.011
Heart rate (beats per minute)	Exposed	71.32 ± 10.11	73.12 ± 12.36	1.26 (49)	50	0.215
	Comparative	71.06 ± 15.09	79.06 ± 12.52	3.37 (49)	50	0.001*
Systolic blood pressure (mmHg)	Exposed	112.62 ± 13.46	117.26 ± 13.60	2.78 (49)	50	0.008*
	Comparative	124.34 ± 19.98	118.26 ± 21.02	2.80 (49)	50	0.007*
Diastolic blood pressure (mmHg)	Exposed	67.78 ± 10.79	67.34 ± 9.89	0.30 (49)	50	0.769
	Comparative	77.74 ± 12.43	72.20 ± 11.45	3.23 (49)	50	0.002*

N=100

*Significant at *p*<0.05

4.5 Changes of Physiological Parameters in Exposed and Comparative Groups

The fifth objective for this study is to determine the relationship between magnitude of heat exposure and changes in physiological parameters for exposed and comparative group. Table 4.5 showed that all changes of physiological parameters (body temperature, heart rate, systolic and diastolic blood pressure) were significantly different among exposed and comparative group before and after work shift.

The changes of body core temperature parameter showed significant different which ($p < 0.05$) with changes difference was 0.63°C for both exposed and comparative group. Exposed group have higher changes which was ($0.80^{\circ}\text{C} \pm 0.59$) compared to comparative group ($0.18^{\circ}\text{C} \pm 0.47$).

The changes of heart rate showed significant different among both groups which ($p < 0.05$) and the changes difference for both exposed and comparative group is 6.20 (bpm). In this parameter, comparative group showed higher value of changes which was ($8.00 \text{ bpm} \pm 16.78$) compare to exposed group ($1.80 \text{ bpm} \pm 10.14$).

The changes of systolic parameter also showed significant different among both groups which ($p<0.05$) and the changes different for both exposed and comparative group is 10.72 mmHg. In this parameter, comparative group also showed higher value of changes which was ($6.08 \text{ mmHg} \pm 15.37$) compared to exposed group ($4.64 \text{ mmHg} \pm 11.80$).

The changes of diastolic parameter showed there was significant different among both groups which ($p<0.05$) and the changes different for both exposed and comparative group was 5.10 mmHg. In this parameter, comparative group showed higher value of changes which was ($5.54 \text{ mmHg} \pm 12.13$) compare to exposed group ($0.44 \text{ mmHg} \pm 10.54$).

Table 4.5: The magnitude of heat exposure and changes in physiological parameters for exposed and comparative group.

Variables	Study group	Mean ± S.D	Mean difference	t-value	df	p-value
Changes of body core temperature	Exposed	0.80 ± 0.59	0.63	5.87	98	<0.001*
	Comparative	0.18 ± 0.47				
Changes of heart rate (beats per minute)	Exposed	1.80 ± 10.14	6.20	2.24	98	0.028*
	Comparative	8.00 ± 16.78				
Changes of systolic blood pressure (mmHg)	Exposed	4.64 ± 11.80	10.72	3.91	98	<0.001*
	Comparative	6.08 ± 15.37				
Changes of diastolic blood pressure (mmHg)	Exposed	0.44 ± 10.54	5.10	2.25	98	0.027*
	Comparative	5.54 ± 12.13				

N=100

*Significant at *p*<0.05

CHAPTER 5

DISCUSSION, CONCLUSION & RECOMMENDATIONS

5.1 Discussion

The aim of this study was to determine the heat exposure and the changes of physiological parameters (body core temperature, heart rate, systolic and diastolic blood pressure) among workers in electronic parts manufacturing industry. All objectives of this study were obtained by determining the respondent's background and also by measuring the environmental parameters, body core temperature, blood pressure (systolic and diastolic) and heart rate of the respondents who working at the electronic parts manufacturing industry. The total respondents in this study were 100 which divided equally into two work section which die-casting section and visual inspection section. Workers that worked in die-casting section were represented as exposed group and workers that worked in visual inspection represented as comparative group. Hence, there were 50 respondents selected from both section respectively.

5.2 Respondent's Background Information

Based on the result that had been summarized in Table 1, all respondents from exposed group consist of male workers but for comparative there were 58% males and 42% females. In hot and dry environments men can dissipate more heat through evaporative cooling compare to women (Kenny, 2000). Majority of the workers were young which their age ranged between 18 to 27 years old for both exposed (46%) and comparative group (52%). Marszalek *et al.*, (2005) was stated that older men had lower work ability in a hot environment compared to younger individuals. Debra (2003) also stated that the older workers have less efficient sweat glands, thus this factor influences the physiological effects on the workers.

The BMI of respondent in both two groups also showed the majority of them have normal BMI which 34% for exposed group and 31% for comparative group. In other word, more than half of the respondents were having normal BMI, thus giving a better heat tolerance (Donoughue and Bates, 2000). Furthermore, all of the respondents had been employed for more than 3 months. Thus, they had acclimatized themselves well with the environment (Shido et al., 2000).

