HAMBURG UNIVERSITY OF APPLIED SCIENCES

FACULTY OF LIFE SCIENCES

MASTER OF PUBLIC HEALTH

IMPACTS OF HEAT STRESS ON THE HEALTH OF WORKING POPULATION DURING SUMMER SEASON IN HAMBURG, GERMANY

MASTER THESIS

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[redacted]

Submission Date: 10/02/2021

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Acknowledgement

Firstly, I would like to express my gratitude to God and thankful for my thesis's successful completion. With deep and sincere respect and thankful to both my supervisor Prof. Dr. Walter Leal, Head, Research and Transfer Centre "Sustainable Development and Climate Change Management," who has provided me constant encouragement and guidance throughout my degree program. Secondly, Prof. Amena Ahmad, Professor for Public Health, for the guidance and valuable comments for the thesis process.

I would also like to thank my friends Ranjeet Dhonkal and Ghazal Khalid for their continuous motivation and constant support during the ups and downs and also at every step of my thesis writing. This accomplishment would not have been possible without them.

Finally, my parents and sister, who have always been my backbone and strength even though being far away, never allowed me to give up and to cheer me through phone calls. I am forever grateful for that.

Aprajita Minhas

10.02.2021, Hamburg, Germany

Abstract

Background and Aim: Heat is a universal threat, and many incidents have been reported on the effects of extreme temperature on humans. The rising temperature can result in a significant impact on health. The aim of the study is to determine the impacts of heat stress on the health of the working population in Hamburg, Germany.

Methods: A cross-sectional quantitative approach was used for data collection using three procedures: Literature Review, Structured Questionnaire Survey, Outdoor Air Temperature, and Air Velocity measurements. The survey included questions about the heat stress symptoms and workplace settings; prevention, and intervention taken at the workplace. In addition, outdoor air temperature measurements were taken using Testo 435 and a thermal probe.

Results: In total, 82 respondents participated in the survey from various working backgrounds. With the help of the chi-square test, there is a significant association between the two variables $p = 0.001$ with working in high temperature is associated with increased frequency of symptoms. A majority of participants (n=75), 91.4%, worked in high temperature, with 89% (n=74) respondents felt unpleasantly warm while working. The highest air temperature recorded was 39.9℃ with an air velocity of 0.11m/s in Schlump. Whereas the lowest temperature recorded was 21.7℃ with an air velocity of 1.09m/s in Wandsbek Gartenstadt.

Conclusion: Based on the cross-sectional quantitative analysis, it can be concluded that working in a high-temperature environment can cause an increased frequency of heat stress symptoms. Furthermore, the subjective feeling of air temperature (self-reported heat stress) can also occur in significance to various factors such as working outdoors, working in high temperature, high humidity, physically demanding job, working more than 6 hours, not drinking enough water. Hence, the results indicate the presence of heat stress impacts on workers' health in Hamburg.

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List of Abbreviations

%	percent
°C	degree Celsius
m/s	meter/second
ANSI	American National Standard Institute
CDC	Centres for Disease Control & Prevention
CI	Confidence Interval
CNS	Central Nervous System
e.g.	For example
EASAC	European Academies Science Advisory Council
IPCC	Intergovernmental Panel on Climate Change
NIOSH	The National Institute for Occupational Safety and Health
NWS	National Weather Service
OSHA	Occupational Safety and Health Administration
p	p-value
PPE	Personal Protective Equipment
RCP	Representative Concentration Pathway
Tmax	Temperature maximum
Tmin	Temperature minimum
US EPA	United States Environmental Protection Agency
WHO	World Health Organisation
WBGT	Wet Bulb Globe Temperature

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1. Introduction

Globally millions of people's living and working conditions will be affected by extreme climate change events. The rising average global temperature is predicted to increase in the year 2100 up to 1.8-4°C (predicted average 3°C) if the greenhouse gas emissions are not reduced (Kjellstorm et al., 2009a). Heat is a universal threat, and many incidents have been reported on the effects of extreme temperature on humans. The rising temperature can result in a significant impact on health. Climate change in the future will also increase heat waves in many areas, and the heat waves episodes will be more severe (Kovats and Hajat, 2008). In the European Region, the prevalence and severity of dangerous events such as heatwaves will increase in the future. For instance, the vulnerable population, such as outdoor workers, is at higher risks; the general consequences and the specific impacts should be acknowledged (Messeri et al., 2019).

The rise in temperature means a higher risk of exposure to heat to humans. These unusual hot conditions will result in a stressful environment for the population who do not have access to air conditioning and cooling devices and affect the working and the living environment. Hence, it will further cause effects on the worker's health and economic conditions (Kjellstorm et al., 2009a). Heat-related illness occurs when the body fails to discharge the metabolic heat produced and preserves more heat, which can eventually lead to severe symptoms resulting in heatstroke and death (Acharya et al., 2018). A study by Kiefer et al. stated that even though substantial research regarding the prospects of climate change on the environment and public health, limited attention has been made to workers' health. The outdoor workers are at significant risk since they are exposed to the effects of climate change (Kiefer et al, 2014).

Transmitting the metabolic heat to the external environment usually happens with sweating and results in cooling. Another way could be convection by contact with a cooling device or air. If the metabolic heat is not reduced, this will result in heat strain and heat stroke (Kjellstorm et al., 2009). During the hot working environment, the workers tend to be at a higher risk of increased internal temperature of the body (above 38°C) due to increased physical activity. Therefore, it results in a decline in physical work efficiency, reduced mental capability, high risk of accidents, and ultimately heat exhaustion or heat stroke (Kjellstorm et al., 2009a).

The core body temperature is 37°C, which is maintained by the homeostasis mechanism in humans. While working (or physical activity), the body generates metabolic heat, which is required to be transmitted to the external environment to prevent the sudden, alarming increase in the internal body temperature (Kjellstorm et al., 2009a; Kjellstorm et al., 2016). Six fundamental factors regulate the body heat balance (thermoregulation): (Kjellstorm et al., 2009a)

1. Air Temperature
2. Radiant Temperature
3. Wind Speed
4. Humidity
5. Clothing
6. Metabolic heat generated by physical activity

Various factors depend on heat stress: temperature, wind, humidity, clothing, physical activity, shade, and other factors. These factors are further considerably dependent on the occupation setting, working environment, and the worker. The workers experience more discomfort (uncomfortable) in the hot and humid environment than in the hot and dry environment. Heat stress is aggravated by the excessive burden of workload and the use of Personal Protective Equipment (PPE). Hence, the worker's heat load is caused by weather conditions, high physical activity, metabolic heat production, and clothing or PPE's thermal effect (Acharya et al., 2018).

To provide the immediate warning system and future projections of extreme heat exposure, air temperature is an essential parameter, and other significant parameters should also be considered. In high-temperature conditions, the only way to maintain the core body temperature is via heat loss as sweat. Furthermore, improper clothing (PPE or religious cause) and lack of cooling can worsen the conditions further (Casanueva et al., 2020). The following data in table 2 shows the comprehensive summary of articles extracted from the literature search, the methods and findings from the studies take into account the heat related illness. The risk of heat stress is increased further if there are any changes in the factors influencing heat stress, such as (Gao et al., 2019)

- Increase in air temperature or increase in frequency of heat events
- Lack of precautionary measures like the absence of fans, Air-conditioning, etc.
- Intense physical activity or no rest breaks.
- Workers that are not trained for heat events.
- Worker susceptible to heat who are un-adjustable and weak.

1.1 Background

In the working environment, heat stress is hazardous, and the severity of heat stress depends on the worker's physical activity. Especially in hot conditions, people working outdoors are at higher risk of not having access to water or shady areas (Lundgren et al., 2013). In developing countries, the high outdoor temperature (lack of automatic cooling) can result in heat exposure more than indoor and outdoor workers' suggested level. Insufficient acknowledgment of the dangers of heat stress has prevented health experts from determining the impacts of heat stress on workers' health and enforce preventive measures to reduce workers' exposure (Balakrishnan et al., 2010). The health impacts caused due to heat stress reply not only on the extreme temperature but also on the population's exposure and vulnerability (Rohat et a., 2019).

Our body's muscles use only 20% of metabolic energy, contributing to the muscular external work output. The remaining heat left should be released into the external environment from the body. The movement of muscles requires significant energy consumption in the body. During high air temperature (above 34–37°C) and high humidity conditions, sweat evaporation is inadequate, and other physiological processes cannot stop the internal body temperature from rising (Kjellstorm et al., 2016). Therefore, heavy labor in high temperature and high humidity conditions can be a severe risk to a person's health. Even though workers can self-pace and lower their work intensity when the heat stress increases, some workers need to finish tasks or for money to continue working beyond their limit. When the internal body temperature increases with extreme sweating, it can result in dehydration, causing severe direct and indirect health complications (Kjellstorm et al., 2016).

The socio-economic factors such as livelihood and urbanization can aggravate the health outcomes of heat stress (Kjellstrom, 2009c). For instance, people working in farm and laborers are exposed to prolonged heat on hot days and are at higher risk of heat stress, contrary to people working in urban areas have normal or high salaries and have the capability to buy air conditioning for their residence and workplace (Kjellstrom et al., 2009d). Furthermore, in the urbanized area, the buildings, roads, and major concrete structures can arrest and absorb solar heat radiations, resulting in an even higher rise in temperature as compared to rural areas because of the Urban Heat Island Effect (USEPA, Heat Island effect). According to the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) classified the effects of Heat Stress into codes following hospital utilization in the US, which are as shown in Table 1 as follows (Acharya et al., 2018; CDC, 2015):

Table 1: Shows the Classification code for the Effects of Heat Stress CDC

Heat Stress	Code
Heat Stroke & Sunstroke	992.0
Heat Syncope	992.1
Heat Cramps	992.2
Heat Exhaustion, Anhidrotic	992.3
Heat Exhaustion due to salt depletion	992.4
Heat Exhaustion, Unspecified	992.5
Heat Fatigue, Transient	992.6
Heat Edema	992.7
Other Specified Heat Effects	992.8
Effects of heat and light, unspecified	992.9
Contact with general heat—atmosphere or environment	ANSI Z16.2 type code 151

(Source: CDC, 2015)

The significant adverse effects cause heat strain, other clinical diseases, health deterioration, and decreased work productivity. These adverse effects occur globally in different countries and can be aggravated by heatwaves and demanding physical work in hot conditions. Likewise, the effects mentioned above are further enhanced by Climate change (Kjellstorm et al., 2016).

According to the IPCC (Intergovernmental Panel on Climate Change), the Fifth Assessment report classified discomfort, tiredness, weakness, exhaustion, heat cramps, and heat stroke as the direct effects of heat stress in humans (Lundgren et al., 2013). In many parts of the world, persistent heating will considerably decrease labor productivity and work capacity. Moreover, some tropical and sub-tropical countries are having high heat stress incidents. In the future, parts of Southern Europe and the USA also be afflicted. Due to heat in various tropical areas, the minimum target for Climate change (average global temperature 1.5°C; RCP 2.6) the loss of daylight work output will increase. The rise in temperature to 2.7°C, RCP 6.0, will amplify heat in the workplace (Kjellstrom et al., 2018).

The health consequences due to heat exposure are evaluated in terms of mortality and hospital patient admissions. The susceptible population, mostly the elderly and people with previous health diseases, and the workers performing heavy workload in hot conditions, are at increased risk of suffering heatstroke and other health impacts (Kjellstorm et al., 2016).

Table 2 : Shows the comprehensive summary of the articles from the Systematic Literature Review

Study & Year	**Study Method**	**Description**	**Findings**
Dessai, 2003 Heat stress and mortality in Lisbon Part II. An assessment of the potential impacts of climate change	Cross-Sectional Study	Two regional climate models were used in the study. Bayesian analysis was carried out investigate sensitivity of result.	The result showed heat related mortality will increase between 5.8 & 15.1 in 2020s and 7.3 & 35.6 in 2050s.
Kovats & Hajat., 2008 Heat Stress and Public Health: A Critical Review	Case-Crossover Study	• Temperature Mortality Relationship • Determinants for heat related mortality & morbidity	The risk of heat related mortality increases with age but also people with physical and social susceptibility are also at risk.
Lundgren et al., 2013 Heat, Human Performance, and Occupational Health: A Key Issue for the Assessment of Global Climate Change Impacts	Cross-Sectional Study	A literature review was carried out to find the impacts of heat stress on the population in relation to climate change in occupational settings.	The findings showed the main factors responsible to exacerbate the heat stress at workplace is Urban Heat Islands effect, physical work and individual differences.
Kjellstrom et al., 2018 Estimating population heat exposure and impacts on working people in conjunction with climate change	Cross-Sectional Study	Quantitative estimation of impacts of climate change on the working population by: • Climate models, • Demographic models • Empirical Models	The findings show continued heat stress will result in reduce work capacity and workers productivity especially southern parts of Europe and USA. By the end of century, the annual avg WBGT will increase by 1.5-2.5 °C.
Błażejczyk et al., 2018 Heat stress mortality and desired adaptation responses of healthcare system in Poland	Cross-Sectional Study	• Heat Related Mortality in various cities in Poland. • Daily mortality & weather data reports were used. • The heat stress is measured by Universal Thermal Climate Index (UTCI).	• During the increase period of heat stress, mortality is increased by 12 and 47% respectively. • The number of deaths will rise from 28,000 to 74,500 in the 21^{st} century.
Pogačar et al.,2018 The effect of hot days on occupational heat stress in the	Case Study	• The climate indices, such as the number of hot days (HD: Tmax above 30 °C), and	• The findings showed increase in climate change projections up

manufacturing industry: implications for workers' well-being and productivity		Wet Bulb Globe Temperature (WBGT) were used to assess the heat conditions in Slovenia. • Survey – 400 workers participants	to 4.5°C for mean temperature. • The no. of hot days was 35 by the end of 21st century. • The WBGT showed sufficient increase for days with high risk of heat stress. • The survey reported that 96% of workers experience unsuitable temperature condition.
Pogačar et al.,2018 Aggravated Occupational Heat Stress Recognition and Mitigation in Slovenia	Cross-Sectional Study	Two surveys conducted in 2016 – 687 participants and 2017 – 117 participants.	• The results showed the Factory workers (77%) experienced worst thermal discomfort in First survey. • The symptoms of heat stress were anticipated by majority of workers such as thirst (79%), excessive sweating (79%) and tiredness (65%), and in a smaller proportion enhanced stress (27%), dizziness (24%) and confusion (13%).
Brode et al., 2018 Estimated work ability in warm outdoor environments depends on the chosen heat stress assessment metric	Cross-Sectional Study	• Heat stress assessment metrics on the Estimated Workability of laborer's was performed. • WBGT was estimated.	• With increased workload, the thermal strain increased and WBGT is higher in hot days as compared to warm humid days.
Pogačar et al.,2019 Heat Waves Occurrence and Outdoor Workers' Self-assessment of Heat Stress in Slovenia and Greece	Cross-Sectional Study	• The study included two different European countries- Slovenia and Greece. • A comparison between annual temperature was also performed. • Survey was conducted in	• A total of 286 respondent were assessed. • The results showed significant heat stress impact on productivity (Greece 69%, Slovenia 71%; $p > 0.05$). The major symptoms experienced were thirst, excessive

		Slovenia in 2017 and Greece 2018. • A total of 800 participants for the survey.	sweating, exhaustion and headache • The reported occurrence of heat stress symptoms, heat induced diseases and hospitalization were statistically significant.
Messeri et al., 2019 Heat Stress Perception among Native and Migrant Workers in Italian Industries—Case Studies from the Construction and Agricultural Sectors	104 Case studies	• Heat Shield Questionnaire was used. • Environmental monitoring such as air temperature, humidity, atmospheric pressure, wind speed and solar radiation was measured. • Heat stress assessment was done using two biometeorological indicators – UTCI & WBGT Index was assessed.	• The results showed that migrant workers required greater efforts as compared to native Italian workers ($\chi2$ = 17.1, p = 0.001). • And recorded less impact from heat on the workers productivity and thermal discomfort ($\chi2$ = 10.6; p = 0.014).

1.2 Temperature conditions in Hamburg, Germany

In Figure 1 shows that, the annual average temperature in Hamburg, Germany has increased from 12.3°C to 14.2°C from the year 1980 to 2020. There is an about 2°C increase over the past 40 years.

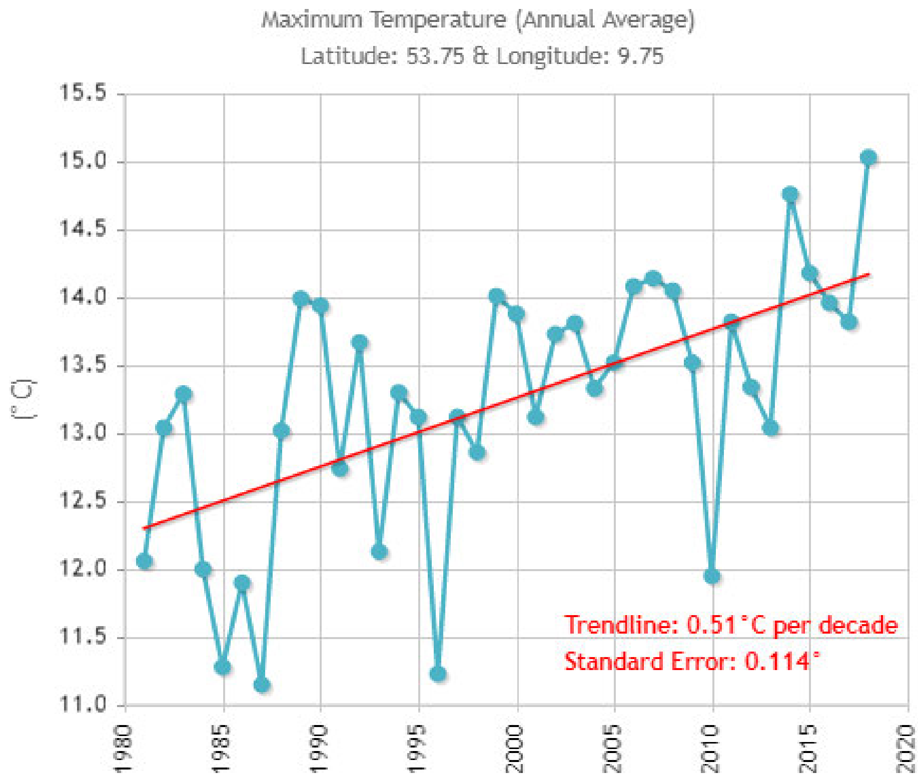


Figure 1: The Maximum Temperature (Annual Average) from 1980 to 2020

(Source: Climate Chip, 2020 https://www.climatechip.org/your-area-climate-data)

The Figure 2 shows that the maximum monthly average temperature is at peak during the month of July and August about 23°C and declines later in September and October (19°C & 14°C). This monthly average temperature value is shown for the year 1981 to 2018.

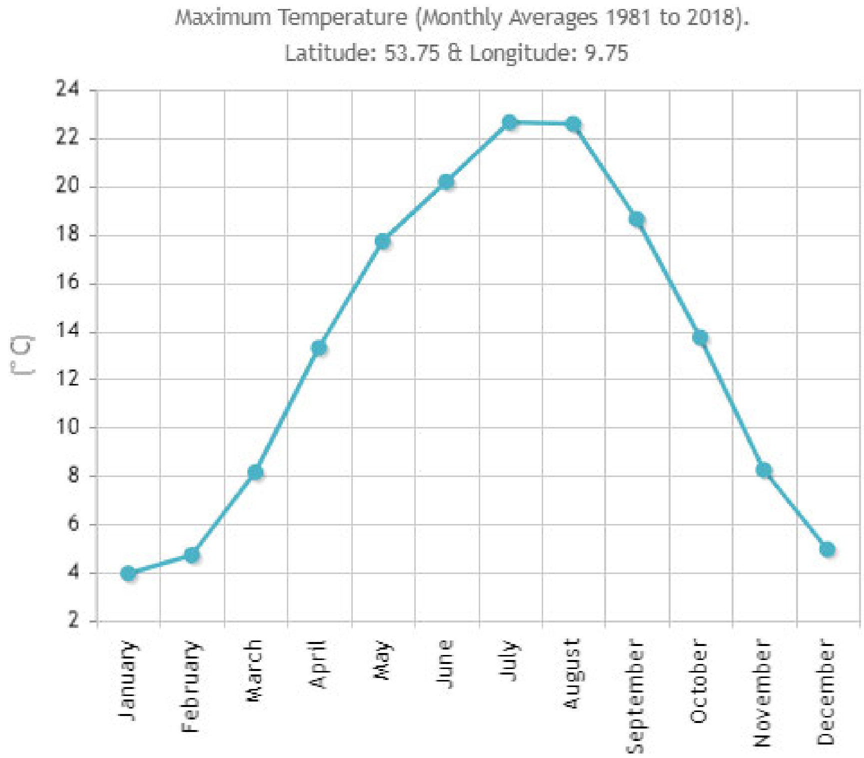


Figure 2: The Maximum (monthly average) temperature of Hamburg

(Source: Climate Chip, 2020 https://www.climatechip.org/your-area-climate-data)

Wet Bulb Globe Temperature (WBGT) is the most commonly used heat stress indices worldwide. It was first developed by the US Army in the 1950s to decrease exposure to the heat. The index is used for the measurement of heat stress in direct sunlight. The WBGT index was used as a screening tool for heat stress assessment (Gao et al., 2018; Hancock and Vasmatzidis, 2003).

