A CROSS-SECTIONAL STUDY OF ASSESSING HEAT STRESS VARIABILITY AND ITS DETERMINANTS AMONG ADULT POPULATIONS IN KAMPAR, PERAK, MALAYSIA

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A CROSS-SECTIONAL STUDY OF ASSESSING HEAT STRESS VARIABILITY AND ITS DETERMINANTS AMONG ADULT POPULATIONS IN KAMPAR, PERAK, MALAYSIA

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled "**A CROSS-SECTIONAL STUDY OF ASSESSING HEAT STRESS VARIABILITY AND ITS DETERMINANTS AMONG ADULT POPULATIONS IN KAMPAR, PERAK, MALAYSIA**" was prepared by **IVAN LING KIENG SHIANG** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Science (Hons) Environmental, Occupational Safety and Health at Universiti Tunku Abdul Rahman.

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Date : 27 April 2026

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ABSTRACT

Background: Heat stress has become an increasing public health concern in tropical countries such as Malaysia, where persistently high temperatures and humidity intensify thermal discomfort and heat exposure. In community settings, daily activities during peak heat hours may increase the risk of heat-related symptoms even among the general population, particularly in rapidly developing semi-urban areas such as Kampar, Perak. Despite growing concerns regarding climate change and rising temperatures, limited local studies have evaluated heat stress at the community level by integrating environmental measurements with individual behavioural and demographic factors. Therefore, understanding heat exposure, associated symptoms, and contributing factors is essential for developing effective mitigation and adaptation strategies. **Objectives:** This study aimed to (i) assess heat exposure levels using the Universal Thermal Climate Index (UTCI) during peak heat hours, (ii) determine the prevalence of heat stress symptoms among adults, and (iii) identify factors associated with heat stress in Kampar, Perak. **Methodology:** A cross-sectional study was conducted among 85 participants using a structured questionnaire and environmental measurements. Heat exposure was evaluated using Wet Bulb Globe Temperature (WBGT) parameters to derive UTCI values. Collected data included sociodemographic characteristics, occupational factors, lifestyle behaviors, health status, adaptive practices, and knowledge related to heat stress. Statistical analyses were performed using nonparametric tests and multiple linear regression to identify significant predictors of the heat stress score. **Results:** The findings revealed that participants were exposed to very strong heat stress conditions, with a mean UTCI of 40.89°C during peak heat hours. A high prevalence of heat stress symptoms was reported, particularly thirst (83.5%), hot, dry skin (63.5%), headache (61.2%), and fatigue (55.3%). Although participants demonstrated relatively high adaptive practices, knowledge levels were moderate. Multiple linear regression analysis identified age (β = -0.252, $p = 0.019$), BMI (β = -0.224, $p = 0.017$), current occupation status (β = 0.243, $p = 0.012$), physical activity level (β = 0.218, $p = 0.024$), nighttime heat disruption (β = 0.301, $p = 0.001$), drinking water accessibility (β = -0.306, $p = 0.001$), and total adaptive score (β = 0.223, $p = 0.011$) as significant predictors of heat stress. **Conclusion:** Heat stress among adults in Kampar is influenced by a combination of demographic, occupational, behavioral, and environmental factors, with nighttime heat disruption and water accessibility emerging as key determinants. While adaptive behaviors are present, they appear to be reactive to experiencing heat stress rather than preventive. These findings highlight the need for targeted interventions, including improved access to drinking water, management of nighttime thermal conditions, workplace adjustments, and promotion of proactive heat adaptation strategies to reduce heat-related health risks in tropical settings.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Climate change signifies a fundamental shift in the planet's climate system, which is primarily caused by anthropogenic greenhouse gases, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which result in the greenhouse effect (World Bank Group, 2021). The key contributors to these emissions include the burning of fossil fuels, deforestation, changes in land use, and industrial production (Wan Usamah, 2024; US PEA, 2024). Since the end of the 19th century, the average surface temperature of the Earth has risen by approximately 1.1 °C as these gases trap outgoing longwave radiation and have driven the climate into an unprecedented state relative to the past 1000 years (Amoadu *et al*., 2023; the Intergovernmental Panel on Climate Change (IPCC), 2021; US PEA, 2024). This warming affects hurricanes by increasing the hydrological cycle, accelerating glacial and ice melting, and rising sea levels. It also exacerbates the occurrence, intensity, and duration of extreme weather events, including heatwaves, heavier rainfall, droughts, and tropical cyclones, which threaten ecosystems, infrastructure, and livelihoods of people across the globe (World Bank Group, 2021; IPCC, 2021; WMO, 2022).

Heatwaves and the urban heat island (UHI) effect are among these extreme events, which pose a significant global health concern to the public, as they can significantly impact human health (An and Dedekorkut-Howes, 2025). Heatwaves refer to prolonged, unusually high temperatures. The severity and frequency of heatwaves have increased in the 21st century, leading to spikes in mortality in Europe, Russia, Latin America, and North America (Sapari *et al*., 2023; Slesinski *et al*., 2025; WHO, 2024). At the same time, UHIs are the events that localised temperature rise in urban areas compared to rural areas (An and Dedekorkut-Howes, 2025) take place because urban areas have less green cover, and industrialisation tends to trap heat due to materials, less vegetation, and heat waste, further increasing risks for city residents (An and Dedekorkut-Howes, 2025; Clark *et al*., 2024). Malaysia's tropical rainforest climate, which characterised by a mean temperature of 25 °C and an average precipitation of 3,085.5 mm annually, has demonstrated an alarming climate warning pattern over the past decades, with an increasing number of heatwave occurrences, duration, and severity (Syed Mahbar and Kusaka, 2024; World Bank Group, 2021). A recent survey conducted in Malaysia has shown an increasing trend of surface temperature and heatwaves in the Peninsular regions in the country, with Greater Kuala Lumpur regions experiencing UHI intensities up to 3 °C warmer than nearby rural areas (Syed Mahbar and Kusaka, 2024). Therefore, such overlapping phenomena increase exposure, emphasising the need for localised heat-health research to enable citizens to better adapt and mitigate risks associated with heat-stress symptoms. Figure 1 shows the annual surface temperature change of Malaysia from 1951 to 2021 based on Wan Usamah (2024).

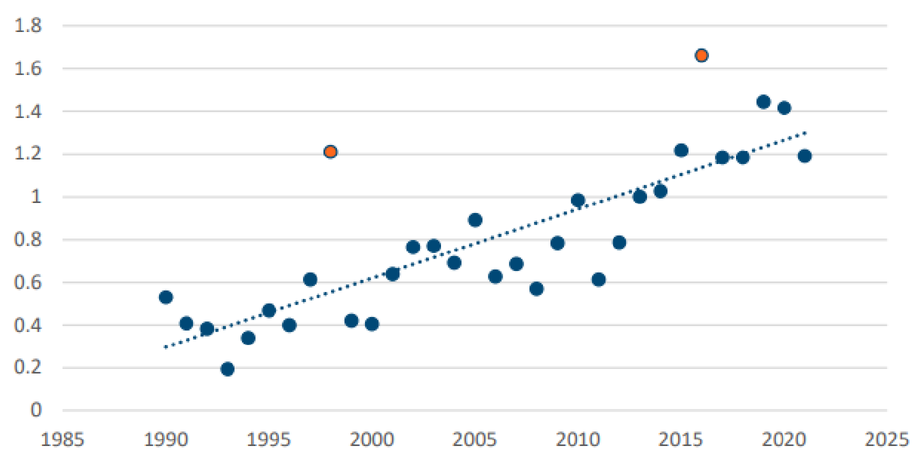

Figure 1.1: Malaysia's annual surface temperature change from 1951 to 2021 (Source: Wan Usamah, 2024)

Humans are homeothermic, meaning they maintain a constant internal temperature. The resting temperatures of the deep tissues of the head and thorax are 36–38°C (Cramer *et al*., 2022; Lim *et al*., 2023). The Human body temperature is an essential physical parameter that significantly affects the structure and functioning of biological tissues, such as plasma membrane fluidity, the rates of transmembrane transport, and the activities of the enzymatic catalysis (Cramer *et al*., 2022). Heat presents a variety of physiological stresses on the human body, which challenge the thermoregulation homeostatic mechanisms that maintain the core temperature around 37 °C (Wan Usamah, 2024). When ambient heat and humidity exceed thermal thresholds, human temperature is regulated through cutaneous vasodilation and eccrine sweating, which are stimulated by the central nervous system (CNS) to enhance convection and evaporative cooling (Cramer *et al*., 2022). However, excessive sweating can lead to hypovolemia and electrolyte disorders, and vasodilation may affect the regulation of blood pressure (Cramer *et al*., 2022). When compensatory mechanisms are overloaded, individuals may experience heat cramps, fatigue, and dizziness, progressing to heat exhaustion (sweating, weakness, and tachycardia) or, in extreme cases, life-threatening heatstroke with core temperature exceeding 40 °C, characterised by central nervous system disorders and multi-organ dysfunction (Che, 2021; Che, 2023; Slesinski *et al*., 2025). Understanding these physiological pathways is essential for assessing heat-stress symptoms in vulnerable populations.

Certain demographic and social groups experience a greater burden of heat-related health issues due to altered thermoregulation resulting from various physiological factors (e.g., age and metabolic rate), disease, or injury (Cramer *et al*., 2022). For instance, children exhibit reduced thermoregulatory abilities due to their incomplete sweating, whereas pregnant women face elevated metabolic heat loads (Baharav *et al*., 2023; Clark *et al*., 2024; Cramer *et al*., 2022; Jegasothy *et al*., 2020; WHO, 2024). The risk is also higher for individuals with clinical disorders (e.g., diabetes, respiratory diseases, and cardiovascular diseases) and those taking medications that impair heat dissipation (e.g., diuretics) (Wan Usamah, 2024; Cramer *et al*., 2022; Slesinski *et al*., 2025). Socio-economic factors also play a role in vulnerability: low-income households often lack access to air conditioning or shaded environments, and manual outdoor workers have limited adaptive resources when exposed to heat (Amoadu *et al*., 2023; Clark *et al*., 2024; Sapari *et al*., 2023; Slesinski *et al*., 2025). These overlapping factors suggest that it is crucial to consider vulnerable groups in heat-stress research and intervention design.

The amount of heat that is accumulated in the human body is influenced by the combination of factors, including the difficulties for expelling the heat that was generated within the body during metabolic processes due to environmental conditions (e.g., high temperature, high humidity, low wind), and the adaptive measures that protect human body through the reduction of body temperature, and heat loading of the human body by external conditions (WHO, 2024). When an individual is exposed to excessive heat that exceeds their heat tolerance, he/she will not be able to cope with the internal temperature; the body will not be able to eliminate the heat accumulated in the body, which will result in a higher risk of heat stress symptoms (Lim, 2020; WHO, 2024). To reduce the burden of heat stress and adapt to it, mitigation and adaptation should include behavioural, infrastructural, and policy measures (Lim, 2020; WHO, 2024). Malaysian citizens will face warmer temperatures because of climate change; the extent of their vulnerability to heat-related health issues can vary (Wan Usamah, 2024). To address these gaps, localised studies that connect objective environmental measures with behavioural and socio-demographic information are essential for developing context-specific, inclusive heat-health interventions. Overcoming these challenges through inclusive planning and continuous investment is vital to enhancing heat-health resilience in vulnerable cities like Kampar.

1.2 Study Objectives

1.2.1 General objective

To assess the variability and determinants of heat stress among the adult population in Kampar, Perak.

1.2.2 Specific objective

The specific objectives of the study that are tailored to this cross-sectional assessment of heat stress in the adult population in Kampar are shown as follows:

i. To describe the sociodemographic, occupational information, lifestyle and health, heat exposure information, adaptive practice, and knowledge level among the adult population in Kampar.
ii. To characterize heat exposure level by using the Universal Thermal Climate Index (UTCI) at specific locations during peak heat hours.
iii. To identify the association between sociodemographic, occupational information, lifestyle and health, and heat exposure information, adaptive practice, and knowledge level with heat stress symptoms.
iv. To determine the relationship between heat stress risk factors and heat stress symptoms.

1.3 Problem Statement

Heatwaves are becoming more frequent, long-lasting, and severe, while global surface temperatures continue to rise. These trends are expected to continue in the coming decades. Some studies also estimate that the global temperature will increase by 1.5°C or more within the next few decades (Wan Usamah, 2024; Amoadu *et al*., 2023; IPCC, 2021; WMO, 2022). The increased frequency of these extremes threatens ecosystem stability, damages infrastructure, disrupts food and water security, and raises public health burdens through direct heat-related illnesses and indirect impacts such as worsening air quality and the spread of vector-borne diseases such as malaria (Wan Usamah, 2024; Jegasothy *et al*., 2020; Sapari *et al*., 2023). Although broad-scale assessments highlight these tendencies, local variations such as land use, urbanisation, and population characteristics in Malaysia's smaller districts have been given less attention. Without detailed, place-specific information, public health strategies risk overlooking critical microclimatic and demographic nuances that influence heat-stress vulnerability.

In Malaysia, the impact of global warming is clearly shown in rising temperatures, altered rainfall patterns, and an increase in the frequency of extreme heat events (Jegasothy *et al*., 2020). It results in a total of 127 cases of heat-related illnesses reported, five of which resulted in deaths (two in 2023 and three in 2024) (Wan Usamah, 2024). These combined trends put more thermal stress on urban populations, especially during the monsoon transition months when evaporation cooling is reduced due to limited daily temperature fluctuations and high humidity. While Kuala Lumpur's UHI enhances urban risks up to 6 °C during nighttime (Harun *et al*., 2020), smaller towns like Kampar, with their tropical rainforest environment, mixed urban-rural settlements, and low elevation, may face different exposure profiles that national averages do not capture. Figure 2 displays the total number of heat-related illnesses reported in each state in 2023 and 2024 based on Wan Usamah (2024).

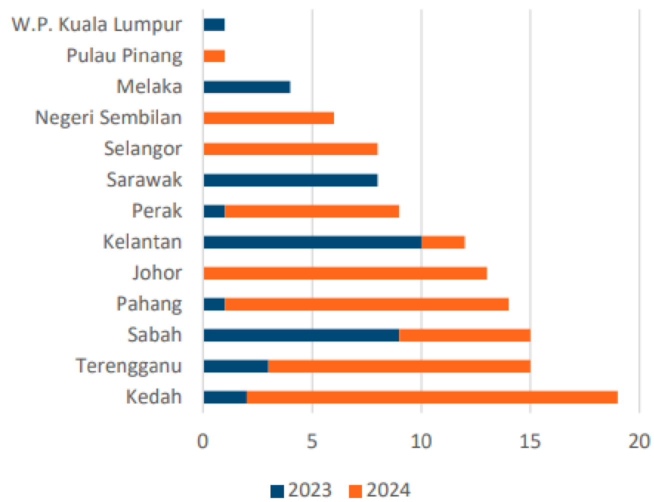

Figure 1.2: Total number of heat-related illnesses reported according to states in 2023 and 2024 (Source: Wan Usamah, 2024)

Exposure to extreme heat presents well-documented risks to human health, ranging from minor heat stress (headache, fatigue, cramps) to severe heat exhaustion and life-threatening heatstroke, which is characterised by hyperthermia, central nervous system malfunction, and multi-organ failure. The Malaysian Ministry of Health's clinical guidelines note that prolonged outdoor work and limited access to cooling systems are factors that increase the risk of heat-related illnesses, which include cramps, exhaustion, stroke, pruritic heat rash, and syncope (DOSH, 2016). Nevertheless, the Malaysian Ministry of Health reported 27 incidents of heat-related illnesses in the first nine epidemiological weeks of 2024, including nine strokes and 18 cases of heat exhaustion (Mail, 2024). Previous studies have focused on heat-related health risks in major urban areas, including Kuala Lumpur (Muhamad *et al*., 2024; Syed Mahbar and Kusaka, 2024; Yola *et al*., 2022) and Selangor (Azizi *et al*., 2021; Jumari *et al*., 2023). This suggests that limited studies have been conducted to assess environmental heat stress in Perak, particularly in smaller areas such as Kampar. Given the high incidence of heat-related illnesses in Perak, with 12 cases including one fatality (The Star Online, 2024), and a recent heatwave event reported by MetMalaysia (Salleh, 2025), investigating the Kampar community is crucial to establish baseline data on heat stress variability. Figure 3 shows one of the heatwave events reported by MetMalaysia on June 2, 2025, based on Salleh (2025).

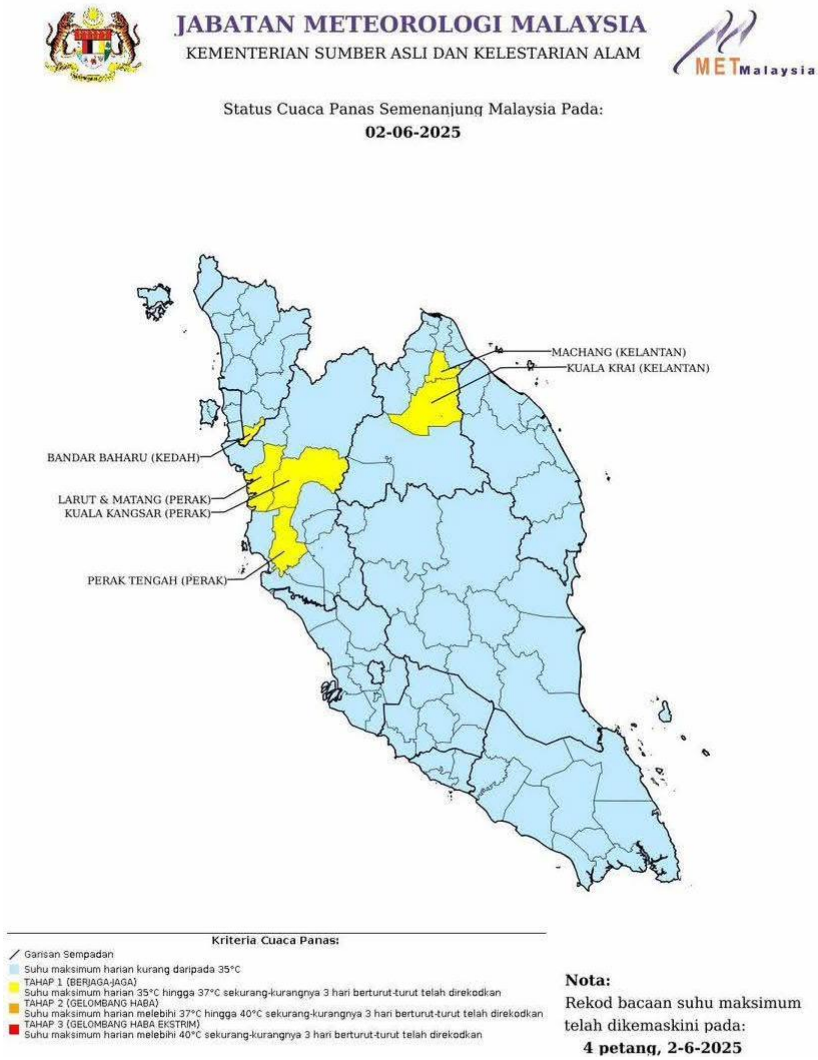

Figure 1.3: Heatwave event reported by MetMalaysia on June 2, 2025 (Source: Salleh, 2025)

Most Malaysian studies have focused on high-exposure occupational groups, particularly sensitive groups or outdoor workers such as construction workers (Amoadu *et al*., 2023; Che, 2021), kitchen workers (Anua *et al*., 2021), or agricultural labourers (Amoadu *et al*., 2023; Lim *et al*., 2023), while broader community-level studies remain scarce. According to How *et al*. (2022), a six-month follow-up of tropical farm workers showed different physiological strains depending on farming practices; however, non-occupational exposures in residential environments were not considered. A single cross-sectional study of kitchen workers in Kampar linked WBGT measurements to reported symptoms (Shu, 2024), but it did not include behavioural adaptation metrics or extend to the adult population. This narrow focus highlights the need for comprehensive, population-based research, which currently limits understanding of environmental heat exposure at the population level, particularly how socioeconomic, demographic, and environmental factors interact across various community settings to influence heat-stress vulnerability.

Methodologically, many existing studies rely on opportunistic or proxy measures of heat exposure, such as satellite-derived land surface temperatures, meteorological station data, or GIS-modelled UHI indices. These methods provide extensive spatial coverage but may be inaccurate in representing personal exposure, especially indoors or at micro-scale locations where people live and work (Azizi *et al*., 2021; Jumari *et al*., 2023). Wet bulb globe temperature (WBGT) monitoring offers a validated integrative metric for ambient heat stress by considering the ambient temperature, humidity, solar radiation, and wind speed of the environment. However, it may overlook the home or environmental conditions where adults spend most of their time (Houmsi *et al*., 2023; Lin *et al*., 2025). To address significant gaps and provide detailed information about real human-level exposures and their relationships within Kampar's adult population, this study will employ WBGT measurements together with a structured questionnaire in both residential and occupational microenvironments.

1.4 Study Justification

As global temperatures rise and heatwaves become more severe, there is an immediate demand to document heat stress symptoms in everyday settings comprehensively and determine the most appropriate mitigation and adaptive measures. Although occupational heat-health standards concentrate on job precautions, many adults may experience heat exposure while exercising, travelling, or sleeping at home, where self-management techniques and symptom detection differ greatly. To ensure that adaptation and mitigation strategies take into account actual needs and experiences, this study aims to assess the frequency and severity of heat-related symptoms and investigate how they relate to individual behaviours (hydration, clothing choices, and rest breaks).

Kampar, Perak, offers an ideal setting for this investigation due to its unique tropical environment, mixed urban-rural landscape, and rapidly evolving socio-economic profile. Residents of Kampar are more susceptible to heat stress due to the region's consistently warm and humid climate, characterised by annual temperatures ranging from approximately 23°C to 33°C, humidity levels exceeding 80%, and rainfall of around 2,800 mm (Che, 2023; Weather Spark,2025). With weather characteristics, the likelihood of heat stress will increase due to the difficulty in sweat evaporation from the skin and the high humidity that makes the environment feel hotter than the actual conditions (Baldwin *et al*., 2023; Che, 2023). Despite these conditions and the presence of vulnerable subpopulations, including factory workers, students, and agricultural labourers, Kampar has received little attention in studies on heat-related illnesses. By concentrating on this district, a large geographic gap will be addressed, and insights that are immediately applicable to comparable mid-sized cities in other equatorial regions will be provided.