5.3 Environmental Parameters

5.3.1 Environmental Temperature

This study result showed the different in environmental temperature between exposed and comparative group, the mean WBGT_{in} at exposed work area (die-casting section) showed 29.8 °C which higher compared to comparative group (visual inspection section) which was 26.0 °C. Exposed group were exceeds the ACGIH Treshold Level Value standard which is 27.5°C for heavy workload. The classification of metabolic work load and work regime was based on standard from ACGIH (2001).

This findings also supported by previous study done by Gomes et al., (2002) which found the workers at the foundry were exposed to higher heat compared to workers at the bottling plant.

From this study, the WBGT_{in} at the exposed work area was higher due to the presence of furnace which having above 500 °C inside the furnace and also near to workers during pouring process from the furnace into mould and collecting the solidified

aluminium plate. Singh *et al.*, (2010) was stated that these two factors were the main source of heat stress at the casting unit.

5.3.2 Relative Humidity

There was different in relative humidity between exposed group and the comparative group. The exposed group was exposed to higher relative humidity compared to the comparative group.

The findings in this study was supported by the study done by Donoghue *et al.*, (2000) which found the underground miners were exposed to high humidity index in their workplace area.

The combining effect of relative humidity and heat at the workplace, the level of comfort showed those exposed groups were having great discomfort with avoid exertion while comparative group showed the level of some discomfort (ACGIH, 2001).

5.4 Prevalence of Heat Stress Disorder

ACGIH (2001) stated that workers that exposed to heat which exceed the Threshold Level Value (TLV) were susceptible to heat stress disorders. Finding in this study showed most of respondents in both exposed (100%) and comparative groups (98%) were reported having fatigue. It was general symptoms that cause by feeling of tiredness or exhaustion after physical strenuous activities during work shift (Minnesota Department of Labour, 2009). However it was beginning stage of heat injury for those expose to high temperature cause by decreasing of effectiveness in someone's circulation due to a loss of fluids in the body (Kamijo *et al.*, 2006).

This study showed that headache and nausea symptoms were higher among exposed group compared to comparative group. Weigand (2007) stated that in the beginning, there is heat exhaustion, characterized by nonspecific symptoms such as malaise, headache and nausea. It showed that exposed group has high prevalence and tendency to heat stress disorders.

From this study, there was 22% of respondent reported having muscle cramp during working in exposed group while there was no incident reported in comparative

groups. According to Vigil (2002), a muscle cramp is the indicator of human body having difficulty in regulating body temperature. Heat cramps is one of severe heat stress disorder and immediate control measures should be taken to avoid the severity.

5.5 Body Physiological Changes

The fourth and fifth objectives were to identify the distribution of physiology characteristic and physiology changes before and after work in both exposed and comparative group.

5.5.1 Body core temperature

Results showed that the body core temperature after work shift was higher compared to before work. Paired t-test was given a result of there is a significant difference ($p < 0.05$) among both exposed group and comparative group. There were also significant difference ($p < 0.05$) in body core temperature changes before and after work shift where the changes value in exposed group ($0.80^{\circ}\text{C} \pm 0.59$) higher than comparative group ($0.18^{\circ}\text{C} \pm 0.47$).

This findings are supported by other previous study conducted by Pierre *et al.*, (2005) and Nurul Ainun (2003) where they were conclude that there is an increase in body core temperature after being exposed to heat and doing some physical activities that require a lot of energy. Vigil (2002) stated that there is an increase in body core temperature after doing some physical activities due to the releasing of excessive heat from body to produce energy.

From this study, exposed group showed higher changes of body temperature before and after work shift compared to comparative group. This result was consistent with the study done by Arwani (2010) which found that the body core temperature of the workers in casting operators was higher compared to others section. Vigil (2002) was found that heat from hot environment can affect human thermal balance and increase the body core temperature. A plausible explanation for such event was that increased in air temperature will force the body to gain and store heat and this heat gain will increase the body temperature (Richardson, 2000).

Finding in this study also showed the body core temperature among the exposed group and comparative group was slightly increased, however still below 38 °C. Donoughue *et al.*, (2000) was reported that the body core temperature among underground miners when exposed to heat was mildly increase and never exceeded 38

°C. According to ACGIH, the body temperature of below 38 °C is considered a safe exposure for the respondents.

5.5.2 Systolic and diastolic blood pressure

Results showed that was significant difference for systolic blood pressure ($p < 0.05$) before and after work shift for both exposed and comparative groups. There were also significant difference ($p < 0.05$) in systolic blood pressure changes rate before and after work shift between exposed and comparative group. In this parameter, comparative group showed higher changes rate ($6.08 \text{ mmHg} \pm 15.37$) compared to exposed group ($4.64 \text{ mmHg} \pm 11.80$).