The index can be measured in a hot environment in the presence or absence of solar radiation. The factors taken into account are temperature, wind speed, humidity, sun angle, and solar radiation (WBGT, NWS). Moreover, the WBGT index can also be calculated by mathematical methods and can be used as an assessment for the impacts of climate change when there is the absence of measurement devices (Tustin et al., 2016). As shown in Figure 3, the WBGT for Hamburg increased from 10°C to 11.4°C from the year 1980 to 2020 with 0.39°C per decade.

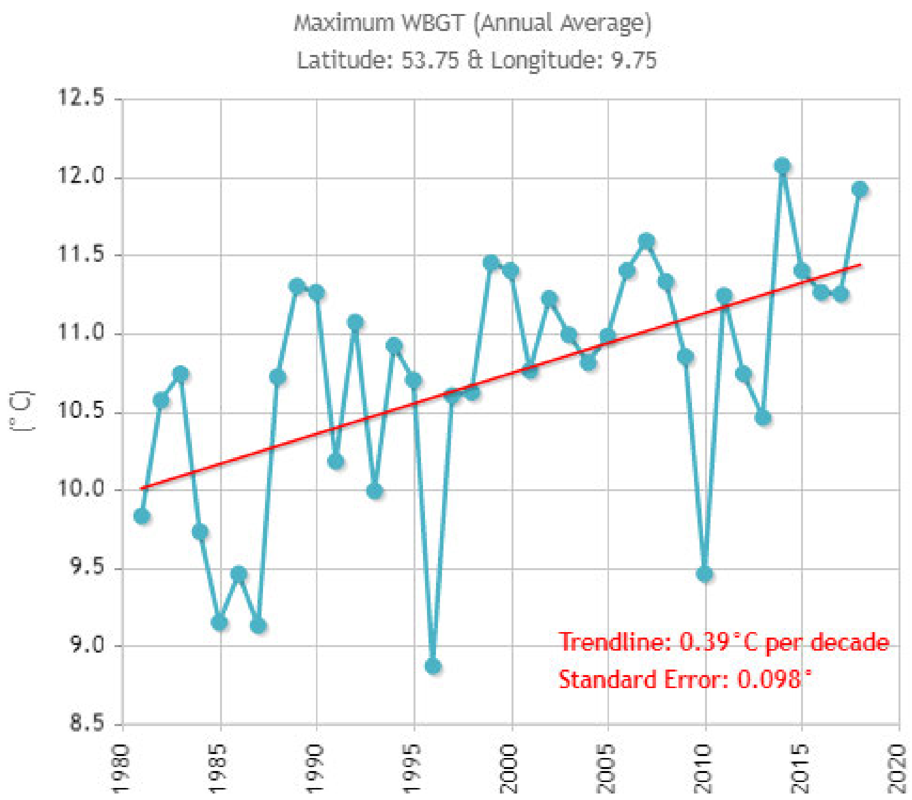


Figure 3: The maximum WBGT (Annual Average) from 1980 to 2020.

(Source: Climate Chip, 2020 https://www.climatechip.org/your-area-climate-data)

In August 2003 in France, more than 1,000 deaths occurred between the ages of 20-70 years due to extreme heat events. The study suggests that most of the deaths occurred in men, and the cause could be exposure to extreme heat during work during that period (no analysis was done). In Europe, heatwaves resulted in approximately 70,000 heat-related deaths, despite no analysis of the occupational health component (Kjellstorm et al., 2016). In a study by Rohat et al., it has been revealed that the European population exposed to a high threat of heat stress will show a constant increase from currently 0.4% to 20.3%, followed by 32.6%, then 48.4% in the year 2050, depending on the scenarios (Rohat et al., 2019).

1.3 Health Impacts of Heat Stress

The health impacts of heat stress affected by factors like a pre-existing medical condition, age, gender, clothing, physical activity, body size, and ability of heat acclimatization (Heat stress OSHA; Tawatsupa et al., 2009). Heat mortality occurs due to the overloading of the cardiovascular and respiratory systems with physiological reactions to heat exposure. The physiological reactions that occur are increased heart rate, increased body temperature, increased sweating, fluctuation of blood flow towards the skin from the central organs, and dehydration (Kjellstrom et al., 2010).

Moreover, persistent exposure to high temperature with continuous exposure to heat results in critical heat stress causing heat-related illness, for instance, heat exhaustion, heatstroke, fatigue, and increased sensitivity to chemical exposure. Increased vulnerability to rising temperature can cause a decrease in attention, leading to higher chances of injury affecting worker's safety.

In addition, high temperature can also cause a rise in air pollution levels (ground-level ozone), the outdoor workers will be exposed to such air pollutants, resulting in chronic effects on health (Kjellstrom et al., 2009b; Nilsson & Kjellstrom, 2010; Gubernot et al., 2014; EASAC; 2019). The following Table 3 shows the health impacts of heat stress on human health.

Table 3: Shows the Health Impacts of Heat Stress

Impacts	**Signs & Symptoms**	**Effect**
Heat Stroke	➢ Body temperature suddenly rises to more than 40°C and is associated with central nervous system abnormalities, such as stupor, confusion or coma. ➢ Hot, dry skin, nausea, hypotension, tachycardia and tachypnoea are often present.	Cardiovascular System, Central Nervous System Abnormality, decreased Kidneys function, and Muscle cramps.
Heat Exhaustion	➢ Severe thirst, weakness, discomfort, anxiety, dizziness, fainting and headache. ➢ Pulse is rapid, with postural hypotension and rapid shallow breathing. ➢ Core body temperature less than 40°C.	Cardiovascular System, Kidneys damage, Muscle cramps, CNS abnormality.
Heat Cramps	➢ Painful muscular spasms occur, in the legs, arms or abdomen, usually at the end of sustained exercise. ➢ This can be led to dehydration, loss of electrolytes through heavy sweating and muscle fatigue.	Muscle spasms, Cardiovascular system, Metabolic system
Heat syncope	➢ This involves brief loss of consciousness or postural hypotension. More commonly seen in patients with cardiovascular diseases or taking diuretics before acclimatization takes place.	Cardiovascular system, Central nervous system, decreased Kidney function.

	➢ It is attributed to dehydration, peripheral vasodilatation and decreased venous return resulting in reduced cardiac output.	
Heat Oedema	➢ Oedema of the lower limbs, usually ankles. ➢ This is attributed to heat induced peripheral vasodilatation and retention of water and salt.	Kidney damage
Heat Rash	➢ Small, red, itchy papules on the face, neck, upper chest, under breast, groin and scrotum areas. ➢ More prevalent in young children.	Affects Skin
Respiratory problems – emission of air pollutants and greenhouse gases	➢ Irritation of airways, coughing and difficulty in breathing. ➢ Aggravation of Asthma and allergic reaction.	Respiratory system
Depression, Aggressive behaviour, Anxiety, Mental stress	Reduced emotional well-bring, irritable, feeling agitated, restlessness, fatigue, increased emergency room visits.	Psychological illness
Vector borne Diseases	Fever, chills, headache, sore muscles, stomach pain, nausea, skin rash	Malaria, Lyme Disease, West Nile virus, Leishmaniases, Yellow Fever
Heat related mortality	Death	Increase mortality risk due to exposure to extreme heat.

(WHO – Heatwave and Health: Guidance on warning system development, 2015)

The body's reaction to heat can also affect other organs, such as increased cardiovascular load, aggravate chronic pulmonary conditions, kidney disorder, and mental illness (McGregor et al., 2015). The core body temperature is 37℃, which is balanced by the physiological mechanism in human beings. If the core body temperature exceeds 42℃, severe heat stroke and even death can occur briefly. In case of core body temperature increase to 38℃ for a few hours, it results in heat exhaustion, reduced motor capacity, and psychometric. When the core body temperature goes above 39℃, unconsciousness and heatstroke can occur (Tord Kejellstorm, 2009). Along with climate change, the impact of heat in the urban area will increase in the future. People working in hot weather involving heavy physical activity without appropriate protection are at increased risk of suffering from heat-related health effects (Heat-health action plans, 2008; Laaidi et al., 2012). The Figure 4 shows the summary of direct effect of heat stress on working population when exposed to heat.

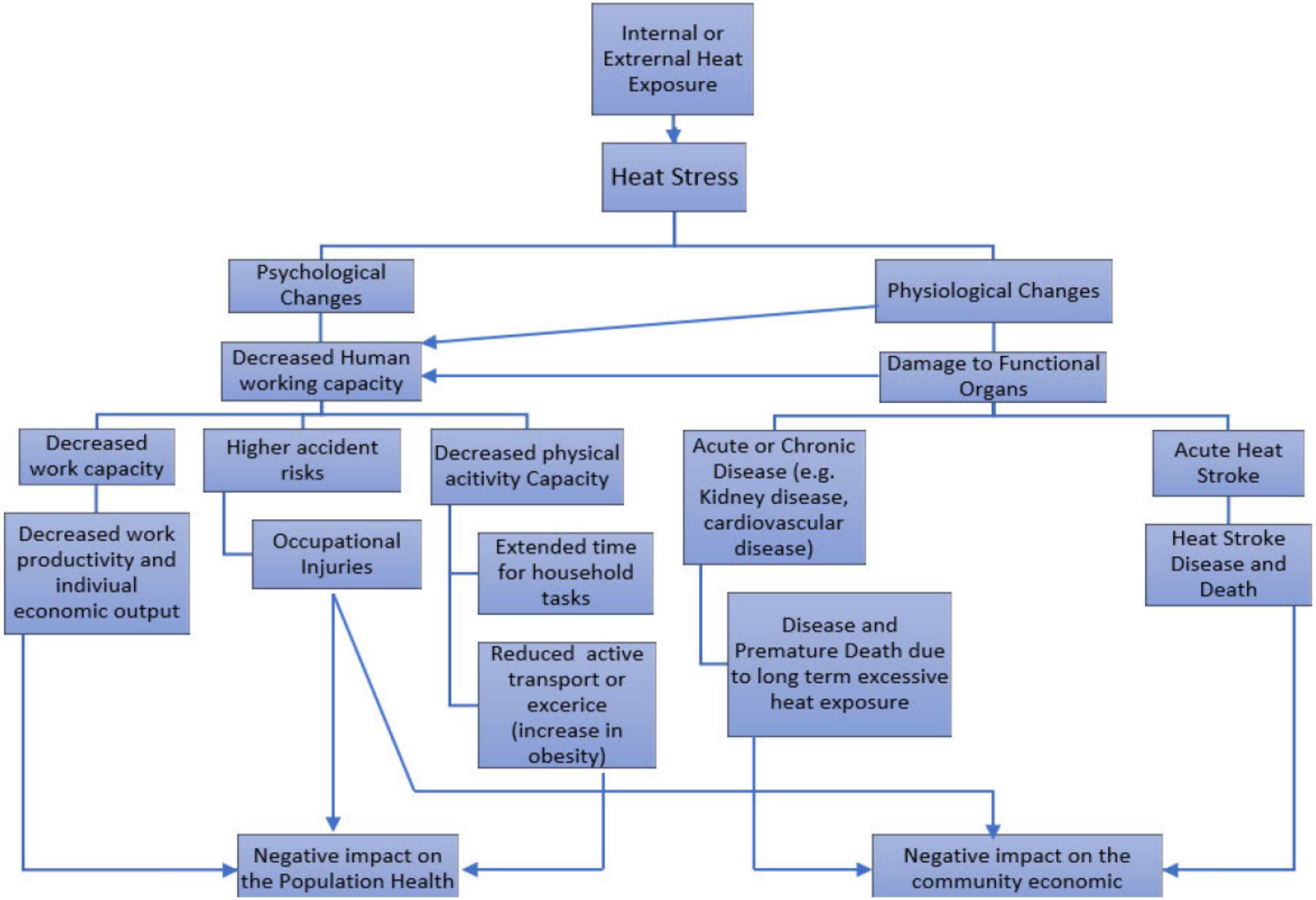


Figure 4: Flowchart of direct health effects of heat stress on working population

Source: Kjellstrom et al, 2016

2. Aim and Objectives

2.1 Aim

The study aims to determine the impacts of heat stress on the health of working population during the summer season in Hamburg, Germany.

2.2 Objectives

1. To determine the underlying health effects of heat stress on working population in different workplace settings.
2. To explore the cause of heat stress at workplace.
3. To determine the adaptive & preventive measures incorporated for prevention of Heat stress at workplace.

2.3 Hypothesis

H0: High temperature does not have an impact on the health of working population.

H1: High temperature does have an impact on the health of working population.

3. Methods

In order to understand the impacts caused by Heat stress on the health, a cross sectional quantitative approach is used for this studies data collection using three procedures:

3.1 Systematic Literature Review

3.2 Structured Questionnaire Survey

3.3 Outdoor Air Temperature and Air Velocity measurements

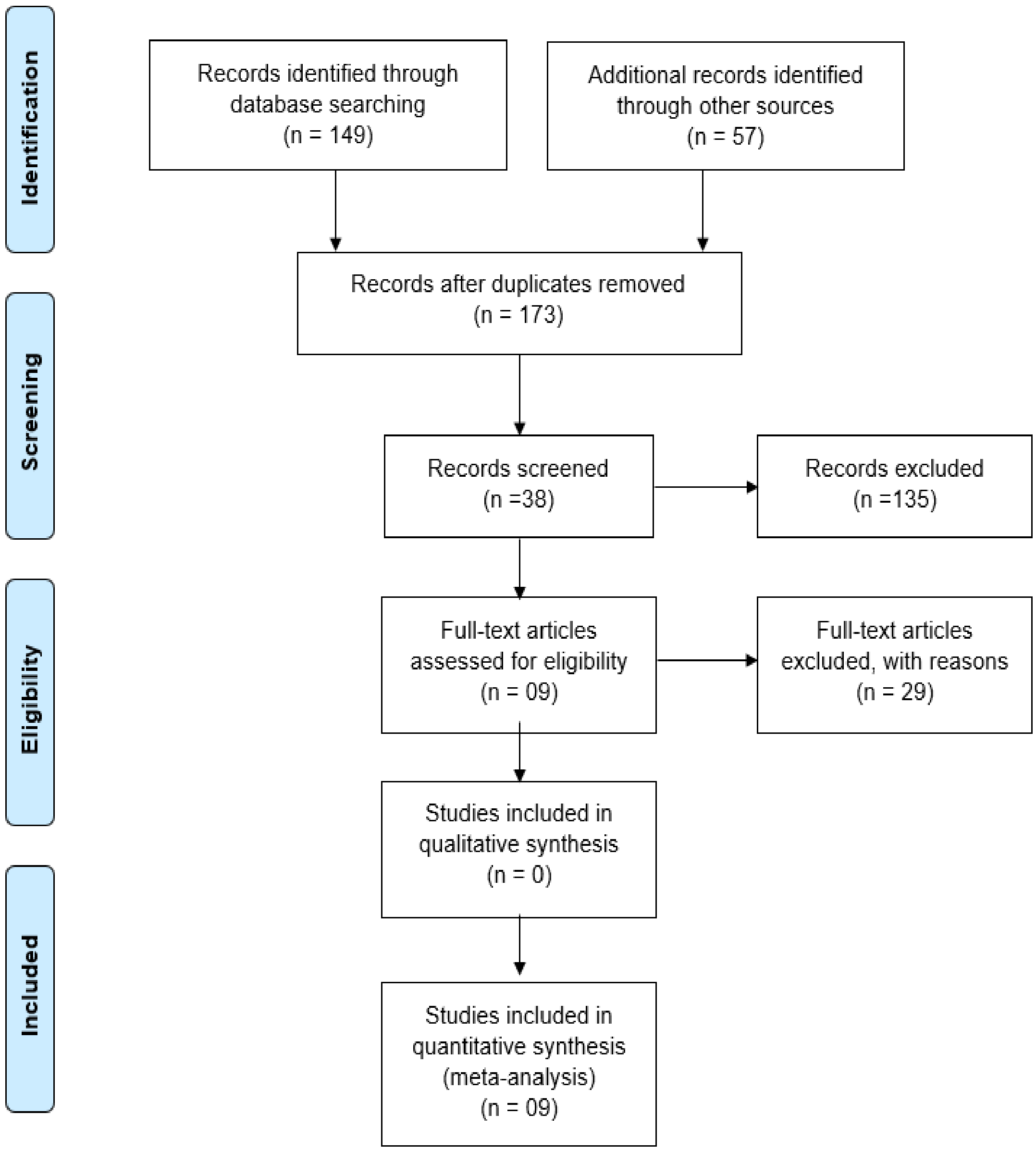
3.1 Systematic Literature Review

A scientific literature review was conducted for the heat stress impacts on the working population in August 2020 using the electronic database, including Pub Med, Research Gate, Science Direct, and Google Scholar. Besides, more articles were traced using the reference section of the primary articles searched. The electronic database searches were supplemented with manual searches for relevant published articles on the subject on international websites such as WHO, the United Nations, and CDC.

A combination of keywords was used to access the Literature: (((((Heat Stress OR Heat-related illness) AND (Climate change)) AND (Health)) AND (Health OR well-being)) AND (Working population OR Workers)) AND (Europe). With the help of search terms and keywords, the PICO Tool was used to formulate the research question. Those articles were selected that met the need for this literature review. The inclusion criteria included articles confined to the English language, the settings included Europe or European countries, and the literature search was limited from 2000 to 2020. The exclusion criteria excluded the studies before year 2000, studies that did not associate heat stress or heat-related illness and health of workers, and articles in other languages apart from English. The articles were first reviewed based on their titles and abstract. Later the Full-text eligible articles were selected based on their inclusion criteria. The PICO tool was used to formulate the research question as shown in table 4 (Turner, 2020). The Literature included Heat stress as the primary exposure of interest. The outcome is the Health impacts or Heat-related illness. The Literature search using the PRISMA guidelines resulted in 206 articles, from which 09 were selected for the review. The table 2 shows the findings from the systematic literature search.

Table 4: Shows the use of PICO tool to formulate a Research Question

Population	Exposure of Interest	Comparator	Outcome	Setting
Workers/ Working Population	Heat stress	-	Health Impacts or Heat related illness	Europe
Research Question	To determine the impacts of Heat stress on the Health of Working population in Europe.			



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

Figure 5: Shows the systematic literature search according to the PRISMA guidelines

3.2. Structured Questionnaire Survey (Annexure I)

A survey was prepared both in English and German language and made available through the online Google forums platform for a period of one month (24th July- 24th August 2020). The Survey consisted of a total of 23 questions, out of which 21 were closed-ended questions, and 2 were open-ended questions; from those 23 multiple choice questions, 2 questions were measured on a 5 Likert scale. The Questionnaire Survey was consecutively used for statistical analysis. The survey design was adopted from a study by Xiang et al., 2014. The Survey was designed to determine the impacts of heat stress on the health of the working population. The questionnaire survey is divided into three sections, Table 5 presents the questionnaire survey's sections, descriptions and components.

Table 5: Presents the Questionnaire survey's section, description and components

Section	Description	Components
1. Demographic	The first section designed to collect the demographic information of the respondent such as gender, age, living status, education level, country of origin, and current occupation.	A total of six questions were included to know about the participant's demographic background.
2. Heat stress & Workplace	The second section outlines the working environment such as the working hours, average break, subjective feeling of air temperature, humidity level, usage of Personal Protective Equipment's (PPE), symptoms experienced, and health consequences associated with heat stress.	A total of 23 questions were used to know about heat stress and workplace.
3. Prevention	The third section illustrates the awareness, intervention taken to prevent heat stress, and preventive measures to be followed at the workplace.	About three items were included to gain insight into worker's perceptions about the prevention and intervention of heat stress. The workers were asked about

		their concerns, and prevention measures are taken to decrease heat stress at the workplace. Moreover, the participants were asked about adaptive strategies required at their workplace to decrease the effect of heat while working indoor and outdoor in summer.

