

**AKENTEN APPIAH- MENKA UNIVERSITY OF SKILLS TRAINING
AND ENTREPRENEURIAL DEVELOPMENT**



MPHIL THESIS

**HEAT STRESS AND MITIGATION STRATEGIES FOR CONSTRUCTION
WORKERS, GHANA**

**BY
PATRICK ADDAE**

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**AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND
ENTREPRENEURIAL DEVELOPMENT**

**HEAT STRESS AND MITIGATION STRATEGIES FOR CONSTRUCTION
WORKERS, GHANA**

**BY
PATRICK ADDAE
(8221930016)**

**A Thesis Submitted to the Department of Public Health Education of the Faculty
of Environment and Health Education, Akenten Appiah-Menka University of
Skills Training and Entrepreneurial Development, in Partial Fulfilment of the
requirements for the award of a Master of Philosophy degree in Environmental
and Occupational Health Education.**

MARCH, 2025

DECLARATION

Candidate's declaration

I hereby declare that, except for references to other people's work, which have been duly acknowledged, this thesis work is the result of my work, and it has neither in whole nor partially been presented elsewhere.

Candidate's Name: PATRICK ADDAE

Signature:

Date:

Supervisors' Declaration

We hereby declare that the preparation and presentation of this thesis were supervised under the guidelines on supervision of the thesis laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

Principal Supervisor's Name: DR. DENIS DEKUGMEN YAR

Signature:

Date:

Co-supervisor's Name: DR. NANA YAA AWUA-BOATENG

Signature:

Date:

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I thank the ALMIGHTY GOD for making this research work and my study very successful. Many have contributed significantly to the completion of this thesis. My earnest appreciation goes to my supervisors, Dr. Denis Dekugmen Yar and Dr Nana Yaa-Awua-Boateng, for their exceptional supervision, advice and support in finishing this thesis. I am also grateful to Mr Ahmed Adjei for his tremendous assistance and support. I would also like to take this opportunity to thank anybody who, in one way or another, helped make my study and this project, a success. To all my friends and loved ones whose support and care helped me overcome setbacks in the course of this work, as well as my entire graduate study, I say a big thank you to you all.

DEDICATION

I dedicate this work to Mrs Vanessa Marfo for her financial support and encouragement throughout my studies. I am also grateful to my family for their support in diverse ways in undertaking this research work.

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ETHICAL APPROVAL LETTER



Kwame Nkrumah
University of Science
and Technology, Kumasi

College of Health Sciences
SCHOOL OF MEDICINE AND DENTISTRY

COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

Our Ref: CHRPE/AP/1247/24

27th November 2024

Dr. Denis Dekugmen Yar
Department of Public Health Education
Akenten Appiah Menka University of
Skills Training and Entrepreneurial Development
AAMUSTED-KUMASI.

Dear Sir,

LETTER OF APPROVAL

Protocol Title: *"Heat Stress and Mitigation Strategies among Construction Workers at the Tema Port Expansion Project, Ghana."*

Proposed Site: *TEMA Port, Expansion Project Phase 2.*

Sponsor: *Self-Sponsored.*

Your submission to the Committee on Human Research, Publications, and Ethics on the protocol named earlier refer.

The Committee reviewed the following documents:

- A Completed CHRPE Application Form.
- Participant Information Leaflet and Consent Form.
- Research Protocol.
- Questionnaire.

The Committee has considered the ethical merit of your submission and approved the protocol. The approval is for one year, renewable from **27th November 2024 to 26th November 2025**. The Committee may, however, suspend or withdraw ethical approval at any time if your study is found to contravene the approved protocol.

Data gathered for the study should be used for the approved purposes only. Permission should be sought from the Committee if any amendment to the protocol or use, other than submitted, is made of your research data.

The Committee should be notified of the actual start date of the project and would expect a report on your study, annually or at the close of the project, whichever one comes first. It should also be informed of any publication arising from the study.

Thank you for your application.

Yours faithfully,

Rev. Prof. John Appiah-Poku,
Honorary Secretary
FOR: CHAIRMAN

PROFESSIONAL EDITORIAL ASSISTANCE

Approval Letter from Tema Port Expansion Project

THE CHAIRMAN
COMMITTEE ON HUMAN RESEARCH, PUBLICATIONS AND ETHICS
KNUST- KUMASI.

ACCEPTANCE LETTER

Mr Patrick Addae, MPhil Environmental and Occupational Health of Akenten Appiah-Menka University, intended to conduct a study titled *“Heat Stress and Mitigation Strategies for Construction Workers at the Tema Port Expansion Project, Ghana”*.

Management of the project has given approval for the study on the condition that ethical approval is obtained from your outfit.

Kindly provide him with the necessary support needed to undertake the study.

Thank you



MR AHMED ADJEI
HEALTH AND SAFETY MANAGER (AECOM) TEMA
Cc: Mr. Patrick Addae (Principal Investigator)

LIST OF ACRONYMS

AAMUSTED	Akenten Appiah-Menka University of Skill Training and Entrepreneurial Development
AECOM	Architecture, Engineering, Construction, Operations, and Management
CDC	Centers for Disease Control and Prevention
CHRPE	Committee on Human Research, Publications, and Ethics
CONSAR	Comisión Nacional del Sistema de Ahorro para el Retiro
GSA	Ghana Standard Authority
GHS	Ghana Health Service
IPCC	Intergovernmental Panel on Climate Change
HIS	Heat Stress Index
IBM; SPSS	International Business Machines; Statistical Package for the Social Sciences
ILO	International Labour Organization
JV	Joint Venture
KNUST	Kwame Nkrumah University of Science and Technology
MELR	Ministry of Employment and Labour Relations
(NIC)	National Insurance Commission
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PPE	personal protective equipment
Ref	Reference
SMS	School of Medical Sciences
TPEP	Tema Port Expansion Project
WBGT	Wet Bulb Globe Temperature
WHO	World Health Organisation

ABSTRACT

This study evaluated heat stress and mitigation strategies among Ghana's Tema Port Expansion Project construction workers. A cross-sectional study design was used to assess the awareness and prevalence of heat stress and its mitigation strategies among workers at the Tema Port Expansion. The study recruited and assessed 84 participants at two Tema Port Expansion project locations. Data on socio-demographic characteristics, knowledge and prevalence of heat stress, and mitigation measures were collected face-to-face using a structured questionnaire. The data was analysed using SPSS version 27. Descriptive statistics and chi-square tests were used to determine the association of knowledge of heat stress, demographics, working experience, the impact of heat stress, and other variables accounting for heat stress. A logistics regression model was employed to assess the association between sociodemographic characteristics, knowledge of heat stress, and mitigation measures with heat stress outcomes. The results showed that most participants in the study were male (73.3%), with half having tertiary education. Awareness of heat stress was high (93%), yet 40.7% had no training, and 20.9% lacked induction on heat stress mitigation. There was no association between the sociodemographic characteristics of construction workers and the impact of heat stress on their health and work performance. However, gender and educational level were associated with heat stress exposure ($\chi^2 = 3.7$, $p = 0.044$ and $\chi^2 = 7.4$, $p = 0.025$, respectively). Female construction workers were four times more likely to suffer from heat stress than males (AOR = 4.2, 95% CI: 1.210-19.788, $p = 0.036$). Participants with tertiary education were 68% less likely to suffer from heat stress than their counterparts (AOR = 0.32, 95% CI: 0.103-0.904, $p = 0.027$). Working experience was associated with a heat stress mitigation plan ($\chi^2 = 11.8$, $p = 0.019$). Construction workers with 3-5 years of experience were 93.3% less likely to acknowledge the presence of a heat stress mitigation plan on site than their counterparts (AOR = 0.067, 95% CI: 0.007-0.605, $p = 0.016$). Construction workers at the Tema Port Expansion Project were highly aware of heat stress but lacked formal training on mitigation. Despite recognizing heat stress as a serious health risk, workers faced pressure to limit water intake and lacked emergency protocols. Heat stress mitigation strategies were inadequate, with no on-site shaded areas, cooling devices, or hydration measures. Many workers reported no formal heat stress plan. In conclusion, this study indicates that construction workers at the Tema Port Expansion Project are highly aware of heat stress and its associated risks. However, no significant correlation was found between sociodemographic factors and the effects of heat stress on workers' health or job performance. Nonetheless, gender and education were identified as factors influencing the experience of heat stress. Additionally, workers with 3–5 years of experience were less likely to recognize the presence of a heat stress mitigation plan on-site than those with more experience. Hence, workers should prioritize staying hydrated and taking frequent breaks, especially during the hottest hours of the day, to minimize the risk of heat-related illnesses. Targeted training should be provided to workers with fewer years of experience to improve their recognition and adherence to heat stress mitigation plans.

KEYWORDS: Heat stress, Headache, Heat rashes, Foot rot, and Construction workers.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Globally, climate change has intensified the frequency and severity of extreme heat events, disproportionately impacting outdoor workers in physically demanding fields such as construction (Schulte *et al.*, 2023). Reports from the Intergovernmental Panel on Climate Change (IPCC) suggest that sweltering days will rise in the coming decades, posing serious health risks to millions of workers worldwide (Alharbi, 2022). Heat stress is characterised by symptoms ranging from heat exhaustion to cardiovascular issues, which are exacerbated by inadequate rest periods, limited hydration access, and insufficient protective measures in many outdoor settings (Ebi *et al.*, 2021). The economic implications of heat stress have global consequences, as noted in a study that suggests extreme heat can significantly decrease labour productivity, especially in physical labour-intensive industries (Day *et al.*, 2019). This reduction would affect workers' health and economic stability and contribute to higher operational costs and diminished overall output, affecting businesses and economies globally (Ayanlade *et al.*, 2022).

The impact of extreme heat on worker health and productivity is not uniform; workers in developing regions, including sub-Saharan Africa, face greater risks due to resource limitations and weaker occupational health infrastructures (Sorensen & Hess, 2022). The World Health Organization (WHO, 2019) and the International Labour Organization (ILO, 2020) have called for targeted interventions to protect vulnerable workers. Their recommendations include implementing comprehensive heat action plans, enhancing workplace regulations, and promoting awareness about heat-related risks (Ponsonby, 2017). Advances in technology, such as wearable sensors that monitor body temperature

and hydration levels, have been instrumental in minimising heat-related incidents in some regions(Wibowo *et al.*, 2024). However, sub-Saharan Africa continues to experience heightened challenges, given the region's high-temperature fluctuations, limited cooling technology, and inadequate workplace policies(Parkes *et al.*, 2022). It has been shown that heat stress can lead to severe health issues, including dehydration and exacerbated chronic illnesses, impacting millions of African workers in sectors like construction and agriculture (Ayanlade*et al.*, 2022).

In Ghana, high temperatures prevail throughout the year, creating particular challenges for the construction sector, a critical component of the country's economic growth (Kayaga *et al.*, 2021). Construction workers often work long hours in direct sunlight and face an elevated risk of heat-related illnesses, including heat rashes, exhaustion, and even heatstroke (Derbile*et al.*, 2022).

The Tema Port Expansion Project in Ghana is one of the most significant infrastructure efforts initiated to enhance cargo-handling capacity, boost trade efficiency, and support economic development(Ansah *et al.*, 2020). Although this large-scale project has created numerous jobs, it has also exposed workers to increased health risks due to the demanding physical labour required under high-temperature conditions. Therefore, construction workers at the Tema Port Expansion Project are susceptible to heat-related ailments due to extended exposure to high temperatures, insufficient shade, and limited access to hydration facilities (Moda *et al.*, 2024).

The study highlights the need to examine heat stress among construction workers in Ghana and emphasises the importance of adequate occupational health measures.

Preliminary reports from the site overseers have noted many heat-related incidents, underscoring the need to evaluate the impact of heat stress and confer better mitigation strategies. The status of heat stress and its ramifications on the workforce has not been fully examined. Moreover, the existing measures, such as work-rest cycles and personal protective equipment, are not consistently enforced, leaving workers vulnerable. Addressing these issues is critical for the workers' health and safety and for maintaining productivity to ensure timely project completion. Localized studies on heat stress in Ghanaian construction settings are scarce.

1.2 Problem Statement

One of Ghana's most ambitious infrastructure developments crucial for enhancing trade capacity and economic growth is the Tema Port Expansion Project. This large scale of 27 hectares construction effort presents significant occupational health challenges, especially for workers exposed to intense heat on-site daily. Furthermore, the physically demanding labour and limited access to shade and hydration make construction workers highly susceptible to heat-related illnesses such as heat rashes, heat stress, and dehydration. Preliminary observations and reports by Borg *et al.* (2021) indicate frequent health issues among workers, which impact their well-being, reduce productivity and increase absenteeism. Despite the evident risks, heat mitigation strategies such as work-rest cycles, hydration provisions, and training on heat stress management are inconsistently implemented, leaving workers vulnerable. Furthermore, limited literature exists on heat stress and its management in the Ghanaian construction industry. Moreover, there are gaps in empirical research findings that are essential for safeguarding workers' health while enhancing productivity to ensure the successful completion of the project. This calls for an urgent need to assess the levels of heat stress and the current mitigation

strategies among construction workers and propose practical and contextually relevant improvements.

1.3 Study Objectives

The main objective of this study was to evaluate heat stress and mitigation strategies employed at the Tema Port Expansion Project.

1.3.1 Specific Objectives

Specifically, the objectives of the research are to:

1. Assess awareness of heat stress among construction workers.
2. Assess the potential impact of heat stress on construction workers' health and work performance.
3. Evaluate relationship between workers' background and job roles and their experience of heat stress at the Tema Port Expansion Project.
4. Determine heat stress mitigation strategies to better protect the health of construction workers at the Tema Port Expansion Project.

1.4 Research Questions

The following research questions were raised to guide the research

1. What is the level of awareness of heat stress among construction workers?
2. How does heat stress affect the health and work performance of construction workers?
3. How do workers' backgrounds and job roles influence their experience of heat stress at the Tema Port Expansion Project?
4. What heat stress mitigation strategies are effective in protecting the health of construction workers at the Tema Port Expansion Project?

1.5 Justification of the Study

Heat stress poses serious health and productivity challenges for construction workers, especially in hot climates like Ghana's. Research shows that heat stress can significantly impair work capacity, increase accident rates, and lead to health-related absenteeism, impacting project timelines and safety (Morrissey *et al.*, 2021). As temperatures rise globally due to climate change, sub-Saharan Africa, is expected to experience particularly severe effects (Ibe & Amikuzuno, 2019). Despite these risks, there is limited research on heat stress specific to Ghana's construction industry, particularly in major projects like the Tema Port Expansion, leaving workers vulnerable. Findings from this study will provide essential data to guide targeted interventions and inform health and safety policies. Additionally, by identifying effective mitigation strategies, this research can suggest strategies to reduce healthcare costs, enhance worker productivity, and ensure completion of infrastructure projects critical to Ghana's economic growth (Lesk *et al.*, 2022).

1.6 Significance of the Study

This study is crucial for improving occupational health for construction workers in Ghana. By examining existing heat stress mitigation strategies and identifying practical improvements, this research provides valuable insights into protecting worker health and boosting productivity. Additionally, it fills a gap in the literature on heat stress in Ghanaian construction settings, offering evidence specific to local conditions. The findings would inform policy recommendations to guide construction industry regulations and promote safer work environments. Ultimately, this study aims to support the development of policies that mandate effective heat stress management across Ghana's construction sector.

1.7 Scope of the Study

This study assesses heat stress and mitigation strategies for construction workers at Ghana's Tema Port Expansion Project. It also evaluated workers' awareness of heat stress, the potential health and productivity impacts, and the effectiveness of current mitigation practices, including adherence levels. The study targeted construction workers across various roles, examining factors like age, gender, and job tasks influencing susceptibility to heat stress. The research used a cross-sectional design to gather data through surveys, observations, and health assessments. The study population consisted of construction workers, and the study site was the Tema Port Expansion Project.

1.8 Thesis Organization

The study is divided into six main chapters. The first chapter addresses the background of the study, the problem statement, objectives, the research question, justification, significance of the study, scope and organisation. The second chapter thoroughly examined relevant literature related to this research topic. Chapter three focuses on presenting the study area and the methodology employed to conduct the research. Moving on to chapter four, the study data is presented. Chapter Five discussed the findings of the study. Lastly, in chapter six, the summary of the results is presented, conclusions based on the main findings are drawn, and recommendations are offered based on the study's outcomes.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter provides a detailed review of existing literature on heat stress and the mitigation strategies implemented to safeguard construction workers. The review critically examines key studies, research findings, and theoretical frameworks that explore various dimensions of heat stress in the construction sector. The purpose is to establish a robust foundation of knowledge for the current investigation into heat stress within the Tema Port Expansion Project, a major infrastructure development in Ghana. The review also covers mitigation strategies implemented in various construction projects worldwide, emphasizing the importance of acclimatisation programs, hydration policies, and the introduction of cooling stations at worksites. Finally, theoretical frameworks such as the Heat Stress Index (HSI) and the Wet Bulb Globe Temperature (WBGT) index have been employed to measure and assess heat exposure risk, contributing to a more comprehensive understanding of the dynamics of heat stress in the construction industry.