The population selected in the existing research paper mostly focuses on particular groups, such as kitchen workers (Shu, 2024) or outdoor workers, including construction workers, miners, and agricultural workers (Anua *et al*., 2021; Che, 2021; Lim *et al*., 2023).

Focusing on the broad adult community rather than a single occupation or age group addresses a key limitation of existing studies, which often concentrate on outdoor workers or clinical cohorts. Adults aged 18 and above engage in diverse daily activities, whether office work, academic study, home care, or informal labor that entail varying durations and intensities of heat exposure. By sampling across different regions within Kampar and including participants from different socio-economic backgrounds, this study captures the full spectrum of community-level vulnerabilities and adaptive capacities. Such a comprehensive approach will enable comparisons of risk profiles between subgroups and support the design of inclusive heat-health policies and programs.

Linking environmental conditions with health outcomes required accurate exposure assessment, yet many previous investigations have relied on satellite-derived temperature or meteorological station data, which fail to represent microclimate variations at the human scale (Jumari *et al*., 2023). Deploying portable Wet Bulb Globe Temperature (WBGT) meters directly in the main activity locations of participants and averaging multiple readings during peak heat hours helps to provide a validated, integrative measure of thermal stress that accounts for temperature, humidity, solar radiation, and wind (Houmsi *et al*., 2023; Lin *et al*., 2025). This mixed-methods approach fills the important methodological gaps when combined with a structured questionnaire that collects socio-demographics, occupational context, adaptive behaviors, and symptom reports. It provides accurate exposure data, as well as practical, individual-level insights into how environmental heat and individual factors together contribute to heat stress in Kampar's adult population.

1.5 Conceptual Framework

The conceptual framework illustrates the dynamic relationship between individual, occupational, environmental, and adaptive factors and the occurrence of heat stress symptoms in the community. The independent variables cover four domains. First, socio-demographic characteristics such as age, gender, education, body mass index, and household income influence a person's baseline vulnerability and their ability to adopt protective measures. These factors interact with lifestyle and health conditions; for example, lower income may limit access to healthcare or cooling facilities, while smoking, alcohol, caffeine intake, physical activity, and sleep quality directly affect thermoregulatory capacity. Second, occupational and heat exposure information reflects the direct pathways of heat exposure: outdoor work, long hours in the sun, insufficient rest cycles, lack of shade, or unsuitable clothing all increase heat stress risks. These are shaped by socio-demographics, as different occupations often correspond to various income and education levels. Third, adaptation and awareness factors, including hydration, cooling strategies, buddy systems, safety policies, and heat alerts, which serve as moderators, either buffering or worsening the impact of exposure depending on their availability and utilisation.

To complement these self-reported determinants, Wet Bulb Globe Temperature (WBGT) measurements provide an objective environmental indicator, capturing the combined effects of air temperature, humidity, radiant heat, and wind. These readings establish the external stressor to which individuals are exposed, while socio-demographic, lifestyle, occupational, and adaptive factors shape how individuals respond to that stressor. The dependent variable, heat stress symptoms, is the outcome of these interrelated influences, which emerge from the interaction between environmental conditions (WBGT) and either personal or behavioral vulnerabilities or protections. Thus, this framework emphasizes that heat stress is not the result of a single factor but rather the combined interplay of environment, individual characteristics, and adaptive capacity, making a holistic approach essential for understanding and mitigating heat-related risks in the Kampar community.

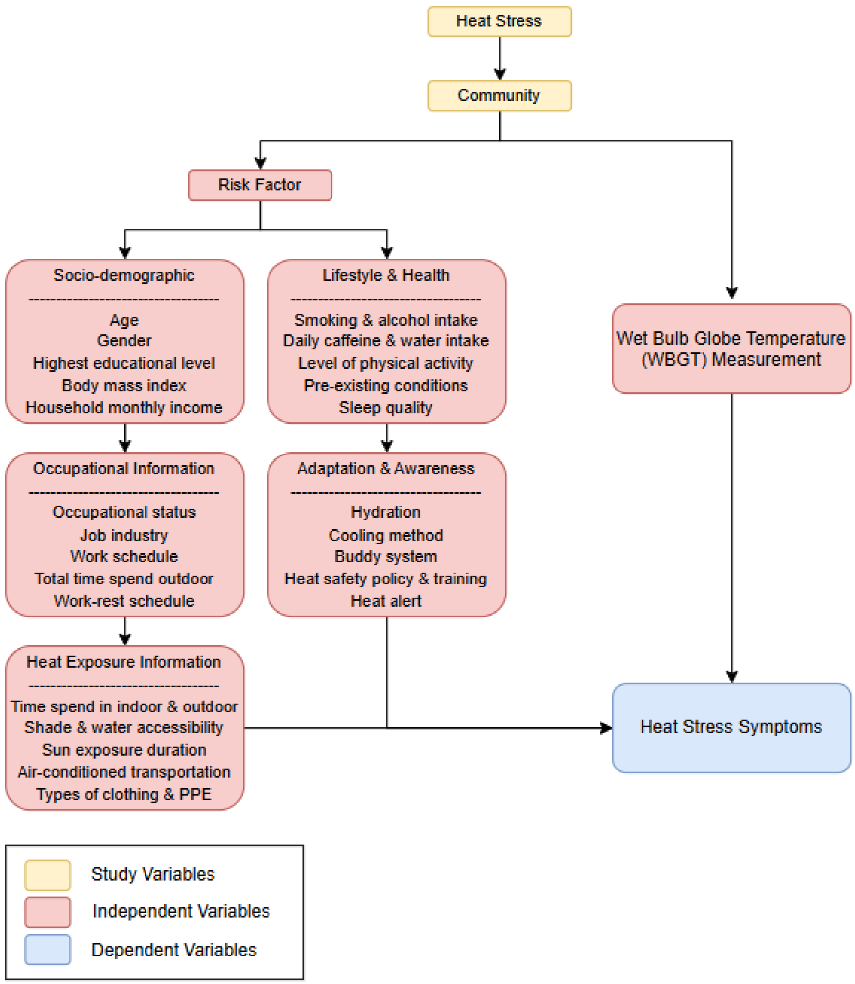

Figure 1.4: Conceptual Framework of the study

CHAPTER 2

LITERATURE REVIEW

2.1 Climate change

Climate change involves the long-term modification of the Earth's climate system, including trends in temperature, rainfall, and the frequency of extreme weather events since the industrial era (IPCC, 2021; WMO, 2022). The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report states that the global average surface temperature from 2011 to 2020 was about 1.1 °C higher than from 1850 to 1900, mainly driven by greenhouse gas emissions (IPCC, 2021; IPCC, 2022). These changes increase the risk of compound events, such as simultaneous droughts and heatwaves, which threaten ecosystems and human health (Jegasothy *et al*., 2020; World Bank Group, 2021). The warming trend is especially significant in tropical regions like Southeast Asia, where high baseline humidity intensifies heat stress risk even with small temperature increases (Aghamohammadi *et al*., 2021; IPCC, 2022).

In Malaysia, climate change manifests through rising average temperatures, shifting rainfall patterns, and changes in monsoon cycles. These changes worsen the country's vulnerability due to its humid tropical climate, rapid urban growth, and socio-economic inequalities. Consequently, Malaysian populations face increasing exposure to climatic stressors that threaten their health, livelihoods, and sustainability (METMalaysia, n.d.; World Bank Group, 2021).

2.2 Global warming

Global warming, the long-term rise in average surface temperature, is the most visible aspect of climate change and a leading cause of intensifying heat extremes. Higher baseline temperatures shift entire temperature distributions upward, resulting in more frequent and severe hot days and nights (IPCC, 2021). The World Bank Group and the Asian Development Bank reported a national temperature increase of 0.14 to 0.25 °C per decade in the climate risk country profile, with more hot days and warm nights expected by mid-century (World Bank Group, 2021). In humid climates such as Malaysia, even small temperature increases can cause disproportionately greater thermal stress because sweat evaporation is affected, leading to a higher risk of heat stress symptoms (Aghamohammadi *et al*., 2021; Che, 2021; Cramer *et al*., 2022). Projections suggest that Malaysia will continue to see increases in "hot days" (⩾ 35 °C) and "warm nights" (⩾ 25 °C), which will worsen nocturnal heat stress and hinder physiological recovery (World Bank Group, 2021; IPCC, 2022).

2.3 Extreme heat events

Extreme heat events (EHEs), which include heatwaves and the urban heat island (UHI) effect, are recognized globally as major public health concerns. Heatwaves are periods of prolonged extreme heat, often exacerbated by high humidity, that substantially elevate morbidity and mortality risks (Slesinski *et al*., 2025; WHO, 2024). In Malaysia, Studies have demonstrated that Peninsular Malaysia has experienced a measurable increase in heatwave frequency and intensity, with spatial variability across different states (Wan Usamah, 2024; Jegasothy *et al*., 2020). In urban areas, the UHI effect further compounds heat stress by raising nighttime temperatures due to heat retention. The heat dissipation is limited due to poor urban planning practices like using concrete building materials and inadequate green cover in the surrounding (Aghamohammadi *et al*., 2021; An and Dedekorkut-Howes, 2025; Clark *et al*., 2024). Studies in Selangor and Kuala Lumpur confirmed the role of urbanization in intensifying land surface temperatures, often several degrees higher than surrounding rural areas (Aghamohammadi *et al*., 2021; Syed Mahbar and Kusaka, 2024). With Malaysia's urbanization expected to reach 80% by 2030, the UHI effect is expected to intensify, placing an increasing number of residents at risk of heat-related illnesses (World Bank Group, 2021).

2.4 Health impacts of heat

2.4.1 Heat stress symptoms

Exposure to extreme heat has significant physiological impacts, ranging from mild conditions such as heat rash, cramps, and dehydration to severe illnesses, including heat exhaustion and life-threatening heat stroke (Che, 2023; Diaconescu *et al*., 2022). Heat stress occurs when the body cannot adequately dissipate heat generated from metabolic processes and gain from the external environment, particularly under conditions of high temperature and humidity that impair sweat evaporation (WHO, 2024). This leads to severe adverse effects like cardiovascular strain, respiratory disorder, electrolyte imbalance, and rising core body temperature (Aghamohammadi *et al*., 2021; Cramer *et al*., 2022). This is because thermoregulation depends on convective/radiative heat loss, as well as sweat evaporation. High humidity impairs evaporation, driving cardiovascular strain, dehydration, and rising core temperature (Che, 2023; Cramer *et al*., 2022). Heat stress can also affect work productivity and increase the risk of accidents (Aghamohammadi *et al*., 2021; Diaconescu *et al*., 2022; WHO, 2024).

2.4.2 Heat stress risk factors

The vulnerability to heat stress can be very different based on different physiological and socio-economic factors (WHO, 2024). Risk factors include age (children), pre-existing health conditions (cardiovascular, renal, and respiratory), pregnancy, outdoor occupations, and socio-economic status (Wan Usamah, 2024; Baharav *et al*., 2023; Clark *et al*., 2024; Cramer *et al*., 2022; IPCC, 2022; Jegasothy *et al*., 2020; Slesinski *et al*., 2025; WHO, 2024). Low-income households, for example, often lack access to cooling systems, making them disproportionately exposed to heat stress (Amoadu *et al*., 2023; Clark *et al*., 2024; Sapari *et al*., 2023; Slesinski *et al*., 2025; WHO, 2024). In the Malaysian context, outdoor workers such as construction and agricultural laborers face heightened risk, with WBGT studies indicating reduced productivity and increased heat-related symptoms as WBGT rises (Che, 2021; Che, 2023).

2.5 Heat Stress Indices

Heat stress indices are used to quantify the human-relevant impact of environmental heat. The Wet Bulb Globe Temperature (WBGT) index incorporates air temperature, humidity, radiant heat, and wind speed, making it one of the most widely used metrics for occupational and community heat-stress assessments. It is standardized under ISO 7243:2017 and endorsed by OSHA and WHO for workplace applications (ISO, 2017; OSHA, 2023). The Universal Thermal Climate Index (UTCI) integrates a thermo-physiological model that simulates human heat exchange processes, allowing for finer assessment of outdoor thermal comfort (Kruger and Di Napoli, 2022). Meanwhile, the Humidex, widely applied in humid climates, combines air temperature and humidity to indicate “felt temperature” but does not account for wind or radiation (Diaconescu *et al*., 2022; Netatmo, 2025; Sandle, 2021).

Each index has advantages and limitations. WBGT is portable and directly linked to health-based thresholds, but it is sensitive to clothing and activity levels. UTCI is physiologically robust but data-intensive, requiring multiple meteorological inputs. Humidex is simple and effective in communication but may underestimate risk in high-radiation conditions (Diaconescu *et al*., 2022; Netatmo, 2025). For community-level field studies in

Malaysia, WBGTout offers practical advantages due to its portability and ability to capture both temperature and humidity, making it highly relevant to this study.

2.6 Heat Exposure and Adaptation Strategies

Human adaptation and mitigation to heat involves both physiological mechanisms and behavioural measures (Aghamohammadi *et al*., 2021; Clarke *et al*., 2025; Lim, 2020). Physiological mechanisms such as improved sweat rate and distribution, plasma-volume expansion, and reduced cardiovascular strain can enhance heat removal and reduce the risks. Whereas behavioural or infrastructural measures, including hydration, cooling centres, shade and greening, reflective surfaces, optimised work-rest cycles, fans or air conditioning with ventilation, and early-warning systems. Community-based behavioural interventions show promise but remain under-evaluated in lower- and middle-income tropical contexts, indicating the need for localised evidence to tailor messages and resources (Clarke *et al*., 2025). In Malaysia, studies on community-based adaptation are limited, especially in semi-urban towns like Kampar. This gap underscores the importance of combining environmental monitoring, such as WBGT, with structured questionnaires to quantify exposure, symptoms, and adaptive capacity within the general adult population.

2.7 Summary of literature review

Table 2.1: Summary of Literature Review

Main Topic	Focus/Key Findings	Citation
Climate Change	Global surface temperature increased ~1.1 °C above pre-industrial levels; it impacts ecosystems, economy, and health.	IPCC (2023); Jegasothy *et al.* (2020); WHO (2024)

Global Warming	Amplifies extreme weather, especially heat extremes in tropics; warming trend in Malaysia 0.14–0.25 °C per decade.	World Bank Group (2021)
Extreme Heat Events	Increasing frequency of heatwaves and Urban Heat Island effects in Malaysia's urban centers (Kuala Lumpur, Selangor).	Aghamohammadi *et al*. (2021); Wan Usamah (2024); Syed Mahbar and Kusaka (2024); Jegasothy *et al.* (2020)
Heat Stress Symptoms	Range from mild (rash, cramps, dehydration) to severe (heat exhaustion, heat stroke, organ failure).	Che (2023); Diaconescu *et al*. (2022)
Heat Stress Risk Factors	Higher risk in elderly, children, outdoor workers, those with chronic diseases, smokers, and low-income groups.	Wan Usamah (2024); Baharav *et al*. (2023); Clark *et al*. (2024); Cramer *et al*. (2022); IPCC, 2022; Jegasothy *et al*. (2020); Slesinski *et al*. (2025); WHO, 2024
Heat Stress Indices	WBGT (occupational gold standard), UTCI (model-based outdoor index), Humidex (perceived heat with humidity).	Diaconescu *et al*. (2022); ISO (2017); Kruger and Di Napoli (2022); OSHA (2023)
Adaptation Strategies	Physiological: acclimatization improves sweating, plasma volume, and cardiovascular response. Behavioral: hydration, shade, urban greening, early warnings.	Aghamohammadi *et al*. (2021); Clarke *et al*. (2025); Lim (2020)

CHAPTER 3

METHODOLOGY

3.1 Study Design

This was a cross-sectional study that examined the variability and determinants of heat stress among the adult population in Kampar, Perak. The study aimed to investigate the prevalence of heat-related symptoms using a two-stage data collection approach, which included the use of a Wet Bulb Globe Temperature (WBGT) meter to estimate the Universal Thermal Climate Index (UTCI) in specific areas, and a structured questionnaire to collect data on the relationships between individual risk factors, occupational information, lifestyle and health, heat exposure levels, and adaptive behaviors against heat stress symptoms reported by each respondents.

3.2 Study Location

The study was conducted in Kampar, one of the districts in Perak. According to July 2025 weather analyses for Kampar, the average daytime temperature was approximately 30°C, with nighttime lows around 22°C (World Weather Online, n.d.). Kampar recorded an average rainfall of 127.95 mm and approximately 14 rainy days per month, with a humidity level of about 78%, resulting in persistently humid conditions influenced by extensive man-made mining lakes and surrounding mountainous areas (World Weather Online, n.d.). Based on the principle that higher humidity increases the perceived temperature and reduces the efficiency of heat dissipation (Che, 2023), Kampar was considered an ideal location for this study due to its consistently high thermal conditions and humidity levels.

3.3 Study Duration

This study was carried out from July 2025 to April 2026. Field data were collected using a WBGT meter from November 2025 until January 2026, corresponding to the Northeast Monsoon season in Malaysia. According to METMalaysia (n.d.), Malaysia experiences four distinct monsoon phases annually. These include the Southwest Monsoon (May–September), which is characterised by hotter, drier weather and lower rainfall; the Northeast Monsoon (November–March), which is the wettest season in Malaysia with heavy, prolonged rainfall and reduced solar radiation; and two inter-monsoon periods (March–May and September–November), which are transitional periods characterised by light and variable winds and short-duration heavy rainfall.

The Northeast Monsoon (November-March) has distinct characteristics that influence Wet Bulb Globe Temperature (WBGT) measurements. Although rainfall frequency is higher and solar radiation is lower during this period, higher air humidity may contribute to increased wet-bulb readings, while potentially lowering average dry-bulb temperatures. However, although overall heat exposure during this period may appear lower than during the Southwest Monsoon, elevated humidity may still significantly contribute to thermal stress and reduce the effectiveness of cooling through sweating (Kamal *et al*., 2024; Syed and Kusaka, 2024).

By focusing the study on the Northeast Monsoon, the results reflected the seasonal impact of Malaysia's climatic cycle on occupational and community heat stress, offering critical insights into how monsoon variability affected environmental heat exposure and human thermal comfort in Kampar, Perak.

3.4 Study Population

The target population consisted of all adult residents of Kampar District aged 18 years and above who had resided in the selected areas for at least six months. These criteria ensured that respondents had established daily routines and sufficient exposure to local climatic conditions. Individuals were required to be able to read and converse in Malay or English in order to complete the questionnaire without translation bias.

3.5 Study Sampling

3.5.1 Sampling Frame

This study involved individuals aged 18 years and above who had resided in Kampar for at least six months. Individuals who did not meet these criteria were excluded from the study. Participants with pre-existing medical conditions affecting thermoregulation were also excluded, as these conditions could have introduced variability into the results. This sampling frame allowed for proportional stratified sampling aligned with the adult population distribution in each region, thereby ensuring comprehensive coverage of urban, semi-urban, and rural settings within Kampar.

3.5.2 Sampling Method

This study consisted of a multi-stage sampling method to ensure representative coverage of the adult population in Kampar, Perak. First, cluster random sampling was used to select seven different regions (clusters) within Kampar to capture varying levels of human activity. Once the clusters were identified, simple random sampling was conducted within each cluster to select individual respondents who were eligible for the study.

This combination of methods allowed for both broad representativeness and unbiased respondent selection, thereby enhancing the reliability of estimates of heat stress exposure and health outcomes across diverse demographic and environmental contexts in Kampar, Perak.

3.5.3 Sampling Unit

The inclusion and exclusion criteria were established to ensure that participants reflected the reliability of the data collected and to minimize potential confounding factors affecting true exposure and health risk patterns associated with local conditions. The inclusive and exclusive criteria for the study are shown in Table 1.

Table 3.1: Inclusion and exclusion criteria(s) of the study

	Inclusion criteria(s)		**Exclusion Criteria(s)**		
Vulnerable group	Age 18 years and above	Has been living in the residential area for more than six months	Existing medical conditions	Pregnant woman	Recent acute illness for the past 2 weeks
Adults (>18 years)	Recruited	Recruited	Excluded	Excluded	Excluded

The sampling unit for this study consisted of individual adult residents in Kampar, Perak, who met the eligibility criteria listed above. Participants were required to be aged 18 years or older and to have resided in the selected area for a minimum of six months to ensure sufficient exposure to local climatic conditions. Individuals with pre-existing medical conditions known to significantly affect thermoregulation were excluded, as their underlying health status could confound the associations between ambient heat and reported symptoms (e.g., cardiovascular disease, diabetes, and respiratory disease) (Wan Usamah, 2024; Cramer *et al*., 2022; Slesinski *et al*., 2025). In addition, pregnant women were excluded from the study due to hormonal variability; women typically experienced altered blood volume and circulation, as well as increased hormonal sensitivity during pregnancy, which could have interfered with the study results (Baharav *et al*., 2023; Clark *et al*., 2024; Cramer *et al*., 2022; Jegasothy *et al*., 2020).

3.5.4 Sampling Size

A pilot study was conducted before calculating the sample size and proceeding with data collection. The purpose of the pilot study was to obtain estimates of key parameters, such as variance, which are essential inputs for determining an adequate and statistically reliable sample size using Cochran's formula. In this study, a total of 20 participants were included in the pilot study to estimate the preliminary prevalence (ρ) of the study.

Using Cochran's formula for estimating a proportion with 95% confidence ($Z = 1.96$), a prevalence of heat stress symptoms of 56.3% (Mohd Shabri, 2024), and a 10% margin of error, the initial sample size calculation yields:

Formula:

$$n_0 = \frac{Z^2 \cdot \rho \cdot (1 - \rho)}{e^2}$$

$$n_0 = \frac{(1.96)^2 \cdot 0.56 \cdot (1 - 0.56)}{(0.1)^2}$$

$$\approx 95$$

where:

n_0 = Estimated sample size

Z = Z-score (confidence level), 95% CI = 1.96

ρ = Estimated proportion of the population, 56.3%

e = Margin of error, 10%

Allowing for a 10% non-response or incomplete data rate, the adjusted target sample size was 105 individuals. This accommodates potential attrition during fieldwork and ensures sufficient power to detect meaningful associations in multivariable models. Response rates were monitored in real time, and additional individuals were sampled if the actual response fell below 80%.