Prior to being finalized, the Survey was pre-tested in Hamburg by colleagues working in different scenarios (n=8), and minor adjustments were made according to the feedback obtained before the final test of the survey instrument.

A stratified random sampling strategy was used for this study. From the population of Hamburg, the people who were working were selected for the study. The working population is categorized into various groups such as construction worker, restaurant worker, food delivery worker, social worker and etc., to represent the population working in different scenarios. Then random selection was made these categories of working people. In order to gain a more understanding of the impact of heat stress on the working population, a survey was circulated among various participants, and responses were collected.

A total of 85 responses were collected from the Survey. The gathered data was checked for missing data and outliers before the analysis. After checking, 82 responses were used for this study. The descriptive and inferential data were analyzed using IBM SPSS Statistics for Windows version 20.0. To understand the two variables, a chi-square test was used. A p-value of less the 0.05 is used to indicate statistical significance.

3.3 Outdoor Air Temperature and Air Velocity Measurements

The outdoor measurements were taken between a period of 4th August to 13th August, 2020 on alternative days. In a total of eight areas in Hamburg were chosen for the study, representing different districts, as shown in Table 6.

Table 6: List of Areas and Districts in Hamburg where Measurements were taken

No.	Area	District
1	Altona	Altona
2	Landungsbrücken	Hamburg-Mitte
3	Bergedorf	Bergedorf
4	Harburg	Harburg
5	Wilhelmsburg	Hamburg-Mitte
6	Wandsbek Gartenstadt	Wandsbek
7	Saarlandstraße	Hamburg-Nord
8	Schlump	Eimsbüttel

The following map in Figure 6 shows the different areas chosen in Hamburg for measurement.

Figure 6: Shows the map of Hamburg and areas where measurements were taken.

(Source: Created using Google Maps)

Table 7: Study parameters measured by Testo 435 and thermal probe

	Hot wire (thermal) Probe	
Measuring Parameters	**Air Temperature (°C)**	**Air Velocity (m/s)**
Measuring Range	0 to +50 °C	0 to 50 m/s
Accuracy	±0.5 °C	±0.03 m/s

(Source: Testo 435-1)

The measurements are taken using Testo 435 and Hot wire (thermal) probe. The Testo 435 is a multifunctional measuring instrument basically used in this research to measure the air temperature and air velocity with thermal probes (Testo 435). The table 7 shows the study parameters range measured by Testo 435 and hotwire probe.

The measurements were taken at different timings in a day. On every alternate day, the measurements were recorded by connecting the Hotwire probe with the Testo 435 device. The Hotwire probe is very sensitive to air temperature and air velocity. The device showed the air velocity in m/s and air temperature in ℃. A total of three different readings were taken in one area at different time intervals. The mean of the temperature and air velocity reading was calculated and later represented graphically in the result section. The following Figures 7 show the device used for the measurement of air temperature and air velocity.

Figure 7: Shows Testo 435 and Hot wire probe

(Source: Own pictures)

4. Results

4.1. Results of Structured Questionnaire survey

4.1.1. Sample Characteristics: A total of 85 respondents participated in the survey. After checking for missing data, 82 responses are used for this study. As seen in Figure 8, a majority of respondents were male, 70.7% and followed by females, 29.3%. In Figure 9, the age group distribution 40.2% respondents belonged to the 21-30 age group followed by 26.8% from age group 31- 40, 23.2% age group 41-50, 6.1% from age group 51-60, and a lower percentage of 3.7% from age group 15-20. Based on their level of education majority of respondents, 36.6% were graduates, 25.6% were diploma holders, 13.4% completed the training course, 12.2 % completed High school, 8.5% were postgraduates, and 3.7% attended no school. (Figure 10)

The participants were asked about the living status (Figure 11) majority of the participants, 34.6% live with a partner, 22.2% live alone in a single household, 18.5% live with partner and children, 11.1% live with a roommate, 6.2% live with relative and other friends, the rest 3.7% live with parents, and 3.7% live with their children.

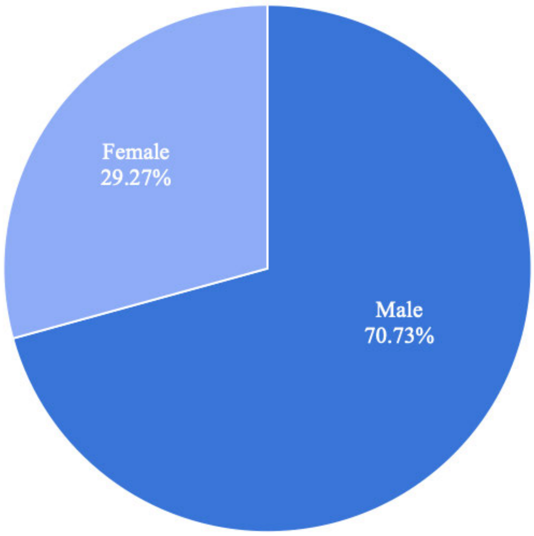


Figure 8:Gender of Participants

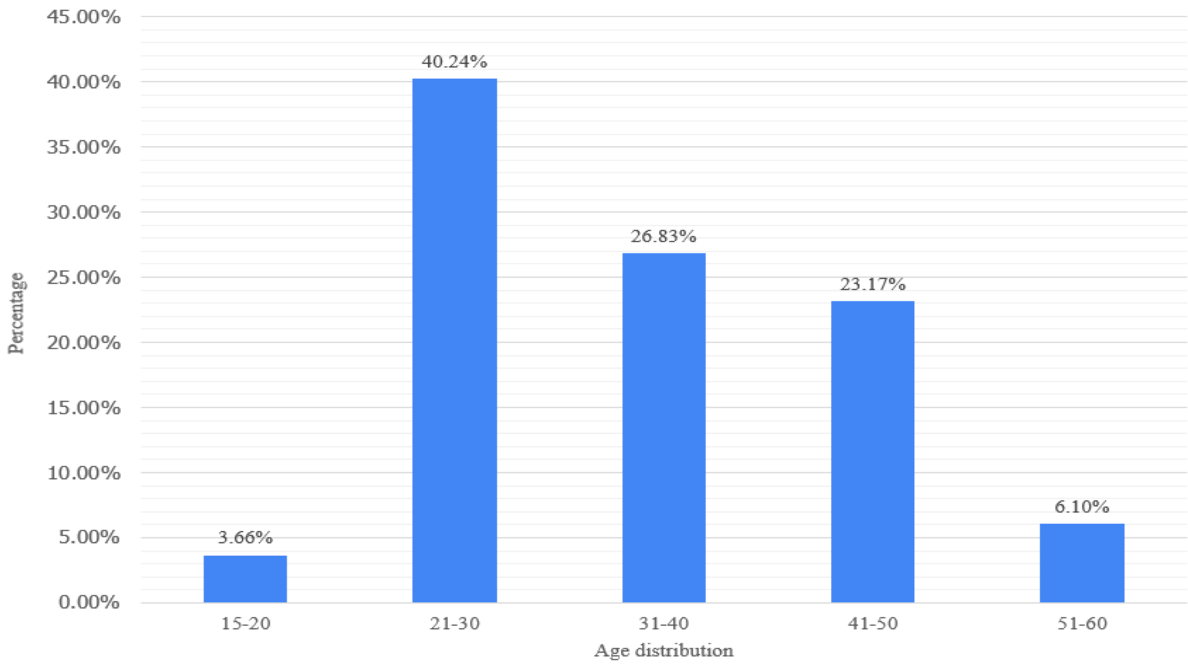


Figure 9: Age of Participants

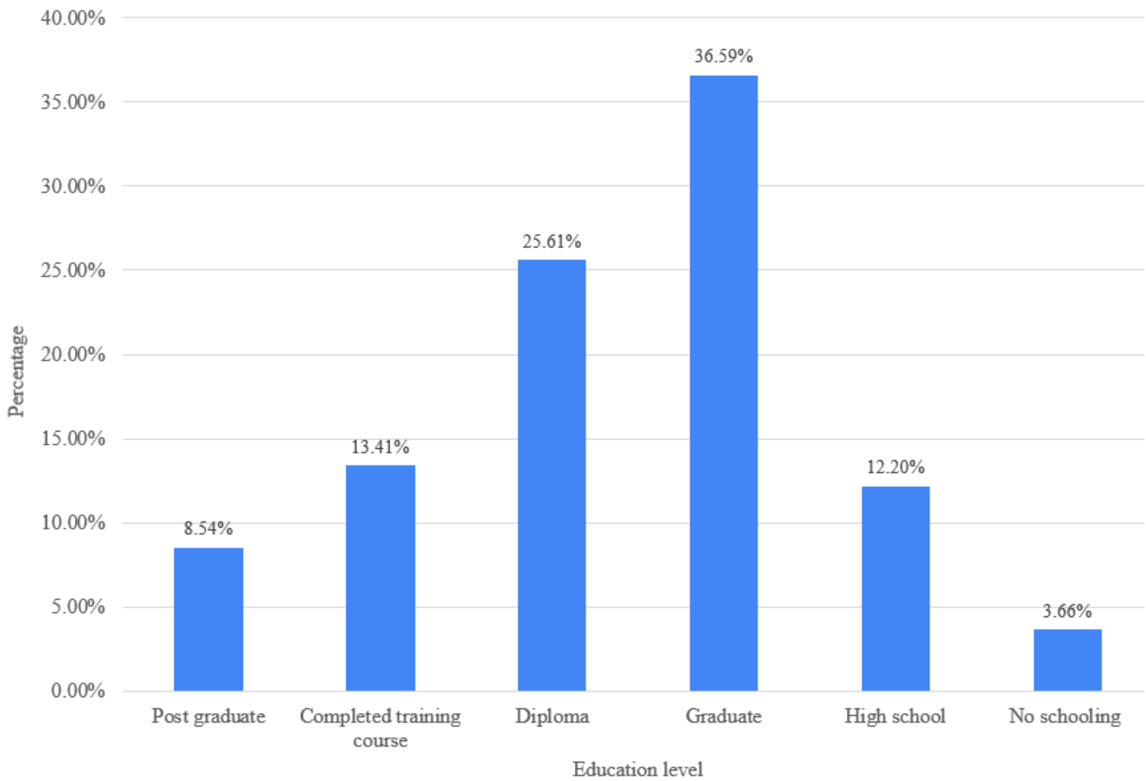


Figure 10: Education Level of Participants

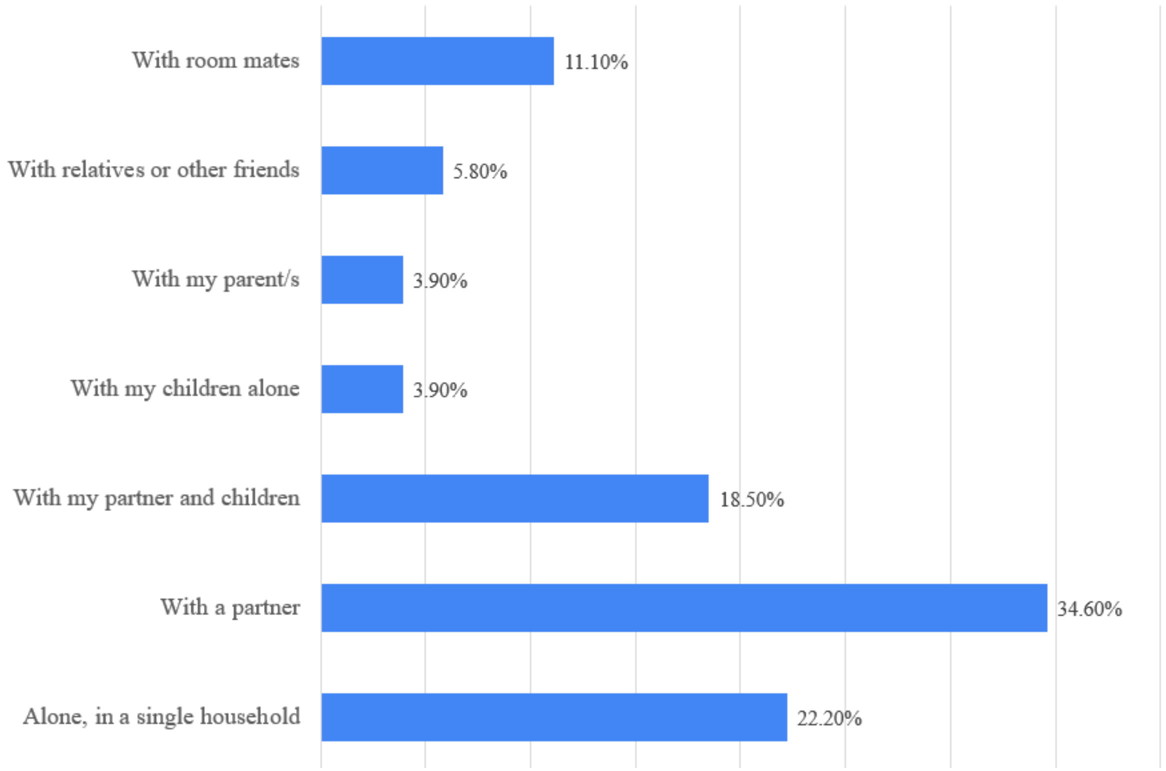


Figure 11: Living Status of Participants

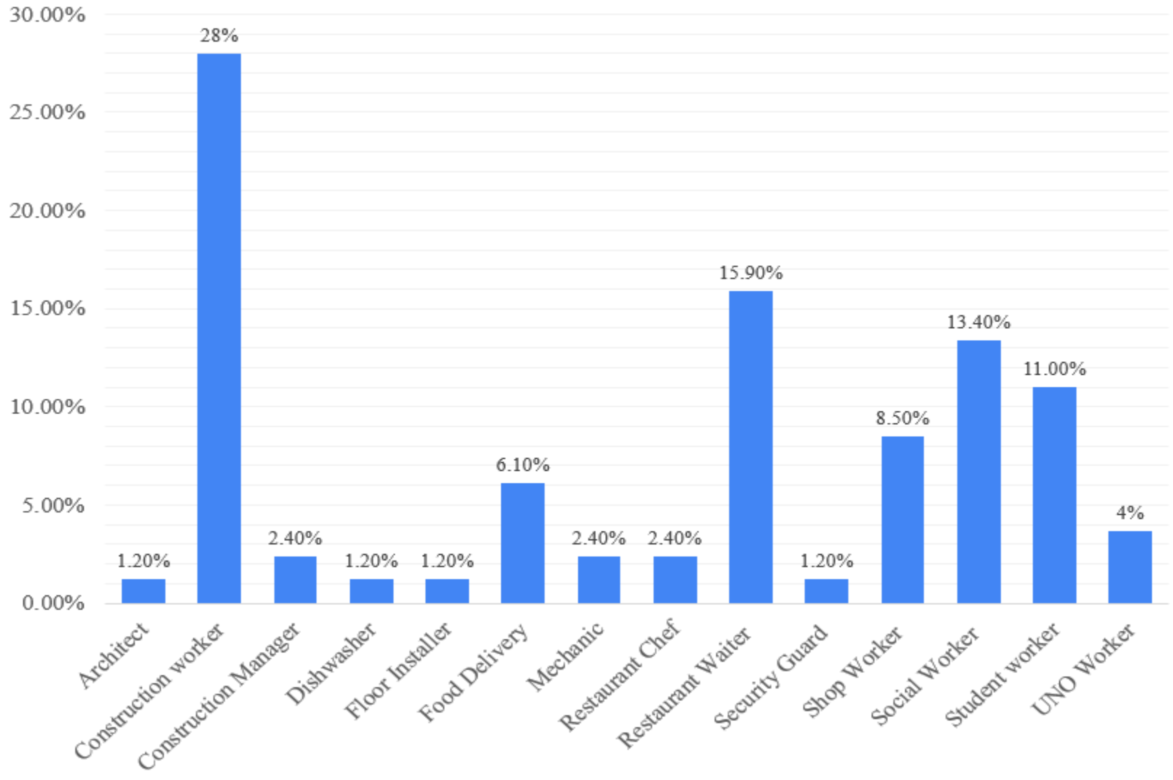


Figure 12: Current Occupation of Participants

As shown in Figure 12, the current occupation of the participants resulted in maximum of participants are Construction workers (28%), Restaurant Waiters (15.9%), Social Workers (13.4%), Student Workers (11%), Shop Workers (8.5%), Food Delivery workers (6.1%), UNO Worker (4%), and the rest belonged to Construction Manager (2.4%), Mechanic (2.4%), Restaurant chef (2.4%), Security Guard (1.2%), Architect (1.2%), Dishwasher (1.2%), and Floor Installer (1.2%).

According to the country of origin, majority of respondents 26.8% are from Germany, followed by 10.9% respondents are from India, 8.5% are from Poland, 7.3% Syria, 6.1% Lebanon, 6.1% Bangladesh, 4.9% Nepal, 4.9% Ghana, 3.7% Pakistan, 3.7% Afghanistan, 3.7% Romania, 2.4% Bulgaria, 2.4% Nigeria, 2.4% Colombia, and the rest 1.2% Indonesia, 1.2% Vietnam, 1.2% Russia, 1.2% France, 1.2% Georgia (Figure 13).

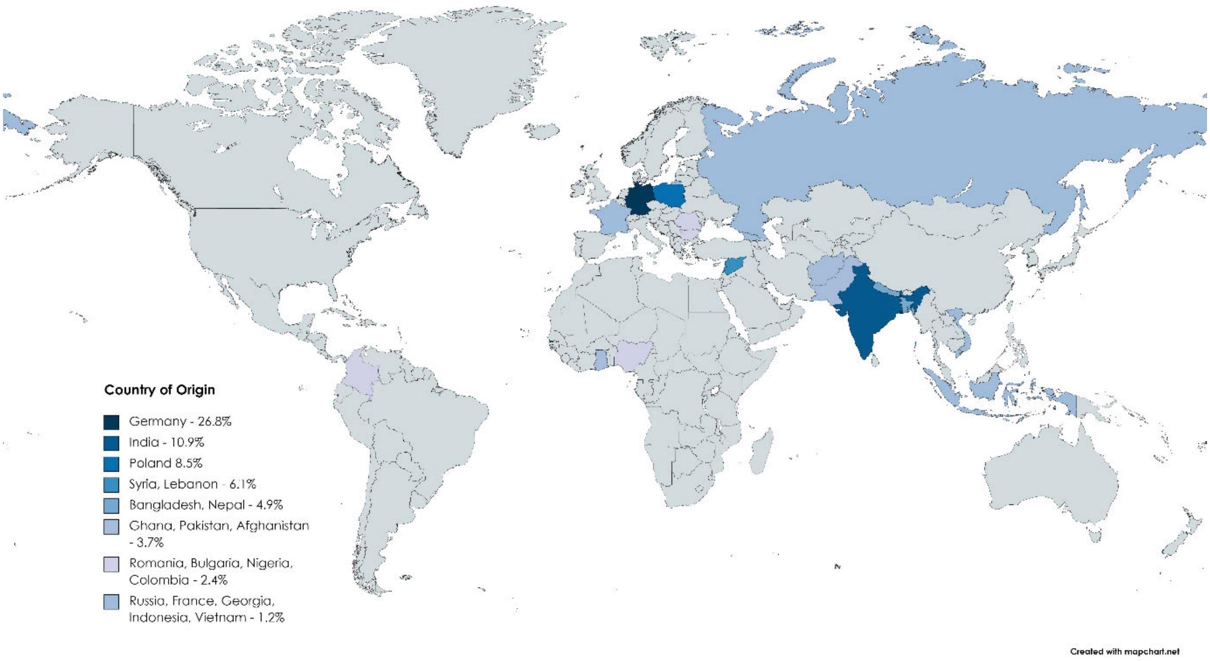


Figure 13: Country of Origin of Participant

Source: Map Chart Link: https://mapchart.net/world.html

4.1.2. Heat Stress and Workplace:

The respondents were asked about the workplace environment they work in 41.5% worked partially indoor and partially outdoor, while 36.6% worked completely outdoor and about 22% worked completely indoor, as seen in Figure 14. Most of the restaurant workers and social workers worked both indoor and outdoor (partially indoor and outdoor). But the construction worker (28%), food delivery workers (6.1%), and security guards (1.2%) worked mostly outdoor.