2.2 Prevalence, Awareness, and Perception of Heat Stress

2.2.1 Heat stress

Heat stress refers to the body's inability to cool itself, leading to increased core temperatures and heat-related illnesses. It is exacerbated by environmental factors like high temperatures, humidity, and physical exertion, particularly in outdoor work. Climate change further escalates heat stress, impacting health and productivity globally. According to the Occupational Safety and Health Administration (OSHA), heat stress can be defined as the net heat load to which a worker may be exposed from the combined

contributions of metabolic heat, environmental factors, and clothing requirements. This process triggers a range of health risks, from mild heat-related disorders such as heat rash and cramps to more severe conditions like heat exhaustion and heat stroke Centers for Disease Control and Prevention [CDC], (2020). Numerous studies, including (Ebi et al., 2021); Abokhashabah et al., 2021), have identified heat stress as prolonged exposure to high temperatures as a growing concern, especially in industries like construction, agriculture, and manufacturing, where outdoor activities and high-energy tasks are every day.

2.2.2 Prevalence of health stress

Heat stress, a growing concern due to global climate change, significantly impacts populations, especially those working in outdoor and high-temperature environments. The WHO and the International Labour Organisation (ILO) have highlighted the growing risks posed by heat stress to millions of workers worldwide, especially in regions such as South Asia, the Middle East, and parts of Africa, where high temperatures are exacerbated by climate change and inadequate workplace safety measures (Ponsonby, 2017). Workers in sectors like agriculture and construction are particularly vulnerable due to the physically demanding nature of their work and the extended hours spent outdoors under direct sun exposure (Moda *et al.*, 2024a).

Heat stress occurs when the body cannot dissipate excess heat, leading to a range of heat-related illnesses, including heat exhaustion, heatstroke, and, in severe cases, even death (Alanazi, 2020). According to recent studies, the global rise in extreme temperatures has intensified these risks, with heatstroke being identified as a leading cause of workplace fatalities in regions with inadequate preventive measures (Abokhashabah *et al.*, 2021).

Moreover, evidence suggests that heat stress not only increases the risk of immediate health issues but also contributes to long-term health conditions, such as cardiovascular diseases and kidney failure, particularly among agricultural and construction workers (Kovats & Hajat, 2008).

Efforts to mitigate the impact of heat stress have been growing, yet gaps remain in implementing effective heat management strategies at both national and organisational levels. For example, acclimatisation programs and personal protective equipment (PPE) designed to reduce heat exposure have shown success in some industries. As climate change continues to escalate, there is an urgent need for global coordination to enhance workplace safety regulations and ensure that vulnerable workers are protected from the life-threatening consequences of extreme heat (Pescaroli *et al.*, 2023).

Studies show that the prevalence of heat stress is increasing, primarily driven by rising global temperatures. According to research by Abokhashabah *et al.* (2021), over 35% of the workforce is exposed to hazardous heat. Moreover, Pence & Bloomer. (2020b), suggest that workers in agriculture and construction are particularly susceptible to these conditions due to prolonged exposure to high temperatures and limited access to hydration and rest. The ILO estimates a loss of productivity of around 2.2% globally, with countries in the hottest regions expected to experience productivity losses of up to 5%. However, construction workers are frequently exposed to high temperatures, direct sunlight, and physically demanding tasks, which place them at heightened risk for heat-related illnesses. According to Al-Bouwarthan *et al.*, (2019), construction workers are often exposed to hazardous heat, particularly in regions with hot climates. This is exacerbated by their need to wear protective clothing and gear, which reduces heat

dissipation and increases internal body temperature. Another research by Westwood *et al.* (2021), highlights that prolonged exposure to heat can lead to conditions ranging from mild heat exhaustion to severe heat stroke, posing significant health risks.

Recent studies emphasise the role of individual factors such as age, gender, acclimatisation, and fitness levels in heat stress prevalence. Male workers, who dominate the construction workforce, tend to be more susceptible due to higher metabolic rates and muscle mass (Westwood *et al.*, 2021). Moreover, workers in developing countries often lack adequate access to health monitoring, training, and personal protective equipment, increasing the risk. In addressing the prevalence of heat stress, Deshayes *et al.* (2024), noted a growing focus on mitigation strategies such as heat acclimatisation programs, hydration protocols, and work-rest cycles. They added that these strategies help to reduce heat-related illnesses, though implementation remains inconsistent across regions.

2.2.3 Awareness & Knowledge

The concepts of awareness and knowledge are fundamental to understanding how individuals and societies process information, make decisions, and engage in behaviours. Heat stress, an escalating concern due to the intensification of climate change and the rise in global temperatures, poses significant risks to construction, agriculture, and manufacturing workers. Research indicates that the prevalence of heat-related illnesses among workers is rising, especially in regions experiencing extreme temperature variations (Heidari *et al.*, 2020). Mitigating the effects of heat stress necessitates a comprehensive understanding of the issue, yet studies highlight that awareness and knowledge levels vary significantly across different regions and industries (Kolyasnikov & Kelchevskaya, 2020). For instance, while some countries have implemented robust

heat stress management protocols, others lag in awareness and regulatory frameworks. This disparity underscores the need for targeted interventions, including improved training, the introduction of heat acclimatisation programs, and stricter workplace heat safety standards (Morrissey, *et al.*, 2021).

A study by Abokhashabah *et al.* (2021), highlights that workers' awareness of heat stress is very high, even in low—and middle-income countries. Many workers, particularly in outdoor occupations, are unaware of the risks associated with prolonged heat exposure, such as dehydration, heat exhaustion, and heat stroke. Lack of awareness contributes to underreporting heat-related illnesses, exacerbating the problem.

The situation is slightly better in developed regions, with workers generally more informed due to structured occupational safety programs. According to Borg *et al.* (2021), companies in sectors such as construction have increasingly integrated heat stress awareness programs. These programs often include training on recognising early symptoms and implementing preventive measures like rest breaks and proper hydration. However, the effectiveness of such programs is closely tied to their accessibility and worker participation.

Gender and education levels play significant roles in awareness and knowledge regarding heat stress. Research by Abokhashabah *et al.* (2021), reveals that male workers, particularly in heavy labour jobs, tend to underreport symptoms due to cultural perceptions of toughness, leading to an incomplete understanding of heat risks. The role of employers in fostering heat stress awareness cannot be overstated. Glaser *et al.* (2022), highlighted that employers' commitment to providing heat stress education and

protective measures significantly improves workers' capacity to identify and respond to heat-related risks. However, in many cases, this knowledge does not translate into practice, often due to economic pressures and insufficient regulatory enforcement.

2.2.4 Perception and Attitude

Perceptions and attitudes towards heat stress significantly influence how workers respond to its risks and adopt mitigation strategies. Current research highlights that workers often underestimate the risks of heat stress. Studies conducted by Ebi *et al.* (2021), in hot regions such as the Middle East, South Asia, and parts of Africa reveal that many workers do not fully understand the potential health implications of prolonged heat exposure.

Socioeconomic status, such as education level and cultural norms, plays a significant role in shaping workers' attitudes toward heat stress. Heidari *et al.* (2020), noted that workers with lower educational backgrounds and those in informal sectors tend to have limited awareness of heat stress and its health consequences. In addition to this, Adegboyega *et al.*(2021). In many developing countries, a lack of regulations and enforcement of occupational health and safety standards exacerbates the issue, leading to a normalisation of unsafe working conditions.

Employers' attitudes significantly shape workers' responses to heat stress, influencing their perceptions and workplace actions. According to Westwood *et al.*(2021), when employers prioritize productivity over safety, workers often receive inadequate training and limited access to essential heat mitigation strategies such as hydration, shade, and rest breaks. Recent studies by Jay *et al.* (2021), support this, highlighting that a safety

culture driven by management directly impacts the effectiveness of heat stress interventions. Companies that emphasize worker well-being foster greater compliance with safety protocols and reduce heat-related incidents.

Furthermore, growing evidence shows that climate change significantly alters workers' perceptions of heat stress. As global temperatures continue to rise, studies such as those by Al-Bouwarthan et al. (2019), highlight that workers and employers are increasingly aware of the escalating risks. However, despite heightened awareness, many industries, particularly in low- and middle-income countries, still struggle to implement effective and sustainable preventive measures Ponsonby, (2017).

2.3 Effect of heat stress on health and work performance

2.3.1 Effect of heat stress on health

Heat stress, a physiological response to excessive heat exposure, has garnered increased attention due to its profound impact on human health, significantly as global temperatures rise. Heat stress occurs when the body cannot adequately dissipate heat, leading to a range of conditions from mild discomfort to severe health complications. This review synthesises recent studies on heat stress's health effects, examining its acute and chronic implications. Acute heat-related illnesses, which have been well-documented, include heat cramps, heat exhaustion, and heat stroke, the latter posing a serious risk of mortality if not treated promptly (Lesk *et al.*, 2022). Heat stroke, characterised by a core body temperature exceeding 40°C, can result in multi-organ dysfunction, neurological impairment, and, in severe cases, death (Alanazi, 2020).

According to recent findings, the global incidence of heat stroke has risen, particularly in vulnerable populations such as outdoor workers and the elderly, exacerbated by climate change and increasing temperatures (Ibe & Amikuzuno, 2019). Chronic exposure to heat has also been associated with long-term cardiovascular strain, kidney dysfunction, and cognitive decline, further underlining the health risks posed by prolonged heat exposure (Adegboyega *et al.*, 2021). Understanding the acute and chronic impacts of heat stress is critical for developing effective prevention and mitigation strategies, especially in regions facing extreme heat due to environmental and occupational factors (Pence & Bloomer, 2020a).

A study by Kletzander & Musliu.(2020) emphasized that individuals exposed to high environmental temperatures, such as outdoor workers, athletes, and the elderly, are particularly vulnerable to these acute conditions. Moreover, the prevalence of these illnesses is exacerbated by pre-existing health conditions like cardiovascular or respiratory diseases.

Chronic exposure to heat stress has longer-term health implications. Sustained heat exposure can exacerbate chronic conditions such as cardiovascular diseases, as it increases heart rate, blood pressure, and overall cardiovascular strain. A review by (Morris et al. (2020), highlights that increased temperatures contribute to higher mortality rates from cardiovascular and respiratory conditions, especially in regions where air conditioning or access to healthcare is limited. Furthermore, heat stress has been linked to kidney dysfunction, particularly among labourers in hot environments, where dehydration and prolonged heat exposure lead to chronic kidney disease, commonly observed among agricultural workers in Central America.

The mental health impacts of heat stress are also gaining recognition. Several studies have shown a correlation between higher temperatures and increased rates of mental health issues, including anxiety, aggression, and suicide. (Morrissey et al., 2021), found that prolonged heat exposure disrupts sleep patterns and cognitive function, further exacerbating mental health problems.

2.3.2 Effect of heat stress on work performance

Heat stress, defined as the body's inability to dissipate excessive heat, disrupts normal physiological and cognitive functions. Studies reveal elevated temperatures decrease focus, attention span, and decision-making abilities. Research by (Ioannou, Tsoutsoubi, et al., 2021) indicates that workers exposed to heat stress are more prone to errors, reduced reaction times, and fatigue, all compromising safety and productivity. Work performance in physically demanding jobs, particularly in construction, agriculture, and manufacturing, significantly declines when exposed to high heat. (Morris et al., 2021), found that productivity can drop by as much as 20-30% in extreme heat conditions, as workers tire more quickly and take frequent breaks to cool down. Climate change, which has led to longer and more intense heat waves globally, exacerbates this trend.

Heat stress is also linked to serious health risks, such as heat exhaustion, heatstroke, and other cardiovascular issues, which further hamper work output. (Szewczyk et al., 2021), suggest that workers exposed to extreme heat are likelier to experience accidents, particularly in sectors where physical labour is dominant. These health risks not only impair immediate work performance but also contribute to increased absenteeism due to illness, significantly affecting long-term productivity (Lesk *et al.*, 2022). Recent studies emphasise the importance of comprehensive heat acclimatisation programs, structured

work-rest cycles, and hydration protocols in mitigating heat stress effects (Szewczyk *et al.*, 2021).

Implementing these strategies not only protects worker health but also enhances overall operational efficiency, aligning with current occupational health standards and guidelines (Ponsonby, 2017). Investing in such interventions is essential for sustaining workforce productivity in high-temperature environments. A review by (Ibe & Amikuzuno, 2019) highlights the importance of such strategies but notes that adaptation measures must be tailored to each job's specific conditions and demands.

2.4 Mitigation, Implementation and Adherence

2.4.1 Mitigation

These health risks impair immediate work performance and increase absenteeism due to illness, significantly affecting long-term productivity (Szewczyk *et al.*, 2021). Recent studies emphasise the importance of comprehensive heat acclimatization programs, structured work-rest cycles, and hydration protocols in mitigating heat stress (Masoud *et al.*, 2024). Implementing these strategies protects worker health and enhances overall operational efficiency, aligning with current occupational health standards and guidelines (Barthwal *et al.*, 2022). Investing in such interventions is essential for sustaining workforce productivity in high-temperature environments. Studies suggest that implementing localised cooling methods, such as misting fans and air-conditioned rest areas, can significantly reduce core body temperature in workers (De Winne *et al.*, 2019). Innovations such as cooling vests and wearable technologies are also gaining traction, offering personal protection against heat (Kolyasnikov & Kelchevskaya, 2020).

Administrative controls are another critical component of heat stress mitigation. These involve adjusting work schedules to reduce workers' exposure, especially during peak heat periods. The "work-rest" cycle, which allows for periodic breaks in cooler environments, is highlighted in several studies as an effective method of preventing heat exhaustion (Ibrahim *et al.*, 2023). Heat acclimatization programs, where workers gradually build tolerance to hot conditions, are shown to reduce the likelihood of heat-related illnesses (Barthwal *et al.*, 2022).

Hydration practices play an essential role in heat stress mitigation. Adequate fluid intake prevents dehydration and helps regulate body temperature. The research underscores the importance of educating workers about hydration strategies, such as drinking small amounts of water frequently and ensuring access to potable water throughout the workday (Westwood *et al.*, 2021). Moreover, recent advancements have seen companies provide electrolyte-enhanced drinks to replace salts lost through sweating. At the policy level, heat stress regulations are becoming more stringent. Governments and international bodies like the WHO have proposed occupational heat exposure limits and mandated heat protection measures in vulnerable industries (Derbile *et al.*, 2022). These regulations often include requirements for heat risk assessments and worker education programs.

2.4.2 Implementation

Implementing heat stress mitigation strategies is essential in construction, agriculture, and manufacturing industries, where workers are frequently exposed to high temperatures. Current literature emphasizes engineering controls as a key mitigation strategy. These include modifying work environments by providing adequate ventilation,

shading, and cooling systems to reduce heat exposure(Ayanlade *et al.*, 2022). For example, air-conditioned break areas, misting fans, and reflective roofing are cited as effective interventions in reducing ambient temperatures in workspaces. Advanced technology, such as wearable cooling vests, has been implemented in some high-risk industries to decrease heat stress on individual workers further(Kletzander & Musliu, 2020). Studies suggest that such engineering controls are critical, particularly in hot climates with high heat stress levels.

Administrative controls, such as rescheduling work hours to cooler parts of the day, ensuring mandatory rest breaks, and rotating work among employees, have been widely discussed as practical approaches to managing heat exposure. Research by Ibrahim *et al.* (2023) demonstrates that implementing work-rest cycles is particularly effective in high-heat industries, such as construction and agriculture, where continuous exposure can lead to heat exhaustion or heat stroke. Organizations have adopted these strategies in regions such as the Middle East and Africa to limit workers' exposure during peak heat hours. Employee training is another essential strategy highlighted in the literature. Training workers on recognizing the signs of heat stress, understanding preventive measures, and providing hydration protocols are core components of heat stress mitigation, according to Adegboyega *et al.* (2021). Awareness programs that emphasize acclimatization to hot environments improve workers' physiological tolerance to heat and significantly reduce incidents of heat-related illnesses. To remain effective, training should be continuous and tailored to specific environmental conditions.

Heat stress mitigation strategies include using personal protective equipment (PPE) to minimise heat exposure. Lightweight, breathable clothing, heat-protective helmets, and

gloves are frequently mentioned as part of comprehensive safety measures. While PPE offers a layer of protection, it must be balanced with the need for comfort, as some PPE may exacerbate heat stress if not carefully selected.