Diastolic blood pressure before and after work shift showed no significant difference ($p > 0.05$) among exposed group but significant ($p < 0.05$) in comparative group. In term of diastolic blood pressure changes rate before and after work shift, there was significant different between exposed and comparative group. However, comparative group showed higher changes rate ($5.54 \text{ mmHg} \pm 12.13$) compare to exposed group ($0.44 \text{ mmHg} \pm 10.54$).

Vengelova *et al.*, (2006) were found that the systolic and diastolic blood pressure of the industrial workers exposed to heat was increased as the temperature increased. Richardson (2000) noted that this occurred due to the body gain and store heat when the air temperatures increase and this heat gain causes the heart works a lot harder to pump blood to periphery for heat loss, giving the rise in the blood pressure.

However, there were opposite findings by Brake and Bates (2002) where found the blood pressure of the underground miners was decreased as the workday progressed due to the workers tend to acclimatized themselves in order to increase the body's ability to lose heat. It also supported by study done by Lu and Zhu (2007) where found that the systolic and diastolic blood pressure decreased when the subjects exposed to heat environments.

From this study, the changes of systolic and diastolic blood pressure were higher among comparative group compared to exposed group due to the nature of works. Although both groups having same heavy workload, workers in comparative group were more exposed to repetitive motion since they worked in operator line. Repetitive motion utilize large group of muscles and cause the heart beating faster to increase oxygen distribution via blood (Cohen *et al.*, 2004).

5.5.3 Heart rate

Results showed that was no significant difference for heart rate ($p>0.05$) before and after work shift for exposed group but significant ($p<0.05$) in comparative group. In term changes rate for heart rate before and after work shift, there was significant different between exposed and comparative group. However, comparative group showed higher changes ($8.00 \text{ bpm} \pm 16.78$) compared to exposed group ($1.80 \text{ bpm} \pm 10.14$).

The nature of works for both exposed and comparative groups were different which exposed group did not involve in operator line like comparative group. The work at operator line was maintained along work shift and they more exposed to repetitive motion. From the observation, workers in exposed group doing some light work instead of heavy work towards the end of the work shift.

From the previous study done by Nurul Ainun (2003), she did not found any significant difference between before works and after work shift for heart rate. This was due to the production process was decreased towards the end of the work shift and thus lead to the decreasing of work demand.

This finding also supported by the study done by Nadia (2009) where the heart rate of palm oil mill workers were decreased as the workday progress due to the workers doing some light work instead of heavy work while waiting for the oil palm stocks to be there for production process.

However, result found in study done by Goh *et al.*, (2004) was found that the heart rate of the workers in the plastic industry increased when exposed to the hot working conditions. The heart rate accelerates to speed up the blood circulation in order to transport the heat from the interior of the body to the skin where the heat is dissipated to the surrounding environment (Rodahl, 2003).

5.6 Conclusion

The heat exposure ($WBGT_{\text{indoor}}$) was slightly higher in the workplace of exposed group (29.8°C) compared to the comparative group (26.0°C). It can be concluded that the workers in exposed group were exceeds the ACGIH Treshold Level Value standard which is (27.5°C) for heavy workload. The combining effect of relative humidity and heat at the workplace showed the level of comfort for exposed groups were great discomfort with avoid exertion while comparative group showed the level of some discomfort. Prevalence of heat stress disorders based on health complaint also higher in exposed group compared to comparative group. Significant difference of physiology changes rate before and after work shift between exposed and comparative group were determined in this study ($p<0.05$). However, only body core temperature and systolic blood pressure showed significant increase ($p<0.05$) after work shift in exposed group.

5.7 Recommendations

This study was found that workers in exposed group have high risk to develop heat stress disorders due to high temperature in their working environment. Workers may develop to more severe heat stress disorders such as heat exhaustion and heat stroke during working if there are no preventives measures taken. Thus there are few recommendation should be followed by employer and employees.

a) Employer

- i. Ventilation system should be well maintained as the schedule to ensure the ventilation can be function properly and effectively.
- ii. Installing heat insulation or barrier at the source of heat to prevent their workers exposed directly to heat.
- iii. Worker rotation or assigning more workers to perform the same task can reduce the exposure time and decrease the physical workload.

- iv. Fluid replacement such as cool water should be made available to the workers place and close to the work area to encourage them to drink small amounts frequently to reduce the effects of exposure to heat.
- v. Installation of water stations such as water cooler near the work areas will minimize the time needed for workers to go to canteen and will ensure that they remain hydrated throughout the working hours.
- vi. Provide cool areas with adequate ventilation instead of common shaded area for employee during break periods.
- vii. Provide education and training regarding heat stress for all workers (priority to workers in hot work section) to create and increase their awareness in heat stress management.
- viii. Conducting health monitoring to monitor workers health status to ensure they are free from heat stress disorders. Workers that identified with heat stress disorders can be transfer to other section or assign them with light task until they get fully recovered.
- ix. Monitor employee who are at risk of heat stress.