3.6 Study Instrument & Methodology

The data collection section of this study involved two main instruments: a structural questionnaire to collect the prevalence of heat stress symptoms and heat stress-associated risk factors, and a Wet Bulb Globe Temperature (WBGT) meter for environmental heat monitoring.

3.6.1 Questionnaire

A self-developed questionnaire was used to collect data on socio-demographic information, occupational information, lifestyle and health, heat exposure, self-reported heat stress symptoms, and adaptive behavior and awareness. The questionnaire was designed in both English and Bahasa Malaysia to accommodate language preferences and was pre-tested on a small sample to assess clarity and reliability. The questionnaire consisted of six (6) sections, as follows:

I. Sociodemographic characteristics: age, sex, ethnicity, education level, BMI, and household income.
II. Occupational information: primary types of work, work schedule, work environment (indoor, outdoor, mixed), hours worked per day, and shift patterns.
III. Lifestyle and health status: alcohol intake, daily water intake, daily caffeine intake, physical activity level, pre-existing conditions, or medicines.
IV. Heat exposure information: average time spent during peak hours, shade and water accessibility, types of clothing, equipped protective equipment, and heatwave alert.
V. Heat stress symptoms: assess the frequency and severity of several common symptoms (hot and dry skin, heavy sweating, thirst/dry mouth, muscle cramps, fatigue/weakness, headache, dizziness/light-headedness, nausea/vomiting, confusion/disorientation, heat rash/skin irritation, and rapid heartbeat) in the past seven days.
VI. Adaptive behaviors: cooling methods (shade seeking, fans, air-conditioning, cool shower, ice packs, cooling towels, adjusted work hours, extra breaks), main barriers for cooling, implementation of buddy system and heat safety policy or training, and knowledge check.

In this study, three composite scores were developed to assess participants' heat-related condition, namely the heat stress score, adaptive score, and knowledge score. Each score was derived from a set of questionnaire items, and higher scores indicate a greater level of the respective construct.

The heat stress score was calculated based on participants' self-reported symptoms associated with heat exposure. These included symptoms such as thirst, headache, dizziness, fatigue, excessive sweating, muscle cramps, nausea, and hot or dry skin. Each symptom was scored according to its presence or frequency, and the total score represents the overall severity of heat stress symptoms experienced by the individual. Higher scores indicate more frequent or severe symptoms.

The adaptive score reflects the extent to which participants engage in heat-related coping and preventive behaviors. This includes practices such as increasing water intake, seeking shade, taking rest breaks, avoiding outdoor activities during peak heat hours, using cooling methods (e.g., fans or air conditioning), and wearing appropriate clothing. Responses were scored and summed to produce an overall adaptive score, with higher scores indicating better adoption of heat adaptation strategies.

The knowledge score was used to assess participants' understanding of heat stress and its prevention. It included items related to recognition of heat stress symptoms, awareness of risk factors, knowledge of preventive measures (e.g., hydration, appropriate clothing, avoiding peak heat), and understanding of heat-related health risks. Each correct response was assigned a score, and the total score reflects the level of knowledge, with higher scores indicating better awareness and understanding of heat stress.

3.6.2 Heat Exposure Monitoring using WBGT

The Universal Thermal Climate Index (UTCI) is measured using the Kestrel 5400 WBGT meter to monitor heat exposure and assess environmental factors, including ambient temperature, radiant temperature, relative humidity, and air velocity.

Figure 3.1: Kestrel 5400 Heat Stress Tracker

(Source: Kestrel 5400 WBGT Heat Stress Tracker (HST) | Weather Meter for detecting Unsafe Heat-Related Conditions, no date)

According to Sharif et al. (2021), the data obtained from the WBGT meter was calculated using the formula of the Universal Thermal Climate Index (UTCI) as follows:

$$UTCI = 3.21 + 0.872t + 0.2459\,Tmrt - 2.5078v - 0.0176RH$$

where:

t = Air temperature (°C)

Tmrt = Mean radiant temperature (°C)

v = Wind speed at 10m above the ground (m/s)

RH = relative humidity (%)

The calculated value was then used to determine the respondents' heat exposure level or thermal stress category based on the UTCI equivalent temperature scale. Figure 3.2 shows the UTCI thermal stress scale based on Kruger and Di Napoli (2022).

UTCI	Stress category
>46	Extreme heat stress
38 to 46	Very strong heat stress
32 to 38	Strong heat stress
26 to 32	Moderate heat stress
9 to 26	No thermal stress
0 to 9	Slight cold stress
-13 to 0	Moderate cold stress
-27 to -13	Strong cold stress
-40 to -27	Very strong cold stress
<-40	Extreme cold stress

Figure 3.2: UTCI Thermal Stress Scale

(Source: Kruger and Di Napoli, 2022)

The WBGT monitor was set to 1.1 meters above floor level to optimise heat stress assessment in accordance with the ISO 7243 standard (International Organization for Standardization, 2017). Measurements were taken during peak hours, from 11:00 a.m. to 4:00 p.m., at five-minute intervals, resulting in 12 readings for each parameter per hour. The average values of four environmental parameters, which are ambient temperature, radiant temperature, relative humidity, and air velocity, were calculated and used in the UTCI formula for thermal stress classification. The equipment was placed within the sampling area. The assessment procedure of WBGT and the setup of the sampling area are as follows:

a) Pre-assessment

1. The Kestrel 5400 WBGT meter was inspected for physical damage and sensor cleanliness.
2. Battery level was checked to ensure sufficient power throughout the measurement period.
3. Measurement settings were configured to display ambient temperature, heat index, relative humidity, and wind speed.
4. The WBGT monitor was calibrated using a calibrator to ensure the sensor reading is accurate.
5. The WBGT meter was attached to a tripod at 1.1 meters above the floor level.
6. The instrument was left for 30 minutes after the WBGT meter was turned on to allow it to reach equilibrium.

b) During assessment

1. The measurement started after the WBGT meter had been left for 30 minutes by pressing the “RUN” button.
2. Measurement was recorded for one hour during the peak heat hours (11.00 am – 4.00 pm).
3. Ongoing observations were made during the monitoring period.

c) Post-assessment

1. The Kestrel 5400 WBGT meter was turned off and carefully cleaned to remove dust or moisture.
2. The sensors were detached and kept in the protective case.

For each population density group, WBGT measurements were conducted at seven different sampling regions to capture spatial variability across distinct micro-environments. Monitoring at each site was conducted continuously over three consecutive days to account for daily fluctuations and short-term weather variability. This approach was consistent with the methodology used by the Malaysian Meteorological Department in heatwave monitoring. The exact sampling locations were determined following a preliminary field visit, which assessed suitability based on accessibility, safety, and representativeness of the surrounding environment.

3.7 Quality Control

3.7.1 Questionnaire

A validity and reliability test has been conducted to establish validity and reliability for the given population. The questionnaire has been validated through content validity with a Scale Content Validity Index (S-CVI) value of 1.0, which is considered an acceptable value according to Yusoff (2019) and Polit and Beck (2006).

A test–retest reliability analysis was conducted to evaluate the stability and consistency of the questionnaire measuring heat stress symptoms over time. The assessment was conducted with 20 participants, with an 8-day interval between the first and second administrations of the questionnaire. The reliability of the instrument was assessed using the Intraclass Correlation Coefficient (ICC), which is commonly used to determine the degree of agreement between repeated measurements. The results demonstrated an ICC value of 0.976, with a 95% confidence interval ranging from 0.939 to 0.991.

Table 3.2: Test-retest reliability for the questionnaire

	Intraclass Correlation	**95% Confidence Interval**	
		Lower Bound	**Upper Bound**
Average Measures	0.976	0.939	0.991

Time interval between assessments: 8 days

This ICC value indicates excellent reliability, as values above 0.90 are generally considered to reflect a very high level of consistency (Han, 2020; Koo and Li, 2016). The narrow confidence interval further supports the precision and stability of the measurement across the two time points. The findings suggest that the questionnaire produces highly consistent results when administered under similar conditions over time, indicating that it is a reliable instrument for assessing heat stress symptoms.

3.7.2 Heat Exposure Monitoring using WBGT

A calibrated Wet Bulb Globe Temperature (WBGT) meter was placed at the selected location to measure ambient thermal conditions. In accordance with ISO 7243:2017, the height of the WBGT meters was set at 1.1 meters above floor level to ensure consistency throughout data collection (DOSH, 2016). After setup, measurements were recorded at five-minute intervals, resulting in a total of 12 samples per hour at each selected location (DOSH, 2016). Data collection was conducted between 11:00 a.m. and 4:00 p.m., corresponding to peak heat hours in Kampar. To ensure data accuracy, weekly cross-calibration with a reference instrument and daily zero checks were performed. Any deviation of more than 0.5 °C from the reference value requires recalibration or replacement of the instrument. The average readings were then calculated and used for the proper estimation and classification of thermal stress using the UTCI.

3.8 Data Analysis

The data collected from the WBGT meter and questionnaire were entered and analysed using IBM SPSS Statistics 27. IBM SPSS is a statistical software package that provides various analytical functions that assist researchers in analysing data, summarizing results, and generating predictions based on research outcomes (IBM, n.d.). Table 2 illustrates the types of data analysis used according to the specific objectives of the study.

Table 3.3: Types of data analysis based on specific objectives

Specific objectives	Statistical analysis
Prevalence of self-reported heat stress symptoms	Descriptive analysis
Wet Bulb Globe Temperature (WBGT) measurement	Descriptive analysis
Association between sociodemographic, occupational information, lifestyle and health, and heat exposure information, adaptive practice, and knowledge level with heat stress symptoms	Mann-Whitney U test/Kruskal-Wallis test
Relationship between heat stress risk factors and heat stress symptoms	Multi-linear regression

3.9 Ethical Consideration

This study obtained ethical clearance from the UTAR Scientific and Ethical Review Committee (SREC) (Appendix 1). Written informed consent was obtained from all respondents before participating in the study.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Response Rate

Questionnaire data collection was conducted from November 2025 to February 2026, while heat exposure monitoring took place from November 2025 to January 2026. The questionnaire was administered to individuals aged 18 years or older who had lived in Kampar for at least six months. A total of 85 of 105 targeted individuals participated in the survey, yielding a response rate of 81%. Most responses were collected on-site during the heat exposure monitoring sessions, while others were obtained through random distribution of the questionnaire to eligible participants. Overall, all respondents met the study's inclusion criteria.

4.2 Descriptive Information from Respondents

The first objective of this study was to describe sociodemographic characteristics, occupational information, lifestyle and health status, heat exposure, adaptive practices, and knowledge level among the adult population in Kampar, Perak. Understanding these baseline characteristics was essential, as they provided important context for interpreting variability in heat stress and identifying potential determinants within the study population. Descriptive information was used to present an overall profile of the respondents, allowing for a clearer understanding of the distribution of these key variables through measures, such as mean, standard deviation, frequencies, and percentages (Wisdom Library, 2026).

4.2.1 Sociodemographic Characteristics

Table 4.1 presents the sociodemographic characteristics of the study participants involved in the cross-sectional study assessing heat stress variability and its determinants among adults in Kampar, Perak. The table summarizes the continuous variables using mean and standard deviation, while categorical variables are reported as frequencies and percentages.

The mean Body Mass Index (BMI) of the participants was 23.04 (SD = 3.78), indicating that, on average, respondents fall within the normal weight range. In terms of age distribution, the majority of participants were 18–29 years old (65.9%, *n* = 56), followed by those aged 30–49 years (29.4%, *n* = 25). Only a small proportion were above 50 years (4.7%, *n* = 4), suggesting that the study population was largely made up of younger adults. The gender distribution was fairly balanced, with slightly more females (51.8%, *n* = 44) than males (48.2%, *n* = 41). The majority of participants were Chinese (82.4%, *n* = 70), while smaller proportions were Malay (11.8%, *n* = 10) and Indian (5.9%, *n* = 5), reflecting limited ethnic diversity in the sample.

For educational attainment, the majority held a bachelor's degree (63.5%, *n* = 54). Smaller proportions reported postgraduate education (12.9%, *n* = 11), no formal/primary/secondary education (14.1%, *n* = 12), and diploma/certificate qualifications (9.4%, *n* = 8). Based on BMI classification, most participants were in the normal range (18.5–24.9) (58.8%, *n* = 50). However, there were also noticeable proportions of participants who were overweight (24.7%, *n* = 21) and underweight (10.6%, *n* = 9), with a smaller group classified as obese (5.9%, *n* = 5). In terms of household monthly income, the largest group fell within the B40 category (< RM5249) (40.0%, *n* = 34), followed by T20 (> RM11820) (20.0%, *n* = 17) and M40 (RM5250–RM11819) (17.6%, *n* = 15). A considerable proportion of respondents preferred not to disclose their income (22.4%, *n* = 19).

Table 4.1: Sociodemographic Characteristics of the study population (n = 85)

Variables	**Mean (SD)**
BMI	23.04 (3.78)
	Frequency, *f* (%)
Age (year)	
18 – 29 years old	56 (65.9)
30 – 49 years old	25 (29.4)
> 50 years old	4 (4.7)
Gender	
Male	41 (48.2)
Female	44 (51.8)
Ethnicity	
Chinese	70 (82.4)
Malay	10 (11.8)
Indian	5 (2,5)
Education level	
No formal education/Primary/Secondary	12 (14.1)
Diploma/Certificate	8 (9.4)
Bachelor's degree	54 (63.5)
Postgraduate	11 (12.9)
BMI scale	
< 18.5	9 (10.6)
18.5 – 24.9	50 (58.8)
25.0 – 29.9	21 (24.7)
30.0 – 34.9	5 (5.9)
Household monthly income (RM)	
Prefer not to say	19 (22.4)
B40 (< RM5249)	34 (40.0)
M40 (RM5250 – RM11819)	15 (17.6)
T20 (> RM11820)	17 (20.0)

The age distribution showed that the majority of participants were between 18 and 29 years old, indicating that the sample was largely composed of young adults. This pattern was expected, as Kampar is widely recognised as an education hub with a substantial student population, particularly due to the presence of higher education institutions such as Universiti

Tunku Abdul Rahman (UTAR) and Tunku Abdul Rahman University of Management and Technology (TAR UMT) (City Population, no date).

The gender distribution was relatively balanced, with a slight predominance of female participants. This trend is consistent with previous studies suggesting that women are generally more likely to participate in health-related surveys (Becker, 2022). In terms of ethnicity, the sample was predominantly Chinese, with smaller proportions of Malay and Indian participants. This distribution reflects the local demographic composition of Kampar, where the Chinese population constitutes a significant proportion of residents (Department of Statistics Malaysia (DOSM), 2020).

The educational attainment of participants was generally high, with the majority holding a bachelor's degree. This may be attributed to the presence of higher education institutions in Kampar, which contributes to a more educated study population. Higher levels of education are often associated with greater participation in research, as individuals may have a better understanding of the study purpose and increased awareness (Reinikainen *et al*., 2017).

The mean BMI of participants was within the normal range, with most respondents classified as having normal weight, followed by smaller proportions who were underweight, overweight, or obese. This pattern is generally consistent among student and young adult populations, particularly among females, who may place greater emphasis on body image and appearance (Akhtari-Zavare *et al*., 2025).

With respect to household income, the largest proportion of respondents belonged to the B40 income group, followed by the M40 and T20 categories, while a notable proportion preferred not to disclose their income. This distribution may be influenced by the mixed urban–rural setting of Kampar, which includes a high proportion of students, young adults, and small business owners (Mohamad *et al*., 2023).

4.2.2 Occupational information

Table 4.2 shows the occupational information of the study participants in Kampar, Perak. The data are summarized using frequency and percentages to describe the distribution of participants according to occupation type, work schedules, outdoor exposure, and work-rest practices.

Regarding current occupation status, the majority of participants were engaged in indoor work (62.4%, *n* = 53), followed by students (27.1%, *n* = 23). A smaller proportion of respondents reported working in outdoor occupations (10.6%, *n* = 9). In terms of work schedule, more than half of the participants reported having a regular day shift (57.6%, *n* = 49). This was followed by those with a flexible schedule (34.1%, *n* = 29). Only a small number of respondents reported rotating shifts (3.5%, *n* = 3), split shifts (3.5%, *n* = 3), and night shifts (1.2%, *n* = 1). For total outdoor exposure between 11.00 am and 4.00 pm, the majority of participants reported spending less than 1 hour outdoors (57.6%, *n* = 49). Smaller proportions reported 1–2 hours (16.5%, *n* = 14), 3–4 hours (11.8%, *n* = 10), and more than 4 hours (14.1%, *n* = 12) of outdoor exposure during this period. Regarding work-rest schedules for outdoor activities, nearly half of the participants indicated that this was not applicable (44.7%, *n* = 38), likely due to their involvement in indoor work or non-outdoor activities. Among those for whom it was applicable, 45.9% (*n* = 39) reported having regular rest breaks, while smaller proportions reported short rest breaks (8.2%, *n* = 7) or no rest breaks (1.2%, *n* = 1).

Table 4.2: Occupational Information of the study population (n = 85)

Variable (s)	Frequency, *f* (%)
Current Occupation Status (Main work)	
Student	23 (27.1)
Indoor	53 (62.4)
Outdoor	9(10.6)
Work schedule	
Regular day shift	49 (57.6)

Rotating shift	3 (3.5)
Flexible schedule	29 (34.1)
Split shift	3 (3.5)
Night shift	1 (1.2)
Total outdoor exposure between 11.00 am – 4.00 pm	
Less than 1 hour	49 (57.6)
1 – 2 hours	14 (16.5)
3 – 4 hours	10 (11.8)
More than 4 hours	12 (14.1)
Work-rest schedule for outdoor	
Not applicable	38 (44.7)
No rest breaks	1 (1.2)
Short rest breaks	7 (8.2)
Regular rest breaks	39 (45.9)

Most participants were engaged in indoor occupations, followed by students, with only a small proportion involved in outdoor work. This distribution is consistent with the socioeconomic structure of Kampar, where employment opportunities are largely concentrated in indoor-based sectors such as services, administration, and retail, alongside a substantial student population. Previous studies have shown that urban and semi-urban populations tend to have a higher proportion of indoor workers due to the nature of local economic activities (International Labour Organization (ILO), 2019).

Most participants reported working regular day shifts, with a considerable proportion also having flexible schedules. This pattern aligns with typical employment structures in Malaysia, where standard daytime working hours are more common, particularly in administrative, educational, and service sectors.

The findings on outdoor exposure between 11:00 a.m. and 4:00 p.m. indicate that most participants spent less than one hour outdoors during peak daytime hours. This is likely reflective of the high proportion of indoor workers and students in the sample. Previous studies have shown that individuals in indoor occupations generally experience lower environmental heat exposure than those in outdoor settings, as they have greater access to cooling measures such as air conditioning, fans, and cold beverages (Shahrujjaman *et al*., 2025; Taggart *et al*., 2023).

In terms of work–rest schedules, nearly half of the respondents indicated that the question was not applicable, which is consistent with the large proportion of indoor workers in the sample. Among those for whom it was applicable, most reported having regular rest breaks. The provision of breaks is a common occupational practice and is widely recommended in workplace settings to maintain worker well-being and productivity (ILO, 2019).

4.2.3 Lifestyle and Health Status

Table 4.3 shows the lifestyle and health status of the study participants in Kampar, Perak. The Continuous variables are summarized using median and interquartile range (IQR), while categorical variables are reported as frequencies and percentages to describe the distribution of participants.

The median daily caffeine intake among participants was 250 ml (IQR = 250), while the median daily water intake was 2000 ml (IQR = 500). Regarding alcohol consumption, most participants reported occasional drinking (60.0%, n = 51), while 40.0% (n = 34) indicated that they did not consume alcohol. In terms of physical activity level, the majority of participants were classified as having light physical activity (68.2%, n = 58), followed by moderate activity (24.7%, n = 21), with only a small proportion engaging in heavy physical activity (7.1%, n = 6). In terms of health status, most participants reported no pre-existing diagnosed medical conditions (87.1%, n = 74), while 12.9% (n = 11) indicated at least one diagnosed condition. Similarly, the majority of respondents reported not taking any prescribed medications (90.6%, n = 77), with only a small proportion (9.4%, n = 8) indicating current use of prescribed medication due to diagnosed conditions. For nighttime heat disruption, the majority of participants reported some degree of disturbance, with 16.7% (*n* = 34) indicating "sometimes" and 15.2% (*n* = 31) reporting "rarely". A smaller proportion reported more frequent disruption, with 4.4% (*n* = 9) indicating "often" and 1.5% (*n* = 3) indicating "always". Only 3.9% (*n* = 8) of participants reported never experiencing nighttime heat disruption.

Table 4.3: Lifestyle and health status of the study population (n = 85)

Variable (s)	**Median (IQR)**
Daily caffeine intake (ml)	250 (250)
Daily water intake (ml)	2000 (500)
	Frequency, *f* (%)
Alcohol intake	
Never	34 (40.0)
Occasionally drink	51 (60.0)
Physical activity level	
Light	58 (68.2)
Moderate	21 (24.7)
Heavy	6 (7.1)
Pre-existing health conditions diagnosed	
Yes	11 (12.9)
No	74 (87.1)
Prescribed medicines	
Yes	8 (9.4)
No	77 (90.6)
Nighttime heat disruption	
Never	8 (3.9)
Rarely	31 (15.2)
Sometimes	34 (16.7)
Often	9 (4.4)
Always	3 (1.5)

Caffeine intake, with a median of 250 ml, reflects a moderate level of consumption within the study population. Caffeinated beverages such as coffee and tea are widely consumed in Malaysia, particularly among young adults and students (Abdul Aziz *et al.,* 2025; Kaur and Say, 2025). Previous studies suggest that caffeine consumption patterns are often influenced by lifestyle factors, work demands, and cultural habits (Abdul Aziz *et al*., 2025).

The median daily water intake of 2000 ml indicates that most participants met general hydration recommendations, which typically suggest an intake of approximately 2 litres per day for adults under normal conditions (Howard *et al*., 2020). In terms of alcohol consumption, most participants reported occasional intake, while a considerable proportion indicated that they did not consume alcohol.