2.4.3 Adherence

Heat stress, exacerbated by climate change, poses significant risks to workers in hot environments, particularly in construction, agriculture, and manufacturing industries. Mitigation strategies, including engineering controls, administrative measures, and personal protective equipment, are essential to safeguard workers' health and productivity. However, ensuring adherence to these strategies remains a critical challenge. Engineering controls, such as ventilation, cooling systems, and shaded areas, are widely regarded as effective heat stress mitigation strategies. Studies emphasise that the success of these measures relies heavily on consistent implementation and worker engagement. For example, a study by (Ibrahim et al., 2023) workers were more likely to use cooling shelters when they were conveniently located and integrated into their daily workflows. Similarly, mechanical cooling solutions like air-conditioned rest areas have been shown to improve compliance when supervisors actively encourage their use (Adegboyega *et al.*, 2021).

Administrative controls, such as work-rest cycles, hydration policies, and heat acclimatisation programs, are critical for reducing heat stress risks. However, adherence to these policies can vary due to organisational priorities, lack of training, or cultural factors. Research by Kletzander and Musliu (2020) found that workers often disregarded recommended rest breaks to meet production targets, especially when supervisors did not strictly enforce rest schedules. In contrast, well-designed heat acclimatization programs,

which gradually expose workers to increasing heat levels, have improved physiological adaptation and reduced the risk of heat-related illnesses when adhered adequately to Gibson *et al.* (2020).

PPE, such as cooling vests and breathable clothing, reduces heat stress. However, adherence to wearing PPE can be hindered by discomfort or a lack of perceived benefit. A survey by Ibrahim *et al.* (2023), found that workers in the Middle East frequently removed cooling vests due to discomfort, even though their use significantly reduced core body temperatures. Behavioural factors, such as the perceived inconvenience of PPE and a lack of understanding of heat stress risks, were identified as key barriers to compliance. A growing body of literature underscores the importance of organisational culture in promoting adherence to heat stress mitigation strategies. Effective training programs, regular safety audits, and supervisor engagement are crucial in fostering a culture of compliance. Pacheco-Zenteno *et al.* (2021), show more excellent adherence rates in organisations that prioritise heat stress education and actively involve workers in the decision-making process regarding mitigation techniques.

2.5 Effectiveness of heat stress mitigation strategies and Potential improvements

2.5.1 Effectiveness of heat stress mitigation strategies

The effectiveness of heat stress mitigation strategies has gained significant attention in occupational health and environmental management due to the increasing frequency and intensity of heat waves driven by climate change. Numerous studies evaluate different approaches, ranging from engineering solutions to behavioural interventions, to reduce the adverse health impacts of heat stress on workers, particularly those in physically

demanding sectors like construction, agriculture, and manufacturing. One of the most effective strategies identified in the literature involves engineering controls, such as improving workplace ventilation, providing shade, and using cooling technologies like air conditioning or evaporative coolers. A study by Pence and Bloomer (2020) highlights that work environments with proper ventilation and access to cool zones reduce the internal body temperature of workers and help maintain productivity, especially in industries such as construction.

Another widely discussed mitigation approach is the implementation of work-rest cycles, where workers are allowed regular breaks in cooler environments. Studies such as those by Morris *et al.* (2020), show that frequent, scheduled breaks combined with hydration strategies help mitigate the physiological strain of prolonged heat exposure. Adequate hydration is crucial, and organisations often emphasize the need for easily accessible drinking water and electrolyte solutions at work sites. These strategies, though effective, require strong organizational commitment and worker compliance to maintain hydration levels and reduce the risk of heatstroke.

Heat acclimatisation programs have also been highly effective, where workers gradually adjust to working in hot conditions for days or weeks. Adaptation increases workers' tolerance to heat, allowing them to work safely in higher temperatures. Gibson *et al.* (2020), report that properly designed acclimatization programs can improve cardiovascular stability, enhance sweating efficiency, and lower core body temperatures. Emerging studies explore using personal protective equipment (PPE) to mitigate heat stress, such as cooling vests and heat-reflective clothing. Additionally, wearable technologies that monitor body temperature and provide real-time data on physiological

conditions are increasingly being adopted. Recent findings by Ibrahim *et al.* (2023) suggest that these innovations can enhance heat stress management, especially when integrated with other mitigation strategies.

2.5.2 Potential improvements

Heat stress poses a significant occupational hazard, particularly in construction, agriculture, and manufacturing, where workers are often exposed to extreme temperatures. Heat stress becomes more prevalent as climate change intensifies, necessitating robust mitigation strategies. Recent literature has focused on identifying gaps and proposing potential improvements to current heat stress mitigation strategies.

One area of focus is the development of wearable technologies that monitor workers' physiological responses to heat. Devices that measure heart rate, core temperature, and sweat rate in real-time can alert workers or supervisors when heat stress risk is elevated Ibrahim *et al.* (2023). These tools allow timely interventions, such as rest breaks or hydration, before workers reach critical heat stress levels. Integrating machine learning algorithms with these devices offers potential improvements in predicting heat stress and tailoring interventions to individual needs (Barthwal *et al.*, 2022). Another improvement involves enhancing heat stress acclimatisation programs. Recent studies have highlighted the importance of tailored training that considers workers' health status, age, and experience (Casey *et al.*, 2021). Heat acclimatisation programs should be more comprehensive, including simulation-based training and increased worker participation to ensure preparedness. Ongoing refresher courses to reinforce heat stress awareness could improve long-term outcomes.

Adjusting workplace policies, such as modifying work/rest cycles, has been widely recommended. Research suggests that work schedules should account for varying environmental conditions, with more flexible policies that allow workers to adjust their activities based on real-time weather data (Karthick *et al.*, 2021). Moreover, paid heat stress breaks and policies that prevent overexertion, particularly during peak heat hours, could significantly reduce risks. Improvements in infrastructure, such as shaded workspaces, cooling stations, and more accessible hydration points, are crucial Ulpiani, (2019). Innovative designs for portable cooling shelters and evaporative cooling technology could enhance worker comfort. Furthermore, encouraging hydration through structured water intake schedules, coupled with providing electrolyte-rich beverages, has been identified as an effective measure for preventing dehydration (Pence & Bloomer, 2020a).

2.6 Theoretical and Conceptual Framework

2.6.1 Theoretical Framework

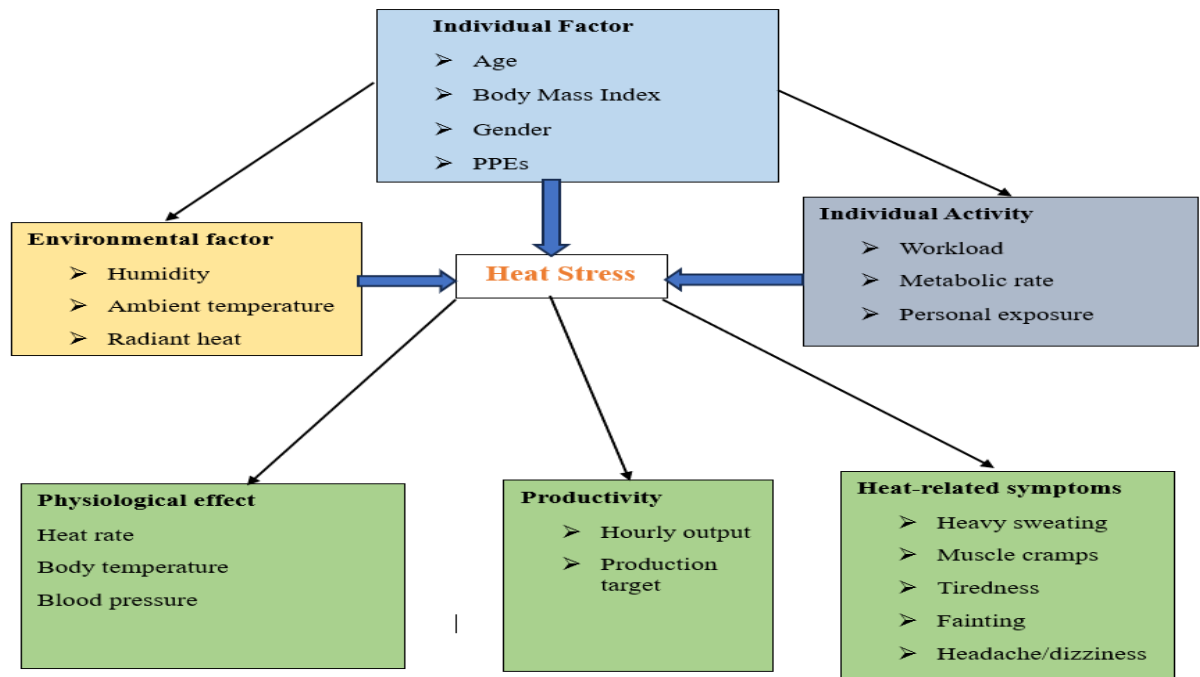
Heat stress among construction workers can be analysed through an integrative framework that combines environmental, physiological, and psychosocial perspectives. Central to this framework is the Heat Balance Theory, which posits that the human body maintains thermal equilibrium by balancing internal heat production with external heat loss (Kim *et al.*, 2023). In construction settings, elevated ambient temperatures, direct sunlight, and intense physical labour can disrupt this balance, leading to increased core body temperature and physiological strain (Kim *et al.*, 2023).

Environmental factors such as ambient temperature, humidity, radiant heat from the sun or hot surfaces, and limited air movement significantly influence the body's ability to

dissipate heat. High humidity impairs evaporative cooling by reducing sweat evaporation rates, while direct sunlight and radiant heat increase the external heat load on workers (Koteng, 2022). Additionally, personal protective equipment, though essential for safety, can impede heat dissipation by restricting airflow and trapping heat close to the body.

From an occupational health perspective, the Thermal Work Limit (TWL) is a critical index used to assess the maximum sustainable metabolic rate for workers in specific thermal environments (Ioannou *et al.*, 2022). TWL considers factors such as air temperature, humidity, wind speed, and radiant heat to determine safe work limits, ensuring that workers' core body temperatures and sweat rates remain within safe thresholds. Implementing TWL-based guidelines has been shown to reduce heat-related illnesses in industries like mining (Kim *et al.*, 2023). The ecological systems theory further contextualizes heat stress by examining the interplay between individual, organizational, and societal factors. Organisational policies, such as work-rest cycles, availability of hydration stations, and enforcement of heat exposure limits, play a pivotal role in mitigating heat stress risks. Societal factors, including regulatory standards and cultural attitudes towards occupational safety, also influence the prevalence and management of heat stress in the construction industry.

2.6.2 Conceptual Framework



(adapted from Schroeter *et al.* 2018, and Ebi *et al.* 2020)

This conceptual framework demonstrates how various factors interact to contribute to occupational heat stress. Environmental factors such as humidity, ambient temperature, and radiant heat interact with personal characteristics like age, body mass index (BMI), gender, and the use of personal protective equipment (PPE). These are further affected by the type of work performed, including workload level, metabolic rate, and duration of exposure. Collectively, these elements influence the development and severity of heat stress. In turn, heat stress prompts physiological responses such as increased heart rate, elevated core body temperature, and blood pressure fluctuations, which may impair physical functioning. These physiological changes can decrease productivity by affecting hourly output and the ability to meet targets. Additionally, workers may experience a variety of heat-related symptoms, including heavy sweating, muscle cramps, fatigue, fainting, and dizziness. This framework offers a basis for identifying intervention points

to mitigate risk, enhance worker safety, and sustain performance under hot working conditions. It underscores the interaction between environmental and personal factors in determining workers' vulnerability to heat stress.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This thesis chapter focuses on the study area and the methodology employed. It discusses the following sections: Study Design, Study Area, Study Population, Inclusion and Exclusion Criteria, Sample Size Estimation, Sampling Techniques, Data Collection Tools and Techniques, Pilot Study, Data Collection Procedures, Data Management, Statistical Analysis, and Ethical Review and Clearance.

3.2 Design of the Study

This study employed a cross-sectional design to evaluate heat stress and mitigation strategies employed at the Tema Port Expansion Project over four months (from August to December 2024). This timeframe was chosen to capture variations in the population and reduce potential biases due to the sampling technique. This approach will provide in-depth insights into the complex dynamics between heat stress and the mitigation strategies employed at the site.

3.3 Study Area

This study was conducted in the Tema Metropolis, specifically the Tema Port Expansion Project. The Tema Port Expansion Project is situated in Tema, a city on Ghana's Gulf of Guinea coast, approximately 25 kilometres (16 miles) east of the capital, Accra. The city covers a total land area of approximately 396 square kilometres. This expansive area accommodates a diverse and growing population of around 292,000 residents. The population density and the city's strategic location have spurred significant industrial and commercial activities, making Tema a hub for business and economic development in Ghana. The region experiences a tropical savanna climate characterized by two main

seasons: a rainy season from April to November and a dry season from December to March. Temperatures in Tema are relatively high throughout the year, with average temperatures ranging from 25°C to 30°C (77°F to 86°F). The combination of high temperatures and humidity creates a challenging environment, particularly for outdoor labour-intensive activities. The expansion project covers an extensive area of 270 hectares, involving deep-sea construction activities. The development includes the construction of new berths, the deepening of existing harbours, and the installation of modern port facilities. These activities require a substantial workforce engaging in physically demanding tasks under harsh environmental conditions.



Figure 3.1: Map of Tema Metropolis (Source: Ghana Statistical Service, GIS; 2021).

3.4 Study Population

The study population at the site was estimated at 600 for this research, including all Architecture, Engineering, Construction, Operations, and Management (AECOM) employees, covering both office-based staff and field supervisors. Additionally, it

encompasses personnel from the Comisión Nacional del Sistema de Ahorro para el Retiro (CONSAR), specifically construction managers and supervisors. The study also includes all Joint Venture (JV) workers from Effiage and Desimone, comprising various roles such as construction workers, supervisors, and managers. This comprehensive population selection allows for a thorough assessment across various levels of responsibility and expertise within the organizations involved in the project.

3.5 Inclusion and Exclusion Criteria

This study focused on workers directly involved in physical construction at the Tema Port Expansion Project, including labourers, machine operators, supervisors, health and safety personnel, and project managers. Eligible participants had at least one month of employment at the site to ensure acclimatization and were generally healthy, without conditions that would heighten vulnerability to heat stress. Participation required informed consent and commitment to surveys, interviews, and monitoring. Workers with less than one month of employment, pre-existing conditions like severe cardiovascular issues, pregnant workers, and those unwilling to participate were excluded to ensure data reliability and participant safety.

3.6 Sample Size Estimation

A sample size of 100 employees was estimated for heat stress and mitigation strategies employed at the Tema Port Expansion Project for the study based on Slovin's formula, adopted by Bassuah (2019), expressed as follows:

$$n = \frac{N}{1+N(e)^2}$$

Where:

Where N = is the targeted population of 100 (all employees of AECOM, encompassing both office-based staff and field supervisors, personnel from CONSAR, including construction managers and supervisors, and all Joint Venture (JV) workers, specifically those from Effiage and Desimone),

e = is the standard error (chosen to be 0.05), and

n = is the sample size.

$$n = \frac{100}{1 + 100(0.05)^2}$$

n=80

This number (80) was increased to 88 to compensate for a possible 10% non-response rate, which signifies a considerable number of employees directly impacted by heat stress at the Tema Port Expansion Project.

3.7 Sampling Technique

This study utilised a multi-stage sampling approach, incorporating purposive and Stratified Random sampling techniques. Firstly, a purposive sampling technique was used to select the study site, while the Stratified random method was used to select the study participants from the Tema Port Expansion Project.

3.8 Data Collection Tool(s) and Techniques

3.8.1 Data Collection Tool(s)

This study employed multiple data collection tools, including a structured questionnaire and Google Form, to gather participant information. The questionnaire consisted of four sections: socio-demographic characteristics, awareness and level of heat stress among construction workers, the potential impact of heat stress on health and work performance,

and heat stress mitigation strategies, including their implementation, adherence, and potential improvements. An observational checklist was also used to compare the contractors' existing health and safety practices against current standards for worker protection. Additionally, in-depth interviews with occupational health, safety, and environmental management experts provided valuable insights, making these tools integral to obtaining comprehensive data for the study.

3.8.2 Pilot Study

The data collection tools were pre-tested at the newly established immigration service office of the Mampong Municipal Assembly, and any discrepancies identified were subsequently revised and updated. Face-to-face data collection and questionnaire completion were practised through hands-on experience before the main study commenced.

3.8.3 Data Collection Procedure

This study utilised a combination of face-to-face interviews and observational methods to gather responses from participants, including construction workers, field supervisors, safety and health supervisors, environmental monitoring teams, engineers, contractors, subcontractors, and managers. The interviews were designed to capture in-depth insights unique to each role, offering a broad perspective on heat stress and mitigation strategies. Additionally, observational studies were conducted using a structured checklist to examine key aspects of heat stress and its mitigation on-site. These observations focused on real-time practices and working conditions, while discussions explored individual experiences and gathered suggestions for potential improvements.

3.9 Data Management and Analysis

3.9.1 Data Management

The electronic data downloaded from Google was checked for completeness and consistency, coded, edited, and cleaned in Microsoft Excel 2016 by the principal investigator. The cleaned dataset from the Excel file was imported into the Statistical Package for Social Science (SPSS) version 27 software for comprehensive statistical analysis.

