DOES TEMPERATURE ALTER THE RELATIONSHIP BETWEEN SLEEP BEHAVIOUR AND NON-COMMUNICABLE DISEASES IN FIVE DIFFERENT POPULATIONS?

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Your love, values, and dreams for me continue to inspire my every step. Though you are no longer with me, your teachings has been my constant companion. This achievement is as much yours as it is mine. I hope to make you proud.

ABSTRACT

Non-communicable diseases (NCDs) account for 71% of global deaths, with over 15 million annual fatalities occurring between the ages of 30 and 69. Emerging evidence links climate change, particularly rising temperatures, to disrupted sleep behaviours. However, the potential role of temperature in modifying the relationship between sleep disruption and NCDs remains underexplored, especially in low- and middle-income countries (LMICs). This study examines whether ambient nighttime temperatures alter the relationship between sleep behaviours and NCDs, focusing on African-origin populations across five diverse geographic locations. A case study approach was used, utilizing clinical data from the longitudinal Modelling the Epidemiologic Transition Study (METS, 2008-2013) and its ancillary studies, including METS-Microbiome (2017-2022) and METS-Sleep (2019-2024). Objective sleep measurements were obtained using actigraphy, while temperature data were sourced from the Iowa Environmental Mesonet (IEM) database. Sleep parameters included sleep onset time, wake-up time, sleep duration, wake after sleep onset (WASO), and sleep efficiency. Data from 809 African-origin adults (aged 35-55 years, 63% women) across Ghana, South Africa, Jamaica, Seychelles, and the US revealed significant variations in nighttime temperatures, ranging from 5°C to 32°C across the sites. Higher nighttime temperatures were associated with longer sleep duration but poorer sleep quality, as indicated by decreased sleep efficiency (-0.05, $p < 0.001$) and increased WASO (-0.005, $p < 0.02$). Poor sleep quality was linked to elevated risks of obesity, hypertension, and diabetes. Temperature minimally mediated the relationship between sleep and hypertension, with no significant mediation for obesity and diabetes.

The project is structured into five sections: Part A (Protocol) reviews existing literature on NCDs, sleep, and climate change in LMICs, outlines the study population, and describes methodologies. Part B (Literature Review) explores how climate change-induced temperature variations may alter the relationship between sleep behaviours and NCDs. Part C (Journal-Ready Article) presents the study's findings, highlighting the complex interplay between temperature, sleep quality, and NCDs. Part D (Appendices) includes supplementary analyses, ethics approvals, and research permissions. Part E (Editorial/Policy Brief) discusses public health policy implications, emphasizing the need to consider temperature and sleep quality in addressing the global NCD burden.

This study highlights the influence of nighttime ambient temperatures on sleep behaviours and their association with NCDs across diverse African-origin populations. The findings underscore the need to integrate climate variables into public health strategies aimed at mitigating the growing burden of NCDs.

Keywords: Climate change; Temperature; Obesity, Type 2 Diabetes, Hypertension, Mediation, Low- and Middle-Income Countries.

ABBREVIATIONS AND ACRONYMS

ACME	Average Causal Mediation Effect
ADE	Average Direct Effect
Arc GIS	Geographic Information System
BMI	Body Mass Index
CI	Confidence Interval
CMD	Cardiometabolic Disease
CVD	Cardiovascular Disease
DALYS	Disease Measured by Disability-Adjusted Life Years
DGHS	Demographic and Health Survey
ESS	Epworth Sleepiness Scale
LMICS	Low-and Middle-Income Countries
METS	Modelling Epidemiologic Transition Study
NCDs	Non-Communicable Diseases
OR	Odds Ratio
PSQI	Pittsburgh Sleep Quality Index
REM	Rapid Eye Movement
SEM	Structural Equation Modelling
SES	Socioeconomic Status
UN	United Nations
WASO	Wake After Sleep Onset
WHO	World Health Organization

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PART A: PROTOCOL

1.1 Background

Non-communicable diseases (NCDs) represent a significant global health challenge, responsible for 71% of all deaths worldwide, with more than 15 million people dying annually from NCDs, primarily aged between 30 and 69 years [25]. The burden of NCDs is particularly pronounced in low- and middle-income countries (LMICs), such as countries in Africa, where 77% of NCD deaths occur [25]. Among NCDs, cardiovascular diseases, cancers, respiratory diseases, and diabetes are the leading causes of premature mortality, accounting for over 80% of global NCD deaths [25].

Novel research suggests that sleep disturbances may be a potential risk factor for the rising prevalence of NCDs globally, including in LMICs [24]. Indeed, poor sleep quality has been extensively associated with an increased risk of NCDs, including obesity, type 2 diabetes, and hypertension [6]. Chronic sleep disturbances may disrupt hormonal regulation, metabolism, and immune function, further exacerbating the risk of NCDs [19]. Notably, insufficient sleep has been associated with increased inflammation, a risk factor for cardiovascular diseases, while sleep disruption can impair glucose regulation, contributing to type 2 diabetes [21,4].

Exposure to extreme ambient heat may directly affect sleep quality by disrupting thermoregulation, thereby altering sleep patterns and circadian rhythms [3,11]. Climate change-induced disruptions in sleep patterns have been suggested to coincide with the increasing burden of NCDs in Africa [24]

The interplay between disrupted sleep patterns and NCDs presents a complex health challenge, especially in regions with diverse climates like those in Africa. Limited access to resources such as air conditioning and healthcare exacerbates the impact of disrupted sleep on NCD prevalence [25]. Understanding the relationship between ambient outdoor temperature, patterns of sleep behaviour, and NCD risk is crucial for developing targeted interventions to mitigate the adverse health effects of disrupted sleep in diverse populations.

1.2 Literature Review

The ongoing pace of climate change and global warming is projected to lead to a significant increase in average global temperatures by 2100, with potential grave consequences for human health [20]. Rising temperatures have been associated with disrupted sleep patterns, potentially contributing to the prevalence

of NCDs [16]. Sleep disorders, particularly insufficient sleep, have been recognized as a public health crisis due to their associated health impacts, including stress, obesity, type 2 diabetes, and hypertension [5].

Temperature variations have been found to disrupt sleep patterns, with hotter nights leading to poorer sleep quality [14]. Mechanisms such as hormonal changes triggered by heat and noise from cooling strategies can impact sleep-wake cycles and exacerbate sleep disturbances [22,8]. Poor sleep quality and shorter sleep duration have been linked to an increased risk of various NCDs, including hypertension, cardiovascular diseases, diabetes, and obesity [9,26].

Studies have highlighted the association between disrupted sleep patterns and the risk of NCDs, particularly cardiovascular diseases, type 2 diabetes, and obesity [1,2,18]. Chronic sleep disturbances disrupt metabolic processes, hormonal regulation, and inflammatory responses, increasing the susceptibility to NCDs [12]. Vulnerable populations, including children, pregnant women, and the elderly, may be particularly sensitive to the combined effects of sleep disruption and NCDs [7,15].

While the relationship between extreme altered sleep patterns and NCDs is complex, evidence suggests their interrelation and potential contribution to the obesity epidemic (13,17]. Altered sleep patterns disrupt circadian rhythms and hormonal regulation, promoting weight gain and hypertension [6, 27]. Stress responses triggered by inadequate sleep can further exacerbate obesity and increase the risk of type 2 diabetes [23]

Despite emerging evidence, very few studies have explored the relationship between sleep patterns and NCDs in depth, particularly in diverse populations across different regions. Understanding the complex interplay between sleep disturbances, temperature variations, and NCDs is essential for developing effective strategies to mitigate the health risks associated with disrupted sleep patterns.

2.1 Aim

The study aims to investigate if temperature alters the relationship between sleeping behaviours and NCDs (obesity, type 2 diabetes risk and hypertension) in Ghana, South Africa and Seychelles, Jamaica and Chicago.

2.2 Objectives of the Study

- Examine the association between disrupted sleep behaviours and NCD outcomes (obesity, type 2 diabetes and hypertension)

- Evaluate the mediating effect of temperature on the relationship between sleep and disruption and NCDs outcomes.
- Quantify the indirect effects of temperature on NCD outcomes through sleep disruptions.

3. 0 Methodology

3.1 Study Design

Data Acquisition and Visualization

This study involves the analysis of secondary data obtained from the Modelling the Epidemiologic Transition Study (METS) and its related studies, METS-Microbiome and METS-Sleep. The primary data collection utilized population-based samples with randomized sampling methods accounting for sex and age stratification. Temperature data will be sourced from Landsat8 satellite imagery and visualized using ArcGIS. Retrospective weather data collection included factors such as humidity and wind, focusing primarily on temperature's impact on health stress. Data collection in 2019, 2021, and 2022 coincides with the sleep and health data, excluding 2020 due to the COVID-19 pandemic.

3.2 Study Population

The study population comprises 2500 young adults aged 25 to 45, sampled from Ghana (Nkwantakesi), South Africa (Khayelitsha, Cape Town), and Seychelles (Victoria). Exclusions were made for individuals diagnosed with infectious diseases, pregnant or breastfeeding women, HIV-positive individuals, and those with conditions hindering typical physical activities. Investigators employed random sampling methods considering sex and age stratification, drawing samples from national census data.

3.3 Data Collection Procedures

Data collection procedures involved participants wearing an Actical accelerometer around their waist for eight consecutive days, excluding water-related activities. Additionally, participants wore an ACTiWatch Spectrum Plus on their non-dominant wrist for seven days to capture wrist actigraphy data. Bioelectrical impedance analysis evaluated body composition, while measurements of height, weight, waist circumference, blood pressure, and fasting plasma glucose levels were taken. Surveys on physical activity, smoking habits, health history, and income were completed. These methods were part of the primary study and will not be repeated. Sleep data, recorded in one-minute epochs, included variables such as average time to fall asleep, waking time, total sleep duration, and sleep chronotype. Health data documented significant diagnoses, existing health risks, and demographic factors such as age, weight, gender, household composition, and construction materials.

3.4 Variable Definitions

Cardiometabolic risk factors:

1. **Type 2 Diabetes**: Individuals are considered to have type 2 diabetes if they self-report as diabetic and are taking medication for diabetes, or if their plasma glucose level is equal to or exceeds 140 milligrams per decilitre.
2. **Hypertension**: This condition is defined as having a systolic blood pressure equal to or greater than 140 millimetres of mercury, a diastolic blood pressure equal to or greater than 90 millimetres of mercury, or if the individual is taking medication for hypertension.
3. **Obesity (%):** This variable categorizes individuals into two groups based on their Body Mass Index (BMI). Those with a BMI greater than or equal to 25 are classified as overweight, while those with a BMI of 30 or higher are considered obese.

Other Variables:

- **BMI (kg/m2):** Body Mass Index, a continuous numeric variable.
- **Body Fat Percentage (%)**: This percentage represents the proportion of body weight that is made up of fat. Various methods, such as bioelectrical impedance analysis or skinfold callipers, can be used to measure it.
- **Waist Circumference**: This measurement is taken at the level of the belly button. For males, a waist circumference of 94 centimetres or higher indicates increased risk, while for females, a measurement of 80 centimetres or higher is considered at risk.
- **Alcohol Use (%):** Indicates whether individuals are currently drinking or not, categorized as 0 for not drinking currently and 1 for currently drinking.
- **Smoking:** A binary categorical variable distinguishing between nonsmokers (0) and current smokers (1).
- **Height (m):** Continuous numeric variable representing individual height in meters.
- **Weight (kg):** Continuous numeric variable indicating individual weight in kilograms.
- **Blood Pressure (mmHg):** Diastolic and systolic blood pressure measurements, both continuous numeric variables.
- **Age:** Continuous numeric variable representing individual age.
- **Location:** Nominal categorical variable denoting the geographical location of participants.
- **Sex:** Binary categorical variable indicating gender, with 0 representing male and 1 representing female.
- **Ethnicity:** Nominal categorical variable representing the ethnic background of participants.

- **SES (Socioeconomic Status):** Nominal categorical variable classifying individuals into low, middle, or high socioeconomic status categories.
- **Diet:** Binary categorical variable categorizing individuals based on diet quality, with 0 indicating a good diet and 1 indicating a poor diet.
- **Physical Activity:** Binary categorical variable indicating whether individuals are active (1) or not active (0).

Altered Sleep. Changes in hormones and metabolism resulting from altered sleep patterns and sleep deprivation can contribute to weight gain and an increased risk of cardiometabolic diseases (CMD). These alterations can be objectively assessed using an actiwatch accelerometer, which captures various sleep parameters including total sleep duration (the overall time spent in bed), sleep efficiency (the percentage of time spent in bed that is actually asleep), sleep quality, and sleep disturbances.

Other variables will be analysed to understand their relationships with extreme temperature variations, altered sleep patterns, and cardiometabolic diseases, with other relevant factors being considered as potential confounders in the analysis.

3.5 Data Processing and Analysis.

Temperature data will be sourced from public websites. RStudio will serve as the platform for processing and analysing the extensive sleep dataset.