REFERENCES

b) Employees

- i. Ventilation system should be function properly. If any defective or damage in ventilation should be report to person in charge immediately.
- ii. Drink water frequently. Drink enough water (approximately 1 cup every 15-20 minutes).
- iii. Avoid drinks with alcohol, large amounts of caffeine or sugar because it can imbalance the body system to tolerate heat in the body.
- iv. Monitor physical condition and if any symptoms of heat stress related illness appear, it should be reported to employer or seek to Occupational Health Doctor (OHD) immediately.
- v. Wear loose-fitting, light-colored, breathable clothing such as cotton. Avoid multiple clothing.

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APPENDIX 1:

Application letter to company

Kami
20 Januari 2012

kepada Sesiapa yang Berkemauan

dan Puan,

PROJEK PENYELIDIKAN:

EAT STRESS EXPOSURE EFFECT ON PSYCHOLOGY AMONG
WORKERS IN ELECTRONIC

ENYELIDIK : AHMAD A

SENTELA : DR. AHMAD

Penyelidikan ini dijalankan oleh Puan dan saya sebagai penolong penyelidik. Penyelidikan ini dijalankan untuk mengetahui kesan tekanan terhadap psikologi pekerja dalam industri elektronik. Penyelidikan ini dijalankan untuk mengetahui kesan tekanan terhadap psikologi pekerja dalam industri elektronik.

Penyelidikan ini dijalankan oleh Puan dan saya sebagai penolong penyelidik. Penyelidikan ini dijalankan untuk mengetahui kesan tekanan terhadap psikologi pekerja dalam industri elektronik. Penyelidikan ini dijalankan untuk mengetahui kesan tekanan terhadap psikologi pekerja dalam industri elektronik.

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APPENDIX 3:

Subject Information sheet

PENERANGAN KEPADA PESERTA

TAJUK KAJIAN:

KAJIAN PERHUBUNGAN ANTARA PENDEDAHAN HABA DAN PERUBAHAN FISILOGI DI KALANGAN PEKERJA DALAM INDUSTRI PEMBUATAN BAHAGIAN ELEKTRONIK.

Terima kasih kerana membantu kami di dalam kajian ini.

Apakah kajian ini?

Kajian ini bertujuan untuk mengenalpasti pendedahan haba dan perubahan fisiologi di kalangan pekerja dalam industri pembuatan bahagian elektronik. Ini kerana pekerja yang terdedah pada suhu persekitaran tempat kerja yang tinggi adalah berisiko mendapat penyakit tegasan haba. Antara masalah yang boleh berlaku adalah seperti kelusan haba, kelumpuhan haba dan kekejangan haba. Kajian terperinci tentang tegasan haba perlu dijalankan kerana ramai pekerja kilang di negara kita yang terdedah pada suhu tinggi. Oleh itu, bagi meningkatkan keselamatan dan kesihatan para pekerja, satu kajian khusus perlu dilakukan agar status kesihatan pekerja dapat ditingkatkan. Justeru, maklumat yang diperolehi daripada kajian ini diharap boleh digunakan oleh pihak majikan agar program kesihatan dan keselamatan boleh digubal dan dilaksanakan bagi mengurangkan masalah tegasan haba di kalangan pekerja.

Apakah tujuan kajian ini?

Kajian ini bertujuan untuk mengenalpasti kesan pendedahan suhu tinggi terhadap kesihatan pekerja pada bahagian produksi dalam industri pembuatan bahagian elektronik.

Berapa ramai responden yang terpilih?

Seramai 100 orang responden akan dipilih di kalangan pekerja produksi yang terdedah kepada suhu yang tinggi di tempat kerja mereka.

Apakah jenis ujian yang akan dijalankan?

Responden akan ditemubual melalui borang soal selidik untuk mengumpul maklumat tentang latarbelakang, sejarah perubatan dan aduan masalah kesihatan di tempat kerja.

Berat badan akan diukur menggunakan '*Tanita Weighing Scale*' dan tinggi responden akan diukur dengan menggunakan '*Seca Bodymeter*'. Parameter fisiologi seperti tekanan darah dan kadar denyutan jantung akan diukur menggunakan alat '*Omron T3 Automatic Blood Pressure Monitor*'. Suhu teras badan pula akan diperiksa menggunakan '*Omron MC-510 Gentle Temperature Ear*' manakala suhu persekitaran pula akan diukur menggunakan alat '*Questemp⁰³⁴*'.

Adakah bayaran dikenakan?

Pengkaji akan menanggung segala pembiayaan ujian yang akan dijalankan dan tiada sebarang bayaran dikenakan terhadap setiap responden.

Adakah maklumat dijamin sulit?

Semua maklumat yang diberikan oleh responden di dalam borang kaji selidik adalah dijamin sulit dan hanya akan digunakan untuk kepentingan kajian dan pembelajaran sahaja. Tiada huraian individu akan dibuat pada mana-mana bahagian di dalam kajian atau penerbitan.

Adakah hak anda?

Kajian ini melibatkan anda secara sukarela. Oleh itu, peserta mempunyai hak untuk menarik diri dari penyertaan dalam kajian ini pada bila-bila masa sekiranya peserta merasa tidak selesa untuk memberikan maklumat kepada pengkaji.