3.9.2 Data Analysis

Relevant data obtained from respondents was analysed by employing descriptive and inferential statistics. Categorical variables were presented as frequency and percentages, whilst parametric continuous variables were presented as means and standard deviations. Chi-square test and logistics regression were used to determine factors associated with and independent predictors of heat stress and mitigation strategies employed at the Tema Port Expansion Project.

3.10 Ethical Considerations:

Ethical approval was acquired from the Committee on Human Research, Publication and Ethics, School of Medical Sciences, Kwame Nkrumah University of Science and Technology (CHRPE/SMS/KNUST). Written and informed consent was also obtained from study participants. Also, written permission was obtained from the AECOM and the other. A thorough explanation of the study protocol and assurance of anonymity was given to the study respondents. The study received approval from the University (AAMUSTED).

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter presents the results and description of the study. The results were presented in a thematic section in the order of the study-specific objectives.

4.2 Demographic Characteristics of Respondents

Table 4.1 shows that 73.3% were male, 50% had tertiary education, 45.3% were consultants, and 31.4% had 1 to 2 years of work experience.

Table 4.1: Demographic Characteristics of Respondents

Variable	Frequency	Percentages %
Gender		
Male	63	73.3
Female	23	26.7
Educational level		
Primary	9	10.5
Secondary	34	39.5
Tertiary	43	50.0
Job Department/Trade		
Client	26	30.3
Consultant	39	45.3
Constructor	21	24.4
Length of service in this role		
< 1 years	12	13.9
1-2 years	27	31.4
2-3 years	11	12.8
3-4 years	11	12.8
> 4 years	25	29.1

Data Source: Field survey, 2024

4.3 Knowledge and Awareness of Construction Workers on Heat Stress

Table 4.2 shows that 93% of the participants were aware of heat stress, all of them were informed about heat-related illness, 40.7% had no training on heat stress, and 34.9% were trained monthly. Also, 20.9% had yet to be inducted on heat stress mitigation, 96.5%

indicated that heat stress training was necessary to participate, 70.9% were prepared to work in hot environments, and 61.6% stated no measures to encourage hydration on-site.

Table 4.2: Knowledge /Awareness of heat stress

Variable	Frequency	Percentages %
Know heat stress		
Yes	80	93.0
No	6	7.0
Workers are informed about heat-related illnesses.		
Yes	86	100.0
No	0	0.0
There are heat stress training sessions.		
Yes	51	59.3
No	35	40.7
How heat stress training is organised on-site		
Monthly	30	34.9
Quarterly	6	7
Weekly	47	54.6
Yearly	3	3.5
Inducted on heat stress mitigation measures		
Yes	68	79.1
No	18	20.9
Heat stress training is necessary.		
Yes	83	96.5
No	3	3.5
It is important to attend this training.		
Yes	83	96.5
No	3	3.5
Ready to work in a hot environment		
Yes	61	70.9
No	25	29.1
There are measures to encourage hydration.		
Yes	33	38.4
No	53	61.6

Data Source: Field survey, 2024

4.3.1 Association of Awareness and Sociodemographic Characteristics of Participants

In Table 4.3, the chi-square test of an independent did not show any statistically significant association between demographic characteristics such as gender, age, education, job department working experience, and awareness of heat stress among construction workers (**P-value > 0.05**).

Table 4.3: Association of Awareness and Sociodemographic Characteristics

Demographic	Awareness of Heat Stress		Independence χ^2	P-value
	Yes (%)	No (%)		
Gender				
Male	58 (92.1)	5 (7.9)	0.330	0.488
Female	22 (95.7)	1 (4.3)		
Age				
19-30	40 (95.2)	2 (4.8)	2.990	0.224
31-40	32 (94.1)	2 (5.9)		
51-50	8 (80)	2 (20)		
Educational Level				
Primary	9 (100.0)	0 (0.00)	0.850	0.653
Secondly	31 (91.2)	3 (8.8)		
Tertiary	40 (90)	3 (7.0)		
Job Department/Trade				
Client	24 (92.3)	2 (7.7)	2.910	0.232
Consultant	38 (97.4)	1 (2.6)		
Contractor	18 (85.7)	3 (14.3)		
Length of service in this role				
< 1 years	12 (100.0)	0 (0.00)	5.690	0.224
1-2 years	24 (88.9)	3 (11.1)		
2-3 years	9 (81.8)	2 (18.2)		
3-4 years	10 (90.9)	1 (9.1)		
> 4 years	25 (100)	0 (0.00)		

Data Source: Field survey, 2024.

4.3.2 Association of Choice/Preference of Training and Sociodemographic Characteristics

In Table 4.4, the chi-square test of an independent did not show any statistically significant association between participant’s demographic characteristics and their choice of training on work-related risks such as heat stress.

Table 4.4: Choice of Training versus Participants Demographics

Demographic	Training should be Provided		Independence χ^2	P-value
	Yes (%)	No (%)		
Gender				
Male	60 (95.2)	3 (4.8)	1.132	0.280
Female	23 (100)	0 (0.0)		
Age				
19-30	42 (100)	0 (0.00)	4.640	0.081
31-40	33 (97.1)	1 (2.9)		
51-50	8 (80)	2 (20)		
Educational Level				
Primary	9 (100)	0 (0.0)	4.750	0.0930
Secondly	31 (91.2)	3 (8.8)		
Tertiary	43 (100)	0 (0.0)		
Job Department/Trade				
Client	26 (100)	0 (0.0)	1.351	0.509
Consultant	37 (94.9)	2 (5.1)		
Contractor	20 (95.2)	1 (4.8)		
Length of service in this role				
< 1 years	12 (100)	0 (0.0)	3.990	0.470
1-2 years	25 (92.6)	2 (7.4)		
2-3 years	10 (90.9)	1 (9.1)		
3-4 Years	11 (100)	0 (0.0)		
> 4 years	25 (100)	0 (0.0)		

Data Source: Field survey, 2024.

4.4 Potential Impact of Heat Stress on Health and Work Performance and Examine Its Relationship with the Knowledge and Awareness of Construction Workers

4.4.1 Potential Impact of Heat Stress

In Table 4.5, 82.6% indicated severe heat stress on-site, and the common signs and symptoms of heat stress experienced frequently reported were headache (30.2%), heat rash (23.3%), and heavy sweating (22.1%). Also, 47.7% felt restrained in their water intake, 53.5% indicated they do not monitor each other while working, and 54.7% stated there was no protocol for heat-related emergencies.

Table 4.5: Impact of Heat Stress

Variable	Frequency	Percentages %
The severity of heat stress on-site		
Somewhat serious	15	17.4
Very serious	71	82.6
Most signs/symptoms of heat stress experienced		
Dry, hot skin	11	12.8
Frequent thirst	10	11.6
Headache	26	30.2
Heat rash	20	23.3
Heavy sweating	19	22.1
Restrained in water intake		
Yes	41	47.7
No	45	52.3
Workers monitor each other onsite.		
Yes	39	45.3
No	47	54.7
There is a protocol for heat-related emergencies.		
Yes	39	45.3
No	47	54.7

Data Source: Field survey, 2024.

4.4.2 Association of Impact of Heat Stress and Sociodemographic Characteristics

In Table 4.6, the chi-square test of an independent did not show any statistically significant association between participant’s demographic characteristics and impact of heat stress.

Table 4.6: Impact of Heat Stress Versus Participants' Demographics

Demographic	How severe is heat stress on-site?		Independence χ^2	P-value
	Somewhat serious (%)	Severe (%)		
Gender				
Male	13 (20.6)	50 (79.4)	1.668	0.167
Female	2 (8.7)	21 (91.3)		
Age				
19-30	5 (11.9)	37 (88.1)	2.223	0.329
31-40	7 (20.6)	27 (79.6)		
51-50	3 (30)	7 (70)		
Educational Level				
Primary	3 (33.3)	6 (66.7)	5.743	0.057
Secondly	2 (5.9)	32 (94.1)		
Tertiary	10 (23.3)	33 (76.7)		
Job Department/Trade				
Client	5 (19.2)	21 (80.8)	1.228	0.541
Consultant	5 (12.8)	34 (87.2)		
Contractor	5 (23.8)	16 (76.2)		
Length of service in this role				
< 1 years	3 (25.0)	9 (75.0)	1.677	0.795
1-2 years	5 (18.5)	22 (81.5)		
2-3 years	1 (9.1)	10 (90.9)		
3-4 Years	1 (9.1)	10 (90.9)		
> 4 years	5 (20.0)	20 (80.0)		

Data Source: Field survey, 2024

Table 4.7: Heat Exposure

Variable	Frequency	Percentages %
Have access to drinking water.		
Yes	78	90.7
No	8	9.3
Water is kept on-site for use.		
In an ice chest	51	59.3
Left on the floor and covered with a wooden slab	11	12.8
On the floor and covered	24	27.9
Have mobile washrooms on site.		
Yes	68	79.1
No	18	20.9
Have sufficient washrooms on-site.		
Yes	41	47.6
No	45	52.4
Experienced heat stress before.		
Yes	66	76.7
No	20	23.3
Ever experienced signs/symptoms of heat stress		
Yes	63	73.3
No	23	26.7
Currently experiencing heat stress.		
Yes	45	52.3
No	41	47.7
Have time to acclimatize on-site.		
Yes	50	58.1
No	36	41.9
There are areas with higher temperatures.		
Yes	74	86.1
No	12	13.9
Areas with high temperatures.		
Earthworks/ Light mast area	31	36.0
Marine area	20	23.3
Office area	11	12.8
Retaining walls	20	23.3
Substation area	4	4.6
Wear breathable clothing during hot hours.		
Yes	49	57.0
No	37	43.0
There is a heat stress monitoring device.		
Yes	34	39.5
No	52	60.5

Data Source: Field survey, 2024

4.5 Heat Stress exposure among construction workers

Table 4.7 reveals that 90.7% of respondents have access to drinking water, of which 27.9% store it covered on the floor. Most (79.1%) participants had access to mobile washrooms; however, 47.7% indicated they were insufficient. The prevalence of heat stress among the workers was 76.7%, with 73.3% reporting symptoms and 52.3% still affected. Additionally, 41.9% did not acclimatise to the warm environment, and 84.9% reported experiencing high temperatures in Earthworks and Light Mast areas, which were identified as the hottest (36%). Furthermore, about 43% lack breathable clothing during hot periods and 60.5% have not seen heat stress monitoring devices on-site.

4.5.1 Association of Exposure to Heat Stress and Sociodemographic Characteristics

In Table 4.8, gender and educational level were associated with heat stress exposure ($\chi^2=3.7$, $p= 0.044$) and ($\chi^2=7.4$, $p= 0.025$), respectively. Female construction workers were four times more likely to suffer heat stress than males [AOR= 4.2, (1.210-19.788), $p= 0.036$]. Participants with tertiary level of education were 68% less likely to suffer from heat stress than their counterparts [AOR= 0.32, (0.103-0.904), $p= 0.027$].

Table 4.8: Exposure of Heat Stress Versus Participants' Demographics

Demographic	Ever suffered heat stress		χ^2 (P-value)	AOR (95%CI) P-value
	Yes (%)	No (%)		
Gender				
Male	45 (71.4)	18 (28.6)	3.729 (0.044)	Ref: 4.2 (1.210, 19.788) 0.036
Female	21 (91.3)	2 (8.7)		
Age				
19-30	35 (83.3)	7 (16.7)	2.790 (0.248)	Ref: 0.30 (0.067, 1.349) 0.116 0.54 (0.123, 2.365) 0.413
31-40	25 (73.5)	9 (26.5)		
51-50	6 (60.0)	4 (40.0)		
Educational Level				
Primary	9 (100)	0 (0.00)	7.377(0.025)	Ref: 2.064E-9([2.064] E-9) NA 0.32 (0.103, 0.9.04) 0.027
Secondly	29 (85.3)	5 (14.7)		
Tertiary	28 (65.1)	15 (34.9)		
Job				
Department/Trade				
Client	20 (76.9)	6 23.1)	1.811 (0.404)	Ref: 0.60 (0.166, 2.172) 0.436 0.44 (0.129, 1.484) 0.185
Consultant	32 (82.1)	7 (17.9)		
Contractor	14 (66.7)	7 (33.3)		
Length of service in this role				
< 1 years	9 (75.0)	3 (25.0)	0.567 (0.967)	Ref: 1.06 (0.214, 5.211) 0.947 1.19 (0.237, 5.961) 0.835 1.19 (0.237, 5.961) 0.835 0.72 (0.189, 2.738) 0.629
1-2 years	22 (81.5)	5 (18.5)		
2-3 years	8 (72.7)	3 (27.3)		
3-4 Years	8 (72.7)	3 (27.3)		
> 4 years	19 (76.0)	6 (24.0)		

Data Source: Field survey, 2024

4.6 Practices and mitigation strategies, implementation, and adherence among construction workers

Table 4.9 shows that 24.4% of the participants reported no heat stress measures on-site, and 76% indicated the absence of a heat stress mitigation plan on-site. However, 53.5% felt existing measures were insufficient, 89.5% noted a lack of shaded areas for rest, 30.2% were unaware of ventilation measures, and 20.9% lacked access to cool water. Most participants (51%) consumed 1–5 sachets or bottles of water daily, 24.4% were encouraged to take breaks, and 53.5% had reminders or flexible schedules to support

breaks. However, 12.8% felt uncomfortable taking breaks, 55.8% lacked access to cooling devices, 40.7% reported no acclimatisation programs, though 92.4% expressed interest in joining one, whereas 47.7% managed heat stress by drinking plenty of water.

Table 4.9: Practices and Mitigation Strategies, Implementation, and Adherence among Construction Workers.

Variable	Frequency	Percentages %
Have heat stress measures on-site.		
Yes	65	75.6
No	21	24.4
There is a heat stress mitigation plan.		
Yes	22	25.5
No	64	74.5
These measures are enough.		
Yes	46	53.5
No	40	46.5
There are shaded areas		
Yes	77	89.5
No	9	10.5
There are ventilation measures.		
Yes	57	66.3
No	29	33.7
Cool water is available throughout the day.		
Yes	64	74.5
No	22	25.5
Number of sachet/bottles of water taken.		
1-5	44	51.1
6-10	42	48.9
Workers are encouraged to take breaks.		
Yes	65	75.6
No	21	24.4
Break measures/Reminders.		
Break reminders/Flexible scheduling	49	56.9
Heat stress monitoring	6	7.0
Hydration reminders	31	36.1
Comfortable taking breaks for hydration.		
Yes	72	83.8
No	14	16.2
Have access to cooling devices?		
Yes	37	43.1
No	49	56.9

Table 4.9: Practices and Mitigation Strategies, Implementation, and Adherence among Construction Workers. (cont')

Variable	Frequency	Percentages %
Have an acclimatisation programme.		
Yes	50	58.1
No	36	41.9
Would join the heat acclimatisation programme.		
Yes	82	95.3
No	4	4.7
How to manage signs/symptoms		
Drink much water	42	48.8
Take a break/rest	29	33.7
Visit site clinic	15	17.5

Data Source: Field survey, 2024

4.6.1 Existence of Heat Stress mitigation plan on site and Sociodemographic Characteristics

In Table 4.10, working experience was associated with the existence of a heat stress mitigation plan ($\chi^2=11.8$, $p=0.019$). Construction workers with 3-5 years of experience were 93.3% less likely to acknowledge the presence of a heat stress mitigation plan on site than their counterparts [AOR= 0.067, (0.007-0.605), $p=0.016$].

Table 4.10: Existence of Mitigation Plan of Heat Stress Versus Participants

Demographics

Demographic	Existence of mitigation plan		χ^2 (P-value)	AOR(95%CI)P-value
	Yes (%)	No (%)		
Gender				
Male	31 (49.2)	32 (50.8)	0.059 (0.808)	Ref: 1.126 (0.433, 2.928) 0.808
Female	12 (52.2)	11 (47.8)		
Age				
19-30	19 (45.2)	23 (54.8)	4.099 (0.129)	Ref: 4.842 (0.917, 25.578) 0.063 4.500 (0.831, 24.376) 0.081
31-40	16 (47.1)	18 (52.9)		
51-50	8 (80.0)	2 (20.0)		
Educational Level				
Primary	2 (22.2)	7 (77.8)	4.035 (0.133)	Ref: 4.861 (0.902, 26.193) 0.066 1.562 (0.632, 3.866) 0.334
Secondly	16 (47.1)	18 (52.9)		
Tertiary	25 (58.1)	18 (41.9)		
Job Department/Trade				
Client	16 (61.5)	10 (38.5)	3.890 (0.143)	Ref: 0.833 (0.258, 2.688) 0.760 2.133 (0.726, 6.272) 0.169
Consultant	15 (38.5)	24 (61.5)		
Contractor	12 (57.1)	9 (42.9)		
Length of service in this role				
< 1 years	3 (25.0)	9 (75.0)	11.788 (0.019)	Ref: 2.00 (0.432, 9.256) 0.375 0.533 (0.177, 1.607) 0.264 0.067 (0.007, 0.605) 0.016 0.800 (0.191, 3.347) 0.760
1-2 years	15 (55.6)	12 (44.4)		
2-3 years	10 (90.9)	1 (9.1)		
3-5 Years	5 (45.5)	6 (54.5)		
> 4 years	10 (40.0)	15 (60.0)		

Data Source: Field survey, 2024

CHAPTER FIVE

DISCUSSION

5.1 Introduction

This chapter systematically discusses the study's outcomes based on the specific objectives. It outlines the study's findings, compares them with relevant literature, identifies contributing factors, and discusses its implications.