Data Cleaning: Rigorous cleaning protocols will be implemented to eliminate any inconsistencies, missing values, or outliers that may distort the results.

Data Integration: Given the diverse origins of the data from sources such as METS, METS-Microbiome, and METS-Sleep, a meticulous process of integration will consolidate them into a unified dataset suitable for comprehensive analysis.

Statistical Analysis: The statistical analysis will undertake a thorough examination of the mediating role of temperature between sleep disruptions and Non-Communicable Diseases (NCDs) like obesity, hypertension, and type 2 diabetes. Descriptive statistics will be applied to summarize continuous variables such as BMI, sleep duration, and temperature variations, utilizing measures such as mean, median, and standard deviation. Furthermore, frequency distributions and data visualization techniques will be

employed to visually inspect data distributions, identify patterns, and identify outliers. Following this, correlation analysis using both Pearson and Spearman correlation coefficients will be conducted to scrutinize the relationships between temperature variations, sleep patterns, and BMI categories, with a particular emphasis on detecting potential non-linear associations. Regression analysis will play a pivotal role in determining the impact of temperature variations and sleep patterns on obesity and related NCDs. Multiple linear regression will be utilized for continuous BMI outcomes, while logistic regression will be applied for binary outcomes such as obesity, hypertension, and type 2 diabetes categories. Additionally, mediation analysis will be employed to delve into the mediating effect of temperature on the relationship between sleep disruptions and NCD outcomes. Subgroup analysis will be conducted by stratifying data based on geographic regions and exploring potential interaction effects with relevant variables to uncover variations and potential modifying factors across different populations. Longitudinal analysis methods, including mixed-effects models, will be employed to account for within-subject correlation and time-varying effects in cases with repeated measurements over time. R software will serve as the primary tool for data analysis due to its versatility and suitability for conducting a wide range of statistical analyses. The results will be interpreted within the context of the research objectives, ensuring transparency and alignment with the study's aims. The analysis section will provide a comprehensive understanding of the methodology used to derive conclusions, taking into account potential limitations and ensuring the robustness of the statistical methods employed.

3.6 Budget

No expenses are necessary to conclude this study as all data collection was conducted during the primary METS. As previously stated, the analysis for this study will be conducted utilizing freely available open-source software, specifically RStudio.

3.7 Data Safety and Monitoring

The primary data was centrally managed at Loyola University Chicago, with files being securely transmitted from various sites through an FTP Bitvise Tunnelier connection. For the current secondary analysis study, data management will be conducted at the University of Cape Town. In adherence to ethical standards, all data collection for this study received approval from the Institutional Review Board or Ethics Committee at each participating institution. The University of Cape Town will manage data for the secondary analysis securely. Data will be transmitted via encrypted channels to prevent unauthorized access, and encryption will further protect files. Access will be restricted to authorized personnel only, following the principle of least privilege. Data will be stored on password-protected servers with robust security measures. Personally identifiable information will be removed or anonymized to preserve

confidentiality. Regular backups will be conducted to prevent data loss, and data retention and disposal will comply with established protocols. Continuous monitoring and auditing will ensure adherence to ethical guidelines and regulatory requirements, with any breaches promptly addressed. These rigorous measures prioritize data security and integrity, maintaining the ethical standards of the research endeavour.

4.0 Significance of the Study

This study holds significant implications for public health policy and practice by shedding light on the intricate interplay between sleep disruptions, temperature variations, and Non-Communicable Diseases (NCDs) like obesity, hypertension, and type 2 diabetes. By examining data from multiple countries and years, the study has the potential to uncover patterns and mechanisms that underlie the relationship between these factors, informing the development of targeted interventions to mitigate the burden of NCDs. Understanding how temperature mediates the link between sleep disturbances and NCDs can guide the implementation of preventive measures, such as improving sleep hygiene and addressing environmental factors, to reduce the risk of developing these chronic conditions. Furthermore, the study's findings may contribute to the growing body of evidence on the impact of climate change on health outcomes, highlighting the need for proactive strategies to adapt to changing environmental conditions and safeguard public health. Ultimately, this research has the potential to inform policies and interventions aimed at promoting healthy sleep patterns and reducing the prevalence of NCDs on a global scale.

5.0 Gaps and Future Research:

While this study aims to illuminate the mediating role of temperature in the relationship between sleep disruptions and Non-Communicable Diseases (NCDs), there are several notable gaps that warrant further investigation. Firstly, the study primarily focuses on young adults aged 25 to 45, potentially overlooking the impact of sleep and temperature on vulnerable populations such as children, the elderly, and individuals with pre-existing health conditions. Future research could explore these populations to gain a more comprehensive understanding of the broader implications. Additionally, while the study considers data from multiple countries, it may benefit from further disaggregation to explore regional variations in climate, socio-economic factors, and health outcomes. Moreover, the study's reliance on retrospective data may limit the ability to capture dynamic changes over time, highlighting the need for longitudinal studies to track the long-term effects of sleep disruptions and temperature variations on NCD outcomes. Lastly, future research could delve into the mechanisms underlying the observed associations, such as the role of circadian rhythms, hormonal regulation, and immune function, to inform targeted interventions and public health strategies aimed at mitigating the burden of NCDs in the context of changing environmental conditions.

6.0 Scope and Limitations

This study endeavours to explore the mediating effect of temperature between sleep disruptions and Non-Communicable Diseases (NCDs) like obesity, hypertension, and type 2 diabetes, utilizing data from the Modelling the Epidemiologic Transition Study (METS) and related studies across multiple countries and years. However, it is essential to acknowledge certain limitations. Firstly, the study's retrospective design may introduce biases inherent to secondary data analysis, potentially limiting the generalizability of findings. Secondly, while the data cover diverse geographic regions and socio-economic contexts, variations in data collection methods and environmental factors across sites may impact comparability. Additionally, the study's reliance on self-reported sleep data and the exclusion of certain population groups, such as those with infectious diseases or disabilities, may introduce sampling biases. The larger study excluded individuals diagnosed with infectious diseases, pregnant or breastfeeding women, HIV-positive and those with conditions hindering typical physical activities, which is a limitation of the secondary data analysis. Despite these limitations, the study's comprehensive statistical analyses and exploration of longitudinal trends offer valuable insights into the complex relationship between sleep patterns, temperature, and NCD outcomes, paving the way for targeted interventions to address this critical public health issue.

7.0 Timeline:

Date	Activity
23 March	Draft Research Proposal
6 April	Draft Research Proposal
22 April	Final written Proposal
8-10 May 22 May	Ethical clearance submission
15 June 22-28 June	Ethical clearance
29 June	Data acquired and downloaded
25 August	Methodology, Results, Discussion
November	Final Thesis Submissions

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PART B: LITERATURE REVIEW

1.0 Background

Globally, non-communicable diseases, (NCDs) are a cause of concern as they highly contribute to the burden of diseases. The greatest number of deaths worldwide have been attributed to NCDs which have also become the major threat in the 21st century. It has been established that countries in the low to middle income category (LMICs) are the most vulnerable as an estimated seventy five percent (75%) of all deaths are caused by NCDs [119]. Rapid urbanization, globalization of unhealthy lifestyles, population aging, limited access to healthcare, lower health literacy, intake of unhealth diet and reduced physical exercises and activities contribute to the prevalence of NCDs in LMICs [1]. Most NCD deaths occurring globally are linked to chronic respiratory diseases, diabetes, cardiovascular diseases and cancer in one way or the other. In the year 2016, 41 million deaths, constituting 71% of the total deaths worldwide were because of NCDs and the mostly affected were aged between 30 and 70 years and in their most productive years. Consequently, this has led to life loss, reduced productivity by the workforce and a burden on the healthcare systems [119,93].

Sleep is fundamental to human health as it significantly impacts the physical, mental, and emotional well-being. It is a biological necessity, and insufficient sleep and untreated sleep disorders are detrimental for health, well-being, and public safety. Adequate sleep duration, healthy sleep requires good quality, appropriate timing, regularity, and the absence of sleep disorders. In that regard, there is a significant need for greater emphasis on sleep health in education, clinical practice, inpatient and long-term care, public health promotion, and the workplace.

Quality sleep is crucial for bodily restoration, cognitive performance, and the regulation of metabolic and immune systems. Short-term sleep deprivation, long-term sleep restriction, circadian misalignment, and untreated sleep disorders can have a profound and detrimental impact on physical health, mental health, mood, and public safety. Common chronic disruptions in sleep patterns such as insufficient sleep duration, poor sleep quality, and irregular sleep schedules are linked to negative health outcomes. Among the outcomes are heightened risks of obesity, diabetes, hypertension, cardiovascular diseases, and mental health disorders. These conditions are categorized as non-communicable diseases (NCDs), which are the leading causes of morbidity and mortality globally.

Poor sleep quality results in metabolic dysregulation, increased inflammation, and impaired immune function which are recognized as significant risk contributors to NCDs. Studies have shown that individuals with sleep disorders exhibit higher levels of inflammatory markers such as C-reactive protein (CRP), which is associated with cardiovascular risks and metabolic syndrome (Cohen et al., 2019; Tzeng et al., 2020). Relatedly, insufficient sleep can disrupt hormonal balance, particularly the regulation of leptin and ghrelin. This can lead to increased appetite and weight gain, thereby further exacerbating obesity and its related conditions [101]. Both high and low temperatures may mediate the relationship between sleep and NCDs by influencing sleep quality. Excessive heat during the night is known to impair sleep quality, potentially contributing to metabolic issues such as insulin resistance and obesity.

Research indicates that elevated nighttime temperatures can lead to increased wakefulness and reduced slow-wave sleep (SWS), which is critical for physical restoration and metabolic health [62]. Furthermore, individuals who experience chronic thermal discomfort may develop habitual poor sleep behaviours, such as irregular sleep schedules or excessive wakefulness during the night. This pattern can create a vicious cycle were poor sleep leads to greater discomfort from temperature extremes, further diminishing sleep quality [41]. Moreover, chronic sleep disturbances are associated with an increased risk of developing mental health disorders. A meta-analysis found that insomnia significantly increases the likelihood of depression and anxiety disorders [127]. The interplay between poor sleep and mental health can be compounded by thermal discomfort; individuals suffering from anxiety may be more sensitive to temperature changes, which can exacerbate their sleep issues whilst on the other hand, cold environments also lead to sleep disturbances. However, the effects are dependent on factors such as bedding and clothing conditions. [125]

Although exposure to heat tends to heighten wakefulness, cold exposure affects the cardiac autonomic response without necessarily altering the sleep stages. The effects are as a result of the body's thermoregulatory responses considering that when exposed to extreme temperatures, the body tries to maintain its core temperature, which in turn interferes with the natural processes that promote sleep. In has been noted that during heat exposure, individuals may experience an elevated heart rate and shallow breathing as their bodies strive to cool down [126]

This struggle against thermal discomfort can lead to fragmented sleep patterns and insufficient restorative sleep. Research has shown that higher ambient temperatures is associated with poorer subjective sleep quality, increased wake after sleep onset (WASO), and reduced REM sleep duration. Furthermore, research has also shown that the negative impact of elevated temperatures on sleep is more pronounced during

warmer months and among vulnerable populations hence the growing concern on climate change and the potential effects on human health [127,128]

In the context of global climate change, temperature variability and the increasing frequency of extreme heat events present significant challenges to healthy sleep patterns. Research has shown that rising nighttime temperatures are linked to a marked decline in sleep quality, with warmer nights leading to an average of 5% more sleep loss globally over recent years [81]. Populations residing in warmer climates, as well as those lacking adequate cooling mechanisms, are particularly vulnerable to temperature-induced sleep disruptions. The impact of extreme heat on sleep is compounded by urbanization, which creates "heat islands" that exacerbate nighttime temperatures [91]. As cities absorb heat during the day and release it at night, residents may find it increasingly difficult to achieve restorative sleep.

2.0 The Role of Climate Change on Health Outcomes

Climate change is the inevitable shifts in weather patterns which are long term. The changes may be attributed to common factors such as earth's orbit, sun movement, volcano emissions, and levels of certain gases. However, from the 17th century human activities were observed as the major cause of the change in whether patterns. Activities such as green houses, power generation, goods manufacturing, deforestation and gas emission have contributed to the process of climate change

Global change of climate is a newly emerging non-traditional threat to humankind and many other living organisms due to its negative impact on the biological and ecological systems as postulated by the Inter-Governmental Panel on Climate Change [49]. Considering current trends in climate change, there is a possibility of an increase in the average global temperature by a range of 1.8^{o}C to 4^{o}C, and consequently all the planet's regions becoming warmer by the year 2100 [84]. It was also projected that in tropical regions which are densely populated and already experiencing temperatures above 40^{o}C, an increase in temperature by 1–3^{o}C was expected by the year 2020 whereas in the year 2080 the increase was estimated to be between 3 and 5^{o}C [49].