Apakah yang anda akan dapat?

Melalui penyertaan anda, beberapa program dapat dilaksanakan oleh pihak majikan dalam usaha untuk meningkatkan taraf kesihatan anda. Selain itu, anda juga dapat mengetahui status kesihatan diri anda secara percuma.

Apakah yang harus anda lakukan?

Anda dikehendaki menandatangani borang penyertaan responden yang menyatakan minat anda untuk menyertai kajian ini. Ianya boleh dilakukan setelah anda membaca dan memahami isi kandungan penerangan ini. Borang penyertaan responden haruslah dikembalikan kepada penyelidik sebelum ujian dijalankan. Sekiranya anda mempunyai

sebarang kemusykilan, penyelidik akan membantu untuk memberi maklumat yang selanjutnya.

Terima kasih atas kerjasama dan bantuan anda.

AHMAD AL-BAIHAQY BIN ARIFFIN BILLAH

147598

Penyelidik

B. Sc. Kesihatan Persekitaran dan Pekerjaan

Unit Kesihatan Persekitaran dan Pekerjaan

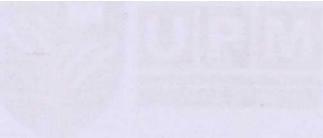
Jabatan Kesihatan komuniti

Fakulti Perubatan dan Sains Kesihatan

Universti Putra Malaysia.

019-3697919

mackey_318@yahoo.com

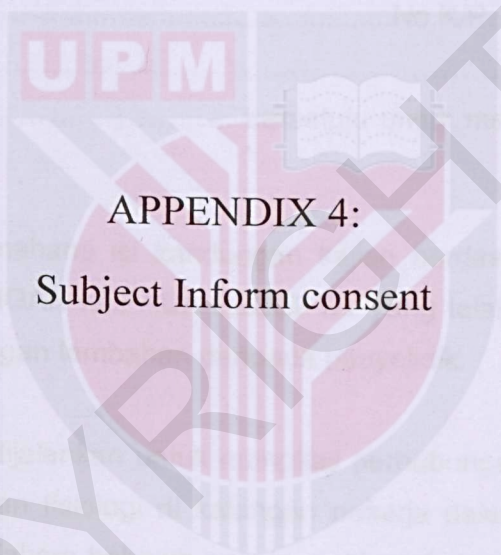


BORANG PEMERIKSAAN RESPONDEN

ISMIAH KAHAN

KAJIAN PERILAKU DAN KEBERKESAMATAN HABA DAN PERUBAHAN
FISIOLOGI DI KALANGAN PENYEROK DALAM INDUSTRI PEMBLATAN BAHAN
BUDUKRONIK

INVELIDIK : AHMAD AL-HAMIDU BIN ARIEFIN DILLAH



APPENDIX 4:

Subject Inform consent



BORANG PERSETUJUAN RESPONDEN

TAJUK KAJIAN :

KAJIAN PERHUBUNGAN ANTARA PENDEDAHAN HABA DAN PERUBAHAN
FISIOLOGI DI KALANGAN PEKERJA DALAM INDUSTRI PEMBUATAN BAHAGIAN
ELEKTRONIK.

PENYELIDIK : AHMAD AL-BAIHAQY BIN ARIFFIN BILLAH

Saya.....No.K/P.....
alamat.....
..... bersetuju untuk menyertai kajian bertajuk
seperti di atas.

Saya telah membaca dan memahami isi kandungan kajian berdasarkan apa yang telah
dinyatakan di dalam 'PENERANGAN KEPADA PESERTA' yang telah dilampirkan bersama
surat kebenaran ini dan penerangan tambahan daripada penyelidik.

Saya faham bahawa kajian ini dijalankan untuk mengkaji perhubungan antara pendedahan
tegasan haba ke atas perubahan fisiologi di kalangan pekerja dalam industri pembuatan
bahagian elektronik. Saya juga faham bahawa segala maklumat yang diberikan dan segala
keputusan yang saya peroleh adalah sulit dan hanya akan digunakan untuk tujuan
penyelidikan dan rujukan penyelidik.

Saya juga faham bahawa maklumat ini boleh digunakan untuk penerbitan tetapi setiap
individu tidak akan dinyatakan identitinya.

Saya faham bahawa saya mempunyai hak untuk menarik diri dan juga mempunyai hak untuk
menarik semula keizinan pada bila-bila masa sekiranya perlu apabila merasa tidak selesa
pada mana-mana ujian atau aktiviti yang dijalankan oleh penyelidik semasa kajian dijalankan
dan tiada sebarang tindakan boleh dikenakan ke atas saya atas tindakan tersebut.

Tandatangan
(Responden)

Tandatangan
(Saksi)

Tarikh :.....

Nama :.....

No. K/P :.....



Saya mengesahkan bahawa saya telah menjelaskan kepada responden sifat dan tujuan penyelidikan klinikal yang tersebut di atas.