5.2 Awareness and Level of Heat Stress among Construction Workers

This current study revealed that most construction workers at the Tema Port Expansion project were aware of heat stress, and all participants were informed about heat-related illness; however, a more significant proportion had no training on heat stress. This is similar to several studies that reported that construction workers were highly aware of heat-related stress (Moda *et al.*, 2024b). However, this study contradicts a study in Nigeria, which reported that 40% of construction workers were unaware of anxiety related to high temperatures (Moda *et al.*, 2024b). The disparities in these studies could be attributed to limited employer-led training programs, resource constraints, and the informal nature of many construction jobs (Ó Murchadha, 2022). Similar studies have reported awareness of heat-related illnesses among workers, yet a lack of structured training or heat stress management protocols persists, particularly in developing countries, including Ghana (Pacheco-Zenteno *et al.*, 2021). This suggests that while workers recognize the risks, employers may not prioritize capacity building, leaving workers vulnerable. Therefore, targeted interventions, including mandatory heat stress training, are imperative to bridge the knowledge-practice gap and enhance on-site safety and health outcomes.

This study discovered that more construction workers were not inducted in heat stress mitigation; nonetheless, most participants indicated that heat stress training is necessary and were willing to participate in time organized. This study affirms several studies that indicated that a higher percentage of construction workers in some departments are not formally oriented on heat stress relief (Ashtekar *et al.*, 2019; Morris *et al.*, 2020). Factors such as inadequate employer commitment, resource limitations, and low awareness of heat stress risks may hinder formal induction programs (Nunfam *et al.*, 2018). Studies show similar trends where workers in high-risk environments report insufficient training but express willingness to engage when opportunities arise (Hussain *et al.*, 2020; Nunfam *et al.*, 2018).

This suggests that while awareness of the risks exists, structural barriers limit proactive measures. This highlights that most participants were prepared to work in hot environments, and the majority indicated that no measures were taken to encourage hydration on-site. This conforms to several studies on construction work in hot climates, highlighting economic pressures and inadequate site-level health measures that lead to continued work under heat stress (Amadi, 2020; Zong *et al.*, 2024). However, this contradicts some studies that report proactive hydration policies and worker education in high-heat environments (Egerer *et al.*, 2020; Ioannou, Mantzios, *et al.*, 2021). The disparities could be ascribed to the effects of economic pressures and inadequate health measures on construction workers in hot climates (Flouris *et al.*, 2018). This suggests that site protocols that promote hydration are urgently needed. Therefore, urgent intervention is needed to increase productivity, reduce health risks, and decrease the likelihood of heat-related incidents on construction sites.

5.2.1 Awareness and Sociodemographic Characteristics of Participants

The study found no association between construction workers' awareness of heat stress and their demographic characteristics, including gender, age, education, job department, and work experience. This aligns with a study by El-Shafei et al. (2018), which reported that formal training of construction workers significantly improves their awareness and knowledge of heat anxiety and heat-related sickness. This suggests that these factors do not predict or influence a worker's level of awareness regarding heat stress. It implies that knowledge of heat stress risks and mitigation may not naturally develop through general work experience or background characteristics. Instead, it could require targeted educational interventions and training across all demographics. These findings highlight the need for comprehensive workplace training programs that reach all workers equally, regardless of their demographic backgrounds, to improve awareness and enhance the prevention of heat-related health risks.

5.2.2 Choice/Preference of Training and Sociodemographic Characteristics

The study found no association between participants' demographic characteristics and their willingness to participate in training on work-related risks like heat stress. A study emphasized that workers with higher personal resources, such as hope and resilience, often participate more significantly in safety initiatives, regardless of their demographic background (Margheritti *et al.*, 2023). A study on cross-cultural differences in workplace participation found that perceptions and engagement in workplace training and safety protocols can vary significantly across countries, suggesting the influence of broader cultural norms rather than individual demographic factors alone (Wu *et al.*, 2022). This suggests that factors like age, gender, education, and work experience may not predict interest in safety training within this context, indicating that motivation for training may

be driven more by workplace culture or perceived personal relevance rather than personal background (Margheritti *et al.*, 2023). This finding implies that training programs should be universally encouraged across all demographics to ensure broad participation and effectiveness. The disparity between studies could be due to variations in workplace environments, differing levels of awareness and organizational support for safety training across regions or industries (Wu *et al.*, 2022).

5.3 Potential Impact of Heat Stress on Health and Work Performance

This current study discovered that most (82.6%) construction workers indicated that the heat stress on-site was severe. This aligns with findings from the International Labour Organization (ILO), which reported that 85% of construction workers see heat stress as a significant occupational hazard (ILO, 2019). Similarly, the National Institute for Occupational Safety and Health (NIOSH) noted that 78% of outdoor workers perceive it as a significant threat (NIOSH, 2018). In contrast, a study published in the Journal of Occupational and Environmental Medicine found that only 45% of construction workers considered heat stress a serious concern (JOEM, 2017). The Australian Institute of Occupational Hygiene (2020) reported that 60% of outdoor workers view heat stress as a moderate concern. These discrepancies may stem from varying climatic conditions and cultural or regional differences in risk perception.

The finding that a significant majority (82.6%) of construction workers perceive on-site heat stress as a "very serious" concern suggests a critical occupational health issue that may impact worker productivity, safety, and overall well-being. This perception indicates that heat stress could lead to physical discomfort, increased risk of heat-related illnesses, and potentially higher rates of accidents due to impaired cognitive and physical functioning. The serious concern accentuates the need for targeted interventions, such as

improved hydration policies, shaded rest areas, heat acclimatization programs, and modified work schedules, particularly during peak heat periods. This will, therefore, ensure a safe and sustainable working environment, reducing absenteeism and turnover and promoting long-term workforce health and efficiency in the construction industry.

This study revealed that the most frequent signs and symptoms of heat stress construction workers experienced were headache, heat rash, and heavy sweating. This current study reported that about half of construction workers feel pressured to limit their water intake; most do not monitor each other and indicated no protocol for heat-related emergencies. This confirms several studies that reported headaches and sweating as the most prevalent signs and symptoms of heat-related anxiety that construction workers face (Koteng, 2022; El-Shafei *et al.*, 2018; Jia *et al.*, 2016). A study by Abokhashabah *et al.* (2020) reported heat stroke and heat rash as the most prevalent signs and symptoms of heat-related anxiety among construction workers (Abokhashabah *et al.*, 2020).

The disparities between this study's findings and other studies may be due to differences in climate, work intensity, and protective measures across regions. In some studies, symptoms like dizziness or muscle cramps may be more frequent, possibly due to higher temperatures or prolonged exposure (Karthick *et al.*, 2022). This study's results emphasize that heat stress symptoms vary based on local conditions and worker exposure, highlighting the importance of context-specific interventions. The findings imply an urgent need to enhance on-site health measures, such as providing shaded areas, encouraging regular hydration, and educating workers on early heat stress signs to prevent more severe health complications and improve workplace safety.

5.3.1 Association Between Heat Stress Impact and Sociodemographic Characteristics

The study revealed no significant association between the sociodemographic characteristics of construction workers and the impact of heat stress on their health and work performance. The study's findings contrast with (Yi *et al.*, 2017), who identified age and alcohol consumption as significant predictors of heat stress impact on construction workers' productivity in Hong Kong. Their model indicated that older workers and those with higher alcohol consumption were more vulnerable to heat stress, resulting in reduced labour productivity. Similarly, the (CDC, 2018) highlights that younger and acclimatized workers experience higher susceptibility to heat-related illnesses, particularly during their initial exposure to high-temperature environments. The disparity may be attributed to climatic conditions, work practices, and access to protective measures across regions. Unlike these studies, the lack of association suggests that external environmental and occupational factors may be more critical in influencing heat stress impacts in Ghanaian construction sites rather than demographic attributes. This finding highlights the need for workplace interventions focusing on environmental modifications and heat management strategies rather than targeting specific demographic groups.

5.4 Heat Stress Exposure among Construction Workers

This study indicates that most construction workers (90.7%) have access to drinking water on-site, although only a smaller portion (27.9%) store it in a covered container on the floor, potentially exposing it to contaminants. The majority (79.1%) also have access to mobile washrooms, though these facilities are reportedly insufficient to meet the needs of all workers. These findings suggest a partial provision of essential amenities, though

inadequate storage practices and washroom facilities could impact workers' health and comfort. To improve on-site conditions, construction companies might consider increasing the number of washrooms and ensuring safer water storage practices. This approach would promote a healthier and more supportive work environment, reducing risks associated with poor hygiene and dehydration.

This study reveals a high prevalence of heat stress among construction workers, with 76.7% affected and 73.3% experiencing symptoms. Many workers (41.9%) reported inadequate time to acclimatize, while 84.9% cited exposure to high temperatures, particularly in Earthworks and Light Mast areas. Additionally, 43% lacked breathable clothing, and 60.5% had not observed heat stress monitoring devices on-site. These findings highlight significant occupational health risks linked to heat exposure and inadequate protective measures. The lack of acclimatization time and breathable attire may intensify workers' vulnerability to heat stress. This calls for increased efforts to improve workplace conditions through acclimatization programs, breathable protective gear, and heat monitoring equipment to enhance worker safety and reduce heat-related health issues.

5.4.1 Heat Stress Exposure and Sociodemographic Characteristics

This study revealed that gender and educational level significantly influence heat stress exposure among construction workers, with female workers being four times more likely to experience heat stress than their male counterparts. These findings align with (Ioannou *et al.*, 2021), who observed that women are more susceptible to heat stress due to physiological factors like lower sweat rates and reduced heat dissipation capacity than men. However, (Yi *et al.*, 2017) highlighted that environmental factors and job roles,

such as the tasks assigned to men and women, can also influence heat stress vulnerability, suggesting that gender differences might not solely be physiological.

Furthermore, the study found that workers with tertiary education were 68% less likely to suffer from heat stress, this reflects earlier research pointing to the impact of education in promoting awareness and adherence to heat mitigation strategies like hydration and work-rest cycles. These findings suggest that educational interventions could be crucial in reducing heat-related risks among construction workers. The disparities between this study and others may result from differences in climate, occupational safety policies, and socio-economic factors across regions. Addressing these disparities through tailored interventions can enhance occupational health and productivity in heat-prone industries.

5.5 Practices and mitigation strategies, implementation, and adherence among construction workers

The study found that many construction workers reported the absence of heat stress measures on-site, with most participants indicating a lack of a heat stress mitigation plan. This is consistent with a study by (Rowlinson *et al.* (2020), that reported diverse causes of heat stress in different construction companies with limited access to mitigation measures on-site (Rowlinson *et al.*, 2020). This finding highlights a critical gap in occupational health and safety practices within the construction industry, suggesting a failure to recognize or address the risks associated with heat exposure. It demonstrates the need for enhanced awareness and implementation of heat stress prevention strategies. The study suggests that construction sites should adopt formal heat stress plans, provide protective gear, and educate workers on heat-related risks.

This study revealed that most construction workers perceived existing heat stress measures as insufficient, citing inadequate shaded areas, lack of awareness about ventilation measures, and limited access to cool water and cooling devices, consistent with several studies.(Habibi *et al.*, 2024; Hatvani-Kovacs *et al.*, 2016; Sairam & Vienna, 2022). This highlights significant deficiencies in the protection of workers from heat-related health risks, which could lead to increased incidences of heat stress and related illnesses (Koteng, 2022)This implies a need for more comprehensive and accessible heat stress management strategies on construction sites. It suggests implementing better cooling facilities, improved awareness, and regular training for workers on heat stress prevention.

This study found that over half of construction workers consumed 1–5 sachets or bottles of water daily, but few were encouraged to take breaks, with some feeling uncomfortable doing so. Most participants reported the absence of acclimatization programs, though nearly all expressed interest in participating in one. About half of the workers managed heat stress by drinking plenty of water (Kühnel *et al.*, 2017; Wesseling *et al.*, 2016). This suggests a need for better workplace policies that promote regular breaks, water intake, and structured acclimatization programs. The findings emphasize the importance of creating a supportive environment to prevent heat stress and improve workers' well-being.

5.5.1 Existence of Heat Stress Mitigation Plans on Site and Sociodemographic Characteristics.

This study found that construction workers with 3-5 years of experience were 93.3% less likely to acknowledge the presence of a heat stress mitigation plan than their more experienced counterparts. This finding contrasts with research by(Choi *et al.*, 2020),

which suggests that workers with more years of experience tend to have better awareness and access to safety measures, including heat stress mitigation plans, due to their familiarity with workplace safety protocols. However, a study by (D'Arcy, 2019) found that workers with moderate experience might not engage with safety policies as proactively as expected, potentially due to complacency or the perception that safety measures are less critical for those with some experience. This suggests that although workers with more experience may be more familiar with heat stress, they may not always acknowledge or implement mitigation plans, potentially due to fatigue or overconfidence in their ability to cope with heat stress.

This finding highlights the need for continuous training and clear communication regarding heat stress prevention across all experience levels. It suggests that mitigation plans should be regularly reinforced, especially for mid-level experienced workers who may assume they are less at risk.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSION, AND RECOMMENDATIONS

6.1 Introduction

This chapter summarizes the study's significant findings, limitations, conclusions from the results obtained, and recommendations for further studies.

6.2 Summary of the Key Findings

Most participants in the study were male (73.3%), with half having tertiary education. Awareness of heat stress was high (93%), yet 40.7% had no training, and 20.9% lacked induction on heat stress mitigation. While 96.5% supported the need for heat stress training, 61.6% indicated no on-site hydration encouragement measures. Demographics like age, gender, and job department showed no link to heat stress awareness ($P > 0.05$). Heat stress was widely regarded as serious (82.6%), with common symptoms being headaches (30.2%), heat rash (23.3%), and heavy sweating (22.1%). Nearly half (47.7%) felt pressure to limit water intake, and 54.7% indicated a lack of emergency protocols. Though most had access to drinking water (90.7%), only 27.9% stored it covered, and 47.7% found mobile washrooms inadequate. Heat stress affected 76.7% of participants, with 73.3% experiencing symptoms and 52.3% still affected. Areas such as Earthworks and Light Mast were reported as the hottest (36%). Few had access to breathable clothing (43%), cooling devices (55.8%), or heat monitoring tools (60.5%). Notably, 76% indicated no heat mitigation plan, and 53.5% felt existing measures were insufficient. A lack of shaded areas (89.5%) and cool water access (20.9%) were also issues. Over half (51%) consumed 1–5 bottles of water daily, while 53.5% had support for breaks. Although 92.4% showed interest in acclimatization programs, 40.7% reported none, and 47.7% managed heat stress by drinking plenty of water.

The study revealed no significant association between the sociodemographic characteristics of construction workers and the impact of heat stress on their health and work performance. However, gender and educational level were associated with heat stress exposure ($\chi^2 = 3.7$, $p = 0.044$ and $\chi^2 = 7.4$, $p = 0.025$, respectively). Female construction workers were four times more likely to suffer from heat stress than males (AOR = 4.2, 95% CI: 1.210-19.788, $p = 0.036$). Participants with tertiary education were 68% less likely to suffer from heat stress than their counterparts (AOR = 0.32, 95% CI: 0.103-0.904, $p = 0.027$). Working experience was associated with a heat stress mitigation plan ($\chi^2 = 11.8$, $p = 0.019$). Construction workers with 3-5 years of experience were 93.3% less likely to acknowledge the presence of a heat stress mitigation plan on site than their counterparts (AOR = 0.067, 95% CI: 0.007-0.605, $p = 0.016$).

6.3 Study Limitation

This study was subject to several limitations. First, the reliance on self-reported information may have introduced recall bias, as participants might selectively recall or report specific details, affecting data accuracy. Participants were assured of confidentiality and strictly maintained anonymity to minimise this risk. Another limitation was the sample size, which was constrained by logistical and time limitations and may not fully represent the entire workforce at the Tema Port Expansion Project. To ensure a variety of viewpoints on heat stress and mitigation strategies, purposive sampling was used to select participants from different job roles, including supervisors, managers, and general workers. Despite these limitations, the findings remain relevant for informing policies to enhance worker safety in high-temperature construction environments.