The change in climate has been greatly attributed to the accumulation of greenhouse gases in the atmosphere because of the fossil fuels combustion process. From the mid-19th century, there has been an increase in human activities. In turn this resulted in a surge in greenhouse gases more particularly carbon dioxide, methane and nitrous oxide in the atmosphere thus increasing the average temperature [49]. The change in the average temperature due to greenhouse effect was also confirmed by other researchers who also projected a 2^{o}C increase in temperature by the year 2050 [84].

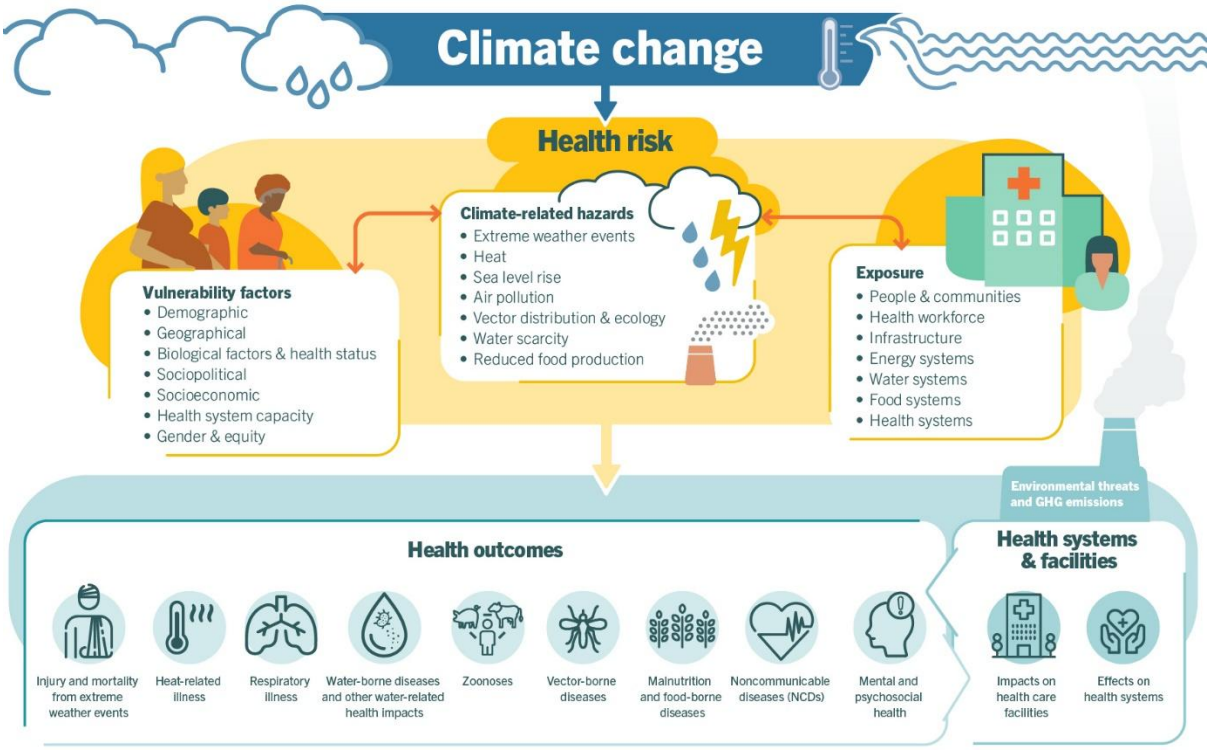
Research conducted on climate change have revealed that, the same a multiplier effect on health outcomes [30]. 5.5 million DALYs were due to climate change in 2000. [70]. It also resulted in loss of lives and burden of diseases which was mostly experienced in poor countries [87]. People living in areas highly susceptible to climate change are estimated to be 3.6 billion and climate change is projected to result approximately 250 000 additional deaths yearly between 2030 and 2050. Furthermore, frequency, intensity and scale of emergencies such as floods, heatwaves, wildfires, and tropical storms among others are expected to increase due to changes in weather patterns, thus posing threats to health [49,87,117]

Pursuant to the assessment of the interplay between changes in climate and health in 1989, WHO made several publications highlighting the concern at the international level to collaborate and intensify research efforts regarding climate change [69.87]. There was a growing concern over the time that had been taken to have issues relating to the global environment, climate and its effect on health appreciated and placed on the international programme. In 2008 the World Health Assembly with other health institutions concurred that extreme weather conditions were likely to affect large populations. Therefore, as a mitigatory measure a resolution on Climate Change and Health (WHA61.19) was acceded [117]. However, an assessment of the major global public health areas revealed that climate change and health is an area that needs much attention [7,23]

Although climate change threatens the wellness of the public and has been considered a public health concern, the relationship between it and NCDs has not been given much attention. [23], Historically, the global perspective has been to perceive NCDs as more prevalent in HICs and communicable diseases prevalent in LICs. Conversely, globally NCDs have now been regarded as the major cause of death [116].

Effects of climate change on NCDs is twofold. Firstly, it can directly or indirectly increase NCDs incidences. On the other hand, the effect can arise from both positive and negative implications of climate change policies on NCDs. Various potential exposure routes and the subsequent impacts on health due to climate change have been observed. It has been noted that the extent of change in climate and places where the vulnerable population is most of its time has a bearing on the effects. Figure 1 below, shows the potential routes of exposure and the outcomes on health.

Figure 1: *An overview of climate-sensitive health risks, their exposure pathways and vulnerability factors. Climate change impacts health both directly and indirectly, and is strongly mediated by environmental, social and public health determinants. Data Source: Intergovernmental Panel on Climate Change (2022) (IPCC AR6).*



The IPCC's 2022 report states that climate change risks are accelerating and intensifying, making it tougher to adapt as the planet warms. Already, 3.6 billion people live in areas highly vulnerable to these changes. Low-income countries and small island nations, despite being the least responsible for emissions, suffer the worst health consequences. Tragically, deaths from extreme weather in vulnerable regions have been 15 times higher than in more resilient areas over the last ten years [50].

Increased mortality due to heat waves in developing countries' large cities were reported [40]. As climate change takes place the likelihood of prolonged periods of exposure to heat and the effects of acute heat stroke increases [50]. There is some convergence among researchers as they agree on the relationship between high temperatures attributed to climate change and NCDs more particularly cardiovascular [31]. Higher temperatures have been linked with increased deaths due to cardiovascular diseases, while heat stress can result in dehydration, heatstroke, and worsening of chronic conditions. On the other hand, cold temperatures have been associated with higher respiratory diseases incidences. This is due to cold air that can impair respiratory function thus increasing susceptibility to infections [32,33].

To establish the effects of exposure to higher mean temperatures research was conducted on troops deployed in arid and hot climates. The results proved high chances of occurrence of kidney stones [24]. The calcium and other compounds in the urine become concentrated due to dehydration and this in turn results in kidney stones developing [24]. In the United States of America 70% of the geographic variation in kidney stone disease is attributed to mean annual temperature differences [11].

Research conducted has revealed three exposure pathways through which the risk of cardiovascular disease (CVD) increases due to climate change. Directly it is increased through air pollution and extreme temperatures whilst indirectly this happens due to changes in diet. Climate change can lead to pollution concentrations, has effects on the distribution and types of airborne allergens, anthropogenic emissions and natural sources of air pollutants. Thus, once there is increased exposure to air pollutants the risks of cardiovascular increases [12]. In the year 2003 a notable contribution by ozone pollution to mortality during the heat wave in France was experienced [28]. Another study was conducted in Paris and the results confirmed that indeed ozone and heat resulted in high mortality daily [25]. Climate change also results in an increase in aero-allergens thereby making many people susceptible to hay-fever or asthma [8].

As temperatures get warmer due to climate change, the cardiovascular and respiratory systems become overloaded, thus resulting in a rise in heat-related mortality and morbidity [46]. Heat exposure is associated with increased sweating, shift of blood flow from central organs to skin, increased core body temperature and increased heart rate. In some instances, it leads to dehydration if enough fluids are taken to keep the body dehydrated. The effects on the cardiovascular system of exposure to heat and air pollutants in times of temperatures were experienced in several places [58]. In Western Europe cardiovascular and respiratory diseases due to the heat wave that occurred in August 2003 caused more than 70 000 deaths [92,42]. Additionally emergency admissions and attendances at hospitals hiked during heat waves [10,80]. California experienced a heat wave in 2006 and likewise an increase in patients suffering from cardiovascular disease was experienced [59].

Pearsons (2003) supported the view that heat exposure results in overloading of the cardiovascular and respiratory systems, thus resulting in high heat mortality [85]. More research also revealed the impact high temperatures on the respiratory and cardiovascular system. A study in Finland reported that the risk of cardiac thrombosis attributed to dehydration at high temperatures had increased [77] whilst in Belgium endothelial dysfunction was identified as a precursor to cardiovascular effects. A study in the Gulf States predicted increased mortality from cardiovascular and respiratory diseases because of heat stress by the year 2070 [47].

While change in climate is a pressing global concern with wide-ranging consequences, one under-recognized yet significant impact is the potential disruption of sleep patterns due to rising ambient temperatures. Climate change projections indicate a rise in global average temperatures, with potential for more frequent heat waves and warmer nights [122]. This trend is likely to exacerbate sleep disturbances, particularly in regions already prone to hot climates. Studies have shown a correlation between a typical nighttime temperatures and increased reports of insufficient sleep [68].

Some studies suggest that climate change act as an intermediary variable. Acting as a variable it contributes indirectly to NCDs through temperature variations which in turn influences quality of sleep [96,20] Although research in the area is still in its infancy stage, the possible consequences of climate change to human sleep is under investigation [86] Climate change has been regarded as a causative to obesity due to disrupted sleep [85]. In that regard this study seeks to establish the relationship between ambient temperature and sleep and the relationship between sleep and NCDs.

3.0 The Impact of Elevated Temperature and Sleep Behaviour.

Sleep behaviour, a critical component of an individual's lifestyle has profound implications on the overall health and well-being of an individual. It is crucial for health and impacts the immune function, metabolism, and cognitive function. The interplay and complex relationship between temperature, sleep patterns, and NCDs in African population is complex and increasingly gaining traction as a research focus and relevant research topic in Africa.

Generally, is understood to be a behavioural state which allows a person to disengage and become unresponsive to the environment, in addition to being subject to control by multiple pathways in the brain, it is normally accompanied by postural recumbence behavioural quiescence and closed eyes. As a combination of behavioural and physiological processes, sleep is critical and beneficial to all creatures [16]. Despite being ubiquitous and playing a vital role in human life, its real purpose remains a mystery [35,41,43].

Arguments advanced by some theorists are that sleep acts as an energy conserver, heat regulator, helps the central nervous system in restoring a state of balance among all body systems needed for the body to function correctly and enables it to process information effectively [35,93]. Krueger (2015) shares the same view but added that sleep removes toxins enhances neural connections and reverse performance loss which happens when a person is awake [63]. Although these arguments have not been conclusively adopted, it has

been generally accepted that sleep involves parts of the brain and has a bearing health (43,79]. Once sleep time less, the immune system is compromised thereby becoming more susceptible to infection [56].

Traditionally, the normal sleeping pattern follows five phases or stages [15]. In 2007, the American Academy of Sleep Medicine (AASM) also affirmed that sleep follows some stages. However, instead of five stages, it noted only three stages to be involved [48]. The length of sleep is influenced by many variables [55,94]. Prior sleep history, age, body temperature, sleep disorders and narcolepsy are some of the factors which have a bearing on sleep and affect the sleep duration [110]. The hours of sleep needed by a person to have the body functions properly vary with individuals [41,75]. Sleep patterns are subject to circadian rhythms and sleep homeostat [79,44].

A dose-response relationship exists between temperature and sleep disruption, with hotter nights leading to poorer sleep. Therefore, deviations from the ideal temperature range can negatively impact sleep [67]. Hot environments disrupt thermoregulation, thereby making it difficult to fall and stay asleep [22]. The body struggles to dissipate heat, thereby leading to increased sweating, restlessness and frequent awakenings throughout the night [107]. This sleep fragmentation reduces overall sleep quality and duration. In turn it leads to daytime consequences such as fatigue, impaired cognitive function and decreased alertness [29].

Research previously conducted shows that ambient temperature plays a role in sleep disruption as discomfort and sweating associated with hot environments makes falling and staying asleep difficult [105;123]. Therefore, sleep initiation and maintenance become difficult when temperatures are high [4,22,]. Study by Obradovich (2017) revealed how sleep has been disrupted due to high temperatures [81].

Human beings exhibit a natural circadian rhythm that regulates sleep patterns. Sleep quality is heavily influenced by the environment, particularly temperature [76]. Cool environments, with temperatures ranging between 15°C and 19°C are considered as ideal for sleep [76,22] Deviations from this temperature makes sleep difficulty [104]. When the environment is too hot, the body struggles to regulate its core temperature, leading to increased sweating and vasodilation [109]. This physiological effort can disrupt sleep architecture and prevent individuals from entering deep sleep stages, which are crucial for restorative functions [16]. Thus, thermoregulation, which is the body's process of maintaining a constant internal temperature, becomes crucial for sleep initiation and maintenance [83].