Tarikh

Tandatangan
(Penyelidik)



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NO. RESPONDEN:

BORANG SOAL SELIDIK

APPENDIX 5:

Questionnaire



**FAKULTI PERUBATAN DAN SAINS KESIHATAN
UNIVERSITI PUTRA MALAYSIA**

NO. RESPONDEN:

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BORANG SOAL SELIDIK

***KAJIAN PERHUBUNGAN ANTARA PENDEDAHAN HABA
DAN PERUBAHAN FISILOGI DI KALANGAN PEKERJA
DALAM INDUSTRI PEMBUATAN ELEKTRONIK***

LOKASI KAJIAN :

TARIKH :/...../.....

MASA :

Borang soal selidik ini mengandungi empat muka surat bercetak (tidak termasuk muka depan).

Sila jawab semua soalan. Terima kasih di atas kerjasama anda

Perhatian untuk responden:

Segala maklumat yang diperolehi adalah dirahsiakan. Maklumat yang diberikan hanyalah untuk penyelidikan dan untuk tujuan penyelidikan sahaja. Kepercayaan dan kerjasama yang diberikan, didahului dengan ucapan terima kasih.

BAHAGIAN A: MAKLUMAT PERIBADI RESPONDEN

SILA ISI DI RUANGAN YANG DISEDIAKAN

1. Nama responden : _____

2. No. Telefon : _____

3. Umur : _____ tahun

4. Jantina : Lelaki ☐ Perempuan ☐

5. Bangsa : Melayu ☐ Cina ☐

India ☐ Lain-lain ☐

6. Agama : Islam ☐ Buddha ☐

Hindu ☐ Kristian ☐

Lain-lain.....(nyatakan)

7. Status : ☐ Bujang

☐ Berkahwin

☐ Bercerai

8. Taraf pendidikan : Tidak bersekolah ☐

Sijil ☐

Sekolah rendah ☐

Diploma ☐

SRP ☐

Ijazah ☐

SPM ☐

9. Pendapatan bulanan :

☐ RM 500- RM 1000

☐ RM 2001-RM 3000

☐ RM 1001-RM 2000

☐ RM3001-RM 6000

10. Adakah anda merokok?

☐

Ya

☐

Tidak

Jika Ya, berapa batang anda menghisap rokok dalam sehari? ____ / hari

11. Adakah anda mengambil minuman keras?

☐

Ya

☐

Tidak

Jika Ya, berapa banyak anda mengambil dalam sehari? ____ / hari

BAHAGIAN B: SEJARAH PERUBATAN

1. Pernahkah anda mengalami sebarang penyakit sebelum bekerja di sini?

☐

Tekanan Darah Tinggi

☐

Kencing Manis

☐

Lelah

☐

Lain-lain : _____

2. Pernahkah anda mengalami sebarang penyakit semasa bekerja di sini?

☐

Tekanan Darah Tinggi

☐

Kencing Manis

☐

Lelah

☐

Lain-lain : _____

BAHAGIAN C : BUTIR-BUTIR PEKERJAAN

1. Pekerjaan sekarang : _____ Tempoh bekerja _____ bulan/tahun
2. Pekerjaan dahulu : _____ Tempoh bekerja _____ bulan/tahun
3. Adakah anda terdedah kepada haba ketika bekerja di sini?

☐ Ya ☐ Tidak

Jika Ya, berapa lamakah anda terdedah kepada haba dalam sehari?

_____ jam/hari

BAHAGIAN C: TANDA AKUT MASALAH KESIHATAN DI TEMPAT KERJA

1. Adakah anda merasa letih semasa bekerja?

☐ Ya ☐ Tidak

Jika Ya, berapa kali seminggu? Sila nyatakan : _____

2. Adakah anda mengalami pening/pening kepala semasa bekerja?

☐ Ya ☐ Tidak

Jika Ya, berapa kali seminggu? Sila nyatakan : _____

3. Pernahkah anda merasa loya/tidak selera makan selepas bekerja?

☐ Ya ☐ Tidak

Jika Ya, berapa kali seminggu? Sila nyatakan : _____

4. Adakah anda kerap mengalami kekejangan otot semasa bekerja?

☐ Ya ☐ Tidak

Jika Ya, berapa kali seminggu? Sila nyatakan : _____

5. Adakah anda pernah pitam/pengsan semasa bekerja?

☐ Ya ☐ Tidak

BAHAGIAN D: UNTUK KEGUNAAN PENYELIDIK SAHAJA

1. Berat badan : _____ kg
2. Tinggi Badan : _____ m
3. BMI : _____ kg/m²

PEMERIKSAAN FISIOLOGI	SEBELUM	SELEPAS
BADAN	BEKERJA	BEKERJA
Suhu Badan (°C)		
Tekanan Darah Sistolik (mmHg)		
Tekanan Darah Diastolik (mmHg)		
Kadar Denyutan Nadi (denyutan/minit)		