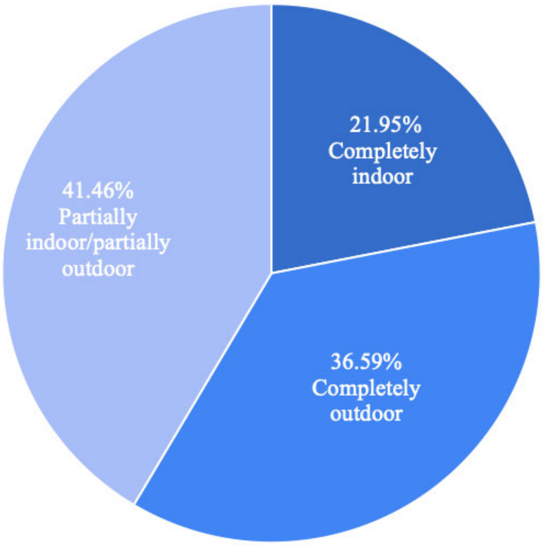


Figure 14: Type of Workplace of Participants

Most respondents (n=37) worked a minimum of 6-8 hours per day, some of them (n=30) worked more than 8 hours, a few (n=10) worked an average of 4-6 hours, and the rest (n=5) worked less than 4 hours on average per day. The participants were then asked about hours they work indoors; about (n=22) worked 4-6 hours indoor, (n=16) worked 6-8 hours, (n=8) worked less than 4 hours, and (n=2) worked more than 8 hours indoor. Moreover, the participants were then asked about hours they work outdoor; mostly (n=18) worked less than 4 hours outdoor, followed by (n=15) worked 4-6 hours outdoor, (n=13) worked more than 8 hours outdoor, and (n=11) worked 6-8 hours outdoor.

An average break of most participant 41.5% last 15-30 minutes, for 35.5% of participants its last 30-45 minutes, followed by 9.8% have for 45-60 minutes, 6.1% have 15 minutes, 4.9% of participants take no break and the rest 2.9% have 60-90 minutes break as seen in Figure 15. The majority of participants, 58.2%, take their break during the afternoon, followed by 35.4% take a break at noon and the rest 6.3% in the evening, as seen in Figure 16.

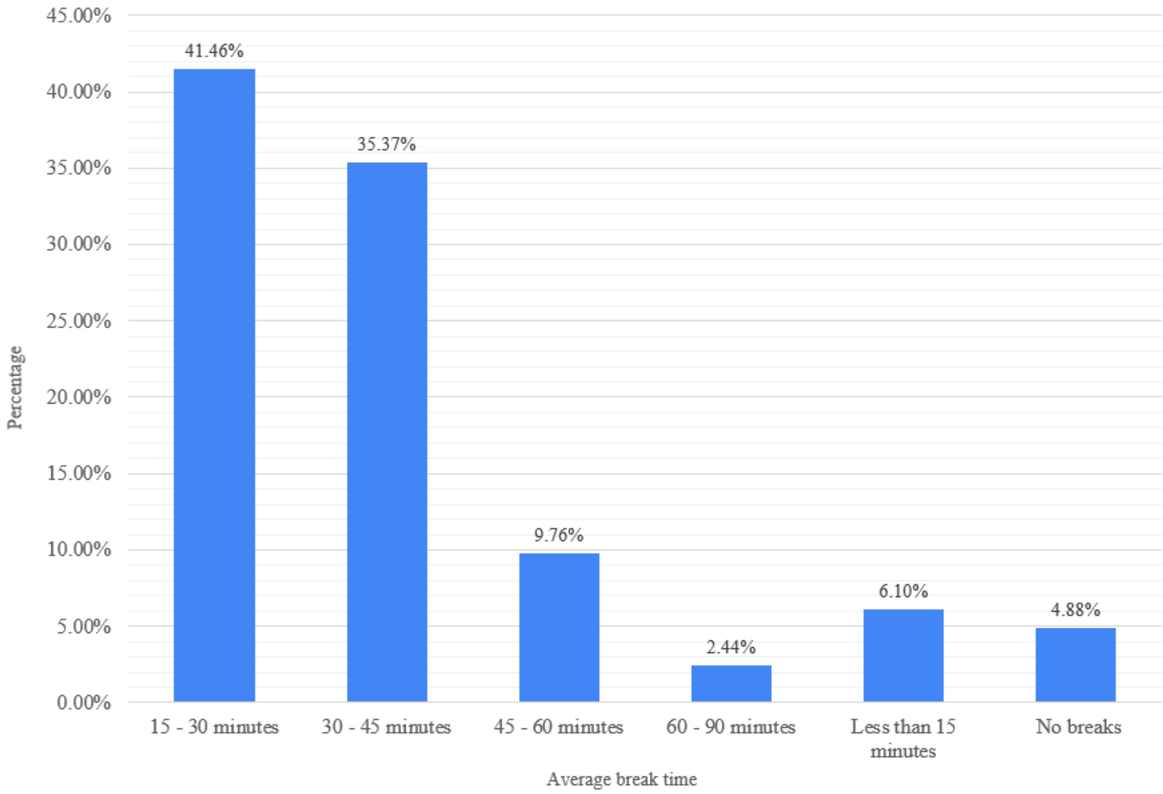


Figure 15: Average break time during the Work

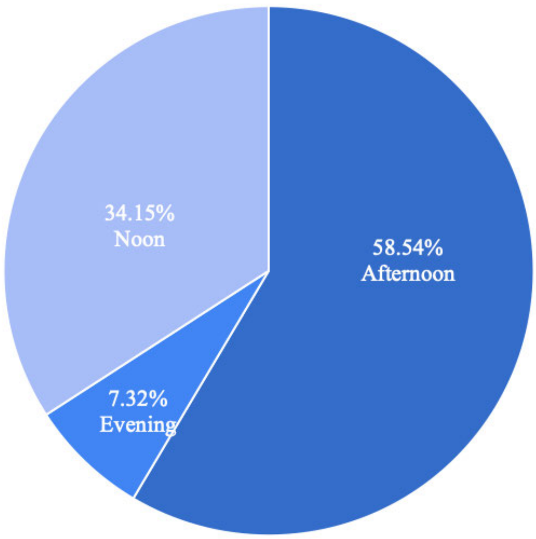


Figure 16: Time of break during the Work

About 37.8% of respondents agreed to their job type as physically demanding, followed by 31.7% considered it a little physically demanding and the rest, 25.6% agreed to their job type very much physically demanding (Figure 17).

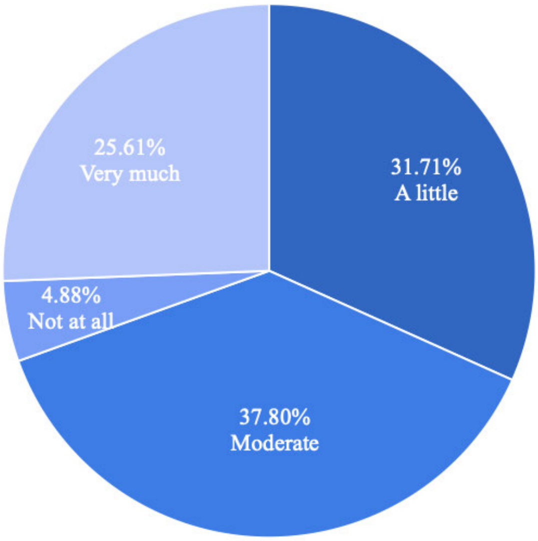


Figure 17: Participants asked about if the Job is physically Demanding

As shown in Figure 18, a high proportion of respondents, 91.4%, agreed to be working in a high temperature (22℃ or above), and the rest, 8.6%, did not work in a high-temperature environment. Furthermore, the participants were asked about how often do they work in a high-temperature environment about 41.6% very often work in a high-temperature environment, 32.5% sometimes worked in a high-temperature environment, whereas the rest, 23.4%, always worked in a high-temperature environment.

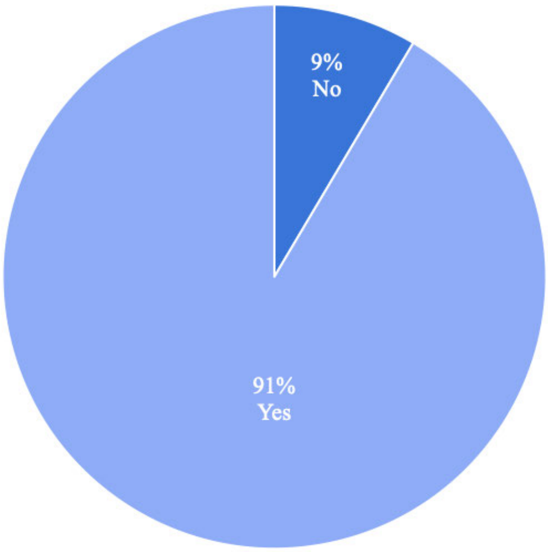


Figure 18: Participants working in High Temperature

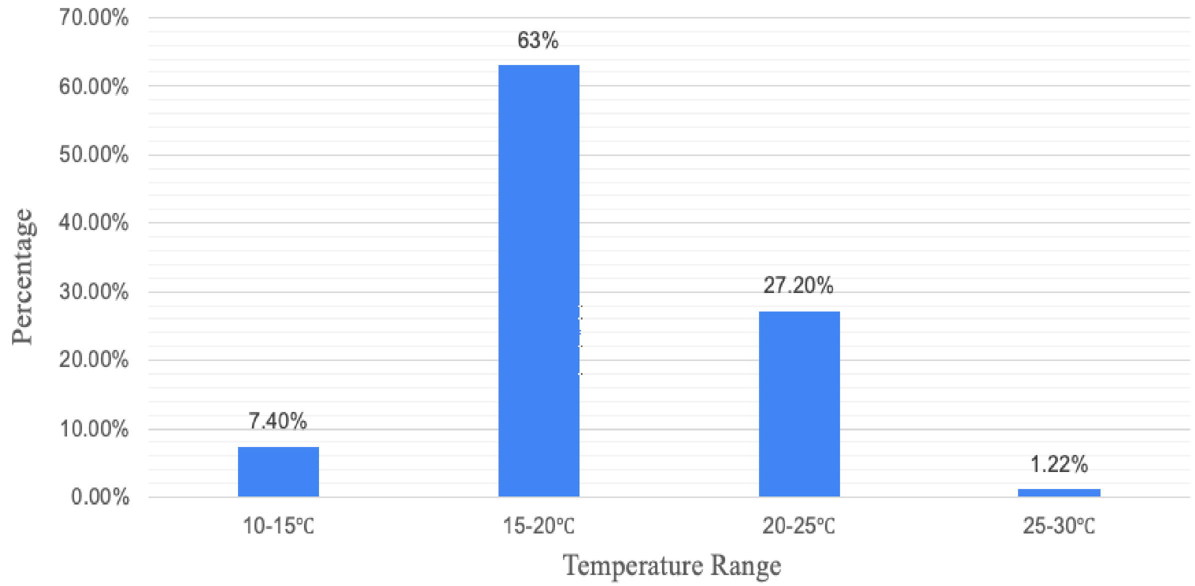


Figure 19: At what temperature range the participants felt comfortable.

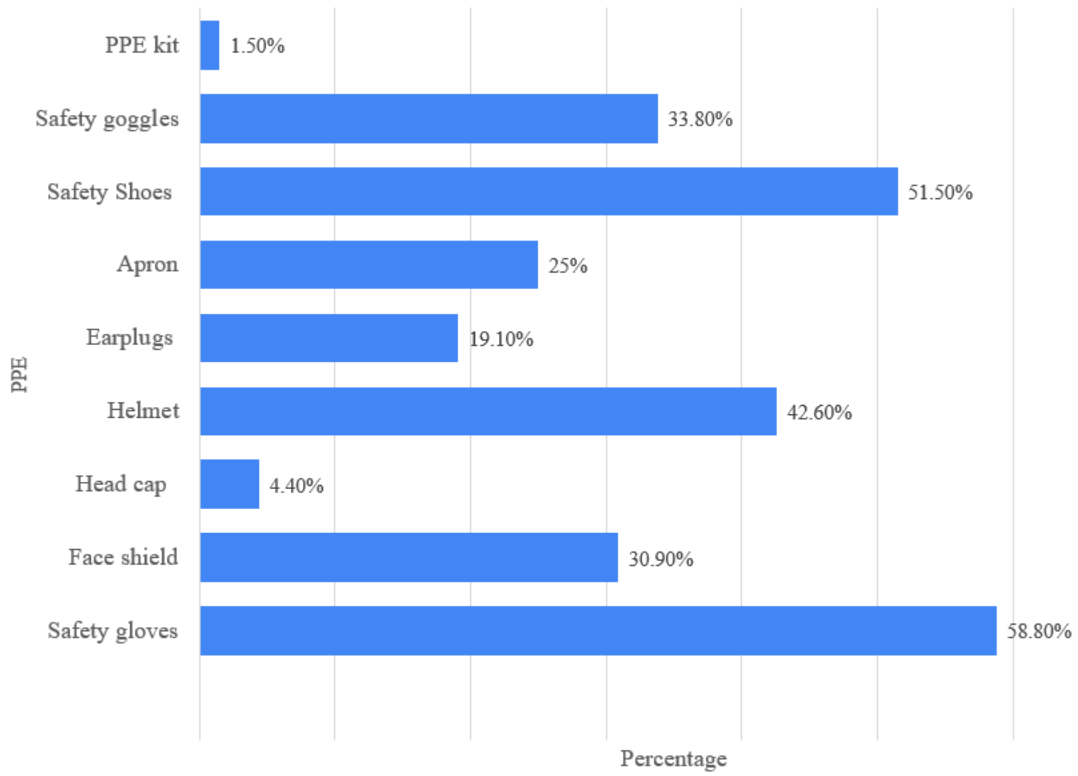


Figure 20: Various types of PPE used

More than 80.5% of participants use Personal Protective Equipment (PPE) while working, and the rest, 19.5%, do not use Personal Protective Equipment. Various Personal Protective Equipment's (PPE) is used by the respondents with the maximum usage of gloves 58.8%, followed by safety shoes 51.5%, helmet 42.6%, safety goggles 33.8%, face shield 30.9%, apron 25%, earplugs 19.1%, head cap 4.4% and PPE kit 1.5% (Figure 20).

About 36.6% of participants very often used PPE, 31% always have to used PPE while working, 21.1% sometimes used PPE, 5.6% rarely and never used PPE.

The use of face mask while working was asked about 57.3% respondents used face mask, 29.27% used face mask on some occasions while working, and the remaining 13.41% did not wear face mask as shown in Figure 21.

Participants were asked about the experience of various symptoms while working with face mask with a majority 84.3% experienced sweating around the mouth, about 48.6% have difficulty in breathing, 32.9% have fogging on glasses, 31.4% experience suffocation, 22.9% have mask anxiety, and remaining 8.6% have nothing as shown in Figure 22. The majority of respondents, 44.4%, wear T-shirts and pants/shorts while working, 39.5% wear lightweight and light-coloured clothes, 9.9% wear loose fitting clothes while working (Figure 23).

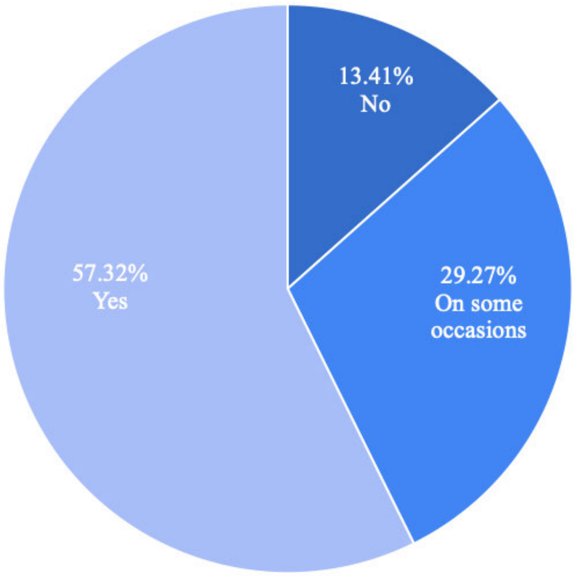


Figure 21: Requirement of Facemask during working by Participants

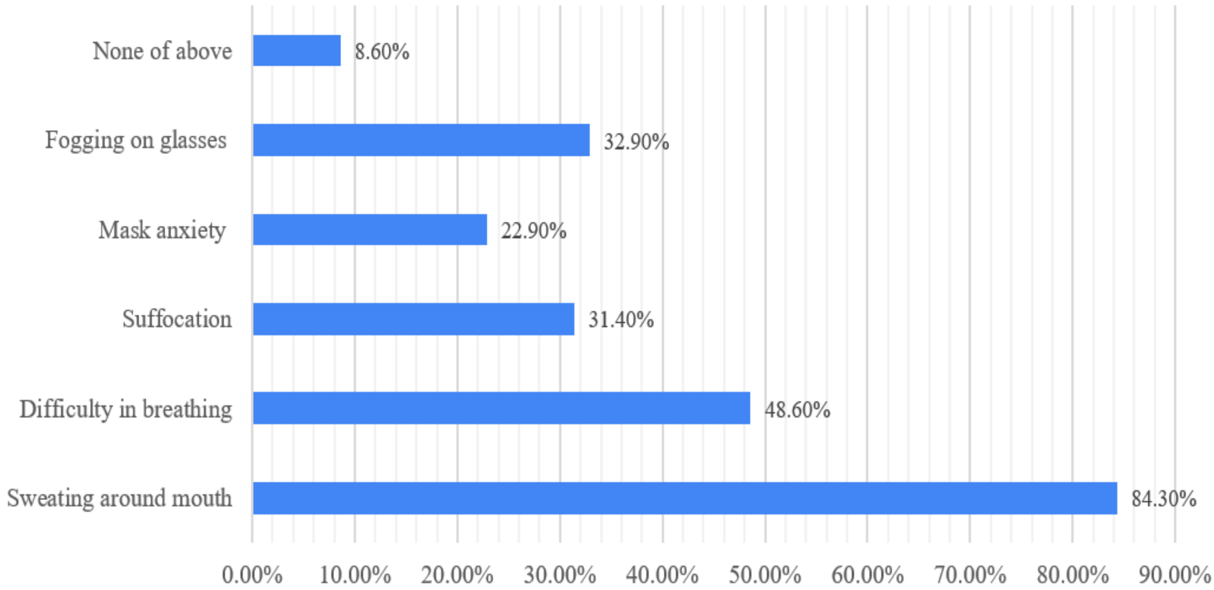


Figure 22: Symptoms experienced by Participants while using Facemask

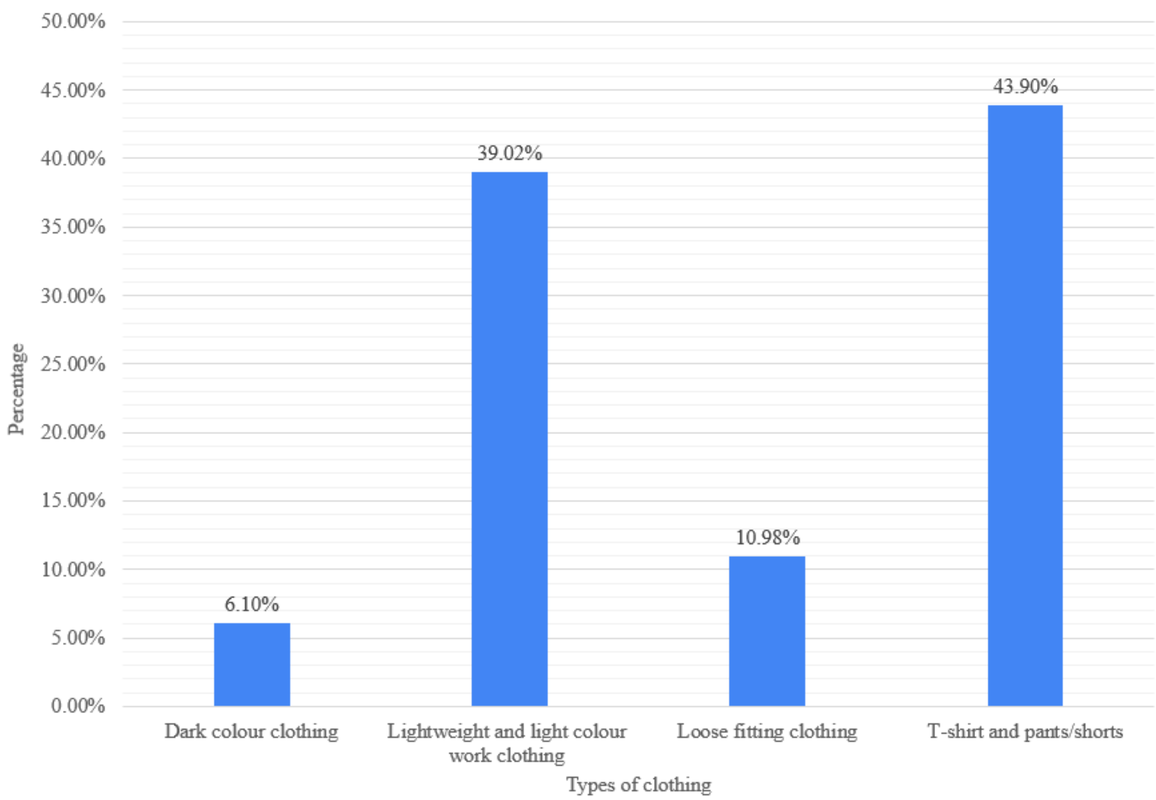


Figure 23: Type of clothing used while working

In the following Figure 24, a majority of participants (89%) felt unpleasantly warm air temperature at the workplace, and 11% felt pleasant and comfortable at the workplace. As seen in Figure 25, the participants were asked about the humidity level at the workplace; about 50.6% of participants felt dryness in throat and mouth, 37% felt too moist and humid, and the rest 12.3% felt the humidity level was appropriate and desirable. They were also asked about fluid consumption during hot weather. About 58.2% drank plenty of fluids regularly at work, and 36.7% agreed to drink too little or only when thirsty (Figure 26).