The impact of rising temperatures on sleep may be more pronounced in older populations and individuals with prior health conditions whose bodies may have a reduced ability to regulate body temperature. This

makes them more susceptible to sleep disruption during hot nights [14]. Socio-economic disparities have been regarded to play a role, considering that access to air conditioning or other cooling strategies can significantly influence sleep comfort. Limited access to air conditioning in low-income settings or cultural practices around nighttime sleeping arrangements could exacerbate the negative effects of hot temperatures on sleep [36]. Research by Ngwenya (2014) and Morrell et al. (2020) suggests that socio economic status, environmental factors, housing conditions and cultural practices can all play a role in how temperature affects sleep [78,72].

4.0 The Impact of Disrupted Sleep Behaviour and Risk for Non-Communicable Diseases.

It has been established that reduced sleep time and poor quality are causatives of type 2 diabetes, hypertension and obesity [37]. Disrupted sleep patterns lead to physiological stress and hormonal imbalances which are contributory factors for NCDs. It has been suggested that both hot and cold environments can affect sleep architecture, through the reduction of the amount of restorative sleep, thus in turn leading to increased metabolic and cardiovascular disorders risk [90]. For instance, individuals experiencing sleep disturbances in hot bedrooms have high risk of suffering from type 2 diabetes than those in cooler environments [108]. A study by Liu (2023) also provided clinical evidence on its link to NCDs [66].

There exists a core relation is an established nexus between the quality of sleep and overall health [21]. Sleep is essential for various physiological processes, and chronic sleep disturbances disrupt hormonal regulation, metabolism, and immune function, potentially leading to NCDs [89]. As sleeping disturbances disrupt these processes, chances of developing NCDs increases [57,91]. Reduced sleep is linked to inflammation, which is contributory to atherosclerosis and cardiovascular disease [54]. Similarly, sleep disruption can impair glucose regulation, thereby potentially resulting in type 2 diabetes [98]. Additionally, insufficient sleep can impair metabolic function and insulin sensitivity, thus, further contributing to weight gain [18].

Disrupted and poor sleep are well-documented risk factors for NCDs [37]. Sleep is a fundamental biological process necessary for physical and mental health. The body undergoes a restorative process, consolidating memories, regulating hormones, and strengthening the immune system during sleep [74]. Many scholars subscribe to the relationship between sleep and NCDs. Cappuccio (2010); Taheri (2004) and Irwin (2003) expressed that sleep disturbances disrupt the body's hormonal balance, leadings to increased levels of stress hormones like cortisol, which can promote weight gain as well as insulin resistance [13,102,52].

In Africa sleep disturbances are a cause of concern given that NCDs, the leading cause of mortality with rising prevalence are linked to poor sleep quality [120]. Considering the established link between sleep disturbances and NCDs, the potential influence of temperature on sleep quality becomes a significant public health concern.

5.0 Associations Between Sleep Behaviour and Obesity Risk.

Obesity also known as overweight is caused by excessive fat deposits in the body. It commonly arises from an imbalance of intake of energy mostly from food consumed and energy used through physical activities. Obesity has been identified as a risk factor for type 2 diabetes and heart disease and has devastating consequences on bone health and reproduction.

Poor sleep influences weight gain through stress hormones that are released. Sleep deprivation disrupts the production and hormonal regulation, more particularly leptin that signals satiety is suppressed during sleep deprivation, thus leading to increased feelings of hunger. Conversely, the production of leptin and ghrelin, hormones which stimulates appetite, is elevated in individuals with insufficient sleep thus increasing feelings of hunger [90]. This hormonal imbalance creates a scenario where individuals are more likely to overeat and consume excess calories. As a result, the hormones influence hunger and satiety feelings [97]. Studies by Chaput et al. (2005) established a correlation between reduced sleep time and increased ghrelin levels, suggesting a potential mechanism for sleep-induced overeating.

Insufficient sleep can impair metabolic function and insulin sensitivity, further contributing to gaining of weight [18]. Patel et al. (2008) revealed that short sleep duration is linked to a higher body mass index (BMI) in adults. Similar views were also shared by other researchers [101]. Spiegel et al., (2004) also revealed that poor sleep quality leads to increased appetite and reduced energy expenditure, thus leading to weight gain [97].

There are physiological and behavioural mechanisms underlying the nexus between disrupted sleep patterns and obesity risks. As the relationship between the two is multifaceted, it has been established that sleeping for less than seven hours may result in weight changes and gain. This happens through either excessive consumption of food stuffs or low burn of energy. Furthermore, when a person has difficulties in sleeping, this results in a “fight or flight” mode, wherein hormones which disrupts sleep are released from the brain. The hormones wake a person before entering the deep sleep mode and in that process the body conserves energy from food consumed thus leading to weight gain. Altered sleep patterns due to disrupted circadian rhythm was therefore identified as potential contributors to the rising obesity rates [17].

Poor sleep can lead to changes in food choices and eating behaviours. When sleep-deprived, individuals may crave for high-calorie and high-carbohydrate foods which provide a quick burst of energy [64]. This can be attributed to altered brain activity in reward centres, thereby making unhealthy foods more appealing at the same time impairing self-control and decision-making abilities. It therefore becomes more difficult to resist unhealthy food choices. Additionally, disrupted sleep patterns can disrupt hunger cues, making hard to differentiate genuine hunger from boredom or fatigue-induced eating [39]. There is a demonstrated correlation between sleep deprivation and high preference for high-fat, high-sugar foods, suggesting a potential behavioural pathway for sleep-induced weight gain.

Sleep disturbances can disrupt the mechanism of the body which control energy balances. Sleep-deprived individuals often have reduced energy levels, which can lead to decreased physical activity and fewer calories burned. Disrupted sleep patterns trigger the release of stress hormones (cortisol), which can promote fat storage and hinder weight loss efforts. Cortisol fills the blood with sugar thus increasing the rate at which the brain absorbs sugar. It then closes the body's mechanism that threatens a person in an emergency. The body's biological response to poor sleep may favour energy conservation (retaining energy stores) rather than energy expenditure (burning calories) thereby resulting in obesity.

In view of the above disrupted sleep patterns can set off a chain reaction that affects hormones, energy regulation, and metabolism, ultimately contributing to obesity. Chronic obesity has also been associated with other disorders such as diabetes, non-alcoholic liver disease, depression and high blood pressure.

6.0 Associations Between Sleep Behaviour and Risk for Hypertension.

Hypertension (high blood pressure) is another major NCD that can be influenced by sleep quality. It is a state when there is high pressure in the blood arteries and vessels. Its symptoms vary and in some cases are not easily detected. However, the common symptoms include severe headaches and chest pain among others.

It has been established that sleep deprivation leads to increased blood pressure, potentially due to heightened sympathetic nervous system activity [61]. Moreover, extreme temperatures can exacerbate this effect by further disrupting sleep patterns [112]. In particular, high temperature has been associated with increased nocturnal blood pressure, showing a relationship among environmental temperature, sleep and hypertension [62].

Disrupted sleep patterns due to insomnia, sleep apnoea or abnormal sleep duration can contribute to hypertension. A nexus has been noted on sleep challenges and high blood pressure risks. Research by Yang et al.; (2017) suggests a strong link on chronic sleep deprivation and hypertension risks. People with sleep apnoea, are more prone to hypertension development [113]. Disrupted sleep patterns, have a relationship with increased risk of hypertension [19].

Chronic sleep disturbances can negatively impact the cardiovascular system through inflammation. Insufficient sleep results in increased level of inflammatory markers and this contributes to atherosclerosis and plaque buildup in arteries [54]. This has a bearing on blood pressure regulation. Disrupted sleep patterns can impair the capacity of the body to control blood pressure, therefore leading to hypertension. Knutson et al. (2006) demonstrated how short-term sleep restriction can lead to increased blood pressure as well as endothelial dysfunction both CVD risk factors. Lastly, sleep disturbances also have a link with metabolic dysfunction [60].

7.0 Associations Between Sleep Behaviour and Type 2 Diabetes Risk.

Diabetes occurs when enough insulin is not produced by the pancreas or when that which is produced is not effectively used by the body. It occurs in two forms which are type 1 when the body fails to produce enough insulin or type 2 arising from its failure to use the insulin it produces leading to high levels of blood.

Disturbed sleep can be a precursor to type 2 diabetes, synonymous with impaired blood sugar control. Sleep deprivation negatively impacts the capacity of the body to process nutrients at the same time regulating metabolism and energy expenditure. Sleep disruption has been shown to affect glucose metabolism and insulin sensitivity, which subsequently increases risks of type 2 diabetes [103]. Environmental temperatures can modulate sleep quality, and consequently, glucose metabolism. For instance, hot environments have been found to impair sleep, leading to poorer glycaemic control when a person has type 2 diabetes [73].

In most cases insulin sensitivity is negatively affected by sleep disruption [98]. Furthermore, hormonal imbalances caused by insufficient sleep can contribute to insulin resistance [18]. Once the body struggles to efficiently use insulin to regulate blood sugar levels and this acts as a precursor to weight gain and later, type 2 diabetes (Khan et al., 2017). Leptikova et al. observed a interplay on reduced sleep duration and impaired insulin sensitivity, in that regard highlighting the metabolic consequences of sleep disruption [65]. Sleep disturbances can disrupt hormonal regulation, including leptin and adiponectin, which in turn influences blood sugar control and further increase CVD risk [9]. In support of this was Wang et al. who

through his research found out that individuals experiencing sleep disturbances in hot bedrooms were susceptible to developing type 2 diabetes unlike those in cooler environments enjoying good sleep [108].

In a bid to ascertain whether there is a relationship between disrupted sleep and type 2 diabetes Zuraikat et al. conducted some research wherein sleep was disrupted for six weeks at 90 minutes intervals [124]. The results showed an increase in insulin among premenopausal women whilst insulin resistance was observed among postmenopausal women. After a considerable time, insulin producing cells were affected by stress thus resulting in development of diabetes. The study revealed the effect of poor sleep on metabolism and insulin producing cells

Sleep disturbances can cause glucose intolerance. Sympathetic nervous system activity increases during disrupted sleep, thereby affecting glucose regulation and glucose intolerance. These act as a precursor to diabetes. A bidirectional link was established between diabetes and poor sleep [21]. Poor sleep contributes to diabetes management whilst diabetes also contributes to sleep problems.

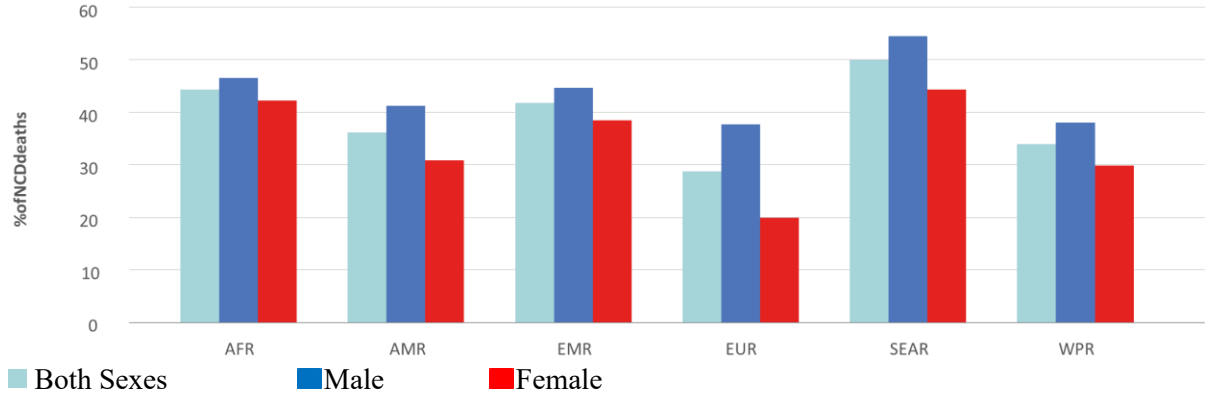
8.0 The Vulnerability of LMICs to Non-Communicable Diseases.

Globally, non-communicable diseases, (NCDs) are a cause of concern as they highly contribute to the burden of diseases. The greatest number of deaths worldwide have been attributed to NCDs which have also become the major threat in the 21st century. It has been established that countries in the low to middle income category (LMICs) are the most vulnerable as an estimated seventy five percent (75%) of all deaths are caused by NCDs [119].

While NCDs have become a worldwide challenge and concern, their prevalence is not uniform across the world, but differs depending on the region, country, age and gender. In 2016 the World Health Organization (WHO) conducted research analysing proportion of deaths due to NCDs based on gender and age in its established regions. Figure 2 shows the findings by WHO regarding the prevalence and distribution of deaths due to NCDs among those aged between 30 to 60 years in different regions.