The findings also indicate that most participants engage in light physical activity, with fewer individuals involved in moderate or heavy activity levels. This distribution may be influenced by the high proportion of students and indoor workers in the study sample, as these groups are more likely to have sedentary or low-intensity daily routines.

In terms of health status, most participants reported having no pre-existing diagnosed conditions and were not taking any prescribed medications. This finding is consistent with the relatively young age distribution observed in the study, as younger populations generally tend to have a lower prevalence of chronic diseases (Yang *et al*., 2025).

The findings indicate that nighttime heat disruption is a common experience among participants, with most individuals reporting at least occasional disturbances. Although only a small proportion reported frequent disruption (“often” or “always”), the relatively higher percentages in the “rarely” and “sometimes” categories suggest that nighttime heat exposure still affects sleep quality for a considerable portion of the population. Nighttime heat can impair temperature regulation during sleep, leading to discomfort, insomnia, and reduced sleep quality (Okamoto-Mizuno and Mizuno, 2012). Even intermittent disruption may have cumulative effects, as poor sleep can contribute to fatigue, reduced cognitive performance, and increased vulnerability to heat-related symptoms during the day (Lan *et al*., 2017).

4.2.4 Heat Exposure Information

Table 4.4 shows the heat exposure information of the study participants in Kampar, Perak. The data are summarized using frequencies and percentages to describe participants' exposure to different environmental conditions, access to resources, and personal practices during peak heat hours (11.00 a.m. – 4.00 p.m.).

The majority of participants reported less than 1 hour of direct sun exposure (88.2%, n = 75) between 11:00 a.m. and 4:00 p.m. Smaller proportions reported 1–2 hours (10.6%, n = 9) and 3–4 hours (1.2%, n = 1) of exposure. For time spent outdoors in shaded areas, more than half of the participants reported less than 1 hour (54.1%, n = 46), followed by 1–2 hours (34.1%, n = 29), 3–4 hours (8.2%, n = 7), and more than 5 hours (3.5%, n = 3). Regarding indoor exposure without air conditioning (AC), 37.6% (n = 32) of participants reported spending less than 1 hour, while 24.7% (n = 21) spent 1–2 hours, 15.3% (n = 13) spent 3–4 hours, and 22.4% (n = 19) reported spending more than 5 hours under such conditions. In contrast, for indoor environments with air conditioning, the majority of participants reported spending more than 5 hours (54.1%, n = 46), followed by 3–4 hours (23.5%, n = 20), less than 1 hour (14.1%, n = 12), and 1–2 hours (8.2%, n = 7).

Most participants reported having access to shade (96.5%, n = 82) and drinking water (98.8%, n = 84) during the specified heat hours. In terms of clothing type, 43.5% (n = 37) reported wearing a combination of short and long clothing, followed by short clothing (40.0%, n = 34) and long clothing (16.5%, n = 14). For clothing colour, slightly more than half of the participants wore dark-coloured clothing (52.9%, *n* = 45), while the remaining participants wore light-coloured clothing (47.1%, *n* = 40).

Regarding the use of personal protective equipment (PPE), the majority of participants reported never using PPE (58.8%, *n* = 50). Smaller proportions are reported sometimes (22.4%, *n* = 19), always (11.8%, *n* = 10), and rarely (7.1%, *n* = 6) using PPE.

Table 4.4: Heat exposure information of the study population (n = 85)

Variable (s)	Frequency, *f* (%)
Direct sun exposure between 11:00 a.m. and 4:00 p.m.	
Less than 1 hour	75 (88.2)
1-2 hours	9 (10.6)
3-4 hours	1 (1.2)
Outdoor in shade between 11:00 a.m. and 4:00 p.m.	
Less than 1 hour	46 (54.1)
1-2 hours	29 (34.1)
3-4 hours	7 (8.2)
More than 5 hours	3 (3.5)
Indoor without AC between 11:00 a.m. and 4:00 p.m.	
Less than 1 hour	32 (37.6)
1-2 hours	21 (24.7)
3-4 hours	13 (15.3)
More than 5 hours	19 (22.4)
Indoor with AC between 11:00 a.m. and 4:00 p.m.	
Less than 1 hour	12 (14.1)
1-2 hours	7 (8.2)
3-4 hours	20 (23.5)
More than 5 hours	46 (54.1)
Shade accessibility	
Yes	82 (96.5)
No	3 (3.5)
Drinking water accessibility	

Yes	84 (98.8)
No	1 (1.2)
Clothing type	
Short	34 (40.0)
Short and Long	37 (43.5)
Long	14 (16.5)
Clothing colour	
Light-coloured	40 (47.1)
Dark-coloured	45 (52.9)
Personal protective equipment (PPE)	
Never	50 (58.8)
Rarely	6 (7.1)
Sometimes	19 (22.4)
Always	10 (11.8)

The majority of participants reported minimal direct sun exposure, with most spending less than one hour under direct sunlight between 11:00 a.m. and 4:00 p.m. This pattern is consistent with the occupational profile of the sample, which was largely composed of indoor workers and students. Previous studies have shown that individuals engaged in indoor occupations typically experience lower levels of direct environmental exposure compared to outdoor workers (ILO, 2024; Taggart *et al*., 2023).

Similarly, time spent outdoors in shaded environments was generally limited, with most participants reporting less than one hour. Shade is widely recognised as an important environmental factor that helps reduce heat exposure, particularly in tropical climates.

Indoor exposure patterns indicated that a substantial proportion of participants spent extended periods in air-conditioned environments, with more than half reporting more than five hours of exposure. This is expected in Malaysia's hot and humid climate, where air conditioning is commonly used in residential, educational, and workplace settings (DOSM, 2020). At the same time, a notable proportion of participants reported spending several hours indoors without air conditioning, suggesting variability in access to cooling environments.

Access to shade and drinking water was reported to be very high among participants, indicating that most respondents had basic environmental resources available during daytime activities. Having access to shade and drinking water can help reduce the likelihood of heat stress symptoms, as shade reduces direct solar exposure while adequate water intake supports hydration and thermoregulation (Bhati and Sheth, 2026; Lim *et al.*, 2023).

Clothing practices varied among participants, with a relatively even distribution between short and mixed clothing types. Slightly more participants reported wearing dark-coloured clothing compared to light-coloured clothing. Clothing characteristics, including colour and material, are known to influence thermal comfort and heat absorption, although actual clothing choices are often shaped by cultural preferences, fashion, and occupational requirements (Di Domenico, 2022; Md. Rashedul Islam, 2023).

The majority of participants reported not using personal protective equipment (PPE), which may be attributed to the low proportion of individuals engaged in outdoor or high-exposure occupations. Among those who reported PPE use, the frequency of usage varied.

4.2.5 Adaptive Practices

Table 4.5 presents the adaptive practice levels among the study participants in Kampar, Perak. Continuous variables are summarized using mean and standard deviation or median and interquartile range, while categorical variables are reported as frequencies and percentages.

The mean adaptive score among participants was 19.0 (SD = 0.57), while the median knowledge score was 4.0 (IQR = 2.00), indicating generally moderate levels of adaptive behaviour and knowledge within the study population. In terms of specific adaptive practices, shade-seeking behaviour varied among participants. While 28.2% (n = 24) reported never seeking shade, a similar proportion (27.1%, n = 23) indicated that they did so daily, with the remaining participants reporting varying frequencies throughout the week. The use of fans was relatively common, with nearly half of the participants (47.1%, n = 40) reporting daily use, followed by 24.7% (n = 21) who used fans two to three times per week.

Similarly, air-conditioning was widely used, with the majority of participants reporting daily use (58.8%, n = 50). For cool showers, the most frequently reported pattern was two to three times per week (30.6%, n = 26), followed by those who never used this method (21.2%, n = 18) and those who used it daily (18.8%, n = 16). In contrast, the use of more specialised cooling methods, such as ice packs (77.6%, n = 66) and cooling towels (87.1%, n = 74), was relatively uncommon, with most participants reporting that they never used these approaches.

Regarding heat-adaptive behavioural adjustments, most participants reported neither adjusting their work hours (70.6%, n = 60) nor taking additional breaks (56.5%, n = 48). However, a smaller proportion reported engaging in these practices at varying frequencies. In terms of perceived barriers, most participants reported experiencing one barrier (44.7%, n = 38) or two barriers (31.8%, n = 27), while only a small proportion reported no barriers (4.7%, n = 4). This suggests that certain constraints may limit the adoption of adaptive behaviours within the study population.

The use of a buddy system was generally low, with 65.9% (n = 56) reporting no use and only a small proportion indicating regular practice. Similarly, the majority of participants reported that no formal heat-related policies or training were available (80.0%, n = 68), while only 20.0% (n = 17) indicated the presence of such measures. Finally, 63.5% (n = 54) of participants reported being aware of heatwave alerts, while 36.5% (n = 31) indicated that they were not.

For the knowledge check assessment, most participants answered:

i. 98.8% (*n* = 84) of the total participants correctly identified that Question 1 (water as the best fluid for hydration) is a TRUE statement.
ii. 91.8% (*n* = 78) of the participants recognized that Question 2 (headaches and dizziness as early warning signs) is a TRUE statement.
iii. 81.2% (*n* = 69) identified that Question 3 (heat stroke requires immediate medical attention) is a TRUE statement.
iv. 77.6% (*n* = 66) of the total participants correctly identified that Question 5 (dark-coloured clothing can help to prevent heat accumulation) is a FALSE statement.

However, lower correct responses were observed for Question 4 (High humidity can reduce the possibility of heat stress). Only 44.7% (*n* = 38) of the total participants identified that the statement is a FALSE statement.

Table 4.5: Adaptive Practice of the study population (n = 85)

Variable (s)	Mean (SD)[a]/Median (IQR)[b]
Adaptive score	19 (0.57)[a]
Knowledge score	4 (2.00)[b]
	Frequency, *f* (%)
Shade seeking	
Never	24 (28.2)
Once a week	13 (15.3)
2-3 times a week	9 (10.6)
4-6 times a week	16 (18.8)
Everyday	23 (27.1)
Fans	
Never	6 (7.1)
Once a week	8 (9.4)
2-3 times a week	21 (24.7)
4-6 times a week	10 (11.8)
Everyday	40 (47.1)
Air-conditioning	
Never	3 (3.5)

Once a week	9 (10.6)
2-3 times a week	9 (10.6)
4-6 times a week	14 (16.5)
Everyday	50(58.8)
Cool shower	
Never	18 (21.2)
Once a week	14 (14.0)
2-3 times a week	26 (30.6)
4-6 times a week	11 (12.9)
Everyday	16 (18.8)
Ice packs	
Never	66 (77.6)
Once a week	9 (10.6)
2-3 times a week	7 (8.2)
Everyday	3 (3.5)
Cooling towels	
Never	74 (87.1)
Once a week	4 (4.7)
2-3 times a week	3 (3.5)
4-6 times a week	1 (1.2)
Everyday	3 (3.5)
Adjusted work hours	
Never	60 (70.6)
Once a week	4 (4.7)
2-3 times a week	12 (14.1)
4-6 times a week	7 (8.2)
Everyday	2 (2.4)
Extra breaks	
Never	48 (56.5)
Once a week	4 (4.7)
2-3 times a week	15 (17.6)
4-6 times a week	9 (10.6)
Everyday	9 (10.6)
Main barriers	
3 barriers	16 (18.8)
2 barriers	27 (31.8)
1 barrier	38 (44.7)
No barrier	4 (4.7)
Buddy system	
None	56 (65.9)
Rarely	13 (15.3)

Sometimes	14 (16.5)
Always	2 (2.4)
Never	34 (40.0)
Heat policy or training	
No	68 (80.0)
Yes	17 (20.0)
Heatwave awareness	
No	31 (36.5)
Yes	54 (63.5)
Knowledge check Q1	
Wrong/not sure	1 (1.2)
Correct	84 (98.8)
Knowledge check Q2	
Wrong/not sure	7 (8.2)
Correct	78 (91.8)
Knowledge check Q3	
Wrong/not sure	16 (18.8)
Correct	69 (81.2)
Knowledge check Q4	
Wrong/not sure	47 (55.3)
Correct	38 (44.7)
Knowledge check Q5	
Wrong/not sure	19 (22.4)
Correct	66 (77.6)

The mean adaptive score indicates a moderate level of adaptive practices among participants, while the knowledge score suggests a generally good level of awareness regarding heat-related information. This pattern is consistent with previous studies, which have reported that populations with higher education levels tend to demonstrate better knowledge of environmental health issues (Fallahi *et al*., 2024; Xu *et al*., 2024).

In terms of specific adaptive behaviours, the use of fans and air-conditioning was common, particularly the daily use of air-conditioning. This pattern is likely influenced by the high proportion of indoor workers and students in the sample. It also reflects typical coping strategies in hot and humid climates such as Malaysia, where mechanical cooling is widely relied upon to maintain thermal comfort (Izzati *et al.*, 2023; Mohammad Zaraa Allah *et al*., 2023). In contrast, the less frequent use of methods such as ice packs and cooling towels suggests that these strategies may be less familiar, less accessible, or perceived as less practical among the general population.

Shade-seeking behavior showed variability, with some participants reporting frequent use while others reported none. This may reflect differences in daily routines, occupational demands, or personal habits. Similarly, the moderate use of cool showers indicates variability in personal cooling practices.

Behavioral adjustments such as changing work hours and taking extra breaks were less commonly reported. This may be influenced by the nature of participants' occupations, particularly among those engaged in structured indoor work or academic settings, where flexibility may be limited. Previous research has highlighted that workplace structure can influence the ability to adopt adaptive behaviors (ILO, 2019).

The presence of perceived barriers among most participants suggests that challenges remain in the adoption of adaptive practices. These barriers may include time constraints, limited awareness, and environmental limitations, as reported in previous studies on behavioural adaptation. Additionally, the nature of outdoor work often involves rigid schedules, heavy workloads, and limited access to essential facilities such as drinking water, shaded rest areas, and protective equipment, which can further restrict individuals' ability to implement recommended practices (Gibb *et al*., 2024; Torbat, 2024). A lack of training and awareness regarding heat stress may also act as a key barrier to effective adaptation (Ioannou *et al*., 2022). In some cases, individuals from lower-income groups, particularly those in the B40 category, may face financial constraints that limit access to cooling resources and supportive environments (Ioannou *et al*., 2022; Torbat, 2024).

The findings also indicate low use of buddy systems and limited availability of heat-related policies or training. This suggests that formal, organizational-level adaptation measures may not be widely implemented within the study population. Previous studies have highlighted the importance of buddy systems in helping individuals monitor one another and recognise early warning signs, thereby supporting the prevention of heat-related illnesses (Edgerly *et al*., 2024; Ioannou *et al.*, 2022).

Finally, more than half of the participants reported awareness of recent heatwave alerts, suggesting a moderate level of awareness within the study population. This level of awareness may be influenced by access to media and information channels, particularly given that Kampar has a relatively large population of young adults and university students (Fallahi *et al*., 2024). This demographic is often more active in using social media, online news sources, and academic resources, which may contribute to increased exposure to relevant information and, consequently, higher awareness levels (Xu *et al*., 2024).

In terms of knowledge, participants demonstrated a generally good level of awareness of basic heat-related concepts, such as hydration, early warning signs, and clothing characteristics that influence heat accumulation. However, the misconception was observed in a specific area, particularly regarding the role of humidity in terms of heat regulation. This suggests that while general awareness is satisfactory, gaps remain in more detailed or technical understanding, which is consistent with findings from other environmental health studies.

4.2.6 Heat Stress Symptoms

Table 4.6 presents the prevalence of self-reported heat stress symptoms among the participants. Overall, a high proportion of respondents reported experiencing at least one symptom associated with heat exposure.

The most frequently reported symptom was thirst or dry mouth, affecting 71 respondents (83.5%), indicating a widespread occurrence of dehydration-related effects. This was followed by hot, dry skin with little sweat (63.5%, *n* = 54) and headache (61.2%, *n* = 52), suggesting considerable physiological strain under heat exposure conditions. Additionally, more than half of the participants reported fatigue (55.3%, *n* = 47), reflecting the impact of prolonged exposure to high temperatures

Moderate prevalence was observed for dizziness (49.4%, *n* = 42), heavy sweating (43.5%, *n* = 37), and rapid heartbeat (43.5%, *n* = 37), which reflect common thermoregulatory and cardiovascular responses to heat stress. Meanwhile, heat rash or skin irritation was reported by 36.5% (*n* = 31) of respondents, and confusion or disorientation by 31.8% (*n* = 27).

The least commonly reported symptom was nausea or vomiting, affecting only 17 respondents (20.0%). Overall, the results indicate that while mild to moderate heat stress symptoms are highly prevalent, more severe symptoms are less frequently experienced among participants.

Table 4.6: Prevalence of Self-Reported Heat Stress Symptoms Among Participants (n = 85)

Variable (s)	**Frequency, *f* (%)**	
	Yes	**No**
Hot, dry skin with little sweat	54 (63.5)	31 (36.5)
Heavy sweating	37 (43,5)	48 (56.5)

Thirst/dry mouth	71 (83.5)	14 (16.5)
Muscle cramps	23 (27.1)	62 (72.9)
Fatigue	47 (55.3)	38 (44.7)
Headache	52 (61.2)	33 (38.8)
Dizziness	42 (49.4)	43 (50.6)
Nausea/vomiting	17 (20.0)	68 (80.0)
Confusion/Disorientation	27 (31.8)	58 (68.2)
Heat rash/skin irritation	31 (36.5)	54 (63.5)
Rapid heartbeat	37 (43.5)	48 (56.5)

The high prevalence of heat stress symptoms observed in this study is consistent with the elevated thermal conditions identified through environmental measurements, particularly the high Universal Thermal Climate Index (UTCI) values recorded during peak heat hours. The predominance of thirst or dry mouth (83.5%) highlights dehydration as a key concern, which is expected in hot and humid environments where fluid loss through sweating is substantial. This finding is consistent with previous studies, which have similarly reported thirst and dry mouth as the most experienced heat stress symptoms (Debela *et al*., 2023; John and Jha, 2023; Saif Eldin *et al*., 2022; Venugopal *et al*., 2023).

The frequent reporting of hot, dry skin, headache, and fatigue suggests that many participants experienced significant thermal strain. These symptoms are commonly associated with early stages of heat-related stress and may indicate that the body's thermoregulatory mechanisms are being challenged. In contrast, the lower prevalence of muscle cramps (27.1%) may suggest that although dehydration is common, electrolyte imbalance severe enough to cause cramps may not be as widespread among participants (Leiva and Church, 2023).

Physiologically, heat stress triggers mechanisms such as increased sweating and elevated heart rate to facilitate heat dissipation (Acevedo *et al*., 2025). However, in Malaysia's hot and humid climate, high humidity reduces the effectiveness of evaporative cooling, thereby increasing thermal discomfort and strain (Baldwin *et al*., 2023; Che, 2023). This may explain the occurrence of symptoms such as heavy sweating, dizziness, and rapid heartbeat, which reflect the body’s attempt to maintain thermal balance under challenging environmental conditions (Vallennie, 2024).

Although more severe symptoms such as nausea or vomiting (20.0%) and confusion (31.8%) were less frequently reported, their presence remains important, as these may indicate progression toward more serious heat-related illnesses if exposure continues. This suggests that while most participants experienced mild to moderate symptoms, there is still a potential risk of more severe health outcomes.

When considered alongside the high UTCI values (indicating very strong heat stress), these findings reinforce the conclusion that participants were exposed to potentially hazardous thermal conditions during peak heat hours. This is particularly relevant for vulnerable groups, such as outdoor workers and individuals from lower-income (B40) categories, who may have limited access to hydration, rest, or protective measures.

Overall, the findings emphasize the importance of implementing preventive strategies, including adequate hydration, provision of shaded areas, and adjustment of activities during peak heat hours. Increasing awareness of early heat stress symptoms is also essential to prevent progression to more severe conditions, particularly in hot and humid environments like Malaysia.

4.2.7 Summary of Heat Stress, Adaptive, and Knowledge Scores

Table 4.7 presents the summary statistics for heat stress, adaptiveness, and knowledge scores among participants. The heat stress score was reported as a median of 10 with an interquartile range (IQR) of 16.00, indicating a wide variability in the level of heat stress symptoms experienced among respondents. The adaptive score showed a mean value of 19 with a standard deviation (SD) of 0.57, suggesting that participants generally demonstrated a high and consistent level of adaptive practices, with minimal variation across individuals. In contrast, the knowledge score had a median of 4 with an IQR of 2.00, indicating a moderate level of knowledge with some variability among participants.

Table 4.7: Summary statistics of heat stress, adaptive, and knowledge scores among participants (n = 85)

Variable (s)	**Mean (SD)[a]/Median (IQR)[b]**
Heat stress score	10 (16.00)[b]
Adaptive score	19 (0.57)[a]
Knowledge score	4 (2.00)[b]

The findings reveal distinct patterns in heat stress, adaptive behavior, and knowledge among participants. The heat score reflects the severity and frequency of heat-related symptoms, with higher scores indicating greater levels of heat stress experienced by the individuals. Conversely, lower scores indicate fewer or less severe symptoms.

In this study, the median heat stress score of 10, with a wide interquartile range (IQR = 16.00), suggests that participants experienced varying levels of heat stress symptoms, ranging from mild to more pronounced conditions. This variability may be influenced by differences in environmental exposure, particularly between indoor and outdoor workers, as well as individual factors such as health status and access to protective measures.

Despite this variation, the adaptive score (mean = 19, SD = 0.57) indicates that most participants reported consistently high engagement in adaptive practices. This may reflect a general awareness of heat-related risks and the adoption of basic coping strategies, such as increasing fluid intake or seeking shade.

The knowledge score (median = 4, IQR = 2.00) indicates a moderate level of understanding regarding heat stress and its prevention. The observed variation suggests that while some participants possess adequate knowledge, others may have limited awareness, which could affect their ability to effectively respond to heat exposure.

When these findings are considered together, an important observation emerges: although participants demonstrated relatively consistent adaptive practices, these did not necessarily correspond to lower levels of heat stress. This suggests that existing adaptive measures may be insufficient under conditions of high thermal stress, as reflected by the elevated Universal Thermal Index (UTCI) value recorded during peak heat hours, a gap that has also been reported in previous studies (Bhati and Sheth, 2026).