6.4 Conclusion

Construction workers at the Tema Port Expansion Project demonstrated high awareness of heat stress and its risks. The study revealed no significant correlation between sociodemographic factors and the effects of heat stress on workers' health or job performance. However, gender and education influenced exposure, with females four times more likely to experience heat stress, while those with tertiary education were 68% less likely to experience heat stress; working experience also influenced the awareness of heat stress mitigation plans. Workers with 3-5 years of experience were much less likely to recognise the presence of a heat stress mitigation plan on site than workers with more experience. To enhance safety and well-being at the Tema Port Expansion Project, workers should prioritise staying hydrated, taking frequent rest breaks during the hottest hours, and actively participating in daily pre-task briefings on emergency protocols. Workers should remove tight clothing and boots during rest periods to promote comfort and cooling. Additionally, they should avoid standing near retaining walls, as these surfaces absorb and radiate significant amounts of heat, posing an additional heat stress risk.

6.5 Recommendations

6.5.1 Ghana Health Service (GHS)

- ✓ The GHS should provide specialized training for healthcare workers to recognize and treat heat stress-related conditions effectively. This training will enhance healthcare delivery and ensure that healthcare professionals can manage heat-related illnesses promptly and efficiently.
- ✓ The GHS should collaborate with other government agencies and employers to establish heat stress monitoring and support programs at the local level.

6.5.2 Occupational Safety and Health Administration (OSHA) Ghana

- ❖ OSHA Ghana should implement and strictly enforce guidelines that require construction companies to have formal heat stress management plans.
- ❖ OSHA Ghana should increase the frequency of on-site inspections to ensure compliance with heat stress management protocols and workplace safety standards.

6.5.3 Ministry of Employment and Labour Relations, Ghana

- The Ministry should develop and implement national occupational heat stress guidelines that standardise prevention and mitigation measures across all industries, especially construction.
- The Ministry should collaborate with employers to facilitate heat stress training programs and provide resources for heat stress mitigation.

6.5.4 Workers

- Gender-specific heat stress training and support for gender-specific vulnerabilities are tailored to hydration strategies, rest breaks, and PPE designed for different body types and needs.
- Education-based heat stress awareness initiatives focus on educating all workers about heat stress risks and mitigation strategies.
- Strengthen heat stress mitigation plans to reinforce the visibility and communication of heat stress mitigation plans, particularly for workers with moderate experience.

- Regular hydration and rest breaks should be promoted among female workers and those with less education, and regular hydration breaks and scheduled rest periods should be mandated.

6.5.5 Other Agencies

- Other Agencies include the Factories, Offices and Shop Act (1970) and the Occupational Safety and Health Act (2011). The Ghana Standards Authority (GSA) and the National Insurance Commission (NIC) should work together to promote a safe and healthy work environment for construction workers in Ghana.

6.5.6 Future Research

- Future research should focus on the long-term health impacts of heat stress among construction workers, examining chronic conditions and potential disabilities linked to prolonged heat exposure.
- Future studies should assess the effectiveness of various heat stress mitigation strategies, such as hydration policies, acclimatization programs, and cooling devices, in reducing heat stress-related symptoms and improving overall worker productivity.

REFERENCES

- Abokhashabah, T., Jamoussi, B., Summan, A., Abdelfattah, E., & Ahmad, I. J. I. J. B., no. (2020). A review of occupational exposure to heat stress, its health effects and controls among construction industry workers, A case of Jeddah, KSA. 35-45.
- Ashtekar, S., Mishra, S., Kapadia, V., Nag, P., & Singh, G. (2019). Workplace heat exposure management in Indian construction workers using cooling garment. *Workplace health & safety*, 67(1), 18-26.
- CDC. (2018). Centers for Disease Control and Prevention (CDC). (2018). Heat Stress in Construction: Prevention Strategies and Symptoms of Heat-Related Illnesses. Retrieved from CDC Blogs.
- Choi, S. E., Simon, L., Barrow, J. R., Palmer, N., Basu, S., Phillips, R. S. J. I. J. o. E. R., & Health, P. (2020). Dental practice integration into primary care: a microsimulation of financial implications for practices. 17(6), 2154.
- D'Arcy, J., K Reilly and A McKeown. (2019). Occupational Heat Stress in the Construction Sector: Understanding the Risk Factors and Mitigation Strategies. *. Journal of Occupational Safety and Health*, 12(3), 171-185.
- El-Shafei, D. A., Bolbol, S. A., Awad Allah, M. B., Abdelsalam, A. E. J. E. S., & Research, P. (2018). Exertional heat illness: knowledge and behavior among construction workers. 25, 32269-32276.
- Habibi, P., Razmjouei, J., Moradi, A., Mahdavi, F., Fallah-Aliabadi, S., & Heydari, A. J. B. p. h. (2024). Climate change and heat stress resilient outdoor workers: findings from systematic literature review. 24(1), 1711.

- Hatvani-Kovacs, G., Belusko, M., Skinner, N., Pockett, J., Boland, J. J. S. C., & Society. (2016). Heat stress risk and resilience in the urban environment. *26*, 278-288.
- Hussain, R., Pedro, A., Lee, D. Y., Pham, H. C., & Park, C. S. (2020). Impact of safety training and interventions on training-transfer: Targeting migrant construction workers. *International journal of occupational safety and ergonomics*.
- Ioannou, L. G., Mantzios, K., Tsoutsoubi, L., Nintou, E., Vliora, M., Gkiata, P.,...health, p. (2021). Occupational heat stress: multi-country observations and interventions. *18*(12), 6303.
- Jia, Y. A., Rowlinson, S., & Ciccarelli, M. J. A. e. (2016). Climatic and psychosocial risks of heat illness incidents on construction site. *53*, 25-35.
- Karthick, S., Kermanshachi, S., & Loganathan, K. (2022). Impact of construction workers' physical health and respiratory issues in hot weather: A pilot study. In *Tran-SET 2022* (pp. 135-145).
- Koteng, P. O. (2022). *Assessment of Heat Stress Exposure on Construction Workers in Warm and Humid Environments* university of nairobi].
- Kühnel, J., Zacher, H., De Bloom, J., Bledow, R. J. E. J. o. W., & Psychology, O. (2017). Take a break! Benefits of sleep and short breaks for daily work engagement. *26*(4), 481-491.
- Margheritti, S., Negrini, A., & da Silva, S. A. J. S. (2023). There Is Hope in Safety Promotion! How Can Resources and Demands Impact Workers' Safety Participation? , *9*(4), 79.
- Morris, N. B., Jay, O., Flouris, A. D., Casanueva, A., Gao, C., Foster, J.,...Nybo, L. (2020). Sustainable solutions to mitigate occupational heat strain—an umbrella

- review of physiological effects and global health perspectives. *Environmental Health*, 19, 1-24.
- Nunfam, V. F., Adusei-Asante, K., Van Etten, E. J., Oosthuizen, J., & Frimpong, K. (2018). Social impacts of occupational heat stress and adaptation strategies of workers: A narrative synthesis of the literature. *Science of the total environment*, 643, 1542-1552.
- Ó Murchadha, E. (2022). A Socio-Ecological, Multi-Stakeholder Investigation of Apprenticeship Training Engagement in the Irish Construction Industry.
- Pacheco-Zenteno, F., Glaser, J., Jakobsson, K., Weiss, I., Arias-Monge, E., & Gyllensten, K. (2021). The prevention of occupational heat stress in sugarcane workers in Nicaragua—an interpretative phenomenological analysis. *Frontiers in Public Health*, 9, 713711.
- Rowlinson, S., YunyanJia, A., Li, B., ChuanjingJu, C. J. A. A., & Prevention. (2014). Management of climatic heat stress risk in construction: a review of practices, methodologies, and future research. 66, 187-198.
- Sairam, A., & Vienna, A. (2022). “Come hail or heatwave, work goes on”: Assessing heat stress vulnerability among female construction workers in Hyderabad, India.
- Wesseling, C., Aragón, A., González, M., Weiss, I., Glaser, J., Rivard, C. J.,...Johnson, R. J. J. B. o. (2016). Heat stress, hydration and uric acid: a cross-sectional study in workers of three occupations in a hotspot of Mesoamerican nephropathy in Nicaragua. 6(12), e011034.
- Wu, S. J., Yuhan Mei, B., & Cervantez, J. J. F. i. P. (2022). Preferences and perceptions of workplace participation: A cross-cultural study. 13, 806481.

- Yi, W., Chan, A. P. J. I. j. o. e. r., & health, p. (2017). Effects of heat stress on construction labor productivity in Hong Kong: a case study of rebar workers. *14(9)*, 1055.
- Abokhashabah, T., Jamoussi, B., Summan, A. S., Abdelfattah, E., & Ahmad, I. (2021). Effects of Heat Stress Exposure and Climate Change on Health and Safety of Outdoor Workers. *Current World Environment*, *16(3)*, 836–847.
<https://doi.org/10.12944/CWE.16.3.15>
- Adegboyega, A. A., Eze, C. E., & Sofolahan, O. (2021). Health and safety (hs) risks normalization in the construction industry: The SMEs perspective. *Independent Journal of Management & Production*, *12(5)*, Article 5.
<https://doi.org/10.14807/ijmp.v12i5.1417>
- Alanazi, J. (2020). *Assessment of Heat Stress for Outdoor Work Conditions in Saudi Arabia* [PhD, West Virginia University Libraries].
<https://doi.org/10.33915/etd.7690>
- Al-Bouwarthan, M., Quinn, M. M., Kriebel, D., & Wegman, D. H. (2019). Assessment of Heat Stress Exposure among Construction Workers in the Hot Desert Climate of Saudi Arabia. *Annals of Work Exposures and Health*, *63(5)*, 505–520.
<https://doi.org/10.1093/annweh/wxz033>
- Amadi, A. (2020). A back-end view to climatic adaptation: Partitioning weather-induced cement demand variance in wet humid environment. *International Journal of Building Pathology and Adaptation*, *ahead-of-print*.
<https://doi.org/10.1108/IJBPA-11-2019-0101>
- Ansah, R. K., Obiri-Yeboah, K., & Akipelu, G. (2020). Improving the freight transport of a developing economy: A case of Boankra inland port. *Journal of Shipping and Trade*, *5(1)*, 10. <https://doi.org/10.1186/s41072-020-00065-z>

- Ayanlade, A., Oluwaranti, A., Ayanlade, O. S., Borderon, M., Sterly, H., Sakdapolrak, P., Jegede, M. O., Weldemariam, L. F., & Ayinde, A. F. O. (2022). Extreme climate events in sub-Saharan Africa: A call for improving agricultural technology transfer to enhance adaptive capacity. *Climate Services*, 27, 100311. <https://doi.org/10.1016/j.cliser.2022.100311>
- Barthwal, V., Jain, S., Babuta, A., Jamir, C., Sharma, A. K., & Mohan, A. (2022). Health impact assessment of Delhi's outdoor workers exposed to air pollution and extreme weather events: An integrated epidemiology approach. *Environmental Science and Pollution Research*, 29(29), 44746–44758. <https://doi.org/10.1007/s11356-022-18886-9>
- Borg, M. A., Xiang, J., Anikeeva, O., Pisaniello, D., Hansen, A., Zander, K., Dear, K., Sim, M. R., & Bi, P. (2021). Occupational heat stress and economic burden: A review of global evidence. *Environmental Research*, 195, 110781. <https://doi.org/10.1016/j.envres.2021.110781>
- Casey, T., Turner, N., Hu, X., & Bancroft, K. (2021). Making safety training stickier: A richer model of safety training engagement and transfer. *Journal of Safety Research*, 78, 303–313. <https://doi.org/10.1016/j.jsr.2021.06.004>
- Day, E., Fankhauser, S., Kingsmill, N., Costa, H., & Mavrogianni, A. (2019). Upholding labour productivity under climate change: An assessment of adaptation options. *Climate Policy*, 19(3), 367–385. <https://doi.org/10.1080/14693062.2018.1517640>
- De Winne, S., Marescaux, E., Sels, L., Van Beveren, I., & Vanormelingen, S. (2019). The impact of employee turnover and turnover volatility on labor productivity: A flexible non-linear approach. *The International Journal of Human Resource*

Management, 30(21), 3049–3079.

<https://doi.org/10.1080/09585192.2018.1449129>

Derbile, E. K., Chirawurah, D., & Naab, F. X. (2022). Vulnerability of smallholder agriculture to environmental change in North-Western Ghana and implications for development planning. *Climate and Development*, 14(1), 39–51.

<https://doi.org/10.1080/17565529.2021.1881423>

Deshayes, T. A., Hsouna, H., Braham, M. A. A., Arvisais, D., Pageaux, B., Ouellet, C., Jay, O., Maso, F. D., Begon, M., Saidi, A., Gendron, P., & Gagnon, D. (2024). Work–rest regimens for work in hot environments: A scoping review. *American Journal of Industrial Medicine*, 67(4), 304–320.

<https://doi.org/10.1002/ajim.23569>

Ebi, K. L., Capon, A., Berry, P., Broderick, C., Dear, R. de, Havenith, G., Honda, Y., Kovats, R. S., Ma, W., Malik, A., Morris, N. B., Nybo, L., Seneviratne, S. I., Vanos, J., & Jay, O. (2021). Hot weather and heat extremes: Health risks. *The Lancet*, 398(10301), 698–708. [https://doi.org/10.1016/S0140-6736\(21\)01208-3](https://doi.org/10.1016/S0140-6736(21)01208-3)

Egerer, M., Lin, B. B., & Diekmann, L. (2020). Nature connection, experience and policy encourage and maintain adaptation to drought in urban agriculture.

Environmental Research Communications, 2(4), 041004.

<https://doi.org/10.1088/2515-7620/ab8917>

Flouris, A. D., Dinas, P. C., Ioannou, L. G., Nybo, L., Havenith, G., Kenny, G. P., & Kjellstrom, T. (2018). Workers' health and productivity under occupational heat strain: A systematic review and meta-analysis. *The Lancet Planetary Health*, 2(12), e521–e531. [https://doi.org/10.1016/S2542-5196\(18\)30237-7](https://doi.org/10.1016/S2542-5196(18)30237-7)

Gibson, O. R., James, C. A., Mee, J. A., Willmott, A. G. B., Turner, G., Hayes, M., & Maxwell, N. S. (2020). Heat alleviation strategies for athletic performance: A

review and practitioner guidelines. *Temperature*, 7(1), 3–36.

<https://doi.org/10.1080/23328940.2019.1666624>

Glaser, J., Wegman, D. H., Arias-Monge, E., Pacheco-Zenteno, F., Prince, H., Chavarria, D., Martinez-Cuadra, W. J., Jakobsson, K., Hansson, E., Lucas, R. A. I., Weiss, I., & Wesseling, C. (2022). Workplace Intervention for Heat Stress: Essential Elements of Design, Implementation, and Assessment. *International Journal of Environmental Research and Public Health*, 19(7), Article 7. <https://doi.org/10.3390/ijerph19073779>

Heidari, H., Mohammadbeigi, A., Khazaei, S., Soltanzadeh, A., Asgarian, A., & Saghafipour, A. (2020). The effects of climatic and environmental factors on heat-related illnesses: A systematic review from 2000 to 2020. *Urban Climate*, 34, 100720. <https://doi.org/10.1016/j.uclim.2020.100720>

Ibe, G. O., & Amikuzuno, J. (2019). Climate change in Sub-Saharan Africa: A menace to agricultural productivity and ecological protection. *Journal of Applied Sciences and Environmental Management*, 23(2), Article 2. <https://doi.org/10.4314/jasem.v23i2.20>

Ibrahim, A. A., Khan, M., Nnaji, C., & Koh, A. S. (2023). Assessing Non-Intrusive Wearable Devices for Tracking Core Body Temperature in Hot Working Conditions. *Applied Sciences*, 13(11), Article 11. <https://doi.org/10.3390/app13116803>

Ioannou, L. G., Foster, J., Morris, N. B., Piil, J. F., Havenith, G., Mekjavic, I. B., Kenny, G. P., Nybo, L., & Flouris, A. D. (2022). Occupational heat strain in outdoor workers: A comprehensive review and meta-analysis. *Temperature*, 9(1), 67–102. <https://doi.org/10.1080/23328940.2022.2030634>