As indicated in Figure 2, in 2016 WHO established that Africa experienced more than 40% deaths of people aged between 30-69 years across all gender [119]. The findings by WHO on the prevalence of NCDs in Africa were further corroborated by the World Bank wherein stated in its 2021 report that, while Africa has historically grappled with infectious diseases only, the widespread presence of NCDs is quickly increasing, thus posing a significant public health challenge [115]. Further, as per the findings by WHO, in Europe, deaths which were recorded of those aged between 30 and 69 years were 20% females, 38% males and

Figure 2. NCD Deaths Among Persons of Different Sex Aged Between 30-69 Years in Various Regions (World Health Organization, 2016)



almost 30% both sexes. Overall, NCDs accounted for 90% of all the deaths in Europe. In the American continents all deaths of those within the same age category in the three sexes were above 30%, while the Eastern Mediterranean region had close to 40% deaths across all gender of the same age category of 30 to 69 years.

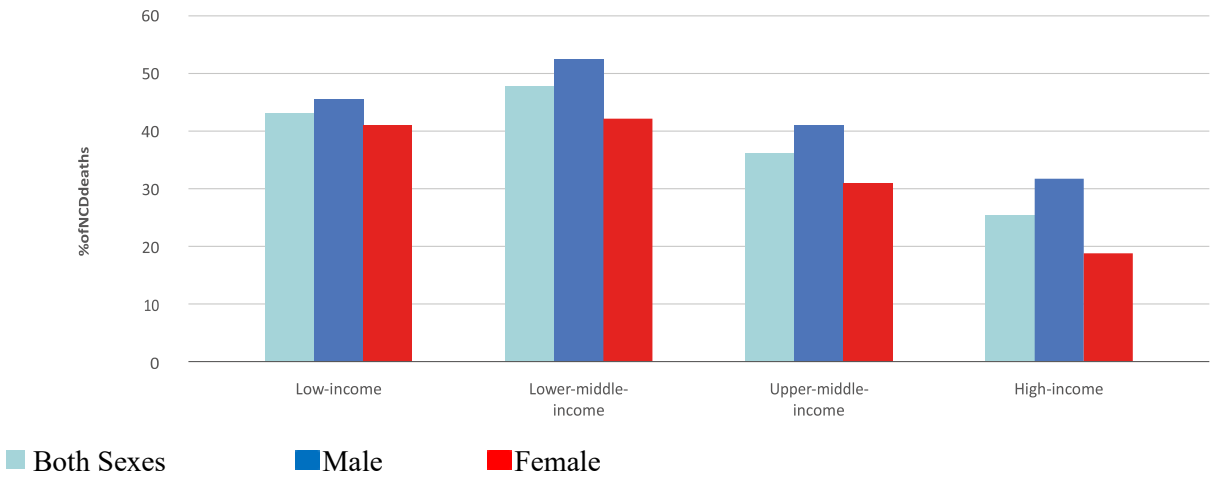
NCD deaths in the Western Pacific Region were almost like those from the America. However, contrary to the statistics by WHO in figure 1, in the June 2014 NCD Roadmap Report on NCDs in the Pacific Region which was presented during the Joint Forum Economic and Pacific Health Minister's brief, the Pacific region was regarded as having higher premature rates compared to other regions in the world. Many deaths were due to NCDs in twelve Pacific Island Countries. In the report it was stated that, the Pacific region had the highest diabetes rates globally and higher rates of premature deaths than countries of a similar income level, or the recorded average worldwide. 60% of the population in each Pacific country was overweight, more than 75% in six countries were overweight while at least half the adult population in four Pacific countries was obese. [115].

The prevalence of NCDs has been regarded as high in LMICs where most deaths including premature deaths are attributed to NCDs [114]. Figure 2 represents the findings by WHO and seeks to show the percentage of deaths due to NCDs which occurred to persons between 30 and 69 years based on income in 2016.

As can be seen in Figure 3, it was established that NCD deaths among people of all sexes aged between 30-69 in LMICs countries were relatively higher than those in the upper middle income and high-income category. As a result of the quest to establish the veracity of the findings by WHO, on the prevalence of NCDs by income, it is worthy to analyse their prevalence in countries falling under different income

categories. Thus, an analysis will be conducted on the health systems in Ghana, South Africa, Seychelles, Jamaica and America.

Figure 3: NCD Death Proportion Among Persons Aged 30-69 Years by Income (World Health Organization, 2021)



Ghana falls under the lower middle income was analysed. As estimated by the WHO in the year 2016 more than 94 000 deaths in Ghana were due to NCDs. The risk of premature death among persons aged between 30 to 70 years was estimated at 21% [121]. Hypertension in older people was estimated to be high as more than 50% among some section of the Ghanaian population was regarded have it [2,3]. Its prevalence in rural Ghanaian men was 22% whilst in women it was 28%. Higher prevalence was experienced in urban Ghana were for men it was 34% whilst for women it was 51% [5]. A Demographic and Health Survey (DGHS) which was done in 2014 revealed an estimated 13% prevalence of hypertension among persons aged 15 to 49 years of both sex (GDHS, 2014) In 2016 the Ministry of Health in its study to assess the global burden of diseases reported an increase on the burden posed by NCDs. INCDs were regarded to be second on the hierarchy of causes of Disability Adjusted Life Years (DALYs). Gatimu et al (2016) also established a rise in NCDs in Ghana and consequently significant public health complications were inevitable [34,26,6]. In 2022 Ghana recorded a total of 86,300 NCD deaths, constituting 45% percentage of deaths from NCDs and 22% probability of premature mortality from NCDs [114].

As per the report by WHO as shown in figure 1 above, the number NCDs related deaths in UMICs were slightly lower than in LMICs. An example of a country falling within the upper middle-income category is South Africa which has not been spared from the growing trend of NCDs. In 2018 WHO reported that NCDs caused roughly 51% of the total deaths in South Africa. The probability of premature deaths lower in females and higher in males but was projected to reduce by the year 2025 [121]. The October 2023 report

on NCDs death notifications by Statistics South Africa (Stats SA), explored the key trends and changes in the landscape of NCDs from the year 2008 to 2018 in South Africa. The department reported an increase in NCDs in South Africa [100]. Pillay-van Wyk et al (2016) in his study also confirmed that NCDs are the leading cause of death in South Africa [88]. The demographic and health survey that was conducted in 2016 also proved the prevalence of hypertension in the same country [100].

Another country falling within the upper middle-income category and worthy analysing to establish the trend of NCDs is Jamaica. It is a small island developing state which has experienced significant public health threats due to NCDs. The Ministry of Health reported that in 2015, roughly seven in every ten people died due to NCDs in Jamaica. In 2016, NCDs resulted in 12,577deaths constituting 68.4 per cent of all deaths of persons who were five years and older. Moreso in 2017, the leading causes of deaths in Jamaica were because of NCDs. The number of deaths due to NCDs between 2010 and 2016 increased by 21.6%. [121]. WHO also confirmed the prevalence of NCDs in Jamaica and established that, in 2016 the same were estimated to have caused more than 80% of the total deaths. It further noted that the probability of premature death was below 20% for both gender and projected linear trends in the reduction of premature deaths due to NCDs to below 10% by the year 2025 [121].

The prevalence on NCDs in high income countries was low as per the WHO's 2016 findings. Countries within the high-income category had the least NCD related deaths. In this category are countries such as Seychelles and America. Seychelles is a small island nation that is situated in the Indian Ocean. The country has experienced a surge from primarily infectious diseases to a growing challenge from non-communicable diseases (NCDs). Factors such as increased life expectancy, changes in lifestyle, and dietary habits have largely contributed to this transition. According to the WHO, in 2016 NCDs related deaths in Seychelles accounted for 81% of all deaths whereas the probability of premature deaths was likely to reduce by the year 2025 [121]. In 2022, 79% percentage of deaths experienced in Seychelles were attributed to NCDs and the probability of premature mortality from NCDs was 21%.

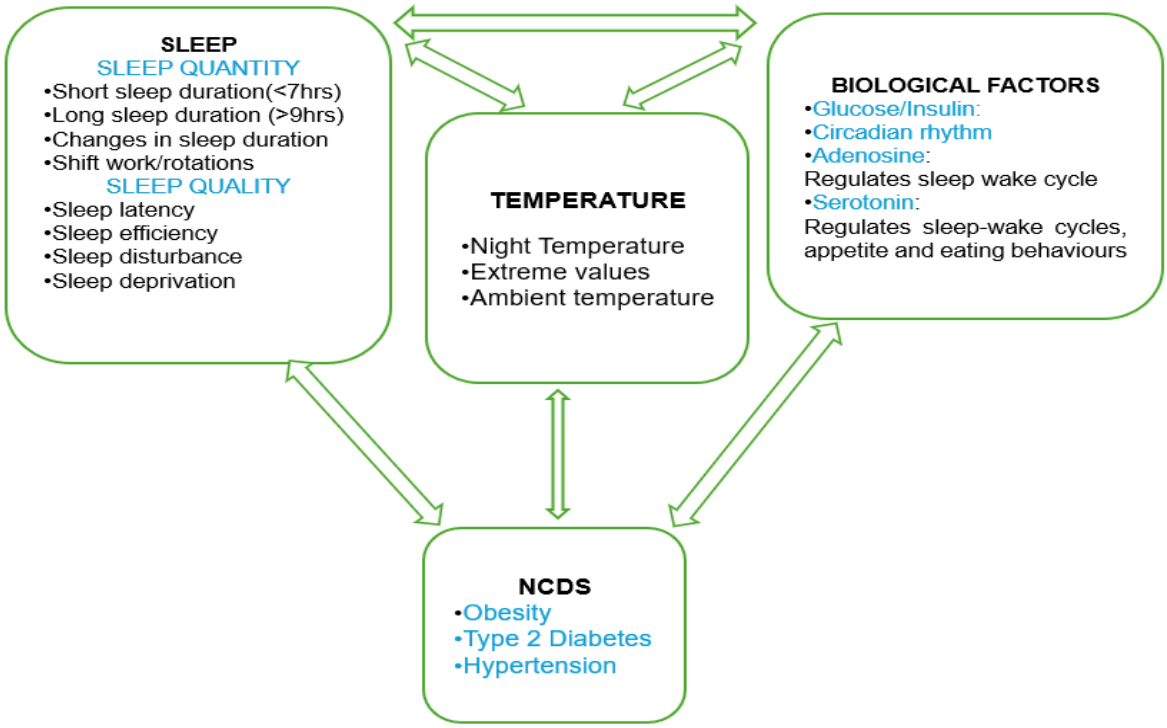
The socioeconomic impact of NCDs is profound, threatening progress towards achievement of 2030 Agenda for Sustainable Development, aimed at reducing premature NCDs mortality by the year 2030 [106]. Poverty and NCDs are closely linked, with NCDs pushing many individuals into poverty due to high healthcare costs. In low-resource settings, the exorbitant costs associated with NCD treatment and loss of income due to illness exacerbate poverty and hinder development [114].

In 2019, the WHO global action plan to prevent and minimise NCDs which was initially scheduled to run from 2013–2020 was further extended to 2030 by the World Health Assembly. The same recommended that strategies be initiated to urgently address the threat posed by NCDs, more particularly the Implementation Roadmap 2023 to 2030. The Implementation Roadmap comprise strategies and initiatives aimed to achieve nine global targets wherein NCDs management and prevention has been a top priority.

Effective management as well as prevention of NCDs require comprehensive approaches involving various sectors, including health, finance, transport, education, and agriculture. Integrated NCD policies focusing on reducing modifiable risk factors through legislation, public health campaigns, and community-specific interventions are essential [119]. Thus, collaborative effort is collaborative efforts tis required for the attainment of the worldwide NCD targets [119].

NCDs pose a formidable challenge to global health, necessitating urgent and coordinated action across multiple sectors. Effective prevention, early detection, and comprehensive management strategies are essential to reduce the NCD burden and achieve sustainable development goals. Continued research and policy reforms are vital to address the multifaceted nature of NCDs and improve health outcomes

Figure 4: Conceptual model of pathways through which temperature alters the relationship between sleep behaviour and NCDs.



worldwide. Figure 4 illustrates a conceptual model of pathways through which temperature alters the relationship between sleep behaviours and NCDs.

9.0 Conclusion

Since time immemorial most studies and research that were conducted focused on the nexus between the changes in temperature due to climate change and NCDs. They considered climate change and temperature to have a direct relationship with NCDs. However, there is very limited research on the possible mediating effect of temperature on the relationship. It is slowly emerging as also revealed in this study that temperature has a bearing on sleep patterns and duration. Therefore, it is disrupted or poor sleep that has a direct relationship with NCDs. As discussed in this study the most common chronic diseases which develop due to poor sleep quality are obesity, hypertension and type 2 diabetes.

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PART C: JOURNAL READY ARTICLE

Does temperature alter the relationship between sleep behaviours and non-communicable diseases in five different countries?