In tropical climates such as Malaysia, heavy sweating and a persistent sensation of thirst are common due to high humidity and elevated radiant temperatures. Consequently, drinking water helps replace lost fluids but does not actually lower the body temperature if the heat can't escape through the skin. Furthermore, previous studies have highlighted that heat stress symptoms are not solely influenced by individual behaviours but are also strongly affected by external factors, such as environmental conditions and occupational exposure, which may play a more dominant role in determining heat-related health outcomes (Acharya *et al*., 2018; Faremi *et al*., 2025; Mohamad *et al*., 2023).

4.3 Heat Exposure Monitoring

The second objective of the study is to characterize heat exposure levels by using the Universal Thermal Climate Index (UTCI) at specific locations during peak hours. In relation to the second objective, Wet Bulb Globe Temperature (WBGT) was used to assess the outdoor thermal condition based on four environmental parameters, which are ambient temperature, radiant temperature, relative humidity, and air velocity. The average readings of these parameters across the seven sampling sites were calculated and subsequently applied in the UTCI formula to determine the heat exposure level and classification of UTCI thermal stress (Sharif *et al*., 2021).

The monitoring is carried out during the peak heat hours, typically between late morning and mid-afternoon (11.00 a.m. – 4.00 p.m.) as this period is associated with the maximum solar radiation and ambient temperature, thereby posing the highest risk of heat-related stress.

Table 4.8 presents the summary of outdoor heat exposure parameters measured using Wet Bulb Globe Temperature (WBGT)-related indicators, expressed as mean and standard deviation. The results show that the ambient temperature recorded a mean of 33.52°C (SD = 3.7), indicating generally high daytime temperatures across the study sites. The radiant temperature was even higher, with a mean of 45.30°C (SD = 2.3), suggesting substantial heat gain from solar radiation. The relative humidity averaged 58.11% (SD = 6.4), reflecting the humid tropical climate conditions typical of Malaysia. Meanwhile, air velocity was relatively low, with a mean of 0.66 m/s (SD = 0.3), indicating limited airflow that may reduce the body's ability to dissipate heat through convection and evaporation.

The Universal Thermal Climate Index (UTCI) level recorded a mean value of 40.89°C (SD = 3.9), which falls within the category of very strong heat stress (Kruger and Di Napoli, 2022).

Table 4.8: Summary of outdoor heat exposure parameters based on WBGT monitoring

	Mean (SD)
Heat parameter	
Ambient temp.	33.52 (3.7)
Radiant temp.	45.30 (2.3)
Relative humidity	58.11 (6.4)
Air velocity	0.66 (0.3)
UTCI level	40.89 (3.9)

Figure 4.1 further illustrates the variation of the UTCI index across seven study sites (A–G). The highest UTCI value was observed at Site E (45.94°C), followed by Site C (43.14°C) and Site B (42.32°C). In contrast, the lowest UTCI value was recorded at Site F (33.51°C). The remaining sites (A, D, and G) showed UTCI values ranging between approximately 39°C and 41°C. Overall, all sites demonstrated elevated UTCI levels, indicating thermal stress across the study locations.

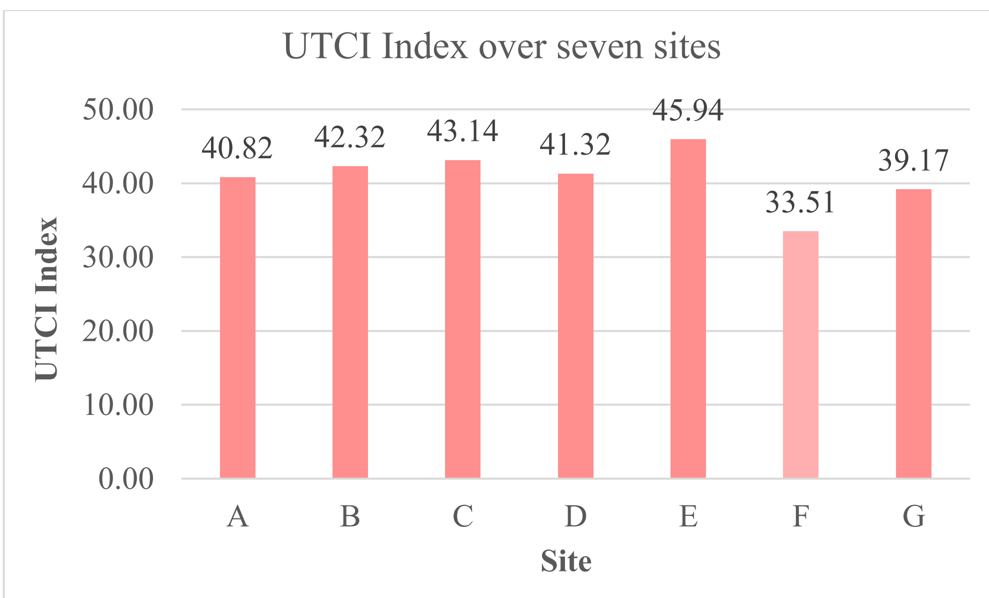

Figure 4.1: Distribution of Universal Thermal Climate Index (UTCI) values across study sites (A – G)

The findings of this study demonstrate that heat exposure levels across the seven selected sites during peak heat hours are consistently high, as reflected by the elevated UTCI values. The mean UTCI of 40.89°C indicates very strong heat stress, while the maximum value recorded at Site E (45.94°C) approaches the threshold of extreme heat stress (Kruger and Di Napoli, 2022). These results confirm that the second research objective has been achieved, as the UTCI index effectively characterizes spatial variations in heat exposure under critical thermal conditions.

The high thermal stress observed can be attributed to the combined effects of elevated ambient temperature, intense radiant heat, moderate-to-high humidity, and low air movement (Ghaffarianhoseini *et al*., no date). Previous studies have shown that radiant temperature is a major contributor to outdoor heat stress, particularly in tropical urban environments where solar exposure is high (Mihalakakou and Romeos, 2026; Tan *et al*., 2013). In addition, high humidity reduces the effectiveness of evaporative cooling, thereby increasing thermal strain on the human body (Che, 2023; Cramer *et al*., 2022).

From a regulatory perspective, these findings raise important concerns regarding occupational heat exposure. The International Organization for Standardization (ISO 7243) recommends the use of the Wet Bulb Globe Temperature (WBGT) index to assess heat stress and determine safe exposure limits in occupational settings (ISO 7243, 2017). According to this standard, as well as findings from previous studies, when heat exposure exceeds recommended thresholds, appropriate control measures should be implemented. These include the provision of adequate work–rest cycles, sufficient hydration, and access to shaded environments to reduce heat strain (Isaac *et al.*, 2025; ISO 7243, 2017; Torbat, 2024) Similarly, the Department of Occupational Safety and Health Malaysia (DOSH) highlights the importance of managing heat exposure in outdoor workplaces, particularly in hot and humid climates such as Malaysia (DOSH, 2016).

Furthermore, the application of the Universal Thermal Climate Index (UTCI) in this study provided a more comprehensive assessment of outdoor thermal stress. The UTCI has been widely validated as a reliable index that integrates multiple meteorological parameters with human thermoregulation models (Havenith *et al*., 2024; Liu and Qin, 2023; Kafy *et al*., 2026; Muhamad *et al*, 2023). Compared to the Wet Bulb Globe Temperature (WBGT), UTCI is more sensitive to environmental variability and is particularly useful for evaluating both thermal comfort and physiological stress under outdoor conditions. This makes it especially suitable for achieving the study objective of characterising heat exposure during peak heat hours.

The variation in UTCI values across the study sites highlights the influence of microclimatic conditions. Previous research has shown that urban design elements, such as shading, vegetation, and surface materials, can significantly affect local thermal environments (An and Dedekorkut-Howes, 2025; Clark *et al*., 2024; Mihalakakou and Romeos, 2026). Site E, which has the highest UTCI value, is located in Kampar Old Town. Kamoar old town is a densely developed area with a high concentration of buildings, roads, and commercial activities, characterized by heat-retaining surface, limited vegetation, reduced air flow, and higher human and vehicle activities. With these characteristics, heat accumulation and thermal stress can be increased and contribute to a higher UTCI value. In contrast, the relatively lower UTCI was observed at Site F due to fewer human activities and better ventilation and spaces between buildings.

Overall, the findings highlight the need for more effective heat mitigation strategies and stronger adherence to occupational safety guidelines, particularly during peak heat hours. This is especially important for vulnerable groups, including outdoor workers and individuals from lower-income (B40) households, who may face both environmental and socioeconomic constraints in adapting to extreme heat conditions.

4.4 Factors Associated with Heat Stress Score

Inferential statistical analyses were conducted to examine the association between the heat stress score and heat-related factors among the study participants. Before the analysis, the data distribution was assessed and found to deviate from normality. Normality was evaluated using p-values, with values greater than 0.05 indicating a normal distribution and values less than 0.05 suggesting a deviation from normality. Table 4.1 presents the results of the normality test for the study variables among 85 respondents.

Table 4.9: Normality distribution of study variables among responses (n=85)

Variable (s)	Statistic	Skewness	Standard error	Z-value	*p*-value	Normality
BMI	23.04	0.50	0.41	0.97	0.75	Normal
Daily caffeine intake (ml)	232.35	0.58	21.25	0.82	< 0.01	Not normal
Daily water intake (ml)	1755.88	< 0.01	59.90	0.91	< 0.01	Not normal
Heat stress score	13.68	1.39	1.42	0.87	< 0.01	Not normal
Total adaptive score	19.40	0.56	0.57	0.98	0.1	Normal
Knowledge score	3.94	-0.28*	0.10	0.85	< 0.01	Not normal

Significant test = Shapiro-Wilk test
*. Significant at p > 0.05

From the table, BMI (p = 0.75) and total adaptive score (p = 0.10) showed p-values above the 0.05 threshold, indicating that these variables were normally distributed. This suggested that their data were symmetrically distributed and suitable for parametric statistical analyses. In contrast, daily caffeine and water intake, heat stress score, and knowledge score all had p-values less than 0.01, indicating statistically significant deviations from normality.

These findings suggested that the distributions of these variables were not symmetrical and may have been influenced by extreme values or skewed response patterns. Therefore, non-parametric statistical methods were used.

Specifically, the Kruskal–Wallis test was used to compare heat stress scores across variables with more than two independent groups, such as age categories (three groups) (McClenaghan, 2024). For variables with only two groups, such as gender, the Mann–Whitney U test was used to assess differences in heat stress scores between groups (McClenaghan, 2024). In addition, Spearman's rank-order correlation analysis was conducted to evaluate the strength and direction of the relationships between heat stress scores and continuous variables, such as daily caffeine and water intake (McClenaghan, 2024).

4.4.1 Heat Stress Score by Sociodemographic Characteristics

Table 4.10 presents the results of the Kruskal–Wallis test examining differences in heat stress scores across selected sociodemographic variables. Among the variables tested, age showed a statistically significant difference in heat stress scores ($x^2 = 10.38$, $df = 2$, $p = 0.006$). Participants aged 18–29 years recorded the highest mean rank (49.13), followed by those aged >50 years (36.13), while respondents aged 30–49 years had the lowest mean rank (30.36). This indicates that younger participants experienced higher levels of heat stress compared to other age groups.

In contrast, no statistically significant differences were observed for ethnicity ($p = 0.95$), education level ($p = 0.13$), BMI ($p = 0.12$), and monthly household income ($p = 0.23$). Although some variation in mean ranks was observed across these categories, the differences were not significant at the 0.05 level.

Table 4.10: Association between sociodemographic characteristics and heat stress scores (Kruskal–Wallis Test)

Variable	n	Mean Rank	df	x^2	p-value
Age					
18-29 years old	56	49.13	2	10.38	0.006*
30-49 years old	25	30.36			
> 50 years old	4	36.13			
Ethnicity					
Chinese	70	43.25	2	0.10	0.95
Malay	10	40.75			
Indian	5	44.00			
Education level					
Diploma/Certificate	8	23.13	2	4.02	0.13
Bachelor's degree	54	39.17			
Postgraduate	11	36.45			
BMI					
< 18.5	9	47.50	3	10.98	0.12
18.5 - 24.9	50	48.53			
25.0 - 29.9	21	33.95			
30.0 - 34.9	5	17.60			
Household monthly income					
B40 (< RM5249)	34	37.24	2	2.93	0.23
M40 (RM5250 - RM11819)	15	31.40			
T20 (> RM11820)	17	27.88			

Statistical test: Kruskal-Wallis Test

*. Significant at the 0.05 level (2-tailed)

**. Significant at the 0.001 level (2-tailed)

The findings of this study indicate that age is a significant factor influencing heat stress levels, with younger individuals (18–29 years) reporting higher heat stress scores compared to older age groups. This result may appear unexpected, as older adults are typically considered more physiologically vulnerable to heat stress due to reduced thermoregulatory capacity, lower cutaneous vasodilation, and lower thermoeffector (Erica *et a*l., 2022; Melaku *et al*., 2024;

Petersen *et al*., 2022). However, the present findings suggest that behavioral and exposure-related factors may play a more important role in determining heat stress in this population.

Previous studies show that younger individuals are more likely to engage in outdoor activities, commuting, and physically demanding tasks, particularly during peak heat hours (Faremi *et al*., 2025; Leiva and Church, 2023; Lim *et al.*, 2023). In addition, younger populations, especially students, may spend more time outdoors or in non-climate-controlled environments, thereby increasing their exposure to high thermal conditions, as reflected by the elevated UTCI values in this study (Leiva and Church, 2023). Hence, this group of individuals is more likely to experience heat stress symptoms such as thirst, dry mouth, and heavy sweating.

Furthermore, younger individuals may have greater awareness or sensitivity in reporting heat-related symptoms, which could contribute to higher reported heat stress scores. In contrast, individuals aged 30–49 years, who recorded the lowest mean rank, may have more stable occupational routines, often involving indoor or controlled environments, which reduce direct exposure to environmental heat.

The absence of significant associations between heat stress and ethnicity, education level, BMI, and household income suggests that, in this study, heat stress is primarily influenced by environmental exposure rather than sociodemographic differences. However, some studies have shown that BMI, education level, and household income are significantly associated with heat stress symptoms (Acharya *et al*., 2018; Cheng *et al*., 2019; Karthick *et al*., 2022; Muhamad *et al*., 2024; Torbat, 2024).

Overall, the significant association between age and heat stress highlights the importance of considering actual exposure patterns and daily activities, rather than relying solely on traditional assumptions of vulnerability. These findings also reinforce the role of high environmental heat exposure, particularly during peak heat hours, as a key contributor to heat stress. Therefore, preventive strategies should not be limited to older or clinically vulnerable populations but should also target younger individuals who may experience higher levels of exposure due to their lifestyle and occupational patterns.

Table 4.11 shows that a Mann–Whitney U test was conducted to determine whether there was a difference in heat stress scores between male and female participants. The results indicated that female participants (mean rank = 46.52) had higher heat stress scores compared to male participants (mean rank = 39.22). However, this difference was not statistically significant (U = 747.00, p = 0.17).

Table 4.11: Comparison of heat stress scores between sociodemographic characteristics (gender) using the Mann–Whitney U Test

	Group	**n**	**Mean Rank**	**Sum of Ranks**	**U**	**p-value**
Gender	Male	41	39.22	1608.00	747.00	0.17
	Female	44	46.52	2047.00		

Statistical test: Mann-Whitney U test
*. Significant at the 0.05 level (2-tailed)
**. Significant at the 0.001 level (2-tailed)

Although no significant association was observed between gender and heat stress symptoms in this study, previous research has reported significant associations between these variables (Karthick *et al*., 2022; Lim *et al*., 2023; Mutic *et al*., 2017).

4.4.2 Heat Stress Score by Occupational Information

Table 4.12 shows the association between occupational characteristics and heat stress scores among participants. The analysis revealed that current occupation and work schedule were significantly associated with heat stress levels.

A statistically significant difference was observed for current occupation (x^2 = 11.12, *df* = 2, *p* = 0.004). Among the groups, outdoor workers recorded the highest mean rank (67.83), followed by students (44.07) and indoor workers (38.32). This indicates that individuals engaged in outdoor occupations experienced significantly higher levels of heat stress compared to those working indoors or studying. Similarly, work schedule showed a significant association with heat stress (x^2 = 11.09, *df* = 4, *p* = 0.026). Participants with split shifts recorded the highest mean rank (73.50), followed by rotating shift workers (55.00) and regular day shift workers (46.26), while those with flexible schedules had the lowest mean rank (32.91).

In contrast, no statistically significant differences were observed for total outdoor exposure during peak hours (*p* = 0.628) and work-rest schedule (*p* = 0.93), despite some variation in mean ranks across categories.

Table 4.12: Association between occupational information and heat stress scores (Kruskal–Wallis Test)

Variable	n	Mean Rank	df	x^2	p-value
Current occupation					
Student	23	44.07	2	11.12	0.004*
Indoor	53	38.32			
Outdoor	9	67.83			
Work schedule					
Regular day shift	49	46.26	4	11.09	0.026*
Rotating shift	3	55.00			

Flexible schedule	29	32.91			
Split shift	3	73.50			
Night shift	1	48.50			
Total outdoor exposure (11 am – 4 pm)					
Less than 1 hour	49	44.90	3	1.74	0.628
1-2 hours	14	45.57			
3-4 hours	10	38.40			
More than 4 hours	12	36.08			
Work-rest schedule					
Not applicable	38	42.09	3	0.46	0.93
No rest breaks	1	48.50			
Short rest breaks	7	48.57			
Regular rest breaks	39	42.74			

Statistical test: Kruskal-Wallis Test
*. Significant at the 0.05 level (2-tailed)
**. Significant at the 0.001 level (2-tailed)

The findings indicate that occupational factors play a significant role in influencing heat stress levels, particularly current occupation and work schedule. The significantly higher heat stress scores observed among outdoor workers are consistent with existing literature, which identifies outdoor work as a major risk factor for heat exposure due to direct sunlight, high ambient temperatures, and limited environmental control (Mansor *et al*., 2019; Torbat, 2024; Vallennie, 2024; van Selm *et al*., 2025). Outdoor workers are more likely to be exposed to extreme thermal conditions, especially during peak heat hours, which increases their susceptibility to heat-related symptoms.

The significantly higher mean rank among participants working split shifts suggests that fragmented work schedules may contribute to increased heat stress. One possible explanation is that split shifts often require workers to be active during multiple periods of the day, including peak heat hours, thereby increasing cumulative heat exposure. Additionally, irregular work patterns may disrupt rest and recovery periods, reducing the body's ability to cope with thermal stress (Lim *et al*., 2023). Previous research has also shown that inadequate recovery time and prolonged exposure to heat can significantly alter physiological adjustments, leading to higher strain toward extreme environments (Mansor *et al*., 2019)

Interestingly, total outdoor exposure during peak hours was not significantly associated with heat stress (p = 0.628). This finding may suggest that the intensity and conditions of exposure, rather than duration alone, play a more critical role in determining heat stress levels. For example, factors such as solar radiation, humidity, and air movement may have a stronger influence on heat stress than exposure to time alone (Lim *et al*., 2023; Nurhartonosuro *et al*., 2023; Torbat, 2024).

Similarly, the lack of a significant relationship between work-rest schedule and heat stress may indicate that existing rest practices are either insufficient or not effectively implemented. Although rest breaks are commonly recommended as a preventive measure, their effectiveness depends on factors such as duration, frequency, and environmental conditions (Gibb *et al*., 2024; International Organization for Standardization, 2017; Taggart *et al*., 2023).

Overall, these findings highlight the importance of occupational exposure and work patterns in influencing heat stress. The significantly higher risk among outdoor workers and those with split shifts underscores the need for targeted interventions, such as adjusting work schedules to avoid peak heat hours, providing shaded rest areas, and ensuring adequate hydration. These measures are particularly critical in Malaysia’s hot and humid climate, where environmental conditions can exacerbate heat stress and increase the risk of heat-related illnesses.

4.4.3 Heat Stress Score by Lifestyle and Health Status

Table 4.13 shows the association between selected lifestyle and health factors and heat stress score. The results indicated that physical activity level was not significantly associated with heat stress score ($x^2 = 6.81$, $df = 2$, $p = 0.33$), although participants with moderate (mean rank = 54.05) and heavy activity levels (mean rank = 49.83) showed higher mean ranks compared to those with light activity (mean rank = 38.29).

In contrast, nighttime heat disruption was significantly associated with heat stress score ($x^2 = 13.235$, $df = 4$, $p = 0.010$). Participants who reported more frequent nighttime heat disruption tended to have higher mean ranks, with the highest observed among those reporting "often" (mean rank = 57.39), followed by "always" (mean rank = 50.17) and "sometimes" (mean rank = 49.72). Participants who reported "never" experiencing nighttime heat disruption had the lowest mean rank (24.50).

Table 4.13: Association between lifestyle and health and heat stress score (Kruskal–Wallis Test)

Variable	n	Mean Rank	df	x^2	p-value
Physical activity level					
Light	58	38.29	2	6.81	0.33
Moderate	21	54.05			
Heavy	6	49.83			
Nighttime heat disruption					
Never	8	24.50	4	13.235	0.010*
Rarely	31	35.53			
Sometimes	34	49.72			
Often	9	57.39			
Always	3	50.17			

Statistical test: Kruskal-Wallis Test
*. Significant at the 0.05 level (2-tailed)
**. Significant at the 0.001 level (2-tailed)

The findings of this study indicate that nighttime heat disruption plays a significant role in heat stress symptoms. Participants who experienced more frequent nighttime disturbances reported higher heat stress scores, suggesting that poor sleep conditions due to heat may contribute to overall physiological strain. Nighttime is an important period for the body to recover from daytime heat exposure, and disruption of this process may impair thermoregulation, affect brain functions, or even lead to cumulative heat stress effects (Lan et al., 2017; Okamoto-Mizuno and Mizuno, 2012). Frequent nighttime heat exposure can interfere with sleep quality by preventing adequate cooling of the body, resulting in discomfort, restlessness, and insufficient rest (Okamoto-Mizuno and Mizuno, 2012).

The findings indicate that physical activity level was not significantly associated with heat stress scores among participants. Although individuals with moderate and heavy physical activity had higher mean ranks than those with light activity levels, the differences were not statistically significant. One possible explanation is that participants engaging in higher levels of physical activity may have developed adaptive behaviors or physiological acclimatization, such as improved sweating efficiency, which helps mitigate heat stress (Fallahi *et al*., 2024; Xu *et al*., 2024). These adaptations may reduce the observable differences in heat stress scores between activity groups.