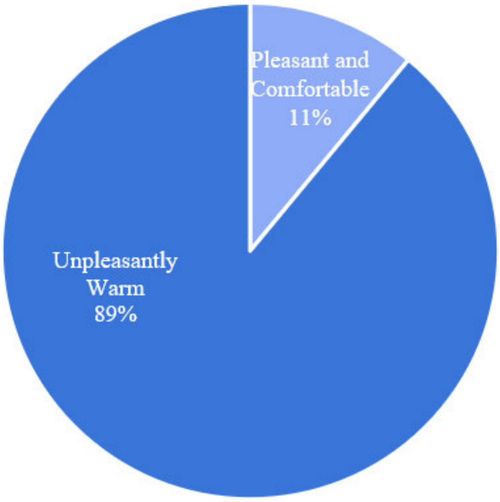


Figure 24: Participants feeling of air temperature

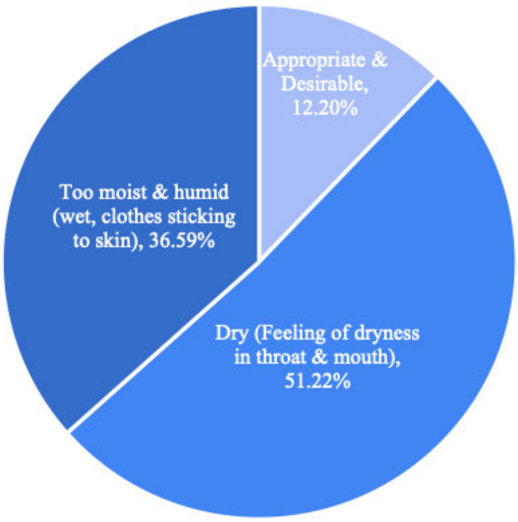


Figure 25: Humidity at workplace

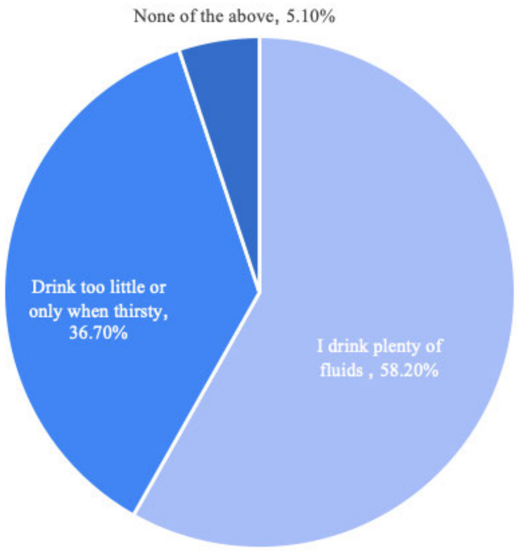


Figure 26: Fluid consumption of participants while working

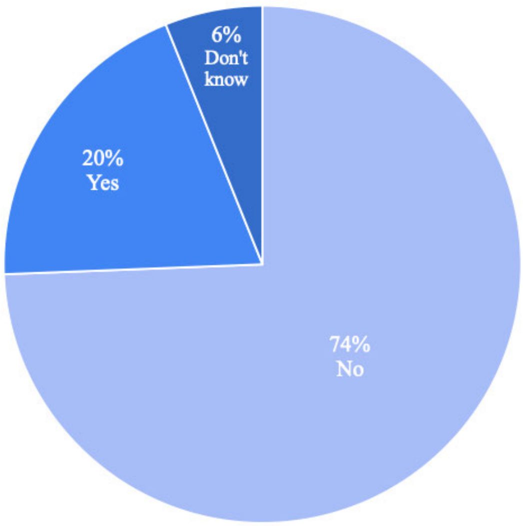


Figure 27: Absence from workplace due to heat

The respondents were asked about their absence from the workplace due to heat. A majority, 74.1%, were not absent due to heat at the workplace, while the rest, 19.8%, agreed to be absent from the workplace due to heat (Figure 27).

In the following Figure 28, the respondents were asked about the experience of any signs or symptoms due to heat at the workplace. A majority of workers, 86.4%, experienced tiredness, followed by 85.2% experienced heavy sweating, about 54.3% had heat-induced headaches, 49.4% experienced weakness, 43.2% had muscle cramps, about 33.3% had sunburns, 29.6%

experienced heat-induced dizziness, 27.2% had a high temperature, 21% had heat-induced anxiety, 9.9% experienced nausea, and the rest 6.2% had vomiting. About 46.3% of respondents experienced the above-mentioned symptoms sometimes, 43.9% very often experienced the symptoms (Figure 29).

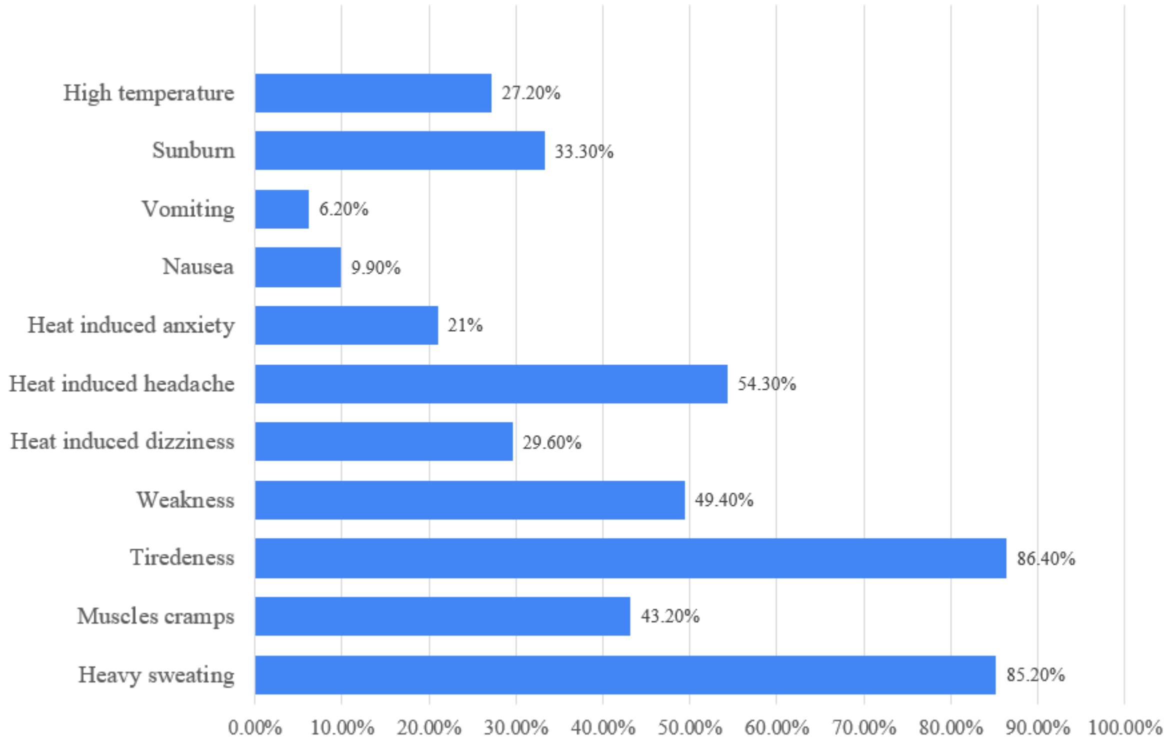


Figure 28: Participants experience of signs or symptoms due to heat

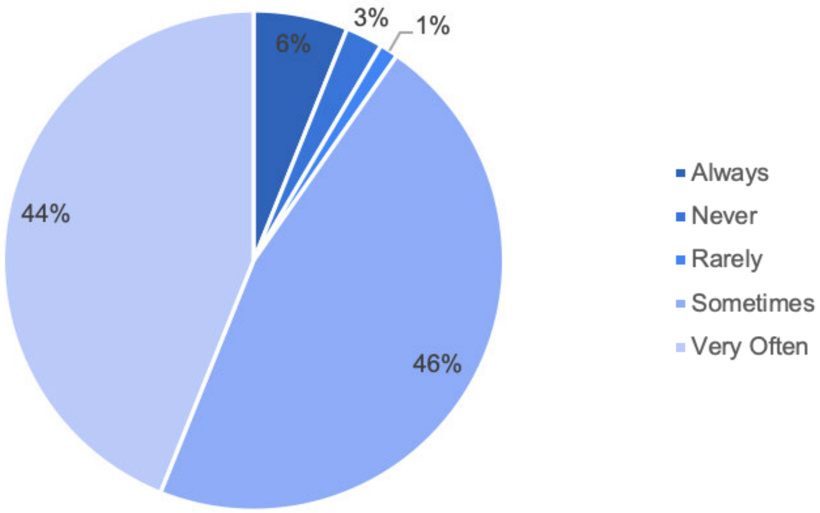


Figure 29: How often the participants experienced the symptoms

4.1.3. Heat Stress Prevention at Workplace

The participants were asked about if they are concerned the risk of heat stress. About 52.44% agreed to be a little concerned, 20.73% are very concerned, 14.63% are moderately concerned, and 12.20% are not at all concerned about the risk of heat stress (Figure 30).

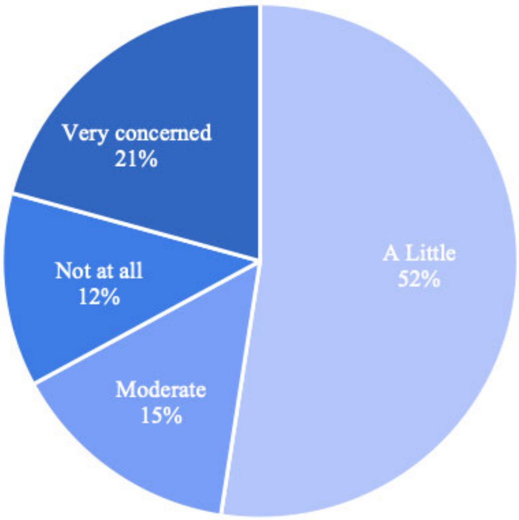


Figure 30: Concern of participants about heat stress

The respondents were questioned about the measures adopted at their workplace during hot weather. The majority of respondents, 89%, were provided cool drinking water for free at their workplace, followed by 53.7% were provided ventilation, 43.9% were provided shady rest areas while working outdoor, 34.1% could reschedule their work time, e.g., the start of work, extend break timings, 32.9% participants were provided electric fans, and 31.7% were provided shades, blinds, and curtains as seen in Figure 31.

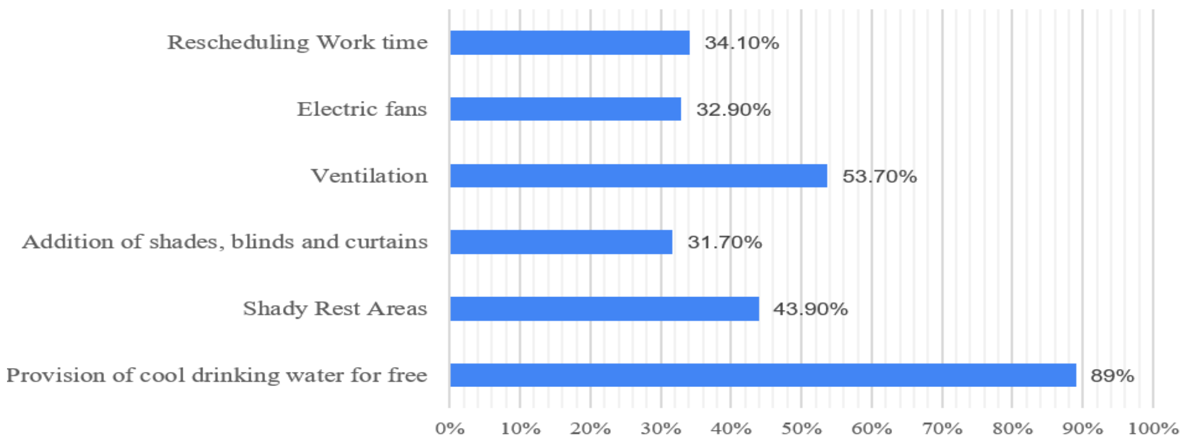


Figure 31: Measure adopted at workplace during heat events

The participants were asked about measures they consider are practical and useful at the workplace based on a Likert scale. About 56.1% of participants strongly agreed to the provision of natural ventilation, 34.1% of participants are expressed neutral agreement for the provision of Automatic ventilation, about 42.1% agreed to modify the workplace schedule, and 43.9% of respondents agreed for frequent rest periods, while working. For the provision of reflective heat-absorbing barriers and shields, 56.1% of participants agreed to the measure. About 46.3% expressed neutral agreement for training the supervisors regarding Heat stress, 47.5% of participants strongly agreed for the provision of cool drinking water at the workplace, 45.1% agreed to encourage workers to drink water and other fluids frequently while working, and 52.4% agreed to consider protective clothing that provides cooling. The following Figure 32 shows the frequency distribution of the results.

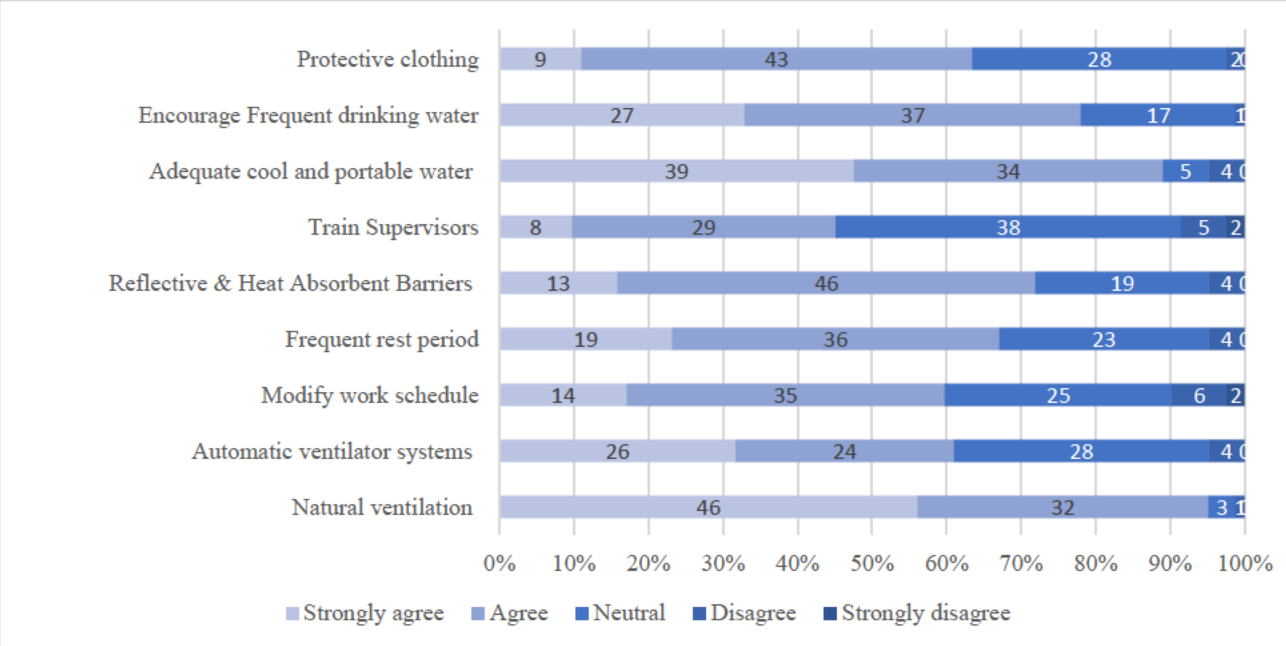


Figure 32: Distribution for the Level of agreement of participants about measures to be implemented at workplace

4.1.4. Statistical Analysis - Chi Square Test

To test the hypothesis, a chi-square test is used to test if high-temperature impacts the health of the working population. A significant association is noted between the two variables $p = 0.001$ with working in high temperature (subjective feeling of air temperature) is associated with increased frequency of symptoms of heat stress, as seen in Figure 33 and Table 8.

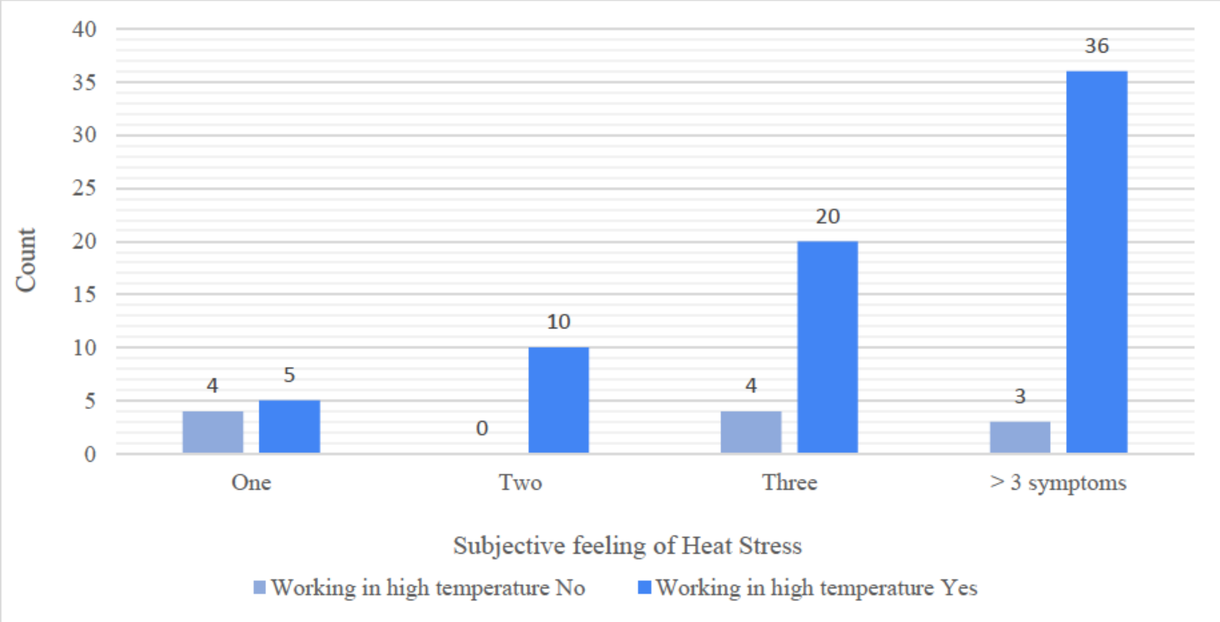


Figure 33: Graphical representation of working in high temperature and symptoms experienced

Table 8: Shows the Chi square test results and respective p-values for number of symptoms and working in high temperature

Variable	**Description**	**Working in high temperature**		**P value**
		No	**Yes**	
Number of Symptoms	One	4	5	0.001
	Two	0	10	
	Three	4	20	
	> 3 symptoms	3	36	
How often the signs are felt	Always	0	5	0.28
	Never	1	1	
	Rarely	0	1	
	Sometimes	3	35	
	Very often	3	33	

Moreover, only eight independent variables showed statistically significant results with a p-value less the 0.05, which are working completely outdoor, working for more than 6 hours, moderate to very much physical demanding jobs, people working in a high-temperature environment, worker's experiencing the humidity level too moist and humid, work that requires the use of PPE, comfortable temperature, and too little consumption of water (Table 9).