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Abstract

Sleep behaviour, which is a critical component of one's individual lifestyle has profound implications on the overall health and well-being, including non-communicable diseases (NCDs) risk. While the changing climate is a pressing global concern, with wide-ranging consequences, one under-recognised issue is whether increasing temperatures alters the relationship between sleep behaviours and NCDs. This study explored the relationship between ambient nighttime temperature and sleep behaviour across five diverse African-origin countries. Overall, 809 African-origin adults (aged 35-55 years, 63% women) from Ghana, South Africa, Jamaica, Seychelles and the US provided objectively measured sleep behaviour using actigraphy. Sleep data from participants with at least five nights of valid data were scored according to the criteria of Patel and colleagues (1), to estimate sleep onset time, wake-up time, sleep duration, wake after sleep onset (WASO), and sleep efficiency. Overall, there were significant variations in night-time temperature patterns across the 5 sites, with some locations experiencing more pronounced seasonal fluctuations than others. The South Africa site had night-time temperature fluctuations between 5°C and 20°C, while in Jamaica, the range was narrower (26°C to 32°C). Higher nighttime ambient temperatures were associated with longer sleep duration, and poorer sleep quality, characterized by a significant decrease in sleep efficiency (-0.05, $p < 0.001$) and increased wakefulness after sleep onset (WASO, -0.005, $p < 0.02$). Poor sleep quality was also linked to increased risks of obesity, hypertension, and diabetes. Temperature exhibited a minimal mediating effect on the relationship between sleep and hypertension, which was not significant for obesity and diabetes. These findings underscore the importance of considering both temperature and sleep quality in addressing the global burden of NCDs.

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Key words: Sleep behaviour, ambient temperature, non-communicable diseases

Background

Globally, climate change increases the frequency of extreme heat events [6] and is expected to increase the average global temperatures by 2100, with potential grave consequences for human health.[21] One suggested pathway linking higher temperatures and health outcomes is through disrupted sleep. Prior research confirms that poor sleep quality, through increased wakefulness and reduced sleep efficiency, is a risk factor for non-communicable diseases (NCDs) including obesity, type 2 diabetes and hypertension. [7,9] While exposure to both extreme hot and cold temperatures has previously been linked to sleep disturbances [3] NCDs are responsible for 71% of all deaths worldwide with more than 15 million people aged between 30 and 69 years dying from NCDs annually.[25]

The emerging relationship between sleep behaviour and NCDs, including the impact on metabolic processes and behavioural patterns has received much attention. Data suggest that disrupted sleep can result in dysregulation of hormones related to metabolism and appetite thereby increasing the risk of obesity and metabolic sequalae including type 2 diabetes.[1] Disrupted sleep affects leptin and ghrelin which are appetite-regulating hormones associated with obesity.[5] Likewise, chronic sleep deprivation is also associated with insulin resistance, a precursor to type 2 diabetes.[2]

Existing evidence suggests that environmental factors, such as temperature, play a role in overall sleep health, which is linked to NCDs [14]. However, most of these studies have mostly been conducted in high-income settings, with limited data exploring these associations in low-middle income countries (LMICs). NCDs killed at least 43 million people in 2021, equivalent to 75% of none NCDs related causes globally. During the same year, 18 million people died from an NCD before age 70 years and 82% of these premature deaths occur in LMICs [26]. It is projected that the impact of climate change will be especially far reaching among LMIC settings, with 73% or people being directly impacted. Coupled with this is that over 80% of premature mortality from NCDs occur in LMICs [27,12].

Leveraging the Modelling the Epidemiologic Transition Study (METS) cohort which used actigraphy-measured sleep behaviour, we sought to quantify the relationship between ambient nighttime temperature and sleep behaviour, including sleep regularity, duration, timing, efficiency. The METS study includes a 5 country's representing diverse climates and socio-economic conditions, all known to impact sleep behaviours and NCDs prevalence. Notable is that participants from the rural Ghanaian setting experience challenges different from those participants in urban environments such as Kingston (Jamaica), Khayelitsha (Cape Town, South Africa), Victoria (Seychelles) and suburban Chicago (US).

Materials and Methods

Study Cohort

The current study is a secondary data analysis leveraging data from the longitudinal Modelling the Epidemiologic Transition Study (METS, 2008-2013) and its related ancillary studies, including METS-Microbiome (2017-2022) and METS-Sleep (2019-2024) [15,16]. Originally, between 2008-2010, To understand the relationship between ambient nighttime temperature and sleep health, retrospective weather data included hourly temperature data. Data collection in 2019, 2021, and 2022 coincides with the sleep and health data. 2020 was excluded due to COVID-19 pandemic. The original METS study population comprised of 2500 adults aged 25 to 45, sampled from Ghana (125), South Africa (191), Jamaica (192), Seychelles (177) and US (124). Individuals diagnosed with infectious diseases, pregnant or breastfeeding women, HIV-positive and those with conditions hindering typical physical activities were excluded. Investigators employed random sampling methods considering sex and age stratification and drawing samples from national census data. The protocol for METS was approved by the Institutional Review Board of Loyola University, Chicago, IL, US (the coordinating center for this international study); the Committee on Human Research Publication and Ethics of Kwame Nkrumah University of Science and Technology, Kumasi, Ghana; the Human Research Ethics Committee of the University of Cape Town (UCT), South Africa; the Board for Ethics and Clinical Research of the University of Lausanne, Switzerland; the Ethics Committee of the Ministry of Health of Seychelles; and the Ethics Committee of the University of the West Indies, Kingston, Jamaica. Written informed consent was obtained from all participants. The current analysis was approved through UCT Human Research Ethics Committee (HREC) number: 287/2024.

Participant Anthropometry, Biochemical Measurements and Sociodemographic

Participants' weight, while barefooted and dressed in light clothing, was recorded to the closest 0.1 kg. A stadiometer was used to measure height to the closest 0.1 cm. Participants with body mass index (BMI) greater than or equal to 30 kg/m^2 were classified as obese [10]. Bioelectrical impedance analysis evaluated body composition (% body fat), while measurements of waist and hip circumference, blood pressure in triplicate, and fasting plasma glucose levels were taken using an automated blood pressure monitor and fingerstick point of care respectively. Participants completed several surveys including a complete health history, lifestyle survey, including smoking status, and physical activity and sleep behaviours. Health data documented significant diagnoses, existing health risks, and demographic factors such as age, gender, household composition, and household construction materials. Work status, alcohol consumption, and biological sex were all binary factors. Participants were questioned if they worked in previous months (1=yes; 0=no). Participants who reported drinking alcohol over the previous week were classified as "yes" (1=yes; 0=no). "How many men and women live in your home?" was the question posed to participants to calculate housing density. Participants were also questioned about the materials used to construct their homes' roofs and walls.

Sleep Behaviour

Participants wore an ACTiWatch Spectrum Plus (Philips Respironics) on the non-dominant wrist for seven days. This device captured wrist actigraphy data where this solid-state piezo-electric accelerometer has the size of a wristwatch. The ACTiWatch Spectrum Plus has a light sensor that measures photopic illuminance (in lux) using colour-sensitive photodiodes to estimate ambient light levels. Participants were advised to push an event marker on the actigraph when falling asleep or waking up. Daily sleep log was completed to record bedtime (lights off and eyes closed), wake-up time (lights on and eyes open), and daytime naps. Only datasets which contained at least five nights were considered valid. Actiware software v.6.0.9 (Philips Respironics, Bend, OR, USA) was used to score actigraphy data in line with the criteria of Patel and colleagues by two of the study team members, who scored half of the actograms and double-scored 10% of the records to ensure ongoing reliability of scoring procedures. Sleep data including variables derived from actigraphy such as sleep duration (minutes from sleep onset to sleep offset), sleep onset time, sleep offset time, and sleep midpoint (midpoint between sleep onset and sleep offset times), sleep efficiency (percent of time scored as sleep between sleep onset and sleep offset), day-to-day regularity (as calculated by coefficient of variation of sleep duration, sleep midpoint, sleep onset and waketime) and wake after sleep onset (WASO) time was recorded in one-minute epochs. Participants' sleep duration was classified as long (>9h) or short (<7h) (70) and sleep efficiency classified as poor if <85% [26].

Sleep Questionnaires

The Epworth Sleepiness Scale (ESS) [15], an 8-item measure that asks participants if they are likely to fall asleep during certain activities, like sitting and reading was used to gauge daytime sleepiness (0=would never doze; 1=slight chance of dozing; 2=moderate chance of dozing; or 3=high change of dozing). After adding all responses, the ESS scores ranged from 0 to 24, where higher scores denoted more daytime sleepiness. The previous month's sleep quality was evaluated using the Pittsburgh Sleep Quality Index (PSQI) [5]. The seven sub-component scores, which range from 0 to 3, measuring subjective sleep quality, sleep onset delay, length, efficiency, sleep disruptions, usage of sleeping pills, and daytime dysfunction were added to find a global score. Higher scores on the global PSQI scale indicate lower subjective sleep quality and are 0 to 21. The Berlin Questionnaire, with three categories —snoring and breathing pauses during sleep (First), daytime sleepiness or drowsy driving (Second), and high blood pressure or BMI > 30 kg/m2 (Third) was used to determine the risk of obstructive sleep apnea (OSA). If more than two categories were present and symptoms persisted (3–4 times per week or almost daily), the participant was at high risk for OSA. A 7, item self-report tool called the Insomnia Severity Index (ISI) examined the subjective symptoms, effects of sleep problems and person's feeling. The prevalence of mild to severe insomnia symptoms like sleeping difficulties or remaining sleeping and waking up early are reported. Participants responded to a study-specific questionnaire on substance

usage and daily outdoor time, particularly, alcohol, coffee, black tea, and other caffeinated beverages drinking frequency in addition cigarettes smoking.

Night-Time Ambient Temperature Data Processing Analysis

RStudio was used for processing and analysing the extensive sleep dataset. Rigorous cleaning protocols were implemented to eliminate any inconsistencies, missing values, or outliers that may distort the results. Temperature data was obtained from publicly available datasets, specifically from the Iowa Environmental Mesonet (IEM) database which provides hourly temperature recordings for Cape Town South Africa, Nkwantaseki (Ghana), Victoria Seychelles, Kingstone (Jamaica) and Chicago (US). [11].

Statistical Analysis

Descriptive statistics, including median and interquartile range, were used to summarize continuous variables. Frequency distributions and data visualization techniques were employed to explore data patterns. Correlation analysis, including Pearson correlation coefficients, was conducted to investigate relationships between temperature variations and sleep patterns. Regression analyses were employed, including multiple linear regression for obesity status and logistic regression for binary outcomes. Mediation analysis was performed to assess if temperature plays a mediating effect. Subgroup analysis was conducted to explore variations across different populations. All analyses were conducted using R software. The results were interpreted within the context of the research objectives, considering potential limitations and ensuring the robustness of the statistical methods.

Study Results

Demographic and Metabolic Profiles of Participants.

Data from 809 participants with complete datasets were used in this analysis. Tables 1, 2 and 3 presents the specific and overall anthropometric and metabolic characteristic across the five sites. Overall, highest median age was 49 years, with South African male being the youngest (39 years). Females from Seychelles had the highest BMIs (median 30 kg/m²), while South African men had the lowest BMIs (21kg/m²). Generally, obesity prevalence is high among females from all sites compared to males. US females (75%) and South African females (64%) were the highest whereas South African males have low obesity rate (4%) (Table 5).

Prevalence of Metabolic Diseases Across Countries

Compared to adults from the 4 other sites, South Africans presented with the lowest fasted glucose levels (86 mg/dL). From table 5 and Figure 6, participants from the US has the highest prevalence of type 2 diabetes (17%), especially among females (20%) whilst participants from Ghana and South Africa had low prevalence (2–4%). Hypertension was highest among the participants from the US (36%), followed by Seychelles (24%) and then Jamaica (23%). However, males from Jamaica and

Seychelles have higher hypertension rates than females. Overall, LMIC (Ghana and South Africa) has lower obesity, hypertension and type 2 diabetes prevalence compared to HIC (Jamaica, Seychelles and US).

Sex-Specific Sleep Patterns Across Countries.

Figures 2 and 3 shows that South African males reported the longest sleep duration (571 minutes), while Jamaican males had the shortest (428 minutes). Sleep efficiency was highest in Seychelles (males: 87%, females: 85%). Contrary, South African males had the lowest efficiency (80%), with 49% falling below the optimal threshold of 80%. Ghanaian males experienced the most frequent wake bouts (median: 52 per night), while South African males had the highest WASO (110 minutes) and spent the largest percentage of time awake (17%). Figures 4 and 5 shows that sleep efficiency is generally low across all sites with Seychelles showing the greatest variability. Most sleep times ranged between 400 to 600 minutes, except for participants from Ghana and Seychelles, who had more diverse sleep times, including extremely short or long sleep durations or low sleep efficiency. The relationship between sleep time and efficiency was consistent across sites, but the distribution of sleep times varied. South Africa and Jamaica had narrower distributions, while Ghana and Seychelles had wider distributions.

Ambient Night-Time Temperature Across All Sites.