Overall, these findings suggest that sleep-related heat exposure is an important but often overlooked factor in heat stress, and improving nighttime thermal conditions may help reduce overall heat stress risk.

Table 4.14 presents the comparison of heat stress scores across selected lifestyle and health-related variables. The analysis showed that pre-existing condition was the only variable significantly associated with heat stress scores ($U = 226.50$, $p = 0.02$). Participants with pre-existing conditions recorded a significantly higher mean rank (59.41) compared to those without such conditions (40.56), indicating greater heat stress levels among individuals with underlying health issues.

In contrast, no significant differences were observed for alcohol intake ($p = 0.33$) and use of prescribed medications ($p = 0.11$), despite some variation in mean ranks between groups.

Table 4.14: Comparison of heat stress scores between lifestyle and health status using the Mann–Whitney U Test

	Group	n	Mean Rank	Sum of Ranks	U	p-value
Alcohol intake	Never	34	39.81	1353.50	758.50	0.33
	Drink	51	45.13	2301.50		
Pre-existing condition	No	74	40.56	3001.50	226.50	0.02*
	Yes	11	59.41	653.50		
Prescribed medicines	No	77	41.64	3206.00	203.00	0.11
	Yes	8	56.13	449.00		

Statistical test: Mann-Whitney U test
*. Significant at the 0.05 level (2-tailed)
**. Significant at the 0.001 level (2-tailed)

The findings indicate that pre-existing health conditions significantly increase susceptibility to heat stress, as evidenced by the higher heat stress scores among affected participants. This result is consistent with existing literature, which highlights that individuals with chronic conditions, such as cardiovascular, respiratory, or metabolic disorders, have impaired thermoregulatory capacity, making them more vulnerable to heat-related stress (Wan Usamah, 2024; Cramer *et al*., 2022; Slesinski *et al*., 2025).

Physiologically, individuals with pre-existing conditions may experience reduced efficiency of heat-dissipation mechanisms, such as sweating and blood circulation. For example, cardiovascular conditions can limit the body's ability to redistribute blood flow to the skin for cooling, while certain chronic illnesses may impair hydration balance (Wan Usamah, 2024; Cramer *et al*., 2022; Slesinski *et al*., 2025). As a result, these individuals are more likely to experience symptoms such as fatigue, dizziness, and rapid heartbeat under high thermal conditions.

The lack of significant association between alcohol intake and heat stress in this study suggests that alcohol consumption may not be a primary determinant of heat stress within this sample. Although alcohol is known to contribute to dehydration and impair thermoregulation, its effect may depend on frequency, quantity, and timing of consumption, which were not deeply explored in this study (Acharya *et al*., 2018; CDC, 2024).

Similarly, the non-significant findings regarding prescribed medication use may be due to heterogeneity in medications among participants. While certain medications, such as antihypertensives for cardiovascular medication and haloperidol for psychiatric medications, are known to increase heat sensitivity and impaired thermoregulation (CDC, 2024)

Table 4.15 presents the correlation analysis between heat stress score, daily caffeine intake, and daily water intake. The results indicate that there were no statistically significant correlations between heat stress score and the examined variables.

Specifically, the correlation between heat stress score and daily caffeine intake was weak and negative ($\rho = -0.048$, $p = 0.661$), while the correlation between heat stress score and daily water intake was also weak and negative ($\rho = -0.044$, $p = 0.689$). Both relationships were not statistically significant at the 0.05 level.

Table 4.15: Correlation between heat stress score, daily caffeine intake, and daily water intake using Spearman's Rank Correlation

	Heat stress score	**Daily caffeine intake**	**Daily water intake**
Heat stress score	1.000		
***p*-value**	-		
Daily caffeine intake	-0.048	1.000	
***p*-value**	0.661	-	
Daily water intake	-0.044	0.170	1.000
***p*-value**	0.689	0.120	-

Statistical test: Spearman's rho

*. Correlation is significant at the 0.05 level (2-tailed)

**. Correlation is significant at the 0.01 level (2-tailed)

The findings indicate that daily caffeine intake and daily water intake were not significantly associated with heat stress scores among participants. Although both variables showed weak negative correlations with heat stress, the relationships were negligible and not statistically significant, suggesting that these factors did not have a measurable influence on heat stress levels in this study.

The weak negative relationship between water intake and heat stress may suggest that increased hydration could potentially reduce heat stress. However, the findings suggest that while staying hydrated is important, water intake alone may not be sufficient to mitigate heat stress under extreme environmental exposure (Habib *et al*., 2021). Other factors, such as duration of exposure, work intensity, and availability of cooling measures, may have a greater impact on heat stress.

Similarly, the absence of a significant relationship between caffeine intake and heat stress suggests that caffeine consumption may not substantially affect thermoregulation under the conditions studied. Although caffeine is often associated with mild diuretic effects, previous research has shown that moderate caffeine intake does not significantly impair hydration status or increase heat stress risk in habitual consumers (Mansor *et al*., 2019; Torbat, 2024).

4.4.4 Heat Stress Score by Heat Exposure Information

Table 4.16 shows the association between heat exposure information and heat stress score. The analysis showed that indoor exposure without air conditioning (AC) was significantly associated with heat stress scores ($x^2 = 8.18$, $df = 3$, $p = 0.04$). Participants who spent more than 5 hours indoors without AC had the highest mean rank (53.50), indicating greater heat stress compared to other exposure durations.

In addition, use of personal protective equipment (PPE) was significantly associated with heat stress scores ($x^2 = 12.47$, $df = 3$, $p = 0.006$). Participants who rarely used PPE (mean rank = 60.67) and those who always used PPE (mean rank = 57.15) reported higher heat stress scores compared to those who never used PPE.

No statistically significant differences in heat stress scores were observed for direct sun exposure, time spent outdoors in shade, indoor exposure with air conditioning, or clothing type ($p > 0.05$).

Table 4.16: Association between heat exposure information and heat stress score (Kruskal–Wallis Test)

Variable	n	Mean Rank	df	x^2	p-value
Direct sun exposure (11 am – 4 pm)					
Less than 1 hour	75	41.53	2	3.75	0.153
1-2 hours	9	57.17			
3-4 hours	1	25.50			
Outdoor in shade (11 am – 4 pm)					
Less than 1 hour	46	39.71	3	5.08	0.17
1-2 hours	29	44.90			
3-4 hours	7	60.79			
More than 5 hours	3	33.67			
Indoor without AC (11 am – 4 pm)					
Less than 1 hour	32	34.94	3	8.18	0.04*
1-2 hours	21	48.24			
3-4 hours	13	39.04			
More than 5 hours	19	53.50			
Indoor with AC (11 am – 4 pm)					
Less than 1 hour	12	50.04	3	1.50	0.68
1-2 hours	7	46.07			
3-4 hours	20	43.03			
More than 5 hours	46	40.68			
Clothing type					
Short	34	45.81	2	0.85	0.66
Short and Long	37	40.43			
Long	14	42.96			
Personal protective equipment (PPE)					
Never	50	35.49	3	12.47	0.006*
Rarely	6	60.67			
Sometimes	19	49.74			
Always	10	57.15			

Statistical test: Kruskal-Wallis Test

*. Significant at the 0.05 level (2-tailed)

**. Significant at the 0.001 level (2-tailed)

The findings of this study highlight that indoor heat exposure without air conditioning is a significant contributor to heat stress symptoms. Participants who spent prolonged periods indoors without AC reported higher heat stress scores, suggesting that indoor environments can become thermally stressful when ventilation and cooling are inadequate or when radiant temperature is high (Melaku *et al*., 2024). This is consistent with previous studies indicating that indoor heat exposure, particularly in poorly ventilated environments, can significantly contribute to heat-related health risks (Habib *et al*., 2021; Vallennie, 2024).

The significant association between PPE usage and heat stress further supports the role of external barriers in impairing heat dissipation. PPE can restrict airflow and reduce the body's ability to lose heat through evaporation and convection, leading to increased thermal burden (Davey *et al*., 2021; Zhu *et al*., 2023).

In contrast, factors such as direct sun exposure and clothing type were not significantly associated with heat stress in this study. The lack of significant associations between heat stress scores and factors such as direct sun exposure, time spent outdoors in shade, and indoor exposure with air conditioning may be attributed to behavioral adaptations and relatively uniform environmental exposure among participants. Individuals may actively limit direct sun exposure by seeking shade or reducing time outdoors during peak heat hours, thereby minimizing its impact on heat stress (Gibb *et al*., 2024; Taggart *et al*., 2023; van Selm *et al*., 2025). Similarly, access to air conditioning can help to reduce body temperature during extreme weather and prevent heat stress symptoms. Furthermore, appropriate clothing characteristics, particularly lightweight and breathable fabrics, have been reported to improve thermoregulation and reduce heat stress (Faremi *et al*., 2025).

Table 4.17 shows that a Mann–Whitney U test was conducted to compare heat stress scores across selected lifestyle and health-related factors. The results showed that there were no statistically significant differences in heat stress scores based on shade accessibility (U = 30.50, p = 0.21), drinking water accessibility (U = 4.00, p = 0.12), and clothing colour (U = 734.50, p = 0.14).

Table 4.17: Comparison of heat stress scores between heat exposure information using the Mann–Whitney U Test

	Group	n	Mean Rank	Sum of Ranks	U	p-value
Shade accessibility	No	3	12.17	36.50	30.50	0.21
	Yes	82	44.13	3618.50		
Drinking water accessibility	No	1	81.00	81.00	4.00	0.12
	Yes	84	42.55	3574.00		
Clothing colour	Light	40	38.86	1554.50	734.50	0.14
	Dark	45	46.68	2100.50		

Statistical test: Mann-Whitney U test
*. Significant at the 0.05 level (2-tailed)
**. Significant at the 0.001 level (2-tailed)

The absence of significant differences in heat stress scores across these variables may be explained by shared environmental conditions and adaptive behaviors among participants in Kampar, Perak. For instance, although shade accessibility was not significantly associated with heat stress, individuals may compensate by limiting outdoor exposure or seeking alternative cooling strategies, thereby reducing its measurable effect. Previous studies, however, have shown that access to shaded environments can significantly reduce heat exposure and thermal strain (Gibb *et al*., 2024; Lim *et al*., 2023).

Similarly, drinking water accessibility was not significantly associated with heat stress in this study, possibly because most participants had generally adequate access to water, resulting in limited variability between groups. Nonetheless, adequate hydration has been widely recognized as a key factor in reducing heat stress and maintaining thermoregulation (Bhati and Sheth, 2026; Gibb *et al*., 2024; Taggart *et al*., 2023).

Clothing colour also did not show a significant association, which may be due to the influence of other clothing characteristics such as material, thickness, and ventilation, which were not fully captured in this study. While darker clothing is often associated with greater heat absorption, previous research suggests that fabric properties and airflow may play a more important role in heat dissipation (Zlatar *et al*., 2021).

4.4.5 Heat Stress Score by Adaptive Practices

Table 4.18 shows the results of Spearman's rank-order correlation between the relationships between heat stress score, adaptive score, and knowledge score. The analysis revealed a moderate positive correlation between heat stress score and adaptive score (ρ = 0.445, $p < 0.001$), indicating a statistically significant relationship.

However, there was no significant correlation between heat stress score and knowledge score ($\rho = -0.068$, $p = 0.534$). Similarly, no significant relationship was found between adaptive score and knowledge score ($\rho = -0.046$, $p = 0.673$).

Table 4.18: Correlation between heat stress score, adaptive score, and knowledge scores using Spearman's Rank Correlation

	Heat stress score	Adaptive score	Knowledge score
Heat stress score	1.000		
***p*-value**	-		
Adaptive score	0.445	1.000	
***p*-value**	0.000	-	
Knowledge score	-0.068	-0.046	1.000

***p*-value**	0.534	0.673	-

Statistical test: Spearman's rho
*. Correlation is significant at the 0.05 level (2-tailed)
**. Correlation is significant at the 0.01 level (2-tailed)

The findings demonstrated a significant, moderate positive relationship between heat stress scores and adaptive scores, suggesting that individuals who experienced higher levels of heat stress symptoms also tended to engage in more adaptive behaviours. This pattern likely reflects a reactive adaptation mechanism, whereby individuals respond to discomfort or symptoms by adopting cooling strategies such as increasing fluid intake, seeking shade, or modifying daily activities. This observation is consistent with previous research, which indicates that direct personal experience of heat stress can act as a key driver of behavioural adaptation (Xu *et al*., 2024).

In contrast, the knowledge score was not significantly associated with the heat stress score, indicating that knowing heat stress does not necessarily translate into reduced symptoms. Individuals may be aware of heat-related risks but may not consistently apply preventive measures due to environmental constraints, habits, or lack of resources. Similar findings have been reported in a previous study, where knowledge did not have an association with protective behavior (Ahmad *et al*., 2021). The observation that high knowledge does not necessarily mitigate heat stress is further supported by Sharif *et al*. (2021), who found that even though 95% of outdoor workers in Melaka possessed 'good' knowledge of heat-related illnesses, a vast majority (71.7%) still reported significant symptoms.

Additionally, the absence of a significant relationship between knowledge score and adaptive score suggests that knowledge does not directly influence adaptive practices in this population. This aligns with findings by Ahmad *et al*. (2021), who observed that high knowledge levels among Malaysian workers did not translate into safer practices. Abidin *et al*. (2022) and Sharif *et al*. (2021) claimed that while individuals may possess a theoretical understanding of heat risks, their actual adaptive behaviors are more heavily influenced by personal experiences, attitude, and external environmental constraints.

4.5 Multiple Linear Regression Analysis of Factors Associated with Heat Stress Symptoms

To address the fourth objective of this study, which was to determine the relationship between heat stress factors and heat stress symptoms, a multiple linear regression analysis was conducted. This analysis allows for the simultaneous examination of multiple independent variables to identify the contributions to the prediction of heat stress scores. Considering that heat stress is influenced by a combination of environmental, behavioural, and individual factors, this method provides a more comprehensive understanding of the key determinants of heat stress symptoms among the study population.

4.5.1 Model summary of multiple linear regression predicting heat stress score

A multiple linear regression analysis was conducted to examine the factors associated with the heat stress score. The model included sociodemographic variables (age, gender, ethnicity, BMI, household income), occupational factors (current occupation, work schedule, outdoor exposure, work-rest schedule), lifestyle factors (alcohol intake, caffeine intake, water intake, physical activity, nighttime heat disruption), health-related variables (pre-existing conditions, prescribed medications), environmental exposure variables (direct sun exposure, indoor/outdoor conditions, accessibility to shade and drinking water), and composite scores (adaptive score, knowledge score, and heatwave awareness). The model summary indicated that the independent variables explained 58.8% of the variance in heat stress score ($R^2 = 0.588$). After adjusting for the number of predictors, the adjusted R^2 was 0.506, indicating that approximately 50.6% of the variance in heat stress score was accounted for by the model. The standard error of the estimate was 9.221, suggesting a moderate level of variation between the observed and predicted heat stress scores.

Table 4.19: Model summary of multiple linear regression predicting heat stress score

R	**R^2**	**Adjusted R^2**	**Standard Error of the Estimate**
0.767	0.588	0.506	9.221

Dependent variable: Heat Stress Score
Statistical test: Multiple Linear Regression
R^2 = coefficient of determination; Adjusted R^2 = adjusted for number of predictors.

Based on the R^2 value in the model summary table, the model provides moderate explanatory power for predicting heat stress symptoms among the study population (Hair *et al*., 2011). The relatively high R value suggests that, collectively, the selected variables have a meaningful relationship with the heat stress score. According to Frost (no date), a low or moderate R^2 and adjusted R^2 can also indicate a good model, especially in studies of human behavior or the health sciences, where variables are more variable and difficult to measure comprehensively. Additionally, self-reported data may introduce variability due to subjective perception and reporting differences. Although the R^2 value indicates that more than half of the variability in heat stress scores can be explained by the model, the noticeable reduction in the adjusted R^2 suggests that some variables may have limited individual contribution when considered alongside others (Hair *et al*., 2019). This may be due to overlapping effects between variables or the inclusion of predictors that are not strongly associated with heat stress.

The standard error of the estimate indicates that some variability in heat stress scores remains unexplained, which is expected given the complex and multifactorial nature of heat stress. Factors such as microclimate variations, individual physiological differences, and real-time exposure conditions may further influence heat stress but were not fully captured in the model.

4.5.2 ANOVA Test of Regression Model

The ANOVA results indicated that the overall regression model was statistically significant, $F = 7.148$, $p < 0.001$, indicating that the set of independent variables collectively contributed to the prediction of heat stress score.

Table 4.20: ANOVA for multiple linear regression model predicting heat stress score

	F	p-value
Regression	7.148	< 0.001

Dependent variable: Heat Stress Score
Statistical test: Multiple Linear Regression

The findings of this study, particularly the R^2 of 0.588 and an adjusted R^2 of 0.506, carry significant weight when viewed through the lens of environmental health and human behavioural sciences. It is important to distinguish these results from the "hard" sciences like physics, which often demand R^2 values exceeding 0.90 to be considered valid; studies involving human participants and biological responses typically yield lower values due to the inherent complexity of human systems (Frost, no date).

By applying the benchmarks set by Muijs (2010), an adjusted R^2 above 0.50 classifies this model as having a strong-to-moderate level of explanatory power. This suggests that more than half of the variability in how residents of Kampar experience heat stress can be accounted for by the factors measured in this study. While there is a remaining 49.4% variance that the model does not capture, this is to be expected. This "unexplained" portion likely stems from highly individualized factors, such as specific genetic heat tolerances, the varying quality of housing insulation, or even personal dietary habits, which will influence thermoregulation.

Furthermore, the statistical significance of the model ($p < 0.001$) confirms that the heat stress observed in Kampar is far from a random occurrence. Instead, it is systematically linked to the determinants identified here. The fact that the Adjusted R^2 remained robust at 0.506, even after accounting for the number of variables, confirms that the selected predictors, like BMI and water accessibility, are not just statistically significant but are practically meaningful. For public health officials in Perak, these results offer a clear roadmap: by implementing interventions that target these specific determinants, there is a theoretical potential to reduce the local heat-related health burden by more than 50%.

4.5.3 Regression Coefficients

Multiple linear regression analysis was performed to identify factors associated with the heat stress score. Several variables were found to be statistically significant predictors of heat stress. Age was significantly associated with heat stress score ($B = -5.703$, $\beta = -0.252$, $p = 0.019$), indicating that older participants tended to report lower heat stress scores. Body mass index (BMI) also showed a significant negative association ($B = -0.779$, $\beta = -0.224$, $p = 0.017$). In contrast, current occupation status ($B = 5.363$, $\beta = 0.243$, $p = 0.012$) and physical activity level ($B = 4.626$, $\beta = 0.218$, $p = 0.024$) were positively associated with heat stress score, suggesting that individuals who were actively working and more physically active experienced higher levels of heat stress. Nighttime heat disruption emerged as a strong predictor ($B = 4.273$, $\beta = 0.301$, $p = 0.001$), with higher levels of disruption associated with increased heat stress scores. Similarly, the total adaptive score ($B = 0.554$, $\beta = 0.223$, $p = 0.011$) was significantly associated with higher heat stress scores. Drinking water accessibility showed a significant negative association ($B = -37.037$, $\beta = -0.306$, $p = 0.001$), indicating that better access to drinking water was linked to lower heat stress scores.

Other variables, including gender, ethnicity, education level, pre-existing conditions, direct sun exposure, indoor exposure without air conditioning, and knowledge score, were not significantly associated with heat stress score ($p > 0.05$). Additionally, all Variance Inflation Factors (VIF) values were below 5, indicating acceptable levels of multicollinearity.

Table 4.21: Multiple linear regression coefficient for factors associated with heat stress score (n = 85)

Variables	Unstandardized Coefficients		Standardized Coefficient	*t* - value	*p* - value	Collinearity Statistics
	B	Standard Error	Beta (β)			VIF
(Constant)	32.875	14.663		2.242	0.028	
Age	-5.703	2.377	-0.252	-2.399	0.019	1.874
Gender	3.554	2.223	0.136	1.599	0.114	1.233
Ethnicity	2.431	1.977	0.102	1.229	0.223	1.163
Education Level	1.493	1.261	0.098	1.185	0.240	1.155
BMI	-0.779	0.318	-0.224	-2.453	0.017	1.422
Current Occupation Status	5.363	2.067	0.243	2.594	0.012	1.492
Physical activity level	4.626	2.011	0.218	2.301	0.024	1.530
Pre-existing conditions diagnosed	1.657	3.610	0.043	0.459	0.648	1.468
Nighttime heat disruption	4.273	1.176	0.301	3.632	0.001	1.171
Direct sun exposure between 11.00 a.m. – 4.00 p.m.	-1.077	3.324	-0.030	-0.324	0.747	1.504
Indoor without AC between 11.00 a.m. – 4.00 p.m.	1.607	0.957	0.144	1.679	0.098	1.257
Drinking water accessibility	-37.037	10.522	-0.306	-3.520	0.001	1.287
Total Adaptive score	0.554	0.213	0.223	2.602	0.011	1.248
Total Knowledge score	-0.044	1.222	-0.003	-0.036	0.971	1.207

Dependent variable: Heat Stress Score

Statistical test: Multiple Linear Regression

*. Significant at the 0.05 level (2-tailed)

**. Significant at the 0.01 level (2-tailed)

The regression findings highlight that heat stress is influenced by a combination of physiological, occupational, and environmental factors, with several key predictors emerging as significant. Age was significantly associated with heat stress ($p = 0.019$), with a negative relationship indicating that younger participants reported higher heat stress scores compared to older individuals. While this finding differs from many established studies, which commonly report greater vulnerability among older adults due to reduced thermoregulatory capacity and higher prevalence of comorbidities (Erica *et a*l., 2022; Melaku *et al*., 2024), the pattern observed in Kampar may reflect contextual lifestyle and occupational differences. Younger individuals in this setting are more likely to engage in outdoor work, commute during peak heat hours, or perform physically demanding activities, thereby increasing their exposure to ambient heat conditions typical of Malaysia's hot and humid climate (Faremi *et al*., 2025; Leiva and Church, 2023).