Table 9: Shows the result of Chi-Square test and respective p-values

		Subjective feeling of air temperature		Chi-square P value
		Pleasant and comfortable	**Unpleasantly warm**	
Type of Workplace	Completely indoors	6	12	0.003
	Completely outdoors	1	29	
	Partially Indoor/ Partially Outdoor	2	32	
Average work hours per day	4 - 6 hours	3	7	0.018
	6 - 8 hours	3	34	
	Less than 4 hours	2	3	
	More than 8 hours	1	29	
Average break	15 - 30 minutes	4	30	0.88
	30 - 45 minutes	3	26	
	45 - 60 minutes	1	7	
	60 - 90 minutes	0	2	
	Less than 15 minutes	0	5	
	No break	1	3	
Break time	Afternoon	6	42	0.69
	Evening	1	5	
	Noon	2	26	
Is the job physically demanding	A little	5	21	0.013
	Moderate	1	30	
	Not at all	2	2	
	Very much	1	20	
Working in a high temperature environment	No	3	4	0.018
	Yes	6	69	
Comfortable temperature	10-15	0	6	0.017
	15-20	4	47	
	20-25	4	20	
	25-30	1	0	
Humidity	Appropriate and desirable	7	3	0.0001
	Dry (feeling of dryness in throat and mouth)	2	40	
	Too moist and humid (wet, Clothes sticking to skin)	0	30	
Clothing	Dark color clothing	0	5	0.165

	Lightweight and light color work clothing	2	30	
	Loose fitting clothing	0	9	
	T-shirt and pants/shorts	7	29	
PPE usage required?	No	4	12	0.045
	Yes	5	61	
Frequency of usage of PPE	Always	2	20	0.22
	Never	1	3	
	Rarely	1	3	
	Sometimes	2	13	
	Very often	0	26	
Measures taken while working in a very hot weather	I drink plenty of fluids regularly while at work	9	40	0.033
	I feel that I probably drink too little or only when thirsty	0	29	
	None of the above	0	4	

The Temperature being unpleasantly warm (subjective feeling of heat stress) has a significant association with working completely and partially outdoor with a p-value of 0.003 as seen in Figure 34. A p-value of less the 0.05 is used to indicate statistical significance.

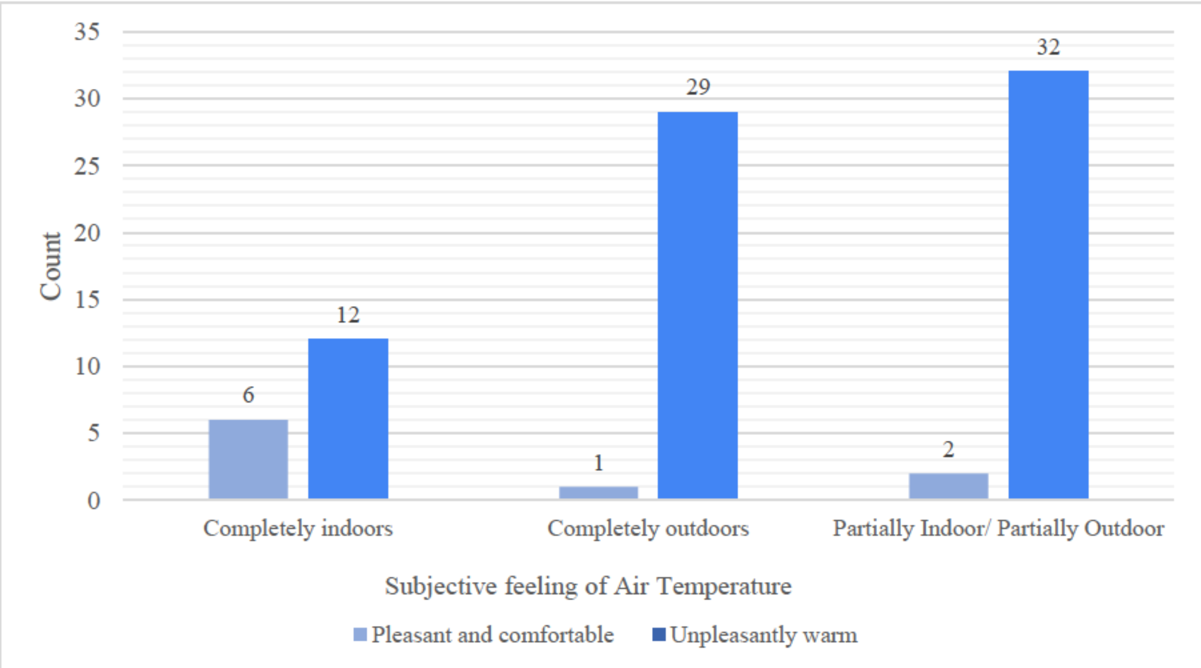


Figure 34: Graphical representation between air temperature and type of workplace

As seen in Figure 35, a significant relationship is noted between the temperature being unpleasantly warm and working for more than 6 hours with a *p*-value of 0.018.

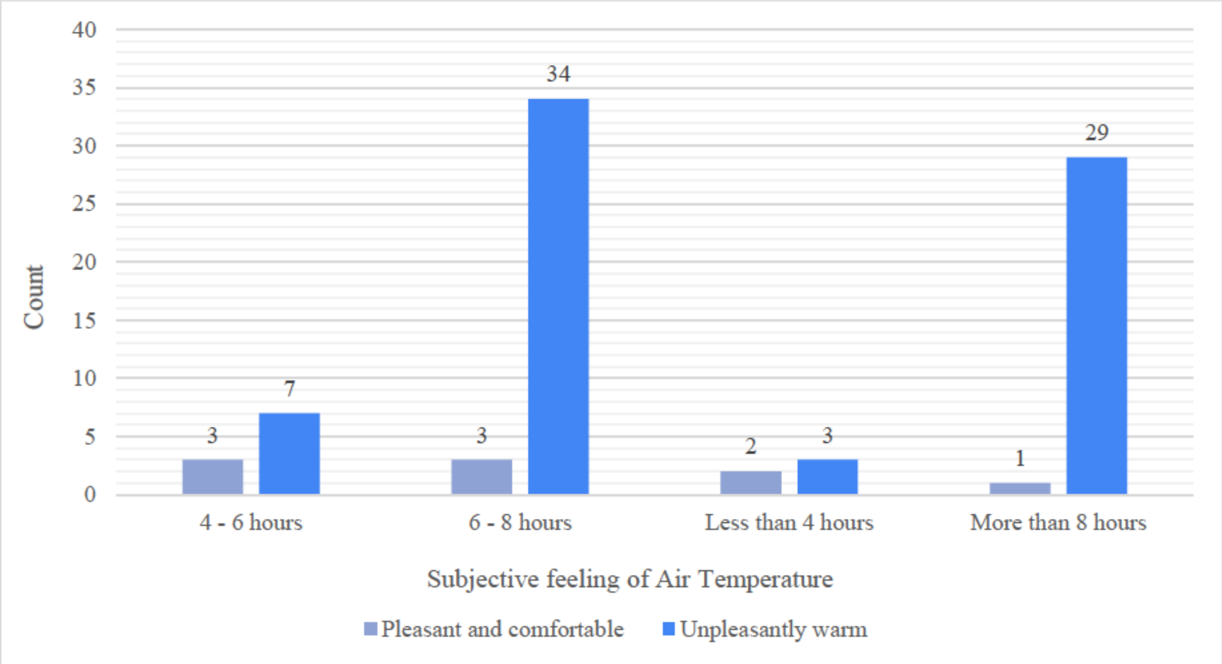


Figure 35: Graphical representation between air temperature and average work hours per day

Moreover, a significance value of 0.013 is seen between temperature being unpleasantly warm (subjective feeling), and little, moderate to very much physically demanding jobs as seen in Figure 36.

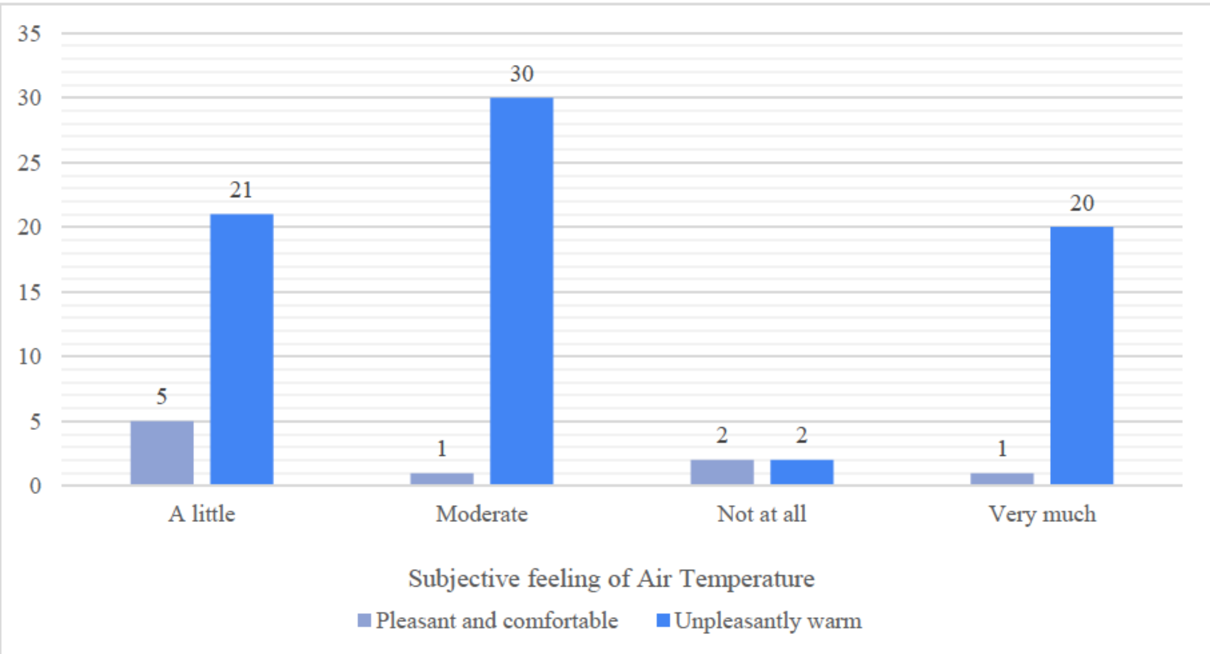


Figure 36: Graphical representation between air temperature and physically demanding job

As shown in Figure 37, a significant relationship is seen between the two variables. People working in a high-temperature environment are more likely to feel unpleasantly warm temperatures (p=0.18). Furthermore, the temperature being unpleasantly warm is significantly associated with workers experiencing too moist and humid (wet, Clothes sticking to the skin) while working with a p-value of 0.0001 (Figure 38).

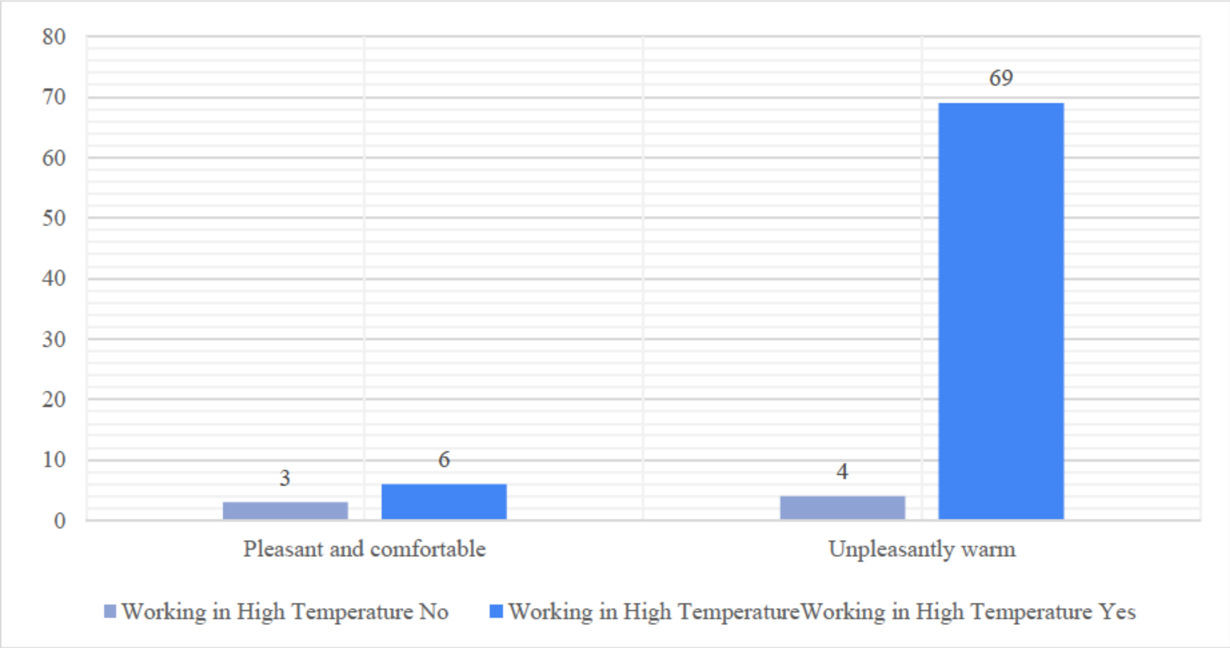


Figure 37: Graphical representation between air temperature and working in high temperature

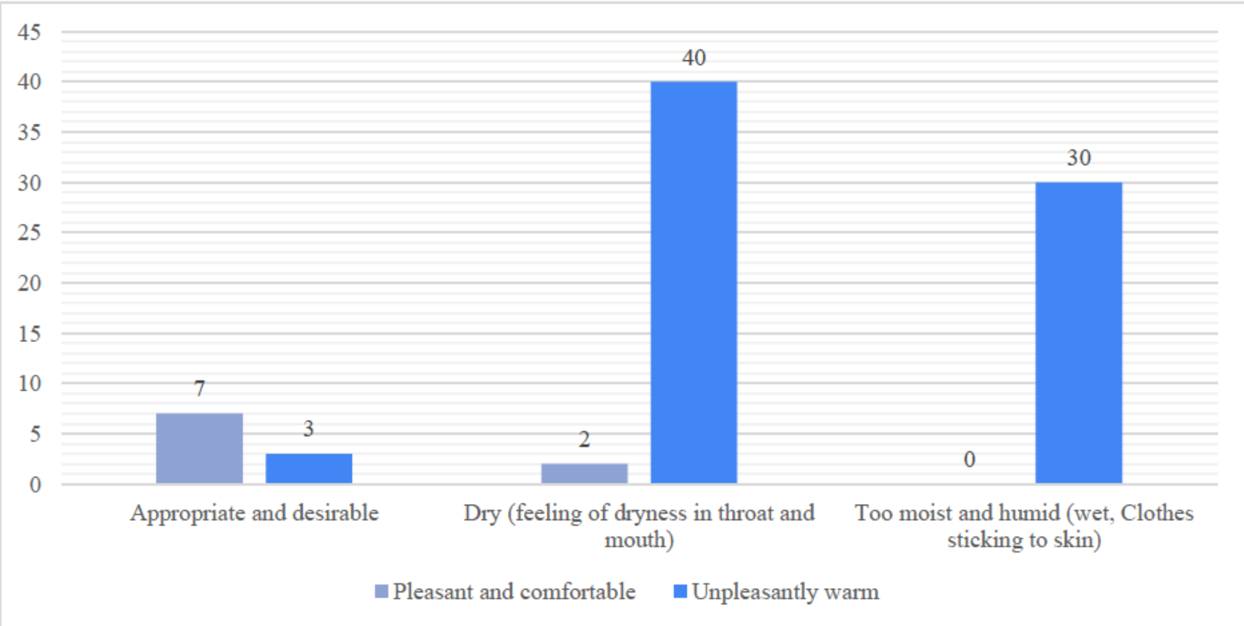


Figure 38: Graphical representation between air temperature and humidity

As shown in Figure 39, a significance value of 0.45 is recorded between temperature being unpleasantly warm and work that requires the use of PPE (Personal Protective Equipment's). Moreover, too little consumption of water is significantly associated with unpleasantly warm temperature with a *p*-value of 0.033 (Figure 40).

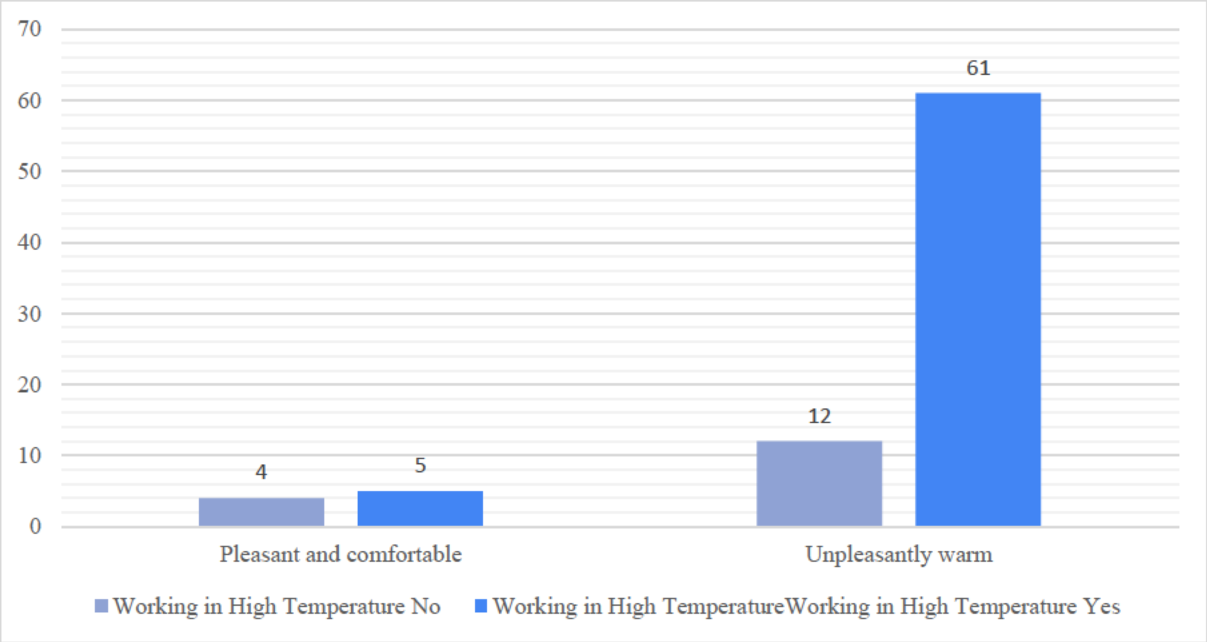


Figure 39: Graphical representation between air temperature and use of PPE

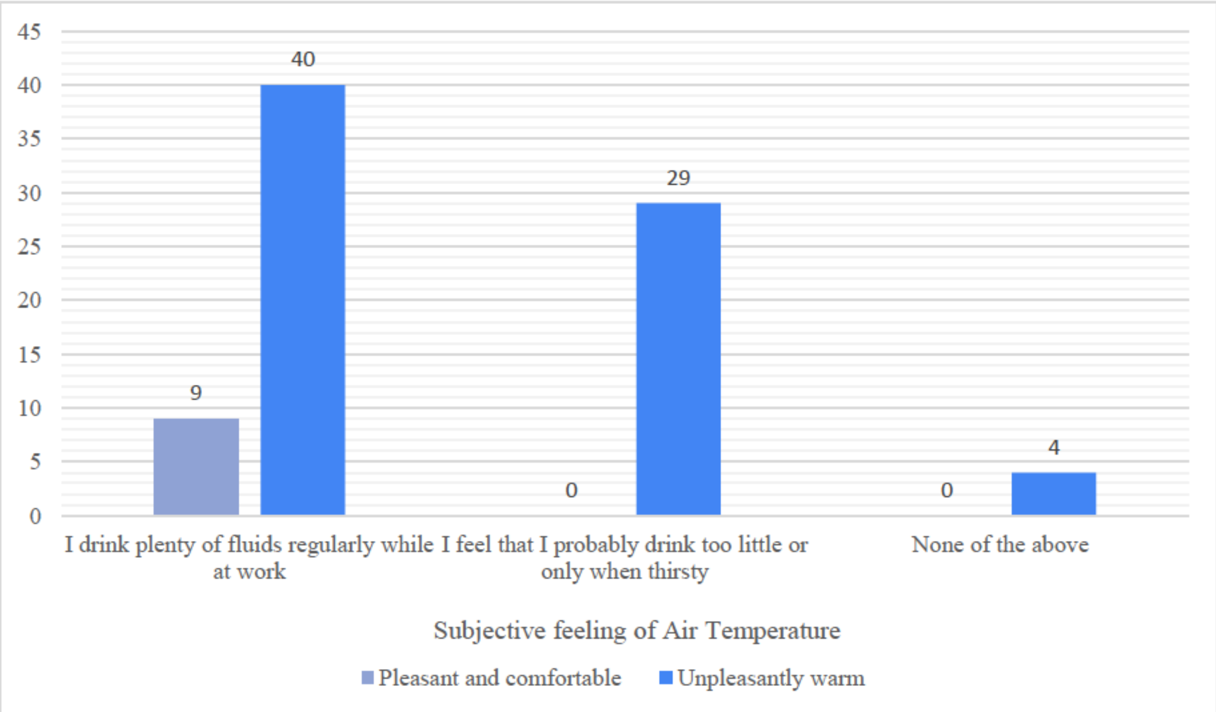


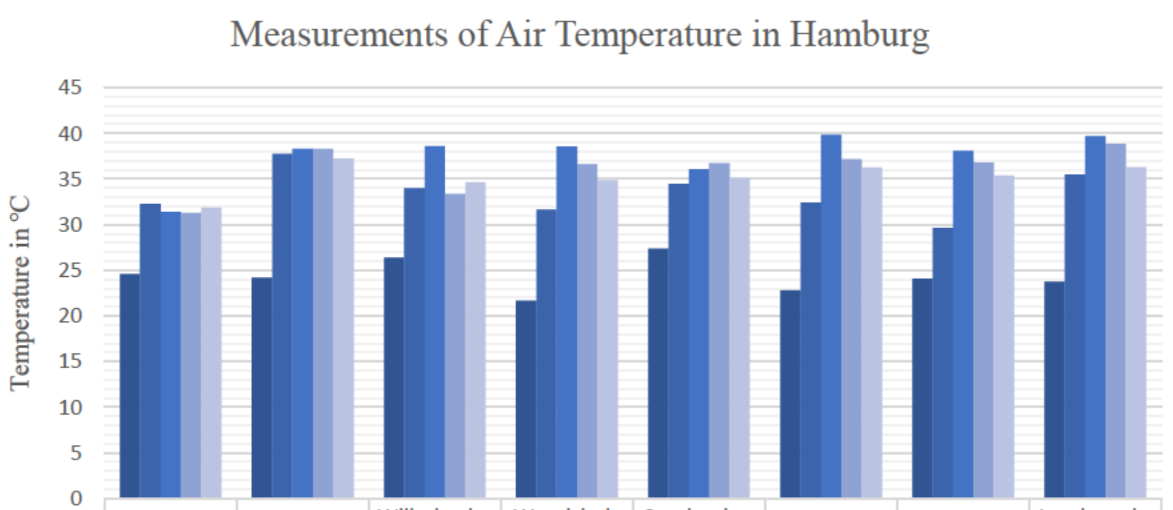
Figure 40: Graphical presentation between air temperature and fluid consumption

No significant association is seen between subjective feeling of air temperature with average breaks taken (p=0.88), break time (p=0.69), type of clothing (p=0.165), and frequency of use of PPE (p=0.22).