As shown in Figure. 1, night-time temperatures varied across the five locations. Ghana and Jamaica experienced stable warm temperatures (22-28°C) whilst Seychelles experienced warm temperatures between 26-30°C. South Africa has temperatures ranging from 5°C to 20°C whereas Chicago displayed hot summers and very cold winters (low of -20°C).

Correlation Between Temperature and Sleep Behaviour

Figure 6 presents the overall data for correlation matrix of temperature and sleep variables. Higher temperatures are generally associated with increased sleep onset latency, decreased total sleep time, and reduced sleep efficiency across all sites. Figures 7a-7e shows that all sites had negative correlation between temperature and sleep time/efficiency as higher temperatures are associated with decreased sleep efficiency and total sleep time, and increased sleep onset latency. Jamaica shows the strongest negative corelation.

Multivariable Linear Regression between Temperature and Sleep Variables.

Figure 8 shows a weak positive association between increasing ambient night-time temperature and sleep efficiency while Table 6 shows a significant negative association between temperature and sleep efficiency (-0.05, p=0.001), WASO (-0.005, p=0.02), sleep duration (-0.002, p=0.001), increased wake bouts (0.05, p=0.001) and percent wake (0.59, p=0.002) on all sites. From Figures 6a-e (country specifics) temperature negatively affected average wake bouts (-0.45, p<0.001) in Ghana. In South

Africa, higher temperatures were associated with increased percent wake (0.22, p<0.001), average wake bouts (2.20, p<0.001), and decreased sleep efficiency (-0.23, p<0.001) and duration (-0.01, p=0.002). Similar trends were also observed in Jamaica. In Seychelles, temperature had minimal impact on sleep and similarly in US temperature showed a weak positive association with sleep efficiency (0.13, p=0.02) and a negative effect on percent wake (-0.13, p=0.03).

Multivariable Linear Regression between NCDs and Sleep Variables Adjusting for Other Variables.

Table 7 (BMI Model) showed no significant association between BMI and sleep efficiency (coefficient 0.02, p=0.16). However, age (coefficient -0.05, p<0.001), sex (coefficient 3.16, p<0.001), alcohol consumption (coefficient -0.63, p<0.001), and country (Jamaica, Seychelles, United States) were significant predictors. Table 7 (Glucose Model) revealed a significant positive association between glucose levels and sleep efficiency (coefficient 0.43, p<0.001). Age (coefficient 0.76, p<0.001), country (Jamaica, Seychelles, US, Ghana, South Africa), sex (coefficient -4.70, p<0.001), alcohol consumption (coefficient 3.01, p=0.01), and work status (coefficient -11.10, p<0.001) also significantly influenced sleep efficiency.

Multivariable Logistic Regression between Outcomes and Sleep Variables Adjusting for Other Variables.

Table 8 shows that age, sex, work status, alcohol consumption, and country significantly influenced the odds of health outcomes. Each additional year of age increased the odds of hypertension (OR=1.08, p<0.001) and diabetes (OR=1.08, p<0.001). Females had higher odds of obesity (OR=3.04, p<0.001) and US had the highest odds of obesity (OR=8.84, p<0.001), hypertension (OR=2.66, p<0.001), and diabetes (OR=2.21, p<0.001). Higher sleep efficiency (OR=0.88, p=0.001) and lower WASO (OR=0.92, p<0.001) were associated with lower odds of obesity and hypertension. Longer sleep duration (OR=1.05, p=0.01) was associated with increased odds of obesity, hypertension, and diabetes (OR=1.18, p<0.001).

Mediation Analyses to Address Whether Temperature Mediates the Relationship between Sleep Behaviour and NCD Risk

The analysis presented in Table 9 showed no meaningful mediation effect of temperature on the relationship between night-time temperature and sleep behaviour and type 2 diabetes and hypertension risk, as indicated by the Average Causal Mediation Effect (ACME) (-0.000139, p = 0.008). Additionally, there was no direct effect of temperature on diabetes outcomes as shown by the Average Direct Effect (p = 0.992), and the total effect remained statistically not significant (p = 0.884). Hypertension exhibited a minimal but statistically significant mediation effect of temperature (p < 0.001), though the overall total effect was non-significant (p = 0.39). On obesity, both mediation

(ACME and ADE, p = 0.37) and total effect (p = 0.37) analyses revealed no significant influence of temperature.

Discussion of Results

The first finding from the study is that higher night-time temperatures were associated with poorer sleep quality, characterized by reduced sleep efficiency, increased wake after sleep onset and shorter total sleep duration. These findings align with existing research indicating that elevated temperatures may disrupt thermoregulation during sleep, leading to increased awakenings and decreased overall sleep quality. Furthermore, thermal discomfort disrupts sleep, increasing wake bouts and affecting sleep architecture by reducing REM and deep sleep stages. [16]

The second finding is that the impact of temperature on sleep behaviours varied across study sites. Participants from South Africa and Ghana, where temperature fluctuations were more pronounced, experienced stronger associations between increased temperature and poor sleep efficiency. In contrast, in consistently warm climates such as Seychelles and Jamaica, the effect was less pronounced, potentially due to adaptation to persistent warmth. Additionally, demographic factors, including age and sex, influenced sleep responses to temperature variations. Older individuals and females exhibited greater susceptibility to sleep disturbances in response to temperature fluctuations, which may contribute to the higher prevalence of NCDs in these groups. These findings confirm previous research indicating that tropical climates with consistently warm temperatures may promote stable sleep patterns [17]

Thirdly, mediation analysis showed that while poor sleep quality was linked to increased risks of obesity, hypertension, and diabetes, the ambient night-time temperature had a minimal mediating effect. A statistically significant but weak mediation effect of temperature was observed between sleep behaviours and hypertension, suggesting that elevated temperatures may contribute slightly to the relationship between sleep disruptions and blood pressure regulation. Regarding type 2 diabetes and obesity, the mediation effect of temperature was not significant, showing that while poor sleep contributes to these conditions, other factors including poor diet, and socio-economic factors may be more important.

Regression analysis showed a nuanced relationship between night-time temperature and sleep outcomes across different sites. Generally higher temperatures were linked to reduced sleep efficiency, increased wake bouts, and shorter sleep duration, aligning with existing research on thermal discomfort disrupting deep sleep. [20] However, this was not consistent, for example in the Seychelles, higher ambient night-time temperature had no significant effect on sleep, likely due to long-term adaptation to consistently warm conditions whereas in Ghana and South Africa, higher temperatures significantly increased wake

bouts and percent wake, negatively impacting sleep efficiency and duration, possibly due to high baseline temperatures and limited cooling resources. In US warmer temperatures unexpectedly improved sleep efficiency and reduced wakefulness, suggesting the influence of air conditioning and greater adaptation to temperature fluctuations. It is notable that over 80% of the US-based households have access to indoor air conditioner units.

Lastly, the study further confirmed that disrupted sleep behaviours, including lower sleep efficiency and increased WASO, were associated with higher odds of hypertension, obesity, and diabetes. Sleep inefficiency is known to contribute to metabolic dysregulation, including increased insulin resistance, weight gain, and elevated blood pressure. However, temperature did not significantly amplify or mitigate these effects, reinforcing the notion that while sleep quality is crucial for metabolic health, external temperature fluctuations play a limited role in directly influencing NCD outcomes.

Comparison with Other Studies and Potential Influences on Results

The results confirm existing literature showing that higher temperatures may alter sleep quality, particularly in environments with extreme seasonal variations or consistently high night-time temperatures. However, the subtle positive correlation between temperature and sleep efficiency in some contexts, (U.S) may indicate that people in these areas are used to temperature fluctuations or have better access to temperature-regulating resources. Warmer climates disrupt continuous sleep through thermal discomfort especially in lower-resource setting populations without access to cooling systems [18,22]. Cultural factors, lifestyle habits, work patterns and socio-economic factors may also influence these results.

Implications and Future Directions

The findings underscore the complex role of temperature in shaping sleep behaviours across different climates, hence the need to consider both environmental and individual factors. Future research should explore how temperature affects sleep among different age groups and socio-economic settings, and possible interventions to improve health outcomes in populations vulnerable to NCDs. By examining the role of temperature on seep behaviours and NCDs in populations from diverse climates, the study contributes valuable insights into the interconnectedness of environmental and health factors, thereby laying the foundation for further research and public health interventions targeting sleep and metabolic health in the context of climate variability. Future research should explore a wider range of environmental and demographic factors, such as humidity, air quality, and a broader age demographic, to provide a more comprehensive understanding of the interplay between temperature, sleep, and health outcomes.

Strengths and Limitations

Our study is significantly strengthened by the robustness and longitudinal METS cohort (METS, METS-Microbiome, METS-Sleep), all using the same procedures, measurements, equipment, staff, and questionnaires. actigraphy and validated questionnaires used provided a comprehensive view of sleep and health. Sampling across five countries with diverse climates enhances generalizability. However, we note some weaknesses including the potential for residual confounding, as factors like socioeconomic status, housing conditions (insulation, ventilation, air conditioning), and individual adaptation strategies (use of fans, bedding adjustments) may influence both sleep patterns and NCD risk independently of temperature. Without fully accounting for these variables, the observed associations may not solely reflect the impact of temperature on sleep and health outcomes. The study does not explicitly consider how other environmental factors such as humidity, noise, and air quality, may also influence sleep and NCDs. The larger study excluded individuals diagnosed with infectious diseases, pregnant or breastfeeding women, HIV-positive and those with conditions hindering typical physical activities, which is a limitation of the secondary data analysis. Nevertheless, our results provide insight into the influence of temperature on the relationship between sleep and NCDs in individuals of African origin across different geographies, stimulating further examination of large-scale studies using more granular environmental data. Future research should incorporate high-resolution climate metrics and individual-level adaptation behaviours to better understand the complex interactions between temperature, sleep, and NCD risk.

Conclusion

This study provides a comprehensive analysis of the interplay between temperature, sleep behaviours and NCDs across diverse geographic and climatic settings. Key findings include, higher temperatures associated with reduced sleep efficiency, increased nighttime awakenings, and shorter sleep durations. Country comparisons reveal how demographic and metabolic factors influence sleep health. The helps in developing possible tailored public health strategies.

Baseline Characteristics of participants per site.

Table 1: Sociodemographic and Work Characteristics

Characteristics	Ghana N=125	SA N=190	Jamaica N=176	Seychelles N=186	US N=132
Sex					
Men	42 (34%)	91 (48%)	56 (32%)	92 (49%)	31 (23%)
Women	83 (66%)	99 (52%)	120 (68%)	94 (51%)	101 (77%)
Age (years)					
Median [IQR]	46 [39-53]	39 [33-46]	49 [42-54]	47 [42-50]	49 [44-53]
Range	33-66	25-56	25-61	33-58	35-58
SES					
House density					
Median [IQR]	5 [4-6]	4 [3-6]	4 [2-5]	4 [3-5]	3 [2-4]
Range					
Alcohol history	24 (19%)	109 (57%)	57 (32%)	106 (57%)	52 (39%)
Work Status	113 (90%)	69 (36%)	143 (81%)	182 (98%)	81 (61%)
Type of work					
Regworksch	95 (90%)	61 (34%)	137 (79%)	166 (97%)	68 (62%)
Shift worker	7 (7%)	14 (9%)	13 (8%)	32 (18%)	35 (41%)
Weight (kg)					
Median [IQR]	69 [63 - 78]	70 [60 - 88]	84 [69 - 96]	81 [71 - 94]	96 [81 - 110]
Range	45 – 132	70 [60 - 88]	45 - 180	51- 141	50 – 163
Height (m)					
Median [IQR]	1.63 [1.57-1.67]	1.65 [1.58 - 1.70]	1.66 [1.60 - 1.74]	1.67 [1.61 - 1.74]	1.67 [1.62 - 1.73]
Range	1.45 – 1.85	1.08 - 1.89	1.48 - 1.84	1.16 - 1.89	1.49 - 1.96
BMI kg/m^2					
Median [IQR]	26 [23-31]	26 [21-34]	30 [25-35]	29 [25-33]	34 [29-40]
Range	18-49	15-70	18-62	18-74	18-58
Glucose mmol/dl					
Median [IQR]	106 [99-113]	86 [80-96]	98 [91-109]	112 [101-125]	99 [91-115]
Range	71-340	31-248	73-313	82-366	45-343

N (%) IQR=Interquartile range SES= Social Economic Status US= United States SA=South Africa Regworksch =Regular Work or School