- Ioannou, L. G., Mantzios, K., Tsoutsoubi, L., Nintou, E., Vliora, M., Gkiata, P., Dallas, C. N., Gkikas, G., Agaliotis, G., Sfakianakis, K., Kapnia, A. K., Testa, D. J., Amorim, T., Dinas, P. C., Mayor, T. S., Gao, C., Nybo, L., & Flouris, A. D. (2021). Occupational Heat Stress: Multi-Country Observations and Interventions. *International Journal of Environmental Research and Public Health*, 18(12), Article 12. <https://doi.org/10.3390/ijerph18126303>
- Ioannou, L. G., Tsoutsoubi, L., Mantzios, K., Gkikas, G., Piil, J. F., Dinas, P. C., Notley, S. R., Kenny, G. P., Nybo, L., & Flouris, A. D. (2021). The Impacts of Sun Exposure on Worker Physiology and Cognition: Multi-Country Evidence and Interventions. *International Journal of Environmental Research and Public Health*, 18(14), Article 14. <https://doi.org/10.3390/ijerph18147698>
- Jay, O., Capon, A., Berry, P., Broderick, C., Dear, R. de, Havenith, G., Honda, Y., Kovats, R. S., Ma, W., Malik, A., Morris, N. B., Nybo, L., Seneviratne, S. I., Vanos, J., & Ebi, K. L. (2021). Reducing the health effects of hot weather and heat extremes: From personal cooling strategies to green cities. *The Lancet*, 398(10301), 709–724. [https://doi.org/10.1016/S0140-6736\(21\)01209-5](https://doi.org/10.1016/S0140-6736(21)01209-5)
- Karthick, S., Kermanshachi, S., Rouhanizadeh, B., & Namian, M. (2021). *Short- and Long-Term Health Challenges of Transportation Workforce due to Extreme Weather Conditions*. 39–51. <https://doi.org/10.1061/9780784483787.005>
- Kayaga, S. M., Amankwaa, E. F., Gough, K. V., Wilby, R. L., Abarike, M. A., Codjoe, S. N. A., Kasei, R., Nabilse, C. K., Yankson, P. W. K., Mensah, P., Abdullah, K., & Griffiths, P. (2021). Cities and extreme weather events: Impacts of flooding and extreme heat on water and electricity services in Ghana. *Environment and Urbanization*, 33(1), 131–150. <https://doi.org/10.1177/0956247820952030>

- Kim, C.-G., Kim, J.-G., Gong, M., & Ostriker, E. C. (2023). Introducing TIGRESS-NCR. I. Coregulation of the Multiphase Interstellar Medium and Star Formation Rates. *The Astrophysical Journal*, *946*(1), 3. <https://doi.org/10.3847/1538-4357/acbd3a>
- Kletzander, L., & Musliu, N. (2020). Solving the general employee scheduling problem. *Computers & Operations Research*, *113*, 104794. <https://doi.org/10.1016/j.cor.2019.104794>
- Kolyasnikov, M., & Kelchevskaya, N. (2020). Knowledge management strategies in companies: Trends and the impact of Industry 4.0. *Upravlenets*, *11*(4), 82–96. <https://doi.org/10.29141/2218-5003-2020-11-4-7>
- Koteng, P. O. G. (2022). *Assessment of Heat Stress Exposure on Construction Workers in Warm and Humid Environments* [Thesis, university of nairobi]. <http://erepository.uonbi.ac.ke/handle/11295/161764>
- Kovats, R. S., & Hajat, S. (2008). Heat Stress and Public Health: A Critical Review. *Annual Review of Public Health*, *29*(1), 41–55. <https://doi.org/10.1146/annurev.publhealth.29.020907.090843>
- Lesk, C., Anderson, W., Rigden, A., Coast, O., Jägermeyr, J., McDermid, S., Davis, K. F., & Konar, M. (2022). Compound heat and moisture extreme impacts on global crop yields under climate change. *Nature Reviews Earth & Environment*, *3*(12), 872–889. <https://doi.org/10.1038/s43017-022-00368-8>
- Masoud, A., McKenna, Z. J., Li, Z., Deyhle, M. R., Mermier, C. M., Schlader, Z. J., & Amorim, F. T. (2024). Strategies to mitigate acute kidney injury risk during physical work in the heat. *American Journal of Physiology-Renal Physiology*, *326*(3), F499–F510. <https://doi.org/10.1152/ajprenal.00350.2023>

- Moda, H. M., Zailani, M. B., Rangarajan, R., Hickey, P., Abubakar, M., Maina, J., & Makarfi, Y. I. (2024a). Safety awareness and adaptation strategies of Nigerian construction workers in extreme heat conditions. *PLOS Climate*, 3(4), e0000380. <https://doi.org/10.1371/journal.pclm.0000380>
- Moda, H. M., Zailani, M. B., Rangarajan, R., Hickey, P., Abubakar, M., Maina, J., & Makarfi, Y. I. (2024b). Safety awareness and adaptation strategies of Nigerian construction workers in extreme heat conditions. *PLOS Climate*, 3(4), e0000380. <https://doi.org/10.1371/journal.pclm.0000380>
- Morris, N. B., Jay, O., Flouris, A. D., Casanueva, A., Gao, C., Foster, J., Havenith, G., & Nybo, L. (2020). Sustainable solutions to mitigate occupational heat strain – an umbrella review of physiological effects and global health perspectives. *Environmental Health*, 19(1), 95. <https://doi.org/10.1186/s12940-020-00641-7>
- Morris, N. B., Levi, M., Morabito, M., Messeri, A., Ioannou, L. G., Flouris, A. D., Samoutis, G., Pogačar, T., Bogataj, L. K., Piil, J. F., & Nybo, L. (2021). Health vs. wealth: Employer, employee and policy-maker perspectives on occupational heat stress across multiple European industries. *Temperature*, 8(3), 284–301. <https://doi.org/10.1080/23328940.2020.1852049>
- Morrissey, M. C., Casa, D. J., Brewer, G. J., Adams, W. M., Hosokawa, Y., Benjamin, C. L., Grundstein, A. J., Hostler, D., McDermott, B. P., McQuerry, M. L., Stearns, R. L., Filep, E. M., DeGroot, D. W., Fulcher, J., Flouris, A. D., Huggins, R. A., Jacklitsch, B. L., Jardine, J. F., Lopez, R. M., ... Yeargin, S. W. (2021). Heat Safety in the Workplace: Modified Delphi Consensus to Establish Strategies and Resources to Protect the US Workers. *GeoHealth*, 5(8), e2021GH000443. <https://doi.org/10.1029/2021GH000443>

- Pacheco-Zenteno, F., Glaser, J., Jakobsson, K., Weiss, I., Arias-Monge, E., & Gyllensten, K. (2021). The Prevention of Occupational Heat Stress in Sugarcane Workers in Nicaragua—An Interpretative Phenomenological Analysis. *Frontiers in Public Health, 9*.
<https://doi.org/10.3389/fpubh.2021.713711>
- Parkes, B., Buzan, J. R., & Huber, M. (2022). Heat stress in Africa under high intensity climate change. *International Journal of Biometeorology, 66*(8), 1531–1545.
<https://doi.org/10.1007/s00484-022-02295-1>
- Pence, J., & Bloomer, R. J. (2020a). Impact of Nuun Electrolyte Tablets on Fluid Balance in Active Men and Women. *Nutrients, 12*(10), Article 10.
<https://doi.org/10.3390/nu12103030>
- Pence, J., & Bloomer, R. J. (2020b). Impact of Nuun Electrolyte Tablets on Fluid Balance in Active Men and Women. *Nutrients, 12*(10), Article 10.
<https://doi.org/10.3390/nu12103030>
- Pescaroli, G., Guida, K., Reynolds, J., Pulwarty, R. S., Linkov, I., & Alexander, D. E. (2023). Managing systemic risk in emergency management, organizational resilience and climate change adaptation. *Disaster Prevention and Management: An International Journal, 32*(1), 234–251.
<https://doi.org/10.1108/DPM-08-2022-0179>
- Ponsonby, W. (2017). Global occupational health. *Occupational Medicine, 67*(5), 331–333. <https://doi.org/10.1093/occmed/kqx068>
- Schulte, P. A., Jacklitsch, B. L., Bhattacharya, A., Chun, H., Edwards, N., Elliott, K. C., Flynn, M. A., Guerin, R., Hodson, L., Lincoln, J. M., MacMahon, K. L., Pendergrass, S., Siven, J., & Vietas, J. (2023). Updated assessment of occupational safety and health hazards of climate change. *Journal of*

Occupational and Environmental Hygiene, 20(5–6), 183–206.

<https://doi.org/10.1080/15459624.2023.2205468>

Szewczyk, W., Mongelli, I., & Ciscar, J.-C. (2021). Heat stress, labour productivity and adaptation in Europe—A regional and occupational analysis. *Environmental Research Letters*, 16(10), 105002. <https://doi.org/10.1088/1748-9326/ac24cf>

Ulpiani, G. (2019). Water mist spray for outdoor cooling: A systematic review of technologies, methods and impacts. *Applied Energy*, 254, 113647. <https://doi.org/10.1016/j.apenergy.2019.113647>

Westwood, C. S., Fallowfield, J. L., Delves, S. K., Nunns, M., Ogden, H. B., & Layden, J. D. (2021). Individual risk factors associated with exertional heat illness: A systematic review. *Experimental Physiology*, 106(1), 191–199. <https://doi.org/10.1113/EP088458>

Wibowo, R., Do, V., Quartucci, C., Koller, D., Daanen, H. A. M., Nowak, D., Bose-O'Reilly, S., & Rakete, S. (2024). Effects of heat and personal protective equipment on thermal strain in healthcare workers: Part B—application of wearable sensors to observe heat strain among healthcare workers under controlled conditions. *International Archives of Occupational and Environmental Health*, 97(1), 35–43. <https://doi.org/10.1007/s00420-023-02022-2>

Zong, H., Yi, W., Antwi-Afari, M., & Yu, Y. (2024). Fatigue in construction workers: A systematic review of causes, evaluation methods, and interventions. *Safety Science*, 176, 106529. <https://doi.org/10.1016/j.ssci.2024.106529>

Dean, L., Tarpoff, A. J., Nickles, K., Place, S., & Edwards-Callaway, L. (2023). Heat Stress Mitigation Strategies in Feedyards: Use, Perceptions, and Experiences of Industry Stakeholders. *Animals*, 13(19), 3029.

- Parsons, K. C. (2021). *Human thermal environments: The effects of hot, moderate, and cold environments on human health, comfort, and performance* (4th ed.). CRC Press.
- Abokhashabah, T., Jamoussi, B., Summan, A. S., Abdelfattah, E., & Ahmad, I. (2021). Effects of Heat Stress Exposure and Climate Change on Health and Safety of Outdoor Workers. *Current World Environment*, 16(3), 836–847.
<https://doi.org/10.12944/CWE.16.3.15>
- Adegboyega, A. A., Eze, C. E., & Sofolahan, O. (2021). Health and safety (hs) risks normalization in the construction industry: The SMEs perspective. *Independent Journal of Management & Production*, 12(5), Article 5.
<https://doi.org/10.14807/ijmp.v12i5.1417>
- Alanazi, J. (2020). *Assessment of Heat Stress for Outdoor Work Conditions in Saudi Arabia* [PhD, West Virginia University Libraries].
<https://doi.org/10.33915/etd.7690>
- Al-Bouwarthan, M., Quinn, M. M., Kriebel, D., & Wegman, D. H. (2019). Assessment of Heat Stress Exposure among Construction Workers in the Hot Desert Climate of Saudi Arabia. *Annals of Work Exposures and Health*, 63(5), 505–520.
<https://doi.org/10.1093/annweh/wxz033>
- Amadi, A. (2020). A back-end view to climatic adaptation: Partitioning weather-induced cement demand variance in wet humid environment. *International Journal of Building Pathology and Adaptation*, ahead-of-print.
<https://doi.org/10.1108/IJBPA-11-2019-0101>
- Ansah, R. K., Obiri-Yeboah, K., & Akipelu, G. (2020). Improving the freight transport of a developing economy: A case of Boankra inland port. *Journal of Shipping and Trade*, 5(1), 10. <https://doi.org/10.1186/s41072-020-00065-z>

- Ayanlade, A., Oluwaranti, A., Ayanlade, O. S., Borderon, M., Sterly, H., Sakdapolrak, P., Jegede, M. O., Weldemariam, L. F., & Ayinde, A. F. O. (2022). Extreme climate events in sub-Saharan Africa: A call for improving agricultural technology transfer to enhance adaptive capacity. *Climate Services*, 27, 100311. <https://doi.org/10.1016/j.cliser.2022.100311>
- Barthwal, V., Jain, S., Babuta, A., Jamir, C., Sharma, A. K., & Mohan, A. (2022). Health impact assessment of Delhi's outdoor workers exposed to air pollution and extreme weather events: An integrated epidemiology approach. *Environmental Science and Pollution Research*, 29(29), 44746–44758. <https://doi.org/10.1007/s11356-022-18886-9>
- Borg, M. A., Xiang, J., Anikeeva, O., Pisaniello, D., Hansen, A., Zander, K., Dear, K., Sim, M. R., & Bi, P. (2021). Occupational heat stress and economic burden: A review of global evidence. *Environmental Research*, 195, 110781. <https://doi.org/10.1016/j.envres.2021.110781>
- Casey, T., Turner, N., Hu, X., & Bancroft, K. (2021). Making safety training stickier: A richer model of safety training engagement and transfer. *Journal of Safety Research*, 78, 303–313. <https://doi.org/10.1016/j.jsr.2021.06.004>
- Day, E., Fankhauser, S., Kingsmill, N., Costa, H., & Mavrogianni, A. (2019). Upholding labour productivity under climate change: An assessment of adaptation options. *Climate Policy*, 19(3), 367–385. <https://doi.org/10.1080/14693062.2018.1517640>
- De Winne, S., Marescaux, E., Sels, L., Van Beveren, I., & Vanormelingen, S. (2019). The impact of employee turnover and turnover volatility on labor productivity: A flexible non-linear approach. *The International Journal of Human Resource*

Management, 30(21), 3049–3079.

<https://doi.org/10.1080/09585192.2018.1449129>

Derbile, E. K., Chirawurah, D., & Naab, F. X. (2022). Vulnerability of smallholder agriculture to environmental change in North-Western Ghana and implications for development planning. *Climate and Development*, 14(1), 39–51.

<https://doi.org/10.1080/17565529.2021.1881423>

Deshayes, T. A., Hsouna, H., Braham, M. A. A., Arvisais, D., Pageaux, B., Ouellet, C., Jay, O., Maso, F. D., Begon, M., Saidi, A., Gendron, P., & Gagnon, D. (2024). Work–rest regimens for work in hot environments: A scoping review. *American Journal of Industrial Medicine*, 67(4), 304–320.

<https://doi.org/10.1002/ajim.23569>

Ebi, K. L., Capon, A., Berry, P., Broderick, C., Dear, R. de, Havenith, G., Honda, Y., Kovats, R. S., Ma, W., Malik, A., Morris, N. B., Nybo, L., Seneviratne, S. I., Vanos, J., & Jay, O. (2021). Hot weather and heat extremes: Health risks. *The Lancet*, 398(10301), 698–708. [https://doi.org/10.1016/S0140-6736\(21\)01208-3](https://doi.org/10.1016/S0140-6736(21)01208-3)

Egerer, M., Lin, B. B., & Diekmann, L. (2020). Nature connection, experience and policy encourage and maintain adaptation to drought in urban agriculture.

Environmental Research Communications, 2(4), 041004.

<https://doi.org/10.1088/2515-7620/ab8917>

Flouris, A. D., Dinas, P. C., Ioannou, L. G., Nybo, L., Havenith, G., Kenny, G. P., & Kjellstrom, T. (2018). Workers' health and productivity under occupational heat strain: A systematic review and meta-analysis. *The Lancet Planetary Health*, 2(12), e521–e531. [https://doi.org/10.1016/S2542-5196\(18\)30237-7](https://doi.org/10.1016/S2542-5196(18)30237-7)

Gibson, O. R., James, C. A., Mee, J. A., Willmott, A. G. B., Turner, G., Hayes, M., & Maxwell, N. S. (2020). Heat alleviation strategies for athletic performance: A

review and practitioner guidelines. *Temperature*, 7(1), 3–36.