The negative association observed with BMI may reflect variations in individual perceptions, symptom reporting, or physiological responses to heat. Despite the conventional view that higher BMI promotes heat retention via insulation, it may also offer a protective mechanism by acting as a reservoir for electrolytes and fluids. This capacity helps maintain hydration status and supports systemic cooling during periods of intense heat exposure (Muhamad *et al*., 2024a).

The positive association between current occupation and heat stress reinforces earlier findings in this study, where outdoor workers exhibited higher heat stress levels (Habibi *et al*., 2024; Ioannou *et al*., 2022; Kjellstrom *et al*., 2024; Taggart *et al*., 2023; van Selm *et al.,* 2025). This suggests that occupational exposure, particularly in outdoor environments during peak heat hours, plays a critical role in determining heat stress due to direct exposure to high temperatures, solar radiation, and limited environmental control.

The significant negative relationship between drinking water accessibility and heat stress emphasizes the importance of hydration in mitigating thermal strain. Access to drinking water enables individuals to maintain fluid balance and support effective thermoregulation through sweating. (Fazirah Samah *et al*., 2025; Gibb *et al*., 2024; Habibi *et al*., 2024; Nurhartonosuro *et al*., 2023) This finding indicates that improving access to hydration facilities may be a practical and effective intervention to reduce heat-related health risks, particularly in high-exposure settings.

Interestingly, the adaptive score was positively associated with heat stress, suggesting that individuals experiencing higher levels of heat stress are more likely to adopt adaptive behaviors (Abidin *et al*., 2022). This reflects a reactive pattern in which individuals respond to visceral discomfort rather than engaging in proactive preventive measures (Aerts *et al*., 2024). It implies that although adaptive behaviors are present, they may not be sufficient to offset the intensity of environmental heat exposure (Ahmad *et al*., 2024). This 'adaptation gap' is particularly evident under conditions of very strong heat stress that exceed the body's capacity for behavioral mitigation (Kjellstrom *et al*., 2024; Sharif *et al*., 2021).

Overall, the results indicate that environmental exposure and access to resources like water are more influential determinants of heat stress than individual lifestyle factors. These findings underscore the need for targeted interventions that focus on occupational settings, improve access to hydration, and promote proactive, rather than reactive, adaptive strategies to effectively reduce heat stress risks in hot and humid environments such as Malaysia.

4.6 Multiple Linear Regression Model for Predicting Heat Stress Score

The final multiple linear regression model was developed to predict heat stress score based on the selected sociodemographic, occupational, lifestyle, environmental, and health-related variables. The model incorporates all independent variables included in the analysis and expresses their combined effect on the dependent variable, heat stress score

(SuperDataScience Team, 2018). Variables with a p-value less than 0.05 were retained in the final model. These included age, body mass index (BMI), current occupation status, physical activity level, nighttime heat disruption, drinking water accessibility, and total adaptive score. The general form of the multiple linear regression equation is presented as follows:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + \dots + b_nX_n$$

where

Y = Heat stress score

a = Constant

b = Regression coefficient

X = Independent variables

The constant value (32.875) represents the estimated heat stress score when all independent variables are held constant. Age demonstrated a significant negative association with heat stress score ($p = 0.019$), indicating that younger participants tended to report higher levels of heat stress compared to older adults. This may be because the majority of respondents were young adults and students who were more frequently exposed to outdoor heat during peak hours, such as walking to and from campus or going out for lunch at cafeterias (Faremi et al., 2025; Leiva and Church, 2023). In contrast, older adults generally have more stable daily routines and may experience lower heat exposure due to spending more time indoors and preparing meals at home.

Similarly, BMI showed a significant negative relationship with heat stress score ($p = 0.017$), indicating that participants with higher BMI tended to report slightly lower levels of heat stress. Although this finding may appear counterintuitive, it may be influenced by both biological and behavioural factors. From a biological perspective, individuals with higher BMI may have greater body mass and fluid reserves, which could temporarily buffer short-term thermal strain and reduce the immediate perception of heat-related discomfort (Biswas, 2025; Shaw *et al*., 2022). In addition, differences in metabolic adaptation, heat perception, and individual thermoregulatory responses may influence how heat stress symptoms are experienced and reported. Adipose tissue may also alter heat storage and heat dissipation patterns, potentially affecting the body's sensitivity and physiological response to environmental heat exposure (Shaw *et al*., 2022). Behaviourally, participants with higher BMI may also engage in less outdoor physical activity and spend more time indoors, resulting in lower direct heat exposure during peak hours.

Current occupation status was positively associated with heat stress score (p = 0.012), indicating that individuals engaged in occupations with higher environmental exposure, particularly outdoor or labor-intensive work, are more likely to experience increased heat stress. Physical activity level also showed a positive and significant relationship (p = 0.024). This suggests that individuals with higher activity levels are more exposed to heat or generate more metabolic heat, thereby increasing their heat stress score.

Nighttime heat disruption emerged as one of the strongest predictors ($p = 0.001$), with a positive association. This indicates that individuals experiencing sleep disturbances due to heat are more likely to report higher overall heat stress, highlighting the cumulative impact of thermal discomfort.

Drinking water accessibility demonstrated a strong negative association ($p = 0.001$), indicating that better access to water significantly reduces heat stress. This reinforces the importance of hydration in maintaining thermal balance and preventing heat-related strain.

Lastly, the total adaptive score was positively associated with the heat stress score ($p = 0.011$). This suggests that individuals experiencing greater heat stress are more likely to adopt adaptive behaviors, reflecting a reactive rather than preventive adaptation pattern.

Overall, the model highlights that heat stress is influenced by a combination of demographic factors, occupational exposure, lifestyle behaviors, environmental conditions, and access to hydration. Among these, nighttime heat disruption and water accessibility appear to play particularly critical roles in determining heat stress levels.

$$\text{Heat Stress Score} = 32.875 - 5.703\,(\text{Age}) - 0.779\,(\text{BMI}) + 5.363\,(\text{Current Occupation Status}) + 4.626\,(\text{Physical Activity Level}) + 4.273\,(\text{Nighttime Heat Disruption}) - 37.037\,(\text{Drinking Water Accessibility}) + 0.554\,(\text{Total Adaptive Score})$$

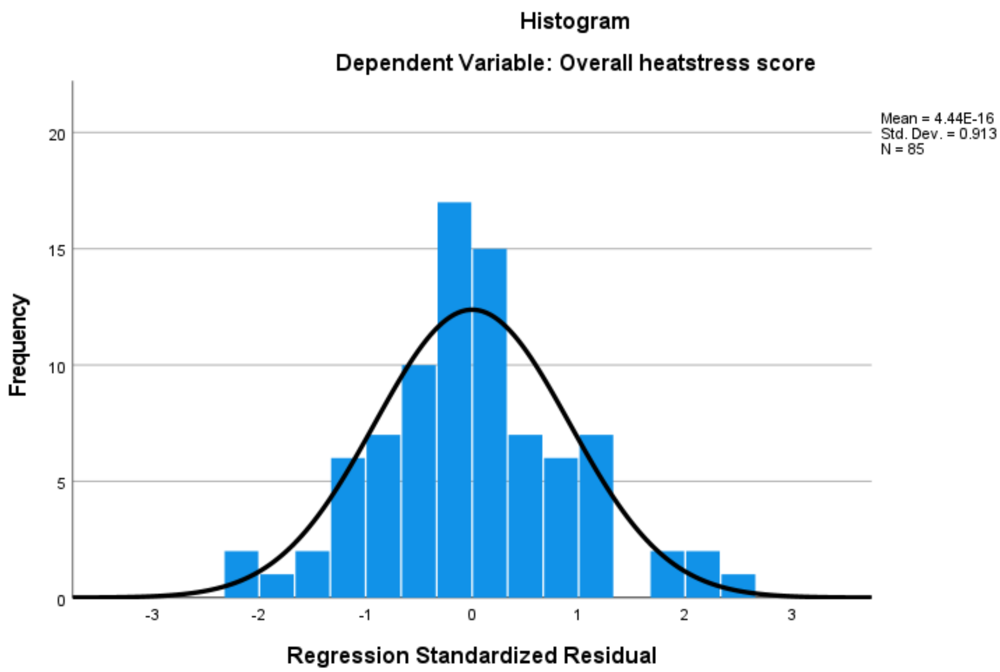

Figure 4.2: Histogram of Regression Standardized Residuals for Heat Stress Score

The histogram of regression standardized residuals shows an approximately bell-shaped distribution, with most values centered around zero. According to Domo (no date), this pattern suggests that the residuals are approximately normally distributed, indicating that the normality assumption of the multiple linear regression model is reasonably met. Although slight deviations may be present, they are not substantial enough to affect the validity of the model.

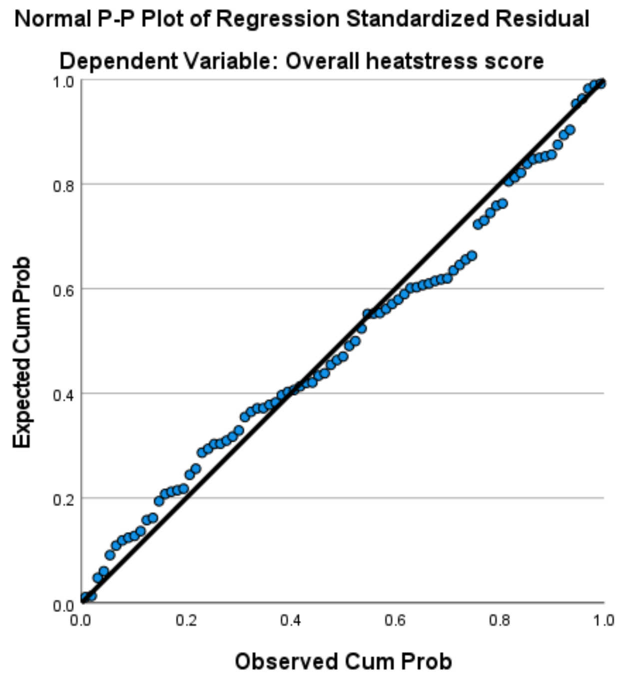

Figure 4.3: Normal P-P Plot of Regression Standardized Residuals for Heat Stress Score

The Normal P–P plot shows that the data points generally follow the diagonal reference line, with only minor deviations observed (Matsaany *et al*., 2016). The close alignment of points along the diagonal line indicates that the residuals are approximately normally distributed (Matsaany *et al*., 2016). This further supports the assumption of normality in the regression model, suggesting that the model's estimates are reliable.

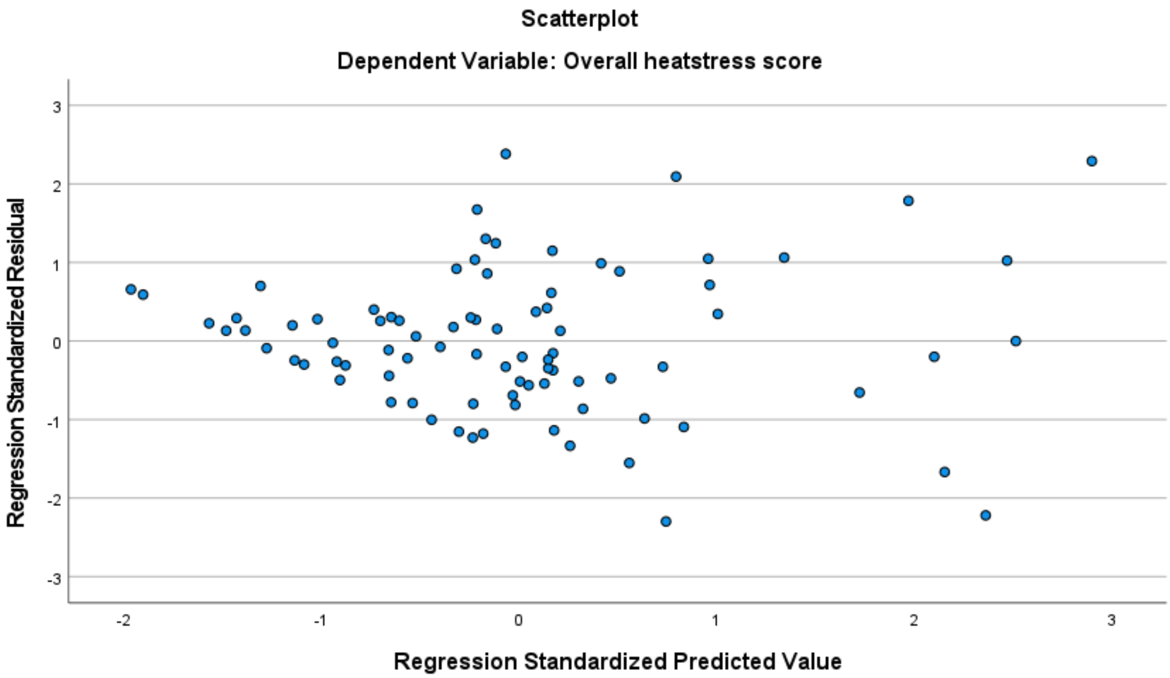

Figure 4.4: Scatterplot of Regression Standardized Residuals versus Predicted Values Heat Stress Score

The scatterplot of standardized residuals versus predicted values shows a random distribution of points with no clear pattern. The random spread of residuals indicates that the assumptions of linearity and homoscedasticity are satisfied (Statistics Solutions, 2025). This suggests that the variance of the residuals is constant across levels of the predicted values, and that the model does not suffer from heteroscedasticity. Therefore, the regression model is considered appropriate for the data.

Overall, the diagnostic plots indicate that the assumptions of normality, linearity, and homoscedasticity were adequately met, supporting the validity of the multiple linear regression analysis.

CHAPTER 5

CONCLUSION

5.1 Conclusion

This study successfully achieved its objectives by examining the level of heat exposure, prevalence of heat stress symptoms, and factors associated with heat stress among adults in Kampar, Perak. The findings provide comprehensive insights into the multifactorial nature of heat stress within a tropical, semi-urban environment.

The assessment of environmental heat exposure using WBGT-derived parameters and the Universal Thermal Climate Index (UTCI) indicated that participants were consistently exposed to very strong heat stress conditions during peak heat hours, with a mean UTCI value of 40.89°C. This confirms that the study area experiences substantial thermal burden, driven by high ambient temperatures, intense solar radiation, elevated humidity, and limited air movement. Such environmental conditions create a high-risk setting for heat-related health effects.

In line with these findings, a high prevalence of self-reported heat stress symptoms was observed. Common symptoms, including thirst, headache, fatigue, and hot, dry skin, reflect significant physiological strain among participants. Although severe symptoms were less frequently reported, their occurrence underscores the potential risk of more serious heat-related illnesses under prolonged or repeated exposure.

Despite widespread exposure and symptom experience, participants demonstrated relatively high levels of adaptive practices, suggesting active engagement in coping strategies such as increased fluid intake and behavioral adjustments. However, the positive association between adaptive score and heat stress indicates that these strategies are largely reactive, adopted in response to discomfort rather than implemented as preventive measures. Additionally, knowledge of heat stress was moderate and not significantly associated with heat stress outcomes, implying that awareness alone may not translate into effective risk reduction.

The multiple linear regression analysis identified several key determinants of heat stress. Age and BMI were negatively associated with heat stress, suggesting that older individuals and those with higher BMI reported lower heat stress levels, potentially due to differences in perception, adaptation, or exposure patterns. In contrast, current occupation status and physical activity level were positively associated with heat stress, indicating that individuals engaged in outdoor or physically demanding activities are at greater risk due to increased environmental and metabolic heat exposure. Nighttime heat disruption emerged as a strong predictor, highlighting the cumulative impact of inadequate thermal recovery during sleep on overall heat stress. Drinking water accessibility demonstrated a significant protective effect, reinforcing the critical role of hydration in mitigating heat strain. Meanwhile, the positive association with adaptive score further supports the presence of reactive coping mechanisms.

Overall, the findings demonstrate that heat stress in Kampar is influenced by a complex interplay of environmental exposure, occupational demands, behavioral responses, and individual characteristics. Notably, the persistence of heat stress despite adaptive efforts points to an adaptation gap, where existing coping strategies are insufficient to offset the intensity of environmental heat and its cumulative effects, particularly those related to disrupted nighttime recovery.

In conclusion, this study highlights the urgent need for comprehensive and proactive heat mitigation strategies in hot and humid settings such as Malaysia. Interventions should prioritize improving access to drinking water, strengthening occupational health protections, especially for outdoor and physically active individuals, and addressing nighttime thermal conditions to support adequate recovery. Additionally, there is a need to shift from reactive to preventive adaptation approaches through targeted education and environmental modifications. These measures are essential to reduce heat-related health risks and enhance community resilience in the face of increasing temperatures associated with climate change.

5.2 Study Strengths and Limitations

5.2.1 Strengths

This study has several notable strengths that enhance the validity and relevance of its findings. First, the study adopted a comprehensive and multidimensional approach by integrating environmental measurements (WBGT parameters and UTCI), self-reported heat stress symptoms, and behavioral as well as sociodemographic factors. This allowed for a more holistic understanding of heat stress, capturing both objective exposure and subjective health outcomes.

Second, the use of the Universal Thermal Climate Index (UTCI) provides a robust and internationally recognized indicator of thermal stress. By incorporating multiple environmental parameters such as ambient temperature, radiant temperature, humidity, and air velocity, the UTCI offers a more accurate representation of real-world heat exposure compared to single-parameter measures.

Third, the study employed multiple statistical analyses, including non-parametric tests and multiple linear regression, to identify significant associations and predictors of heat stress. This strengthens the analytical rigor and allows for better control of potential confounding variables.

Additionally, the inclusion of adaptive behavior and knowledge variables adds value to the study by highlighting the role of human responses to heat exposure, which is often overlooked in purely environmental or physiological studies.

5.2.2 Limitations

Despite its strengths, this study has several limitations that should be considered when interpreting the findings. First, the study utilized a cross-sectional design, which limits the ability to establish causal relationships between variables. While associations can be identified, it is not possible to determine the directionality of these relationships.

Second, the reliance on self-reported data for heat stress symptoms, water intake, and behavioral practices may introduce recall bias and subjective interpretation. Participants may overestimate or underestimate their experiences, which could affect the accuracy of the findings.

Third, the study was conducted in a specific geographical location (Kampar, Perak) with a relatively small sample size (n = 85), which is suitable only for regions with similar environmental or sociodemographic characteristics.

Furthermore, although environmental conditions were assessed using standardized indices, the measurements were taken during specific time periods (peak heat hours) and may not reflect variations throughout the day.

Lastly, the regression model showed a noticeable difference between R^2 and adjusted R^2, suggesting that some variables included in the model may have limited explanatory power, and there is a possibility of overfitting.

5.3 Recommendations

5.3.1 Recommendations for Future Study

Based on the findings and limitations of this study, several recommendations are proposed to guide future research on heat stress and its associated factors. First, future studies should consider adopting a longitudinal study design to better understand the causal relationships between heat exposure and health outcomes. Unlike cross-sectional studies, longitudinal research would allow for the assessment of changes in heat stress levels over time and provide stronger evidence on the directionality of associations.

Second, it is recommended that future research include a larger and more diverse sample size, covering multiple geographical locations. Expanding the study beyond Kampar, Perak would improve the generalizability of findings and allow for comparisons across different climatic, occupational, and socio-economic settings.

Third, future studies should incorporate more detailed and continuous environmental monitoring, including variations across different times of the day. This would provide a more comprehensive understanding of heat exposure patterns and their impact on human health, especially in tropical climates where conditions can fluctuate significantly.

In addition, there is a need to improve the measurement of behavioral and lifestyle variables. Future research should use more precise methods to assess hydration status, physical activity, and adaptive practices, such as objective measurements or real-time monitoring, rather than relying solely on self-reported data. This would enhance the accuracy and reliability of the findings.

Lastly, given the increasing impact of climate change, future research should examine the long-term implications of rising temperatures on human health and productivity, particularly in developing countries. Integrating climate projections with health data would provide valuable insights for policy planning and heat risk management.

5.3.2 Recommendation for Heat Stress Risk Reduction

At the community level, increasing awareness and adoption of preventive behaviors is essential. Individuals should be encouraged to maintain adequate hydration by drinking sufficient water throughout the day, even in the absence of thirst, as dehydration can exacerbate heat stress. In addition, wearing appropriate clothing, such as lightweight, loose-fitting, and breathable fabrics, can facilitate heat dissipation and improve thermal comfort. Furthermore, individuals should aim to avoid prolonged exposure to high temperatures, particularly during peak heat hours (typically midday to early afternoon). When outdoor activities are unavoidable, seeking shaded areas and taking regular breaks can help reduce heat strain. Public health campaigns and community education programs may play an important role in promoting these protective behaviors.

At the workplace and policy level, structural and organizational interventions are crucial in mitigating heat stress risks. Employers should always ensure adequate access to safe drinking water, allowing workers to maintain proper hydration during work hours. Additionally, the provision of shaded areas or cooling spaces is recommended to allow workers to rest and recover from heat exposure. Implementing scheduled rest breaks, particularly in hot environments, can significantly reduce the risk of heat-related illnesses. Work schedules should also be adjusted to minimize exposure during peak heat periods, for example, by shifting physically demanding tasks to cooler times of the day, such as early morning or late afternoon. Policymakers and relevant authorities should consider establishing and enforcing heat stress management guidelines to protect workers, especially those in outdoor or high-risk occupations.

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APPENDICES

Appendix A: (Ethical Approval for Research Project)

UNIVERSITI TUNKU ABDUL RAHMAN DU012(A)
Wholly owned by UTAR Education Foundation Co. No. 578227-M

Re: U/SERC/78-643/2025

8 November 2025

Dr Zafarullah Nizamani
Head, Department of Environmental Engineering
Faculty of Engineering and Green Technology
Universiti Tunku Abdul Rahman
Jalan Universiti, Bandar Baru Barat
31900 Kampar, Perak.

Dear Dr Zafarullah,

Ethical Approval For Research Project/Protocol

We refer to the application for ethical approval for your student's research project from Bachelor of Science (Honours) Environmental, Occupational Safety and Health programme enrolled in course UGNB4916. We are pleased to inform you that the application has been approved under Expedited Review.