4.2. Results of Outdoor Temperature Measurements

The air temperature and air velocity measurements were taken on alternate days during different hours in various districts of Hamburg (Figure 41 and 42).

- On Day 1 of measurement, the highest temperature was recorded in Saarlandstraße 27.4°C with an air velocity of 0.48m/s, and the lowest was recorded in the Wandsbek Gartenstadt area 21.7°C with an air velocity of 1.09m/s.
- On Day 3 of measurement, in Harburg, the highest temperature was recorded 37.7°C with an air velocity of 0.51m/s, and the lowest was 29.6°C in Altona with 0.73m/s air velocity.

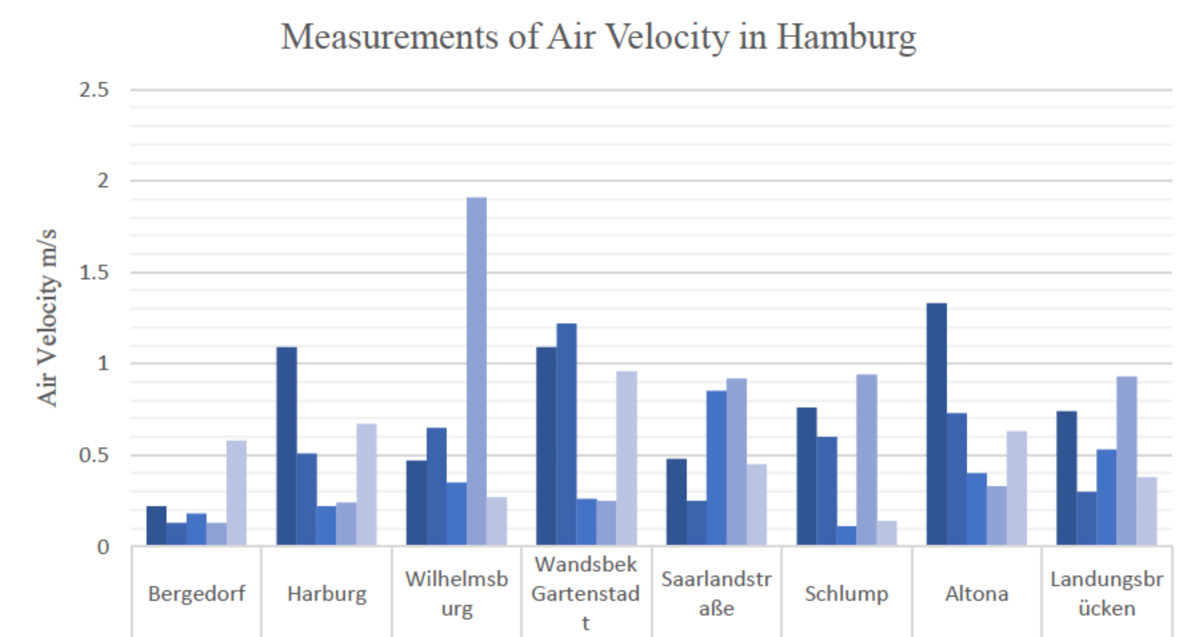


	Bergedorf	Harburg	Wilhelmsburg	Wandsbek Gartenstadt	Saarlandstraße	Schlump	Altona	Landungsbrücken
Day 1	24.60	24.20	26.40	21.67	27.40	22.83	24.10	23.77
Day 3	32.27	37.77	34.00	31.67	34.47	32.40	29.63	35.50
Day 5	31.40	38.30	38.63	38.57	36.10	39.87	38.10	39.70
Day 7	31.27	38.30	33.40	36.63	36.73	37.20	36.80	38.87
Day 9	31.87	37.27	34.67	34.87	35.13	36.27	35.40	36.30

Figure 41: Measurement of Air temperature in Hamburg, Germany

- On Day 5 of measurement, in Schlump, the highest temperature was 39.9°C; air velocity 0.11m/s and the lowest 31.4°C with air velocity 0.18m/s in Bergedorf.

- On Day 7, the highest temperature was recorded in Landungsbrücken 38.9°C; air velocity 0.93m/s, and the lowest was recorded in 31.3°C; air velocity 0.13m/s in Bergedorf.
- On Day 9, in Harburg, the highest temperature was 37.3°C; air velocity 0.67m/s, and the lowest was 31.9°C with an air velocity of 0.58m/s in Bergedorf.



	Bergedorf	Harburg	Wilhelmsburg	Wandsbek Gartenstadt	Saarlandstraße	Schlump	Altona	Landungsbrücken
Day 1	0.22	1.09	0.47	1.09	0.48	0.76	1.33	0.74
Day 3	0.13	0.51	0.65	1.22	0.25	0.6	0.73	0.3
Day 5	0.18	0.22	0.35	0.26	0.85	0.11	0.4	0.53
Day 7	0.13	0.24	1.91	0.25	0.92	0.94	0.33	0.93
Day 9	0.58	0.67	0.27	0.96	0.45	0.14	0.63	0.38

Figure 42: Measurement of Air Velocity in Hamburg, Germany

5. Discussion

5.1. Main findings:

Heat stress depends on different variables such as temperature, humidity, air, clothing, physical activity, shade, and other factors. The results indicate a significant association between the two variables p =0.001 with working in high temperature is associated with increased frequency of symptoms. The p-value is less than 0.05, which in terms support the H1: an alternate hypothesis. The alternate hypothesis is H1: High temperature does have an impact on the health of working population.

Moreover, the subjective feeling of air temperature while working is significantly associated with working completely outdoor (p=.003), working more than 6 hours (p=.018), moderate to very much physical demanding jobs (p=.013), working in hot temperature environment (p=.018), working in too moist and humid weather (p=.0001), using PPE while working (p=.045), and drinking too little water (p=.033). On the other hand, no significant association is seen between the subjective feeling of air temperature and an average break taken (p=.88), break time (p=.69) while working, clothing's (p=.165), and frequency of PPE usage (p=.22).

A similar study conducted in Thailand for a large national cohort (>40,000 subjects) reported similar findings that 18% population worked under heat stress conditions (self-reported heat stress) or working in uncomfortable high temperature at work, which further deteriorated the overall health and caused psychological distress in the workers. Heat stress more frequently occurred in males than females at work (Tawatsupa et al., 2010; Tawatsupa et al., 2013).

In a study by Xiang et al., 2014, it has been reported that about 70% of workers were dehydrated in Western Australia (Xiang et al., 2015). Similarly, Wagoner et al. 2020, also reported that the hydration status of outdoor workers with 50% of workers (n=48) was dehydrated in Costa Rica. People working in an agricultural and physically demanding occupation commonly report dehydration (Wagoner et al., 2020). Constant severe dehydration can impact kidney function, causing kidney dysfunction, acute renal failure, and hypotension (Nerbass et al., 2017; Venugopal et al., 2020).

A majority of participants (n=75), 91.4%, worked in high temperature, with 89% (n=74) respondents felt unpleasant while working. The increased vulnerability to heat during working is expected to occupational health risks and decrease labor productivity unless the preventive measures are not implemented (Kjellstrom et al., 2009a). Heat-related illness will be prevalent in construction workers, outdoor workers, and community service workers (Kjellstrom et al., 2016).

The data suggested that the workers' main symptoms due to heat were 86.4% tiredness, 85.2% experienced heavy sweating, 54.3% has heat-induced headaches, 49.4% weakness, 43.2% muscle cramps, 33.3% sunburns, 29.6% heat-induced dizziness, and 21% heat-induced anxiety. According to the IPCC (Intergovernmental Panel on Climate Change), the Fifth Assessment report classified discomfort, tiredness, weakness, exhaustion, heat cramps, and heat stroke as the direct effects of heat stress in humans (Lundgren et al., 2013).

Continuous heat exposure can result in heat-related health effects such as fatigue, exhaustion, muscle cramps, rashes, and kidney abnormalities (Crowe et al., 2015, Mac et al., 2017, Nerbass et al., 2017, Jayasekara et al., 2019). In an epidemiological review, it was stated that in summer, a self-administered questionnaire of 115 construction workers, Japanese male reported heat related subjective symptoms 63.7% reported feeling thirsty, 41.2% tiredness, 13.2% headache, 11.8% dizziness. These symptoms may cause an increased risk of occupational injuries (Xiang et al., 2014b).

5.2. Results in context of current scientific knowledge:

The survey-based study indicates the presence of impact of heat stress on the health of the working population. This study reports a significant association for heat stress impacts on workers' health in Hamburg, Germany. Furthermore, the study also identified other factors responsible for causing heat stress and the workers' prevention measures for future implementation to avoid heat stress at the workplace. The study also revealed that about 52% of the respondents were concerned about the impacts of heat stress. Even though heat stress is prevalent in developing countries but has not been reported in Germany, there should be adequate awareness and warning system regarding the consequences of heat stress at the workplace. In a cross-sectional study, about 90% of participants were informed about the heat warnings, but most participants did not consider themselves at heat risk, and only a few express changes in behavior after the warning (Kovats & Hajats, 2008).

By the end of the 21st century, the European working population will be affected by heat stress. The reason will be due to increased heat exposure, and the frequency of such situations will become prevalent in large areas of the continent. The South European continent will also be affected part of Central and Northern Europe, particularly for workers active in outdoor sunlight (Casanueva et al., 2020).

Climate change has worsened the heat effects for many workers and even in some places cooling systems or air conditioners are not available and are hard to provide. Heat stress is seen to be associated with diminishing muscle performance and decreased work capacity (Brode et al., 2018).

5.3. Result in context to the outdoor temperature measurement:

The highest air temperature recorded was 39.9°C with an air velocity of 0.11m/s in Schlump district. The reason might be due to the presence of more urban infrastructure and high traffic in the area. This effect is called the Urban Heat Island effect, is an area which exhibits high temperature compared to the rural or suburban surrounding. This effect is due to various factors such as air pollution in the urban area, anthropogenic heat, urban architecture, and variations in precipitation patterns (Filho et al., 2017; Heaviside et al., 2017). Whereas the lowest temperature recorded was 21.7°C with an air velocity of 1.09m/s in Wandsbek Gartenstadt, the reason for low temperature could be due to this district's presence on the outskirts with surrounded by more vegetation. The air velocity was seen to decrease with a rise in air temperature. The district in Hamburg, such as Landungsbrücken, Harburg, and Altona, recorded a high temperature above 35°C due to high traffic and more urban infrastructure. In many cities, the temperature is already close to 40°C and increasing over time. An addition of 3.58°C will make work (e.g., construction work) difficult during hot days in the cities (Kjellstrom et al., 2009).

5.4. Limitations of study

- The cross-sectional quantitative study done in Hamburg is not representative for other cities and regions in Germany. One main reason could be the frequency of temperature difference across the country. Moreover, the results cannot be generalised to other countries.
- In addition, a low response rate is seen for the survey participation as there were no voluntary participation. The construction workers and restaurant workers reported lack

of time for participation in the survey. Measurement errors could also occur due to participant misunderstanding the survey questions.

- With the sampling strategy a complete representation of the sample was not possible.
- No index measurement of Heat stress was performed which could have given appropriate results for the study.
- There is a limitation to the statistical power of any comparison due to small sample size.

6. Recommendation

Heat Illness can be prevented in the future. The main integral part of heat prevention is Heat risk awareness and knowledge. Implement effective Heat stress management at the workplace requires extensive cooperation and efforts by the various stakeholders such as Occupational Health safety providers, Government organizations, employers, and workers. The involvement of various stakeholders will help form heat prevention and adaptation guidelines at the workplace for the warming climate (Heat overview, OSHA).

In the working environment, workplace heat stress can be reduced by implementing the following (NIOSH, 2016; CDC, 2018; NIOSH, CDC, 2020):

I. Engineering Control
    a. Decrease humidity
    b. Increase air velocity
    c. Use heat-absorbing or reflective barriers
II. Practices at work
    a. Decrease exposure to heat
    b. Decrease physical activity
    c. Increase number of workers for one task
    d. Train supervisors and workers about heat stress
    e. Provision of cool drinking water
    f. Implementation of heat alarm program
    g. Develop acclimatization plan
    h. Emphasize the need for appropriate clothing's
    i. Heat-related illness surveillance

Acclimatization:

Acclimatization a process of physiological adaptations (e.g., increased sweating) which occurs after gradual exposure to a heat related environment. The following steps should be considered:

- Slowly increase the worker's time spent in the hot environment over a 7-14 days period.

- For previous workers, the acclimatization plan should be as follows day 1-50%, day 2-60%, day 3-80%, day 4-100%.
- For new workers, the plan should be no more than 20% for day one, and the same should be maintained for the additional days (NIOSH, 2016; CDC, 2018).

Hydration:

Appropriate means of hydration should be provided to workers:

- Encourage workers to drink frequently
- If the work is moderate, it is recommended to drink 1 cup of water every 15-20 minutes.
- In case of prolonged excessive sweating, drink electrolyte drinks such as sports drinks.
- Avoid sugar, alcohol and high caffeine (NIOSH, 2016; CDC, 2018).

7. Conclusion

This research aimed to determine the effects of heat stress on the health of the working population. Based on the cross-sectional quantitative analysis, it can be concluded that working in a high-temperature environment can cause an increased frequency of heat stress symptoms. Furthermore, the subjective feeling of air temperature (self-reported heat stress) can also occur in significance to various factors such as working outdoors, working in high temperature, high humidity, physically demanding job, working more than 6 hours, not drinking enough water. Hence, the results indicate the presence of heat stress impacts on workers' health in Hamburg. The air temperature measurements also indicate the rising temperature in Hamburg due to climate change.

Heat stress is an acknowledgeable occupational health problem, and adequate measures are required to maintain the workers' health and productivity. With an increase in global warming and ambiguous weather conditions, heat stress will become more frequent. To maintain a balance for the occurrence of heat stress, a proper early warning system is required, accurate methods are necessary to measure and determine heat exposure.

To better understand this research's implication, there is an urgent need for researchers to contribute to heat stress, especially in the European region. Even though heat stress is extensively researched in the past, but there is a lack of information on the future heat stress and its consequences on the human population in Europe. While developing the adaptive and preventive measures, the social, economic, and environmental aspects should be considered. Future research should focus on identifying the risk factors for the heat stress on workers and providing mitigation.

Furthermore, there should be a development and implementation of the heat action plan. The workers should be trained and should follow proper protocol in case of heat exposure during an emergency. Moreover, provision of ventilation and air condition should be made in public transports, offices, homes, etc. to decrease the heat stress during summer. If the work productivity is decreased due to heat stress, the country's economic growth will also be affected.

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9. Annexure I

9.1. Questionnaire Survey - English

Impacts of Heat stress on the Health of Working population during Summer Season in Hamburg, Germany.

My name is Aprajita Minhas. This questionnaire is part of study for my Master thesis at the Hamburg University of Applied Sciences. This questionnaire filling will take 5-10 minutes.
Please note that the information collected in this questionnaire is kept strictly confidential and is only used for the evaluation for the purpose of this study. Thank You in advance for your participation. Your contribution is greatly appreciated.

Part 1: Demographic

1. Gender
- Male
- Female
- Other

2. Age
- 15-20
- 21-30
- 31-40
- 41-50
- 51-60
- 60 and above

3. Do you live alone, or with others?
- alone, in a single household
- with a partner
- with my partner and children
- with my children alone
- with my parent/s
- with relatives or other friends
- with room mates

4. Education Level
- Post Graduate
- Graduate
- Diploma
- Completed Training Course
- High School
- No Schooling

5. Country of Origin? _____________

6. What is your current occupation? ________________

Part 2 – Heat stress & Workplace

7. What type of workplace environment do you currently work?
- Completely indoors
- Completely outdoors
- Partially Indoor / Partially Outdoor

8. Please indicate how many hours on average you work per day and how much of that working time is spent indoors and how much outdoors.

	Less than 4 hours	4-6 hours	6-8 hours	More than 8 hours	Not applicable
Average working hours per day					

How many hours Indoor?					
How many hours outdoor?					