<https://doi.org/10.1080/23328940.2019.1666624>

Glaser, J., Wegman, D. H., Arias-Monge, E., Pacheco-Zenteno, F., Prince, H., Chavarria, D., Martinez-Cuadra, W. J., Jakobsson, K., Hansson, E., Lucas, R. A. I., Weiss, I., & Wesseling, C. (2022). Workplace Intervention for Heat Stress: Essential Elements of Design, Implementation, and Assessment. *International Journal of Environmental Research and Public Health*, 19(7), Article 7. <https://doi.org/10.3390/ijerph19073779>

Heidari, H., Mohammadbeigi, A., Khazaei, S., Soltanzadeh, A., Asgarian, A., & Saghafipour, A. (2020). The effects of climatic and environmental factors on heat-related illnesses: A systematic review from 2000 to 2020. *Urban Climate*, 34, 100720. <https://doi.org/10.1016/j.uclim.2020.100720>

Ibe, G. O., & Amikuzuno, J. (2019). Climate change in Sub-Saharan Africa: A menace to agricultural productivity and ecological protection. *Journal of Applied Sciences and Environmental Management*, 23(2), Article 2. <https://doi.org/10.4314/jasem.v23i2.20>

Ibrahim, A. A., Khan, M., Nnaji, C., & Koh, A. S. (2023). Assessing Non-Intrusive Wearable Devices for Tracking Core Body Temperature in Hot Working Conditions. *Applied Sciences*, 13(11), Article 11. <https://doi.org/10.3390/app13116803>

Ioannou, L. G., Foster, J., Morris, N. B., Piil, J. F., Havenith, G., Mekjavic, I. B., Kenny, G. P., Nybo, L., & Flouris, A. D. (2022). Occupational heat strain in outdoor workers: A comprehensive review and meta-analysis. *Temperature*, 9(1), 67–102. <https://doi.org/10.1080/23328940.2022.2030634>

- Ioannou, L. G., Mantzios, K., Tsoutsoubi, L., Nintou, E., Vliora, M., Gkiata, P., Dallas, C. N., Gkikas, G., Agaliotis, G., Sfakianakis, K., Kapnia, A. K., Testa, D. J., Amorim, T., Dinas, P. C., Mayor, T. S., Gao, C., Nybo, L., & Flouris, A. D. (2021). Occupational Heat Stress: Multi-Country Observations and Interventions. *International Journal of Environmental Research and Public Health*, 18(12), Article 12. <https://doi.org/10.3390/ijerph18126303>
- Ioannou, L. G., Tsoutsoubi, L., Mantzios, K., Gkikas, G., Piil, J. F., Dinas, P. C., Notley, S. R., Kenny, G. P., Nybo, L., & Flouris, A. D. (2021). The Impacts of Sun Exposure on Worker Physiology and Cognition: Multi-Country Evidence and Interventions. *International Journal of Environmental Research and Public Health*, 18(14), Article 14. <https://doi.org/10.3390/ijerph18147698>
- Jay, O., Capon, A., Berry, P., Broderick, C., Dear, R. de, Havenith, G., Honda, Y., Kovats, R. S., Ma, W., Malik, A., Morris, N. B., Nybo, L., Seneviratne, S. I., Vanos, J., & Ebi, K. L. (2021). Reducing the health effects of hot weather and heat extremes: From personal cooling strategies to green cities. *The Lancet*, 398(10301), 709–724. [https://doi.org/10.1016/S0140-6736\(21\)01209-5](https://doi.org/10.1016/S0140-6736(21)01209-5)
- Karthick, S., Kermanshachi, S., Rouhanizadeh, B., & Namian, M. (2021). *Short- and Long-Term Health Challenges of Transportation Workforce due to Extreme Weather Conditions*. 39–51. <https://doi.org/10.1061/9780784483787.005>
- Kayaga, S. M., Amankwaa, E. F., Gough, K. V., Wilby, R. L., Abarike, M. A., Codjoe, S. N. A., Kasei, R., Nabilse, C. K., Yankson, P. W. K., Mensah, P., Abdullah, K., & Griffiths, P. (2021). Cities and extreme weather events: Impacts of flooding and extreme heat on water and electricity services in Ghana. *Environment and Urbanization*, 33(1), 131–150. <https://doi.org/10.1177/0956247820952030>

- Kim, C.-G., Kim, J.-G., Gong, M., & Ostriker, E. C. (2023). Introducing TIGRESS-NCR. I. Coregulation of the Multiphase Interstellar Medium and Star Formation Rates. *The Astrophysical Journal*, *946*(1), 3. <https://doi.org/10.3847/1538-4357/acbd3a>
- Kletzander, L., & Musliu, N. (2020). Solving the general employee scheduling problem. *Computers & Operations Research*, *113*, 104794. <https://doi.org/10.1016/j.cor.2019.104794>
- Kolyasnikov, M., & Kelchevskaya, N. (2020). Knowledge management strategies in companies: Trends and the impact of Industry 4.0. *Upravlenets*, *11*(4), 82–96. <https://doi.org/10.29141/2218-5003-2020-11-4-7>
- Koteng, P. O. G. (2022). *Assessment of Heat Stress Exposure on Construction Workers in Warm and Humid Environments* [Thesis, university of nairobi]. <http://erepository.uonbi.ac.ke/handle/11295/161764>
- Kovats, R. S., & Hajat, S. (2008). Heat Stress and Public Health: A Critical Review. *Annual Review of Public Health*, *29*(1), 41–55. <https://doi.org/10.1146/annurev.publhealth.29.020907.090843>
- Lesk, C., Anderson, W., Rigden, A., Coast, O., Jägermeyr, J., McDermid, S., Davis, K. F., & Konar, M. (2022). Compound heat and moisture extreme impacts on global crop yields under climate change. *Nature Reviews Earth & Environment*, *3*(12), 872–889. <https://doi.org/10.1038/s43017-022-00368-8>
- Masoud, A., McKenna, Z. J., Li, Z., Deyhle, M. R., Mermier, C. M., Schlader, Z. J., & Amorim, F. T. (2024). Strategies to mitigate acute kidney injury risk during physical work in the heat. *American Journal of Physiology-Renal Physiology*, *326*(3), F499–F510. <https://doi.org/10.1152/ajprenal.00350.2023>

- Moda, H. M., Zailani, M. B., Rangarajan, R., Hickey, P., Abubakar, M., Maina, J., & Makarfi, Y. I. (2024a). Safety awareness and adaptation strategies of Nigerian construction workers in extreme heat conditions. *PLOS Climate*, 3(4), e0000380. <https://doi.org/10.1371/journal.pclm.0000380>
- Moda, H. M., Zailani, M. B., Rangarajan, R., Hickey, P., Abubakar, M., Maina, J., & Makarfi, Y. I. (2024b). Safety awareness and adaptation strategies of Nigerian construction workers in extreme heat conditions. *PLOS Climate*, 3(4), e0000380. <https://doi.org/10.1371/journal.pclm.0000380>
- Morris, N. B., Jay, O., Flouris, A. D., Casanueva, A., Gao, C., Foster, J., Havenith, G., & Nybo, L. (2020). Sustainable solutions to mitigate occupational heat strain – an umbrella review of physiological effects and global health perspectives. *Environmental Health*, 19(1), 95. <https://doi.org/10.1186/s12940-020-00641-7>
- Morris, N. B., Levi, M., Morabito, M., Messeri, A., Ioannou, L. G., Flouris, A. D., Samoutis, G., Pogačar, T., Bogataj, L. K., Piil, J. F., & Nybo, L. (2021). Health vs. wealth: Employer, employee and policy-maker perspectives on occupational heat stress across multiple European industries. *Temperature*, 8(3), 284–301. <https://doi.org/10.1080/23328940.2020.1852049>
- Morrissey, M. C., Casa, D. J., Brewer, G. J., Adams, W. M., Hosokawa, Y., Benjamin, C. L., Grundstein, A. J., Hostler, D., McDermott, B. P., McQuerry, M. L., Stearns, R. L., Filep, E. M., DeGroot, D. W., Fulcher, J., Flouris, A. D., Huggins, R. A., Jacklitsch, B. L., Jardine, J. F., Lopez, R. M., ... Yeargin, S. W. (2021). Heat Safety in the Workplace: Modified Delphi Consensus to Establish Strategies and Resources to Protect the US Workers. *GeoHealth*, 5(8), e2021GH000443. <https://doi.org/10.1029/2021GH000443>

- Pacheco-Zenteno, F., Glaser, J., Jakobsson, K., Weiss, I., Arias-Monge, E., & Gyllensten, K. (2021). The Prevention of Occupational Heat Stress in Sugarcane Workers in Nicaragua—An Interpretative Phenomenological Analysis. *Frontiers in Public Health, 9*.
<https://doi.org/10.3389/fpubh.2021.713711>
- Parkes, B., Buzan, J. R., & Huber, M. (2022). Heat stress in Africa under high intensity climate change. *International Journal of Biometeorology, 66*(8), 1531–1545.
<https://doi.org/10.1007/s00484-022-02295-1>
- Pence, J., & Bloomer, R. J. (2020a). Impact of Nuun Electrolyte Tablets on Fluid Balance in Active Men and Women. *Nutrients, 12*(10), Article 10.
<https://doi.org/10.3390/nu12103030>
- Pence, J., & Bloomer, R. J. (2020b). Impact of Nuun Electrolyte Tablets on Fluid Balance in Active Men and Women. *Nutrients, 12*(10), Article 10.
<https://doi.org/10.3390/nu12103030>
- Pescaroli, G., Guida, K., Reynolds, J., Pulwarty, R. S., Linkov, I., & Alexander, D. E. (2023). Managing systemic risk in emergency management, organizational resilience and climate change adaptation. *Disaster Prevention and Management: An International Journal, 32*(1), 234–251.
<https://doi.org/10.1108/DPM-08-2022-0179>
- Ponsonby, W. (2017). Global occupational health. *Occupational Medicine, 67*(5), 331–333. <https://doi.org/10.1093/occmed/kqx068>
- Schulte, P. A., Jacklitsch, B. L., Bhattacharya, A., Chun, H., Edwards, N., Elliott, K. C., Flynn, M. A., Guerin, R., Hodson, L., Lincoln, J. M., MacMahon, K. L., Pendergrass, S., Siven, J., & Vietas, J. (2023). Updated assessment of occupational safety and health hazards of climate change. *Journal of*

Occupational and Environmental Hygiene, 20(5–6), 183–206.

<https://doi.org/10.1080/15459624.2023.2205468>

Szewczyk, W., Mongelli, I., & Ciscar, J.-C. (2021). Heat stress, labour productivity and adaptation in Europe—A regional and occupational analysis. *Environmental Research Letters*, 16(10), 105002. <https://doi.org/10.1088/1748-9326/ac24cf>

Ulpiani, G. (2019). Water mist spray for outdoor cooling: A systematic review of technologies, methods and impacts. *Applied Energy*, 254, 113647. <https://doi.org/10.1016/j.apenergy.2019.113647>

Westwood, C. S., Fallowfield, J. L., Delves, S. K., Nunns, M., Ogden, H. B., & Layden, J. D. (2021). Individual risk factors associated with exertional heat illness: A systematic review. *Experimental Physiology*, 106(1), 191–199. <https://doi.org/10.1113/EP088458>

Wibowo, R., Do, V., Quartucci, C., Koller, D., Daanen, H. A. M., Nowak, D., Bose-O'Reilly, S., & Rakete, S. (2024). Effects of heat and personal protective equipment on thermal strain in healthcare workers: Part B—application of wearable sensors to observe heat strain among healthcare workers under controlled conditions. *International Archives of Occupational and Environmental Health*, 97(1), 35–43. <https://doi.org/10.1007/s00420-023-02022-2>

Zong, H., Yi, W., Antwi-Afari, M., & Yu, Y. (2024). Fatigue in construction workers: A systematic review of causes, evaluation methods, and interventions. *Safety Science*, 176, 106529. <https://doi.org/10.1016/j.ssci.2024.106529>

APPENDICE

QUESTIONNAIRE

NO	QUESTIONS AND FILTERS	CODING CATEGORIES
SECTION A: Socio-Demographic Characteristics (Tick)		
I would like to start by asking you a few questions about yourself.		
1.	Gender	Male.....1 Female.....2
2.	Age	19-30.....1 31-40.....2 41-50.....3 51 and above.....4
3.	Educational Level?	Primary1 Secondary.....2 Tertiary3 Others Specify.....4
4.	Job Title1
5.	Department/Trade1
6.	Length of service in this role	0-10 months.....1 1-2years.....2 2-3years.....3 3-4years.....4 4 and above.....5
SECTION B: Knowledge/Awareness		
7.	Do you know about heat stress?	Yes.....1 No.....2
8.	What do you know about heat stress?	Increased body temperature.....1 Prolonged exposure to high-temperature...2 Intense physical activity.....3 Lack of sufficient fluid intake.....4 Excessive sweating.....5 Dizziness.....6 Headache.....7 Weakness.....8
9.	Have you ever suffered from heat stress before?	Yes.....1 No.....2
10.	Do you currently suffer from heat stress working on site?	Yes.....1 No.....2
11.	What are the signs and symptoms of heat stress?	Dizziness.....1 Nausea.....2 Excessive sweating.....3 Muscle cramps.....4

		Headache.....5 Rapid heartbeat.....6 Confusion.....7
12.	Have you ever experienced any of the signs and symptoms before?	Yes.....1 No.....2
13.	In your estimation which of these is the most serious one	Heat rash.....1 Headache.....2 Dry, hot skin.....3 Heavy sweating.....4 Frequent Thirst.....5 Others Specify.....6
14.	What do you do when you experience heat stress while working on site?	Take a break/rest.....1 Drink a lot of water.....2 Visit site clinic.....3 Take a day off.....4
15.	Are there measures put in place to address heat stress on site?	Yes.....1 No.....2
16.	What measures are in place to address heat stress on site?	Advise during morning meetings.....1 Safety supervisors always give talks on site2 Provision of enough drinking water.....3 Provision of sufficient canopies on site.....4 Provision of standard and acceptable PPE for workers.....5
17.	Are these measures sufficient enough to mitigate heat stress on site?	Yes.....1 No.....2
18.	Were you given an induction on heat stress and its mitigation measures?	Yes.....1 No.....2
19.	Was there enough information to help you?	Yes.....1 No.....2
20.	Were you given training on heat stress and its related illness?	Yes.....1 No.....2
21.	If yes, how often is heat stress management training organised on site?	Weekly.....1 Monthly.....2 Quarterly.....3 Yearly.....4
22.	Do you think training should be provided on heat stress management?	Yes.....1 No.....2
23.	Do you think it important to attend these training?	Yes.....1 No.....2
24.	In your opinion, how serious of a threat is heat stress on construction sites?	Very serious.....1 Somewhat serious.....2 Not vey serious3
25.	How will you describe the weather of your working area?	Warm.....1 Very Warm2

		Humid.....3 Very humid.....4
26.	Are there any areas within the work environment with noticeably higher temperatures than others?	Yes.....1 No.....2
27.	If yes please which areas have the high temperatures	Retaining walls.....1 Light mast areas.....2 Substation areas.....3 Marine areas.....4 Earthworks areas.....5 Office areas.....6 Acopod.....7
28.	Are there any additional measures in place, such as using air purifiers or open windows, to enhance ventilation?	Yes.....1 No.....2 Somehow.....3 Not really.....4
SECTION C: Heat Exposure		
29.	Does your workplace have a written heat stress mitigation plan?	Yes.....1 No.....2
30.	Are there shaded or cool areas accessible for breaks?	Yes.....1 No.....2
31.	Is cool water readily available to workers throughout the day?	Far.....1 Very far.....2 Extremely far.....3
32.	Are workers encouraged to take frequent breaks in cool, shaded areas?	Yes.....1 No.....2
33.	What measures are in place for workers to take a break during hot weather?	Yes.....1 No.....2
34.	Does your workplace provide cooling vests or other personal cooling devices for workers?	Yes.....1 No.....2 Don't know.....3

35.	Are workers permitted to wear loose-fitting, breathable clothing during hot weather?	Yes.....1 No.....2
36.	Are there any training sessions conducted to educate workers about recognizing and preventing heat stress?	Yes.....1 No.....2
37.	Is there a monitoring system in place to track the heat index or temperature levels on-site	Yes.....1 No.....2
38.	Does your workplace have a protocol for responding to heat-related illnesses or emergencies?	Yes.....1 No.....2
39.	Are workers informed about the signs and symptoms of heat stress and heat-related illnesses?	Yes.....1 No.....2
40.	Is there a buddy system in place to ensure that workers monitor each other for signs of heat stress?	Yes.....1 No.....2
SECTION D: Hydration Practices		
41.	Do you have access to drinking water throughout your workday?	Yes.....1 No.....2
42.	How is the water kept?	In an ice chest.....1 On the floor and cover it with a wooden slab.....2 Leave it on the floor and exposed to the sun.....3
43.	Do you have access to mobile washrooms on site?	Yes.....1 No.....2
44.	Are they sufficient?	Yes.....1 No.....2 Somehow.....3
45.	How readily are they accessible to you?	Yes.....1 No.....2 No really.....3 Depending on your location.....4
46.	On average, how many water sachets/bottles do you drink during your workday?	1-3.....1 4-6.....2 7 and above.....3
47.	Do you feel pressure to limit your water intake due to work demands (e.g., infrequent breaks, cost, availability)	Yes.....1 No.....2 Others Specify.....3

48.	Are there any measures in place to encourage frequent water intake?	Yes.....1 No.....2 Others Specify.....4
49.	If yes, please describe these measures.1
50.	Do you feel comfortable taking breaks for water consumption throughout your shift?	Yes.....1 No.....2
51.	If not, please explain why.
SECTION E: Acclimatization Practices		
52.	Is there currently a program to gradually introduce new workers or those returning from leave to hot work environments?	Yes.....1 No.....2
53.	What are some of the things you are trained on?	
54.	Do you think the program is sufficient?	Yes.....1 No.....2
55.	Are you given time to acclimatise?	Yes.....1 No.....2
56.	Do you feel adequately prepared to work in hot environments?	Yes.....1 No.....2
57.	Would you participate in a program designed to increase your tolerance to heat stress gradually?	Yes.....1 No.....2 Maybe.....3