Nama & tandatangan penyelidik: _____

Tarikh : _____

Sekian terima kasih

UPM

APPENDIX 6:
WBGT result

HEAT STRESS REPORT

File Name _____ Questemp 34 Rev 1.10
Serial # TEG110016
Employee _____
Facility _____ Session (1)
Start: 16-JAN-12 08:03:49
Department _____ Stop: 16-JAN-12 10:10:50
Job _____ Printed: 18-JAN-12 10:51:07
Comments/Notes _____

Logging Interval: 5 minutes

Degrees Celsius

MAXIMUM LEVELS, Sensor 1

WBGT IN	29.8	16-JAN-12	09:13:54
WBGT OUT	29.4	16-JAN-12	09:13:54
WET BULB	27.2	16-JAN-12	10:04:23
DRY BULB	32.5	16-JAN-12	09:36:35
GLOBE	36.2	16-JAN-12	09:37:06
HUMIDEX	41	16-JAN-12	08:19:56
REL HUMIDITY	81%	16-JAN-12	08:03:50

Session: 1

Page 2

Sensor: 1

wbgt-exposed group

Degrees Celsius

TIME	WBGTi	WBGT0	WET	DRY	GLOBE	RH(%)	HUMDX
08:08	27.4	27.1	25.5	29.3	32.0	73	39
08:13	27.7	27.4	25.5	29.8	33.0	67	40
08:18	28.1	27.8	25.9	30.3	33.3	65	39
08:23	28.2	27.8	25.8	30.5	33.8	62	39
08:28	28.0	27.6	25.6	30.2	33.6	60	38
08:33	28.4	28.1	26.1	30.5	34.0	60	38
08:38	28.9	28.5	26.5	31.0	34.7	59	40
08:43	29.1	28.7	26.6	31.3	35.1	58	39
08:48	29.4	29.0	26.9	31.6	35.4	56	41
08:53	29.3	29.0	26.8	31.7	35.4	56	41
08:58	29.5	29.1	26.8	32.1	35.8	54	40
09:03	29.5	29.1	26.8	32.0	35.8	54	40
09:08	29.5	29.1	26.9	32.0	35.7	53	40
09:13	29.7	29.4	27.1	32.4	36.0	53	40
09:18	29.4	29.0	26.8	32.1	35.6	53	40
09:23	29.0	28.7	26.4	31.8	35.3	52	40
09:28	29.2	28.8	26.5	32.1	35.5	51	39
09:33	29.3	28.9	26.6	32.1	35.8	51	39
09:38	29.2	28.9	26.4	32.2	36.0	50	39
09:43	29.0	28.7	26.3	32.0	35.5	50	39
09:48	29.2	28.8	26.5	32.0	35.5	52	40
09:53	29.1	28.8	26.6	32.2	35.1	52	40
09:58	29.1	28.8	26.6	32.3	35.2	52	40
10:03	29.3	29.1	26.9	32.3	35.2	52	40
10:08	28.9	28.6	26.3	32.1	35.2	50	39

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wbgt-comparative group

QUEST TECHNOLOGIES
HEAT STRESS REPORT

Page 1

File Name _____ Questemp 34 Rev 1.10
Serial # TEG110016
Employee _____
Facility _____ Session (3)
Start: 20-JAN-12 08:01:00
Department _____ Stop: 20-JAN-12 14:42:02
Job _____ Printed: 20-JAN-12 19:45:48
Comments/Notes _____

Logging Interval: 5 minutes
Degrees Celsius

MAXIMUM LEVELS, Sensor 1

WBGT IN	26.0	20-JAN-12	08:01:00
WBGT OUT	26.0	20-JAN-12	08:01:00
WET BULB	25.2	20-JAN-12	08:28:37
DRY BULB	27.9	20-JAN-12	08:05:31
GLOBE	28.0	20-JAN-12	08:01:00
HUMIDEX	38	20-JAN-12	08:27:08
REL HUMIDITY	78%	20-JAN-12	08:27:08