9. How long is your average break while at work?
- No break
- Less than 15 minutes
- 15 – 30 minutes
- 30 – 45 minutes
- 45 minutes – 60 minutes
- 60 minutes – 90 minutes
- More than 90 minutes

9.1. How many breaks on average do you take in a usual working day?

Breaks	**0**	**1**	**2**	**3**	**4**	**5**
Short Break						
Long Break						
Cannot Say						

9.2. At what time of the day do you take your break?
- Morning
- Noon
- Afternoon
- Evening

10. Is your job physically demanding?
- Not at all
- A little
- Moderate
- Very much

11. Do you work in a high temperature environment (22℃ or above)?
- Yes
- No

11.1. If Yes, how often?
- Always
- Very often
- Sometimes
- Rarely
- Never

12. At which temperature range do you feel comfortable at?
- 10 ℃ – 15 ℃
- 15 ℃ – 20 ℃
- 20 ℃ – 25 ℃
- 25 ℃ – 30 ℃
- 30 ℃ or more

13. Does your job require the use of Personal Protective Equipment's (PPE)?
- Yes
- No

13.1. If Yes, please specify what type of Personal Protective Equipment's? (Multiple options can be selected)
- Safety Gloves
- Face shield
- Headcap
- Helmet
- Earplugs
- Apron
- Safety shoes

- Safety Goggles
- Others (Please specify) ___________

13.2. If Yes, how often do you use Protective clothing's?
- Always
- Very often
- Sometimes
- Rarely
- Never

13.3. On a scale of 1 to 5, how comfortable are you wearing the Personal Protective Equipment's?

Very uncomfortable ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Very comfortable

14. Are you required to wear face mask?
- Yes
- No
- On some occasion

14.1. If Yes, do you experience any of the following? (Multiple options can be selected)
- Sweating around mouth
- Difficulty in breathing
- Suffocation
- Mask anxiety
- Fogging on glasses
- Others (Please specify) ___________

15. What type of clothing's do you wear while working?
- T-shirt and pants/shorts
- Lightweight and light colour work clothing
- Loose fitting clothing
- Dark colour clothing
- Other (Please specify) _________

16. How do you feel about the air temperature at your workplace in the summer season?
- Pleasant and comfortable
- Unpleasantly Warm
- Unpleasantly Cold

17. How do feel about the humidity level at workplace?
- Dry (feeling of dryness in throat and mouth)
- Appropriate and desirable
- Too moist and humid (wet, Clothes sticking to skin)

18. Which of the following applies when you are working during very hot weather?
- I drink plenty of fluids regularly while at work
- I feel that I probably drink too little or only when thirsty
- None of the above

19. Have you been absent from work on account of heat (such as heat rashes, heat exhaustion or heat stroke etc) at work?
- Yes
- No
- Don't Know

19.1. If Yes, How often?
- More than 4 times a year
- Less than 4 times a year

20. Do you experience any of the following signs at your work place?
- Heavy sweating
- Muscle cramps
- Tiredness

- Weakness
- Heat induced Dizziness
- Heat induced Headache
- Heat induced anxiety
- Nausea
- Vomiting
- Sunburn
- High Temperature
- Other (Please specify) ________

20.1. How often do you feel the above-mentioned signs?
- Always
- Very often
- Sometimes
- Rarely
- Never

Part 3 – Prevention

21. How concerned are you about the risk of heat stress at work during hot weather?
- Not at all
- A little
- Moderate
- Very concerned

22. What measures are adopted in your workplace during hot weather?
- Provision of cool drinking water for free
- Shady rest areas
- Addition of shades, blinds, and curtains in the room
- Ventilation
- Electric fans
- Rescheduling work time e.g., start of work, extended break time
- Others (please specify) ___________

23. Which measures do you consider practical, appropriate and useful to make the workplace temperature pleasant? Please indicate your level of agreement with the following statements:

	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
Provision of natural ventilation (via windows)					
Provision of automatic ventilation system; electric fans, A/C at workplace (while working indoor)					
Modify work schedules.					
Arrange frequent rest periods.					
Use reflective or heat-absorbing shielding or barriers.					
Train supervisors and workers about heat stress.					
Provide adequate amounts of cool, portable water near the work area.					
Encourage workers to drink frequently.					
Consider protective clothing that provides cooling.					
Provision of shades, blinds, curtains to block heat indoor.					

9.2. Questionnaire Survey – German

Auswirkungen von Hitzestress auf die Gesundheit der arbeitenden Bevölkerung während der Sommersaison in Hamburg, Deutschland.

Mein Name ist Aprajita Minhas. Dieser Fragebogen ist Teil der Studie für meine Masterarbeit an der Hochschule für Angewandte Wissenschaften Hamburg. Das Ausfüllen des Fragebogens dauert 5-10 Minuten.

Bitte beachten Sie, dass die in diesem Fragebogen gesammelten Informationen streng vertraulich behandelt werden und nur für die Auswertung zum Zweck dieser Studie verwendet werden. Wir danken Ihnen im Voraus für Ihre Teilnahme. Ihr Beitrag wird sehr geschätzt.

Teil 1: Demographisch

1. Geschlecht
   - Männlich
   - Weiblich
   - Andere

2. Alter
   - 15-20
   - 21-30
   - 31-40
   - 41-50
   - 51-60
   - 60 und darüber

3. Leben Sie allein oder mit anderen?
   - allein, in einem einzigen Haushalt
   - mit einem Partner
   - mit meinem Partner und meinen Kindern
   - mit meinen Kindern allein
   - mit meinen Eltern
   - mit Verwandten oder anderen Freunden
   - mit Zimmergenossen

4. Ausbildungsstand
   - Postgraduierter
   - Absolvent
   - Gymnasium
   - Keine Schulbildung

5. Herkunftsland? ______________

6. Was ist Ihr derzeitiger Beruf? _________________

Teil 2 - Hitzebelastung & Arbeitsplatz

7. In welcher Art von Arbeitsumgebung arbeiten Sie derzeit?
   - Vollständig drinnen
   - Völlig im Freien
   - Teilweise drinnen/teilweise draußen

8. Bitte geben Sie an, wie viele Stunden Sie im Durchschnitt pro Tag arbeiten und wie viel dieser Arbeitszeit in Innenräumen und wie viel im Freien verbracht wird.

	Weniger als 4 Stunden	4-6 Stunden	6-8 Stunden	Mehr als 8 Stunden	Nicht anwendbar

Durchschnittliche Arbeitsstunden pro Tag					
Wie viele Stunden Innenraum?					
Wie viele Stunden draußen?					

9. Wie lang ist Ihre durchschnittliche Pause während der Arbeit?
   - Weniger als 15 Minuten
   - 15 - 30 Minuten
   - 30 - 45 Minuten
   - 45 Minuten - 60 Minuten
   - 60 Minuten - 90 Minuten
   - Mehr als 90 Minuten

9.1. Wie viele Pausen machen Sie im Durchschnitt an einem normalen Arbeitstag?

Pausen	**0**	**1**	**2**	**3**	**4**	**5**
Kurze Pause						
Lange Break						
Kann nicht sagen						

9.2. Wann machen Sie Ihre Pause? ___________

10. Ist Ihre Arbeit körperlich anstrengend?
    - Überhaupt nicht.
    - Ein wenig
    - Moderieren
    - Sehr viel

11. Arbeiten Sie in einer Hochtemperaturumgebung?
    - Ja
    - Nein

11.1. Wenn ja, wie oft?
   - Immer
   - Sehr oft (Täglich)
   - Manchmal (mindestens zweimal im Monat)
   - Selten (einmal pro Monat oder weniger)
   - Niemals

12. In welchem Temperaturbereich fühlen Sie sich wohl?
    - 10 ℃ – 15 ℃
    - 15 ℃ – 20 ℃
    - 20 ℃ – 25 ℃
    - 25 ℃ – 30 ℃
    - 30 ℃ oder mehr

13. Erfordert Ihre Arbeit die Verwendung von Schutzkleidung?
    - Ja
    - Nein

13.1. Wenn ja, geben Sie bitte welche Art von Schutzkleidung an? (Es können mehrere Optionen ausgewählt werden)

- Sicherheitshandschuhe
- Gesichtsschutz
- Kopfbedeckung
- Helm
- Ohrstöpsel
- Vorfeld
- Sicherheitsschuhe
- Schutzbrille
- Andere (bitte angeben) ____________

13.2. Wenn ja, wie oft verwenden Sie Schutzkleidung?
- Sehr oft
- Manchmal
- Selten
- Niemals

14. Sind Sie verpflichtet, eine Gesichtsmaske zu tragen?
- Ja
- Nein

14.1. Wenn ja, haben Sie eine der folgenden Erfahrungen? (Es können mehrere Optionen ausgewählt werden)
- Schwitzen um den Mund
- Atemschwierigkeiten
- Erstickung
- Masken-Angst
- Keiner der oben genannten
- Andere (bitte angeben) ____________

15. Welche Art von Kleidung tragen Sie bei der Arbeit?
- T-Shirt und Hosen/Shorts
- Leichte und farblose Arbeitskleidung
- Lose sitzende Kleidung
- Kleidung in dunkler Farbe
- Sonstiges (bitte angeben) _________

16. Wie denken Sie über die Lufttemperatur an Ihrem Arbeitsplatz in der Sommersaison?
- Angenehm und komfortabel
- Unangenehm warm
- Unangenehm kalt

17. Was halten Sie vom Feuchtigkeitsgehalt am Arbeitsplatz?
- Trocken (Trockenheitsgefühl in Rachen und Mund)
- Angemessen und wünschenswert
- Zu feucht und feucht (nass, Kleidung klebt auf der Haut)

18. Welcher der folgenden Punkte gilt, wenn Sie bei sehr heißem Wetter arbeiten?
- Ich trinke bei der Arbeit regelmäßig viel Flüssigkeit
- Ich habe das Gefühl, dass ich wahrscheinlich zu wenig trinke oder nur, wenn ich durstig bin
- Keiner der oben genannten

19. Waren Sie bei der Arbeit wegen Hitze (wie z.B. Hitzeausschläge, Hitzeerschöpfung oder Hitzschlag usw.) abwesend?
- Ja
- Nein
- Weiß es nicht

19.1. Wenn ja, wie oft?
- Mehr als 4 Mal pro Jahr
- Weniger als 4 Mal pro Jahr
- Niemals

20. Erleben Sie an Ihrem Arbeitsplatz eines der folgenden Zeichen?
- Starkes Schwitzen
- Muskelkrämpfe
- Müdigkeit
- Schwäche
- Hitzebedingter Schwindel
- Hitze-induzierter Kopfschmerz
- Hitzebedingte Angst
- Übelkeit
- Erbrechen

20.1. Wie oft spüren Sie die oben genannten Anzeichen?
- Sehr oft (einmal im Monat)
- Manchmal (einmal pro Jahr)
- Selten
- Niemals

Teil 3 – Prävention

21. Wie besorgt sind Sie über das Risiko von Hitzestress am Arbeitsplatz bei heißem Wetter?
- Überhaupt nicht.
- Ein wenig
- Moderieren
- Sehr besorgt

22. Welche Maßnahmen werden an Ihrem Arbeitsplatz bei heißem Wetter ergriffen?
- Kostenlose Bereitstellung von kühlem Trinkwasser
- Schattige Rastplätze
- Hinzufügen von Jalousien, Rollos und Vorhängen im Raum
- Elektrische Ventilatoren
- Umplanung der Arbeitszeit z.B. Arbeitsbeginn, verlängerte Pausenzeit
- Andere (bitte angeben) ___________

23. Welche Maßnahmen halten Sie für praktisch, angemessen und nützlich, um die Temperatur am Arbeitsplatz angenehm zu gestalten? Bitte geben Sie an, inwieweit Sie mit den folgenden Aussagen einverstanden sind:

	Stimmen nachdrücklich zu	Stimmen zu	Neutral	Nicht zustimmen	Stark anderer Meinung
Bereitstellung einer natürlichen Belüftung (über Fenster)					
Bereitstellung eines automatischen Belüftungssystems; elektrische Ventilatoren, Klimaanlage am Arbeitsplatz (bei der Arbeit in Innenräumen)					
Ändern Sie die Arbeitszeitpläne.					
Vereinbaren Sie häufige Ruhezeiten.					
Verwenden Sie reflektierende oder wärmeabsorbierende Abschirmungen oder Barrieren.					
Schulung von Aufsichtspersonen und Arbeitern über Hitzestress.					
Stellen Sie in der Nähe des Arbeitsbereichs ausreichende Mengen an kühlem, tragbarem Wasser bereit.					

Ermutigen Sie die Arbeitnehmer, häufig zu trinken.					
Ziehen Sie Schutzkleidung in Betracht, die für Kühlung sorgt.					
Bereitstellung von Jalousien, Rollläden, Vorhängen, um die Wärme im Inneren zu blockieren.					

9.3. Frequency Distribution of Study Variables

Variable	**Description**	**N**	**%**
Type of workplace	Completely indoors	18	22.0
	Completely outdoors	30	36.6
	Partially Indoor/ Partially Outdoor	34	41.5
Gender	Female	24	29.3
	Male	58	70.7
Age	15-20	3	3.7
	21-30	33	40.2
	31-40	22	26.8
	41-50	19	23.2
	51-60	5	6.1
Level of Education	Completed training course	11	13.4
	Diploma	21	25.6
	Graduate	30	36.6
	High School	10	12.2
	No Schooling	3	3.7
	Post Graduate	7	8.5
Average work hours per day	4 - 6 hours	10	12.2
	6 - 8 hours	37	45.1
	Less than 4 hours	5	6.1
	More than 8 hours	30	36.6
Average break per day	15 - 30 minutes	34	41.5
	30 - 45 minutes	29	35.4
	45 - 60 minutes	8	9.8
	60 - 90 minutes	2	2.4
	Less than 15 minutes	5	6.1
	No break	4	4.9
Break time	Afternoon	48	58.5
	Evening	6	7.3
	Noon	28	34.1
Is the job physically demanding	A little	26	31.7
	Moderate	31	37.8
	Not at all	4	4.9

	Very much	21	25.6
Working in high temperature environment?	No	8	9.8
	Yes	74	90.2
Comfortable temperature	10-15	6	7.3
	15-20	51	62.2
	20-25	24	29.3
	25-30	1	1.2
Does your job require the use of Personal Protective Equipment (PPE)?	No	16	19.5
	Yes	66	80.5
Are you required to wear a face mask?	No	11	13.4
	On some occasions	24	29.3
	Yes	47	57.3
Type of clothing at work	Dark color clothing	5	6.1
	Lightweight and light color work c	32	39.0
	Loose fitting clothing	9	11.0
	T-shirt and pants/shorts	36	43.9
How do feel about the humidity level at the workplace?	Appropriate and desirable	10	12.2
	Dry (feeling of dryness in throat and mouth)	42	51.2
	Too moist and humid (wet, Clothes sticking to skin)	30	36.6
Which of the following applies when you are working during very hot weather?	I drink plenty of fluids regularly while at work	49	59.8
	I feel that I probably drink too little or only when thirsty	29	35.4
	None of the above	4	4.9
Have you been absent from work on account of heat (such as heat rashes, heat stroke, etc) at work?	Don't Know	5	6.1
	No	61	74.4
	Yes	16	19.5
How often do you feel the signs of heat stress?	Always	5	6.1
	Never	2	2.4
	Rarely	1	1.2
	Sometimes	38	46.3
	Very often	36	43.9
How concerned are you about the risk of heat stress at work during hot weather?	A little	43	52.4
	Moderate	12	14.6
	Not at all	10	12.2
	Very concerned	17	20.7

9.4. SPSS Syntax:

```
DATASET ACTIVATE DataSet1.

CROSSTABS

  /TABLES=Type_of_Workplace Gender Age Education Average_Work_hours_perday Avrage_break Timeofbreak

    HOwmanybreaks Physically_demanding Working_in_high_temperature Comfortable_temperature PPE

    Face_Mask_Required_at_work Type_of_clothing Humidity_Subjective Hot_weather_measures_teken

    Absent_from_work_dueto_Heat Heat_stress_signs Symptoms Living_With Country_origin Occupation

    How_often Concerned_about_risk Measure_taken_in_workplace NAtural_Ventilation_Windows

    Automatic_V_system MOdify_wowk_schedule Frequent_rest_periods Reflective_Heat_absorbing_barriers

    Train_supervisors Cold_water Encourage_Frequent_drinking_water Protective_clothing

    Shades_blinds_curtains BY Air_Temperature_Subjective

  /FORMAT=AVALUE TABLES

  /STATISTICS=CHISQ

  /CELLS=COUNT

  /COUNT ROUND CELL.


CROSSTABS

  /TABLES=Symptoms How_often BY Working_in_high_temperature

  /FORMAT=AVALUE TABLES

  /STATISTICS=CHISQ

  /CELLS=COUNT

  /COUNT ROUND CELL.


FREQUENCIES VARIABLES=Type_of_Workplace Air_Temperature_Subjective Gender Age Education

    Average_Work_hours_perday Avrage_break Timeofbreak HOwmanybreaks Physically_demanding

    Working_in_high_temperature Comfortable_temperature PPE Face_Mask_Required_at_work Type_of_clothing
```

```
   Humidity_Subjective Hot_weather_measures_teken Absent_from_work_dueto_Heat
Heat_stress_signs
   How_often Concerned_about_risk Measure_taken_in_workplace
NAtural_Ventilation_Windows
   Automatic_V_system MOdify_wowk_schedule Frequent_rest_periods
Reflective_Heat_absorbing_barriers
   Train_supervisors Cold_water Encourage_Frequent_drinking_water Protective_clothing
   Shades_blinds_curtains Symptoms Living_With
  /PIECHART FREQ
  /ORDER=ANALYSIS.

FREQUENCIES VARIABLES=Country_origin Occupation
  /BARCHART FREQ
  /ORDER=ANALYSIS
```

9.5. Measurement of Air Temperature and Air Velocity:

9.5.1. Measurement Day 1

Place	Temperature 1 (°C)	Air Velocity 1 (m/s)	Temperature 2	Air Velocity 2	Temperature 3	Air Velocity 3
Bergedorf	23.7	0.25	24.7	0.12	25.4	0.3
Harburg	24.3	0.8	23.6	2.2	24.7	0.26
Wilhelmsburg	24.3	0.44	26.6	0.48	28.3	0.5
Wandsbek Gartenstadt	22.1	1.34	21.5	0.8	21.4	1.14
Saarlandstraße	27.3	0.65	28.2	0.3	26.7	0.5
Schlump	22.1	1.24	24	0.18	22.4	0.86
Altona	24.2	2.1	23.6	1.67	24.5	0.21
Landungsbrücken	23.4	0.9	24.9	0.62	23	0.71

9.5.2. Measurement Day 2

Place	Temperature 1 (°C)	Air Velocity 1 (m/s)	Temperature 2	Air Velocity 2	Temperature 3	Air Velocity 3
Bergedorf	30.6	0.11	31.6	0.16	34.6	0.11
Harburg	35.4	0.54	38.9	0.68	39	0.3
Wilhelmsburg	32.4	0.77	34.6	0.14	35	1.05
Wandsbek Gartenstadt	31.7	0.55	30.9	2.51	32.4	0.61
Saarlandstraße	33.6	0.1	35.4	0.28	34.4	0.38
Schlump	32.2	0.12	31.9	0.59	33.1	1.08
Altona	22.9	0.67	33.3	1.12	32.7	0.39
Landungsbrücken	35	0.28	36.9	0.41	34.6	0.22

9.5.3. Measurement Day 3

Place	Temperature 1 (°C)	Air Velocity 1 (m/s)	Temperature 2	Air Velocity 2	Temperature 3	Air Velocity 3
Bergedorf	30.8	0.08	31.4	0.33	32	0.12
Harburg	37.8	0.19	39.2	0.33	37.9	0.13
Wilhelmsburg	37.2	0.48	38.3	0.15	40.4	0.41
Wandsbek Gartenstadt	37.7	0.23	38.8	0.2	39.2	0.36
Saarlandstraße	35.9	0.56	37	0.18	35.4	1.82
Schlump	39.7	0.12	40.2	0.06	39.7	0.15
Altona	37	0.24	39.1	0.38	38.2	0.57
Landungsbrücken	38.6	1.29	39.5	0.27	41	0.02

9.5.4. Measurement Day 4

Place	Temperature 1 (°C)	Air Velocity 1 (m/s)	Temperature 2	Air Velocity 2	Temperature 3	Air Velocity 3
Bergedorf	30.5	0.08	31.3	0.23	32	0.09
Harburg	37.7	0.3	38.1	0.05	39.1	0.38
Wilhelmsburg	34	1.61	33.2	1.84	33	2.27
Wandsbek Gartenstadt	36.2	0.28	36.5	0.25	37.2	0.22
Saarlandstraße	36.2	1.57	36.9	0.26	37.1	0.94
Schlump	36.4	0.89	37.2	1.24	38	0.7
Altona	36	0.23	37	0.56	37.4	0.19
Landungsbrücken	38.2	0.19	38.9	1.22	39.5	1.39

9.5.5. Measurement Day 5

Place	Temperature 1 (°C)	Air Velocity 1 (m/s)	Temperature 2	Air Velocity 2	Temperature 3	Air Velocity 3
Bergedorf	31	0.12	31.6	0.78	33	0.83
Harburg	36.4	0.3	37.5	0.8	37.9	0.9
Wilhelmsburg	34	0.08	34.7	0.21	35.3	0.53
Wandsbek Gartenstadt	34.2	2.34	34.9	0.08	35.5	0.47
Saarlandstraße	34.3	0.3	35.2	0.36	35.9	0.7
Schlump	35.5	0.21	36.2	0.07	37.1	0.14
Altona	34.7	0.83	35.5	0.84	36	0.23
Landungsbrücken	35.1	0.36	36.4	0.72	37.4	0.06

10. Annexure II - Declaration

<u>Declaration</u>

I declare that I have written and developed this Thesis "**Impacts of Heat Stress on the Health of Working Population during Summer season in Hamburg, Germany**" for the Masters Program in Public Health. The information provided for the thesis is duly acknowledged with proper citations and references. This Master thesis has not been presented for another degree program or published anywhere else.

Aprajita Minhas 10.02.2021, Hamburg