The details of the research projects are as follows:

No	Research Title	Student's Name	Supervisor's Name	Approval Validity
1.	Assessing Heat Stress Variability and Its Determinants Among Adult Population in Kampar, Perak	Ivan Ling Kieng Shiang	Dr Siti Nurfahirah Binti Muhamad	8 November 2025 - 7 November 2026

The conduct of this research is subject to the following:

(1) The participants' informed consent be obtained prior to the commencement of the research;

(2) Confidentiality of participants' personal data must be maintained; and

(3) Compliance with procedures set out in related policies of UTAR such as the UTAR Research Ethics and Code of Conduct, Code of Practice for Research Involving Humans and other related policies/guidelines.

(4) Written consent be obtained from the institution(s)/company(ies) in which the physical or/and online survey will be carried out, prior to the commencement of the research.

Kampar Campus : Jalan Universiti, Bandar Barat, 31900 Kampar, Perak Darul Ridzuan, Malaysia
Tel: (605) 468 8888 Fax: (605) 466 1313
Sungai Long Campus : Jalan Sungai Long, Bandar Sungai Long, Cheras, 43000 Kajang, Selangor Darul Ehsan, Malaysia
Tel: (603) 9086 0288 Fax: (603) 9019 8868
Website: www.utar.edu.my

Should the students collect personal data of participants in their studies, please have the participants sign the attached Personal Data Protection Statement for records.

Thank you.

Yours sincerely,

Professor Dr Zuraidah Abd Manaf
Chairman
UTAR Scientific and Ethical Review Committee

c.c Dean, Faculty of Engineering and Green Technology
Director, Institute of Postgraduate Studies and Research

Kampar Campus : Jalan Universiti, Bandar Barat, 31900 Kampar, Perak Darul Ridzuan, Malaysia
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Sungai Long Campus : Jalan Sungai Long, Bandar Sungai Long, Cheras, 43000 Kajang, Selangor Darul Ehsan, Malaysia
Tel: (603) 9086 0288 Fax: (603) 9019 8868
Website: www.utar.edu.my

Appendix B: Personal Data Protection Notice

PERSONAL DATA PROTECTION NOTICE

Please be informed that in accordance with Personal Data Protection Act 2010 ("PDPA") which came into force on 15 November 2013, Universiti Tunku Abdul Rahman ("UTAR") is hereby bound to make notice and require consent in relation to collection, recording, storage, usage and retention of personal information.

1. Personal data refers to any information which may directly or indirectly identify a person which could include sensitive personal data and expression of opinion. Among others it includes:

   a) Name
   b) Identity card
   c) Place of Birth
   d) Address
   e) Education History
   f) Employment History
   g) Medical History
   h) Blood type
   i) Race
   j) Religion
   k) Photo
   l) Personal Information and Associated Research Data

2. The purposes for which your personal data may be used are inclusive but not limited to:

   a) For assessment of any application to UTAR
   b) For processing any benefits and services
   c) For communication purposes
   d) For advertorial and news
   e) For general administration and record purposes
   f) For enhancing the value of education
   g) For educational and related purposes consequential to UTAR
   h) For replying any responds to complaints and enquiries
   i) For the purpose of our corporate governance
   j) For the purposes of conducting research/ collaboration

3. Your personal data may be transferred and/or disclosed to third party and/or UTAR collaborative partners including but not limited to the respective and appointed outsourcing agents for purpose of fulfilling our obligations to you in respect of the purposes and all such other purposes that are related to the purposes and also in providing integrated services, maintaining and storing records. Your data may be shared when required by laws and when disclosure is necessary to comply with applicable laws.

4. Any personal information retained by UTAR shall be destroyed and/or deleted in accordance with our retention policy applicable for us in the event such information is no longer required.

5. UTAR is committed in ensuring the confidentiality, protection, security and accuracy of your personal information made available to us and it has been our ongoing strict policy to ensure that your personal information is accurate, complete, not misleading and updated. UTAR would also ensure that your personal data shall not be used for political and commercial purposes.

Consent:

6. By submitting or providing your personal data to UTAR, you had consented and agreed for your personal data to be used in accordance to the terms and conditions in the Notice and our relevant policy.

7. If you do not consent or subsequently withdraw your consent to the processing and disclosure of your personal data, UTAR will not be able to fulfill our obligations or to contact you or to assist you in respect of the purposes and/or for any other purposes related to the purpose.

8. You may access and update your personal data by writing to us at_______________.

Acknowledgment of Notice

[ ] I have been notified and that I hereby understood, consented and agreed per UTAR above notice.

[ ] I disagree, my personal data will not be processed.

…………………………
Name:
Date:

Appendix C: Questionnaire

BACHELOR OF SCIENCE (HONS) ENVIRONMENTAL, OCCUPATIONAL HEALTH AND SAFETY

FACULTY OF ENGINEERING AND GREEN TECHNOLOGY

UNIVERSITI TUNKU ABDUL RAHMAN

KAMPAR, PERAK

RESEARCH QUESTIONNAIRE

ASSESSING HEAT STRESS VARIABILITY AND ITS DETERMINANTS AMONG ADULT POPULATION IN KAMPAR, PERAK

The questionnaire consists of FIVE (5) sections, which are:

Section A: SOCIODEMOGRAPHIC INFORMATION

Section B: OCCUPATIONAL INFORMATION

Section C: LIFESTYLE AND HEALTH

Section D: HEAT EXPOSURE INFORMATION

Section E: HEAT TRESS SYMPTOMS

Section F: ADAPTIVE PRACTICES AND AWARENESS

PARTICIPANT INFORMATION AND CONSENT FORM

Introduction

You are invited to participate in a research study for my Final Year Project. This study aims to assess the heat stress variability and understand how weather conditions, work environments, and personal factors influence heat stress symptoms among adults in Kampar, Perak. Your participation is entirely voluntary. The questionnaire will take approximately 10-15minutes to complete. Please be assured that this is not a medical diagnosis or health assessment.

What will happen?

If you agree to participate, you will be asked to complete a paper questionnaire about your experiences with heat, your environment, and general health symptoms.

Confidentiality

All your responses will be kept strictly anonymous and confidential. Your name will not be written on the questionnaire. The data collected will be used solely for the purpose of this academic project. No personally identifiable information will be published.

Eligibility

To participate in this study, you must

- Be aged 18 years or above
- Have you been living, working, or studying in Kampar for at least 6 months

Contact Information

If you have any questions or concerns about this study, please contact:

Researcher: Ivan Ling Kieng Shiang at *ivan2002@1utar.my / 019-8156360*

Project Supervisor: Dr. Siti Nurfahirah binti Muhamad at *nurfahirah@utar.edu.my*

Section A: Sociodemographic Information

1.	Age	________ years			
2.	Gender	☐	Male	☐	Female
3.	Ethnicity	☐	Malay	☐	Chinese
		☐	Indian	☐	Others (please state):
4.	Education Level	☐	No formal education/Primary school/Secondary school		
		☐	Diploma/Certificate	☐	Bachelor's degree
		☐	Postgraduate		
5.	Weight (kg)	________ kg			
6.	Height (cm)	________ cm			
7.	Household Monthly Income (RM)	☐	< RM5,249 (B40)	☐	RM5,250 – RM11,819 (M40)
		☐	> RM11,820 (T20)		

Section B: Occupational Information

8. Current Occupation Status

☐	Indoor work	☐	Outdoor work
☐	Unemployed	☐	Retired
☐	Student	☐	Others (please state): ____________

9. In which industry are you currently involved?

- [ ] Agriculture/Plantation
- [ ] Construction
- [ ] Transportation / Delivery / Logistics
- [ ] Manufacturing (with outdoor tasks)
- [ ] Mining / Quarrying
- [ ] Oil & Gas / Energy
- [ ] Landscaping / Groundskeeping
- [ ] Security / Defence / Enforcement
- [ ] Public Works / Utilities
- [ ] Others (please state): ______________
- [ ] Not applicable

10. Which work schedule do you currently follow?

- [ ] Regular day shift (e.g., 8.00 am – 5.00 pm)
- [ ] Night shift
- [ ] Rotating shifts
- [ ] Flexible schedule
- [ ] Split shifts
- [ ] Others (please state): ______________

11. How many hours in total do you work outdoors between 11.00 am – 4.00 pm?

- [ ] Less than 1 hour
- [ ] 1 – 2 hours
- [ ] 3 – 4 hours
- [ ] More than 4 hours

12. Which is your usual work/rest schedule on hot days (for outdoor workers)?

- [ ] No rest breaks
- [ ] Short rest breaks
- [ ] Regular rest breaks
- [ ] Not applicable

Section C: Lifestyle & Health

13. Smoking status
- ☐ Never smoked
- ☐ Former smoker (quit)
- ☐ Current smoker

14. Alcohol intake
- ☐ Never drink
- ☐ Heavy/frequent drinker
- ☐ Occasional/social drinker
- ☐ Former drinker (quit)
- ☐ Regular drinker (weekly)

15. Caffeine intake (e.g., coffee, tea) __________ Cups / day (1 cup = 250ml)

16. Daily water intake __________ Liters / day

17. What is your level of physical activity on a hot day?
- ☐ Light (e.g., sitting, driving, light hand tools)
- ☐ Heavy (e.g., carrying loads, construction, farming, digging)
- ☐ Moderate (e.g., walking, gardening, using heavier tools)
- ☐ Very heavy (e.g., intense manual labor, mining, logging)

18. Do you have any pre-existing conditions that is diagnosed by medical practitioners? (select all that apply)
- ☐ Cardiovascular disease
- ☐ Hypertensive
- ☐ Diabetes
- ☐ Kidney disease
- ☐ Respiratory disease (e.g., asthma)
- ☐ Thyroid disease
- ☐ Mental health
- ☐ Skin condition
- ☐ None
- ☐ Others (please state): ______________

19. Do you currently take any prescribed medicines for medical conditions?

- ☐ Yes
- ☐ No

If yes, please state the taken medicines: _____________

20. Did nighttime heat disrupt your sleep?

- ☐ Never
- ☐ Often
- ☐ Rarely
- ☐ Always
- ☐ Sometimes

Section D: Heat Exposure Information

21. What is the average time you spent on hot days between 11.00 am – 4.00 pm?

- ☐ hours outdoors directly in sun
- ☐ hours indoor non-AC
- ☐ hours outdoors in shade
- ☐ hours with AC

22. Do you have access to shade at your workplace or study area?

- ☐ Never
- ☐ Rarely (1-2 hours)
- ☐ Sometimes (3-4 hours)
- ☐ Always (> 5 hours)

23. Do you have access to drinking water at your workplace or study area?

- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Always

24. What is the primary type of transportation you use the most?

- [ ] Family car
- [ ] Heavy transport (e.g., lorry)
- [ ] Van
- [ ] Bus
- [ ] Motorcycle
- [ ] Bike
- [ ] Walking

25. What type of clothing do you usually wear on hot days?

- [ ] Long sleeves
- [ ] Long trousers
- [ ] Short sleeves
- [ ] Short pants
- [ ] Head covering (e.g., hat)
- [ ] Others (please state): ____________

26. What is the colour of the clothing you usually wear?

- [ ] Light-coloured
- [ ] Dark-coloured

27. Do you wear any personal protective equipment (PPE) during work?

- [ ] Always
- [ ] Rarely
- [ ] Sometimes
- [ ] Never

28. How would you describe your clothing/PPE?

- [ ] Mostly breathable (e.g., cotton, mesh)
- [ ] Mixed/partly breathable
- [ ] Mostly impermeable (e.g., rubber, coated)
- [ ] I don't wear PPE/not applicable

29. Are you aware of the recent heatwave warnings over the past few months?

- [ ] Yes
- [ ] No

Section E: Heat Stress Symptoms

30. For each heat stress symptom below, indicate the **frequency** in the past 7 days. Please tick (/) your answer.

	Symptoms	Never **(0)**	Once a week **(1)**	2-3 times a week **(2)**	4-6 times a week **(3)**	Everyday **(4)**
a.	Hot, dry skin with little sweat					
b.	Heavy sweating					
c.	Thirst/dry mouth					
d.	Muscle cramps					
e.	Fatigue					
f.	Headache					
g.	Dizziness					
h.	Nausea/vomiting					
i.	Confusion/disorientation					
j.	Heat rash/skin irritation					
k.	Rapid heartbeat					

31. For each heat stress symptom(s) you ticked in item **No. 32**, indicate the **severity** you experienced in the past 7 days. Please tick (/) your answer.

	Symptoms	None (0)	Mild (no activity limitation) **(1)**	Moderate (some limitations) **(2)**	Severe (help needed) **(3)**

a.	Hot, dry skin with little sweat					
b.	Heavy sweating					
c.	Thirst/dry mouth					
d.	Muscle cramps					
e.	Fatigue					
f.	Headache					
g.	Dizziness					
h.	Nausea/vomiting					
i.	Confusion/disorientation					
j.	Heat rash/skin irritation					
k.	Rapid heartbeat					

32. Have you received any treatment/been hospitalized due to any related heat illnesses (e.g., heat exhaustion, heat stroke, heat syncope) in the past 12 months?

☐ Yes ☐ No

If yes, please state the heat-related illnesses: ______________

Section F: Adaptive Practice and Awareness

33. Do you usually bring drinking water with you daily?

☐ Always ☐ Rarely

☐ Sometimes ☐ Never

34. Do you usually add electrolytes/salt to your drinking water?

☐ Always ☐ Rarely

☐ Sometimes ☐ Never

35. Which of the following cooling methods have you used at home and workplace in the past 7 days? Please tick (/) all that apply.

	Methods	Never **(0)**	Once **(1)**	2-3 times **(2)**	4-6 times **(3)**	Daily **(4)**
a.	Shade seeking					
b.	Fans					
c.	Air-conditioning (AC)					
d.	Cool shower					
e.	Ice packs					
f.	Cooling towels					
g.	Adjusted work hours					
h.	Extra breaks					
i.	Others (please state): ________					

36. What are the main barriers that prevent you from cooling or staying hydrated?

- ☐ Lack of access to drinking water
- ☐ Not allowed to carry water during work
- ☐ Lack of access to shade/cooling areas and facilities (fans/AC)
- ☐ Forgot to drink water
- ☐ Work demands / limited break time
- ☐ PPE / clothing makes it difficult
- ☐ Others (please specify): ______________

37. Does your workplace or study environment use a buddy system to monitor heat safety?

- ☐ Always
- ☐ Rarely
- ☐ Sometimes
- ☐ None

38. Does your workplace or study environment have a heat safety policy or provide heat safety training?

- ☐ Yes
- ☐ No

39. Do you know where to check heat alerts (e.g., Malaysia Meteorological Department, Department of Environmental, Ministry of Health)?

- ☐ Yes
- ☐ No

If yes, please state: ______________

40. How confident are you that you know how to stay safe during extreme heat?

- ☐ Very confident
- ☐ Slightly confident
- ☐ Somewhat confident
- ☐ Not confident at all

41. Knowledge check: Please indicate whether the following statements are (true, false, or if you don't know)

	Statement	True	False	Don't know
a.	Water is the best fluid for hydration.			
b.	Headache and dizziness are early warning signs.			
c.	Heat stroke requires immediate medical care.			
d.	High humidity can reduce the possibility of heat stress.			
e.	Dark-coloured clothing can help to prevent heat accumulation.			

Appendix D: Validation Format for Data Collection Questionnaire

Validation Format for Data Collection Questionnaire (Form for Content Validity Index)

Title: Assessing Heat Stress Variability and Its Determinants Among Adult Population in Kampar, Perak

Dear Experts:

I would like to seek your expert opinion on how relevant each item/parameter is measured in the questionnaire for my study. This validation form helps to assess the content validity of the questionnaire. The instructions are provided below to guide you with your analysis. Please use the following rating scale and rate each item/parameter as objectively as possible throughout your review.

Instructions:

This instrument is used for the Expert Evaluator to assess the relevance and effectiveness of the instrument being validated. You are required to place the punctuation that you consider appropriate to the different statements and tick (/) only one from the selection according to the following scale:

1: Not Relevant 2: Somewhat Relevant 3: Quite Relevant 4: Highly Relevant

Section A: Sociodemographic Information

	Questionnaire Item	Scale				Remarks/ Comments
		Not Relevant (1)	Somewhat Relevant (2)	Quite Relevant (3)	Highly Relevant (4)	
1.	Age					
2.	Gender					
3.	Ethnicity					
4.	Marital Status					
5.	Education Level					

6.	Weight (kg)					
7.	Height (cm)					
8.	Household Monthly Income (RM)					

Section B: Occupational Information

	Questionnaire Item	Scale				Remarks/ Comments
		Not Relevant (1)	Somewhat Relevant (2)	Quite Relevant (3)	Highly Relevant (4)	
9.	Current occupation status					
10.	Current job industry					
11.	Work Schedule					
12.	Total time spent working outdoors between 11.00 am – 4.00 pm					
13.	Work/rest schedule on hot days (for outdoor workers)					

Section C: Lifestyle & Health

	Questionnaire Item	Scale				Remarks/ Comments
		Not Relevant (1)	Somewhat Relevant (2)	Quite Relevant (3)	Highly Relevant (4)	
14.	Smoking status					
15.	Alcohol intake					
16.	Caffeine intake (e.g., coffee, tea)					
17.	Daily water intake					
18.	Physical activity on hot day					

19.	Pre-existing conditions					
20.	Current prescribed medicines taking					
21.	Sleep quality in the past 7 days					
22.	Disruption of nighttime heat					

Section D: Heat Exposure Information

	Questionnaire Item	Scale				Remarks/ Comments
		Not Relevant (1)	Somewhat Relevant (2)	Quite Relevant (3)	Highly Relevant (4)	
23.	Average time spent on hot days between 11.00 am – 4.00 pm					
24.	Access to shade at work/study					
25.	Access to drinking water at work/study					
26.	Direct sun exposure between 11.00 am – 4.00 pm					
27.	Primary transportation air-conditioned					
28.	Clothing type					
29.	Any protective equipment					
30.	Description of clothing (breathability)					
31.	Awareness of recent heatwave					

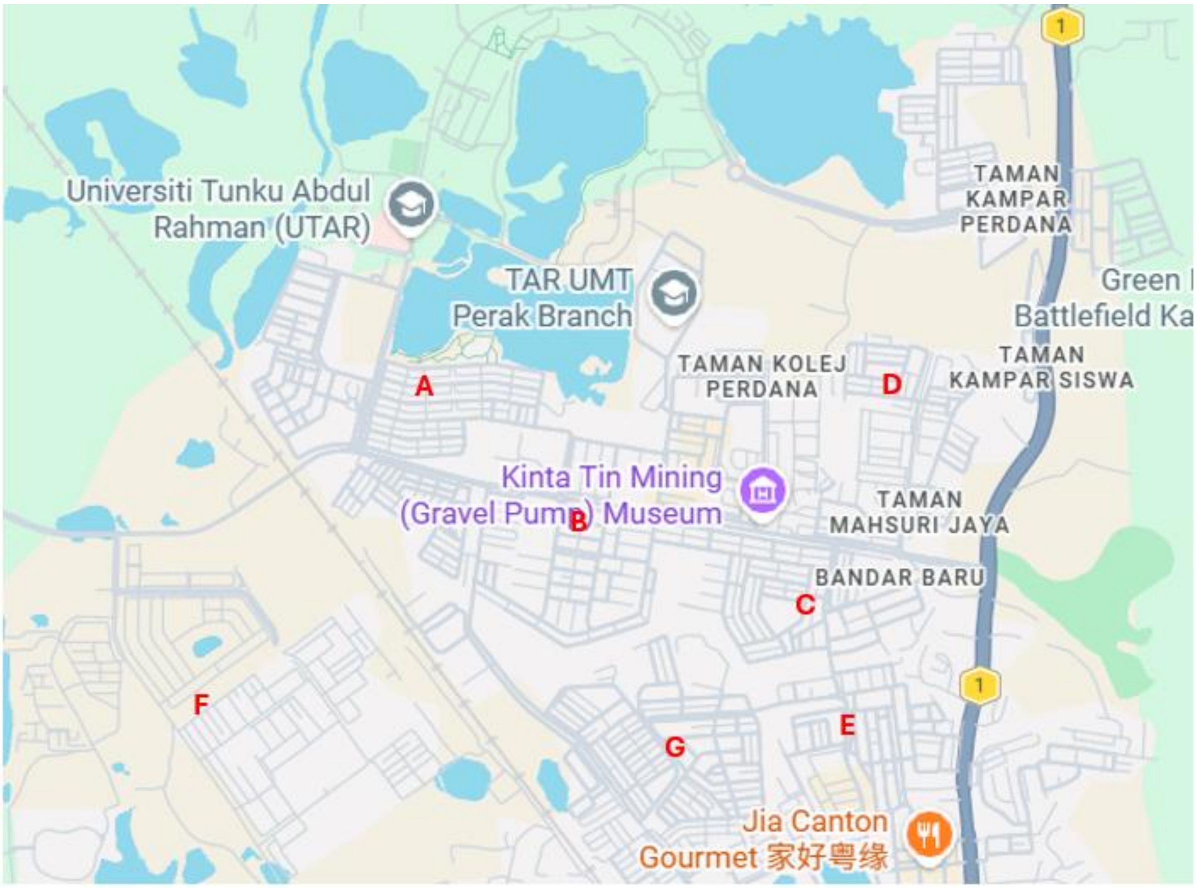
Section E: Heat Stress Symptoms

	Questionnaire Item	Scale				Remarks/ Comments
		Not Relevant (1)	Somewhat Relevant (2)	Quite Relevant (3)	Highly Relevant (4)	
32.	Frequency of heat stress symptoms in the past 7 days					
33.	Severity of heat stress symptoms in the past 7 days					
34.	Any treatment or hospitalisation received due to heat-related illness before					

Section F: Adaptive Practices & Awareness

	Questionnaire Item	Scale				Remarks/ Comments
		Not Relevant (1)	Somewhat Relevant (2)	Quite Relevant (3)	Highly Relevant (4)	
35.	Bring drinking water daily					
36.	Electrolytes/salt added to drinking water					
37.	Cooling method used in the past 7 days					
38.	Barriers to cooling or staying hydration					
39.	Buddy system used					
40.	Heat safety policy or training provided					
41.	Heat alert					
42.	Confidence in heat safety					
43.	Knowledge check on statements					

Appendix E: Heat Exposure Monitoring Sites



Appendix F: Turnitin Report

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