Session: 3
Sensor: 1
Degrees Celsius

Page 2

TIME	WBGTi	WBGT0	WET	DRY	GLOBE	RH(%)	HUMDX
08:06	25.9	25.9	25.1	27.9	27.9	77	38
08:11	25.9	25.9	25.1	27.9	27.9	77	38
08:16	26.0	26.0	25.2	27.9	27.9	77	38
08:21	25.9	25.9	25.1	27.9	27.9	77	38
08:26	25.9	25.9	25.1	27.9	27.8	77	38
08:31	25.9	25.9	25.2	27.8	27.8	78	38
08:36	25.9	25.9	25.2	27.8	27.8	78	38
08:41	25.9	25.9	25.1	27.8	27.8	77	38
08:46	25.9	25.9	25.1	27.8	27.8	77	38
08:51	25.9	25.9	25.1	27.8	27.8	77	38
08:56	25.8	25.8	25.0	27.7	27.8	78	38
09:01	25.8	25.8	25.1	27.7	27.7	78	38
09:06	25.8	25.8	25.1	27.7	27.7	78	38
09:11	25.8	25.8	25.1	27.6	27.7	78	38
09:16	25.8	25.8	25.0	27.6	27.7	77	38
09:21	25.5	25.5	24.7	27.6	27.6	77	38
09:26	25.6	25.6	24.8	27.6	27.6	76	38
09:31	25.6	25.5	24.7	27.6	27.7	76	38
09:36	25.5	25.5	24.7	27.6	27.6	76	38
09:41	25.5	25.5	24.7	27.7	27.6	76	38
09:46	25.5	25.5	24.7	27.6	27.6	76	38
09:51	25.5	25.5	24.7	27.6	27.6	76	38
09:56	25.5	25.5	24.7	27.6	27.6	76	38
10:01	25.5	25.5	24.6	27.6	27.6	75	38
10:06	25.5	25.5	24.6	27.6	27.6	75	38
10:11	25.5	25.5	24.6	27.6	27.6	75	38
10:16	25.4	25.4	24.5	27.5	27.6	75	38
10:21	25.4	25.4	24.5	27.5	27.5	75	38
10:26	25.4	25.4	24.5	27.5	27.5	75	38

wbgt-comparative group

10:31	25.4	25.4	24.5	27.5	27.5	75	38
10:36	25.4	25.4	24.6	27.5	27.5	75	38
10:41	25.4	25.4	24.6	27.5	27.5	76	38
10:46	25.5	25.4	24.6	27.5	27.6	76	38
10:51	25.4	25.4	24.6	27.5	27.5	76	38
10:56	25.4	25.4	24.6	27.4	27.4	76	36
11:01	25.3	25.3	24.5	27.4	27.4	76	36
11:06	25.4	25.4	24.6	27.4	27.4	77	36
11:11	25.5	25.5	24.7	27.4	27.4	77	36
11:16	25.4	25.4	24.6	27.3	27.4	77	36
11:21	25.4	25.4	24.6	27.3	27.3	77	36
11:26	25.4	25.4	24.7	27.3	27.3	77	36
11:31	25.4	25.4	24.6	27.3	27.3	78	36
11:36	25.4	25.4	24.6	27.2	27.3	78	36
11:41	25.3	25.3	24.6	27.2	27.2	77	36
11:46	25.2	25.2	24.4	27.1	27.1	77	36
11:51	25.0	25.0	24.3	27.0	26.9	77	36
11:56	25.0	25.0	24.3	26.9	26.9	77	36
12:01	25.1	25.1	24.4	27.0	27.0	77	36
12:06	25.1	25.1	24.3	27.0	27.0	77	36
12:11	25.0	25.0	24.3	27.0	26.9	77	36

Session: 3

Sensor: 1

Degrees Celsius

Page 3

TIME	WBGTi	WBGT0	WET	DRY	GLOBE	RH(%)	HUMDX
12:16	25.0	25.0	24.3	26.9	26.8	77	36
12:21	24.9	24.9	24.2	26.9	26.8	77	36
12:26	24.9	24.9	24.2	26.8	26.8	77	36
12:31	24.9	24.9	24.2	26.8	26.7	77	36
12:36	24.9	24.9	24.2	26.8	26.7	77	36
12:41	25.0	25.0	24.2	26.9	26.9	78	36
12:46	25.1	25.1	24.3	27.0	27.0	78	36
12:51	25.0	25.0	24.3	26.9	26.9	78	36
12:56	25.0	25.0	24.3	26.9	26.9	78	36
13:01	25.0	25.0	24.3	26.9	26.8	78	36
13:06	25.0	25.0	24.3	26.9	26.9	78	36
13:11	25.1	25.1	24.4	27.0	26.9	78	36
13:16	25.0	25.0	24.3	26.9	26.8	77	36
13:21	25.0	25.0	24.3	26.8	26.7	78	36
13:26	25.0	25.0	24.3	26.8	26.8	78	36
13:31	25.0	25.0	24.3	26.8	26.8	78	36
13:36	24.9	24.9	24.2	26.8	26.8	78	36
13:41	24.9	24.9	24.2	26.8	26.8	77	36
13:46	24.9	24.9	24.2	26.8	26.7	77	36
13:51	24.9	24.9	24.2	26.7	26.7	77	36
13:56	24.9	24.9	24.2	26.7	26.7	77	36
14:01	24.9	24.9	24.2	26.7	26.7	78	36
14:06	24.9	24.9	24.2	26.7	26.7	78	36
14:11	24.9	24.9	24.2	26.7	26.7	78	36
14:16	24.9	24.9	24.2	26.7	26.7	78	36
14:21	24.9	24.9	24.2	26.8	26.7	78	36
14:26	24.9	24.9	24.2	26.8	26.8	78	36
14:31	24.9	24.9	24.2	26.8	26.7	78	36
14:36	25.0	25.0	24.3	26.8	26.8	78	36
14:41	25.0	25.0	24.3	26.9	26.9	78	36

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