Sleep Variable summaries per site

Table 2: Sleep Variables per Site

Characteristics	Ghana N=125	SA N=190	Jamaica N=176	Seychelles N=186	US N=132
Average Duration (Mins)					
Median [IQR]	455 [416 - 485]	558 [496 - 603]	445 [399 - 489]	434 [393 - 476]	436 [389 - 490]
Range	263 – 588	304 - 869	241 – 646	218 – 614	244 - 649
Onset Latency (mins)					
Median	9 [5-15]	11 [7-17]	7 [5-11]	6 [4-10]	8 [5-12]
Range	0 – 32	0 - 104	1 – 42	1 – 56	1 - 41
Efficiency (%)					
Median [IQR]	83 [80 - 86]	81 [76 - 85]	85 [82 - 88]	87 [84 - 90]	87 [83 - 89]
Range	67 – 91	48 - 99	65 – 93	66 – 95	54 - 95
Average WASO					
Median [IQR]	66 [51 - 82]	96 [71 - 126]	59 [48 - 73]	48 [37 - 63]	49 [38 - 70]
Range	31 – 150	4 - 286	23 – 136	17 – 136	12 - 155
Percent Wake (%)					
Median [IQR]	15 [12 - 18]	17 [13 – 22]	13 [11 - 17]	11 [9 - 14]	11 [9 - 15]
Range	7 – 30	1 - 49	6 – 34	5 – 30	3 - 41
Number-of-wake bouts mean					
Median [IQR]	46 [37 - 57]	61 [50 - 73]	41 [33 - 51]	39 [29 - 48]	38 [27 - 47]
Range	18 – 88	4 - 138	15 – 81	13 – 86	15 - 139
Average wake b					
Median [IQR]	1 [1 - 2]	2 [1 - 2]	1 [1 - 2]	1 [1 - 2]	1 [1 - 2]
Range	1 – 3	1 - 4	1 – 3	1 – 3	1 - 4
Sleep time (mins)					
Median [IQR]	383 [346 - 409]	449 [403 - 500]	376 [344 - 419]	383 [347 - 419]	384 [348 - 426]
Range	229 – 544	244 - 690	211 – 554	190 – 503	191 - 541
Percent sleep (%)					
Median [IQR]	85 [82 - 88]	83 [78 - 87]	87 [83 - 89]	89 [86 - 91]	89 [85 - 91]
Range	70 – 93	51 - 99	66 – 94	70 – 95	59 - 97
Average Number of sleep bouts					
Median [IQR]	46 [38 - 56]	60 [49 - 73]	41 [33 - 51]	38 [29 - 48]	37 [27 - 47]
Range	18 – 88	5 - 140	14 – 81	15 – 86	15 - 139
Average sleep b					
Median [IQR]	9 [7 - 11]	8 [7 - 11]	10 [8 - 13]	11 [9 - 13]	12 [9 - 15]
Range	4 – 24	4 - 119	4 - 23	5 – 51	2 - 29

IQR – Interquartile Range WASO- Wake After Sleep Onset US= United States SA=South Africa

Table 3: Descriptive statistics at baseline of 5 different countries by SEX.

	Ghana N= 124		**SA N= 190**		**Jamaica N=176**		**Seychelles N=186**		**US N=132**	
	Males N=42	**Females N=82**	**Males N= 91**	**Females N=99**	**Males N= 56**	**Females N=120**	**Males N=92**	**Females N=94**	**Males N=31**	**Females N=101**
Age (years)										
Median [IQR]	49 [41-55]	45 [39-52]	39 [33-45]	40 [33-47]	48 [41-53]	49 [42-50]	47 [43-50]	45 [40-50]	49 [46-53]	49 [44-53]
Range	33-66	30-59	25-54	27-56	25-58	31-61	37-58	33-55	36-57	35-58
Weight (kg)										
Median [IQR]	67 [64-76]	72 [62-83]	62 [57-73]	85 [67-102]	77 [65-89[	85 [72-98]	86 [75-99]	78 [67-89]	91 [79-110]	97 [81-110]
Range	49-132	45-121	42-152	45-148	53-150	45-180	53-142	51-115	50-149	54-163
Height (m)										
Median [IQR]	1.68 [1.65-1.73]	1.59 [1.55-1.64	1.71 [1.66-1.75]	1.60 [1.55-1.63]	1.75 [1.69-1.79]	1.60 [1.12-1.67]	1.74 [1.57-1.66]	1.62 [1.57-1.66]	1.74 [1.70-1.81]	1.66 [1.60-1.70]
Range	1.51-1.85	1.45-180	1.08-1.89	1.32-1.73	1.12-1.84	1.12-181	1.12-1.86	1.08-1.89	1.62-1.96	1.49-1.77
BMI (kg/m^2)										
Median [IQR]	24 [22-26]	29 [25-32]	21 [20-25]	33 [27-40]	25 [21-29]	32 [27-37]	28 [25-32]	30 [26-34]	30 [27-34]	35 [30-40]
Range	19-44	18-49	15-59	18-70	18-49	18-62	18-46	20-74	27-34	20-58
Glucose (ml/dl)										
Median [IQR]	105 [97-111]	108 [99-116]	86 [80-96]	85 [80-96]	99 [92-109]	99 [92-109]	116 [106-130]	109 [97-121]	102 [91-120]	98 [91-113]
Range	85-340	71-229	85 [80-96]	31-206	81-194	81-194	84-278	82-366	56-172	45-343
SES										
Alcohol History	13 (31%)	11(13%)	71 (78%)	38 (33%)	33 (59%)	24 (20%)	57 (62%)	49 (52%)	18 (58%)	34 (34%)
Work Status	42 (100%)	70 (85%)	32 (35%)	37 (37%)	51 (91%)	92 (77%)	91 (99%)	91 (97%)	16 (52%)	65 (64%)
Type of Work										
Regworksch	32 (100%)	63 (86%)	28 (31%)	33 (36%)	50 (91%)	87 (73%)	81 (93%)	85 (98%)	16 (62%)	52 (63%)
Shift worker	2 (7%)	5 (7%)	7 (9%)	7 (9%)	4 (7%)	9 (8%)	22 (23%)	10 (11%)	8 (44%)	27 (40%)

SA= South Africa US=United States IQR = Interquartile Range BMI= Body Mass Index SES = Social Economic Status Regworksch=Regular work or School

Table 4: Descriptive statistics of sleep variables for 5 African Origin sites by Sex

	Ghana N= 124		**SA N= 190**		**Jamaica N=176**		**Seychelles N=186**		**US N=132**	
	Males N=42	**Females N=82**	**Males N= 91**	**Females N=99**	**Males N= 56**	**Females N=120**	**Males N=92**	**Females N=94**	**Males N=31**	**Females N=101**
Duration(mins)										
Median	457 [420-487]	455 [416-484]	571 [529-631]	531 [485-583]	428 [371-488]	445 [414-489]	418 [384-463]	447 [411-478]	436 [383-488]	437 [395-495]
Range	324-588	263-567	304-869	347-678	293-646	241-602	218-555	334-614	246-567	244-649
Onset Latency (mins)										
Median	7 [5-13]	10 [6-16]	12 [6-18]	11 [7-16]	7 [4-11]	8 [4-11]	6 [4-11]	6 [4-10]	9 [5-13]	8 [5-12]
Range	2-31	0-32	0.3-104	1-45	1-42	1-42	1-56	1-29	1-40	1-41
Efficiency (%)										
Median	83 [79-87]	84 [80-86]	80 [74-85]	81 [77-85]	84 [81-88]	85 [82-88]	87 [83-90]	88 [85-90]	83 [77-87]	87 [84-90]
Range	69-91	67-91	48-92	68-99	65-93	71-92	66-95	73-94	54-93	74-95
Below 85%	27(64%)	49(60%)	70(77%)	62(62%)	32(57%)	53(44%)	38(41%)	22(23%)	16(52%)	32(31.68%)
Above 85%	15(36%)	33(40%)	21(23%)	27(27%)	24 (43%)	67(56%)	54(59%)	72(77%)	15(48%)	69(68%)
WASO										
Median	71 [54-89]	65 [51-81]	110 [76-135]	90 [69-106]	59 [48-73]	61 [45-80]	48 [37-63]	48 [37-65]	58 [41-87]	47 [37-65]
Range	38-140	31-150	36-286	4-158	23-136	23-136	17-136	17-136	27-155	12-107
Wake (%)										
Median	15 [12-18]	14 [12-18]	17 [13-22]	16 [13-20]	14 [11-18]	13 [11-16]	12 [9-16]	11 [8-13]	14 [10-20]	11 [8-14]
Range	7-28	7-30	0.76-49	0.76-29	6-34	7-27	5-30	0.76-49	6-41	3-22
Wake Bouts (n)										
Median	52 [40-62]	45 [37-56]	67 [55-81]	55 [47-65]	45 [34-54]	39 [33-48]	40 [32-50]	36 [28-45]	46 [34-52]	35 [26-42]
Range	29-87	18-88	28-138	4-94	23-81	15-74	16 -86	13-73	18-139	15-81
Sleep bouts										
Median	8 [6-10]	9 [7-11]	8 [6-10]	9 [7-11]	9 [7-11]	11 [9-13]	10 [8-12]	12 [10-15]	9 [7-12]	13 [10-16]
Range	4-17	4-24	4-119	4-119	4-23	5-19	5-21	6-51	2-26	5-29
Sleep time (mins)										
Median	373[352-397]	385[341-410]	460[408-517]	436[398-494]	361 [31 - 420]	384[359-419]	363[334-407]	399[363-422]	378[312-406]	390[351-436]
Range	275 – 544	228 – 495	244 - 690	285 - 548	246 - 554	211 - 550	190 – 503	308 - 496	191 - 527	213 - 541
Sleep (%)										
Median	85 [82-88]	86 [82- 88]	82 [77 - 86]	84 [80-87]	86 [82-89]	87 [84-89]	88 [84-91]	89 [87-92]	86 [80-90]	89 [86-92]
Range	72 – 93	70 – 93	51 - 93	71 - 99	66 - 94	73 - 93	70 – 95	77 - 95	58 - 94	78 - 97

SA= South Africa US=United States IQR = Interquartile Range WASO= Wake After Sleep Onset Mins=Minutes.

Table 5: Outcome variables at baseline for the 5 African origin by sex.

Characteristics	**Ghana N= 124**			**South Africa N=190**			**Jamaica N=176**			**Seychelles N=186**			**US N=132**		
	Overall	**Males N=42**	**Females N=82**	**Overall**	**Males N= 91**	**Females N=99**	**Overall**	**Males N= 56**	**Females N=120**	**Overall**	**Males N=92**	**Females N=94**	**Overall**	**Males N=31**	**Females N=101**
Diabetes	5 (4%)	1 (2%)	4 (5%)	4 (2%)	2 (2%)	2 (2%)	17 (10%)	3 (5%)	14 (12%)	13 (7%)	6 (7%)	7 (7%)	23 (17%)	3 (10%)	20 (20%)
Hypertension	16 (13%)	5 (12%)	11 (13%)	26 (14%)	10 (10%)	16 (16%)	40 (23%)	9 (16%)	31 (25%)	44 (24%)	22 (24%)	22 (23%)	48 (36%)	17 (54%)	31 (31%)
Obese	34 (28%)	5 (12%)	29 (36%)	67 (35%)	4 (4%)	63 (64%)	84 (48%)	11 (20%)	73 (61%)	80 (43 %)	35 (38%)	45 (48%)	91 (69%)	15 (48)	76 (75%)

N (%) US=United States

Table 6: Multivariable Linear regression model showing association between temperature and sleep variables with corresponding p values and adjusting for other variables for all the sites.

Characteristics	**Sleep onset Latency**	**Sleep Efficiency**	**WASO**	**Percent Wake**	**Average Wake Bout**	**Duration**
Temperature	0.01 (0.15)	-0.05 (0.001)	-0.005 (0.02)	0.05 (0.001)	0.59 (0.002)	-0.002 (0.001)
Age	0.01 (0.34)	0.01 (0.05)	-0.008 (0.54)	0.01 (0.59)	0.01 (0.64)	0.01 (0.32)
BMI	-0.01 (0.46)	-0.009 (0.49)	-0.0004 (0.70)	-0.01 (0.56)	-0.01 (0.43)	-0.01 (0.38)
Sex (Women)	-1.69 (<0.001)	-1.63 (<0.001)	-1.68 (<0.001)	-1.63 (<0.001)	-1.72 (<0.001)	-1.64 (<0.001)
Hypertension	1.25 (<0.001)	1.24 (<0.001)	1.29 (<0.001)	1.24 (<0.001)	1.26 (<0.001)	1.27 (<0.001)
Employed	-0.99 (<0.001)	-0.91 (<0.001)	-0.88 (<0.001)	-0.90 (0.002)	-0.88 (<0.001)	-1.05 (<0.001)
Alcohol	-0.77 (<0.001)	-0.80 (<0.001)	-0.79 (<0.001)	-0.80 (<0.001)	-0.80 (<0.001)	-0.73 (<0.001)
Roof	0.02 (0.89)	0.03 (0.83)	-0.02 (0.88)	0.03 (0.83)	-0.02 (0.86)	0.04 (0.78)
Wall	-0.05 (0.42)	-0.05 (0.440	-0.07 (0.32)	-0.06 (0.40)	-0.07 (0.31)	-0.07 (0.32
House density	0.004 (0.89)	0.003 (0.93)	-0.0003 (0.99)	0.003 (0.92)	0.008 (0.81)	0.01
South Africa	-12.88 (<0.001)	-12.97 (<0.001)	-1.3 (<0.001)	-12 (0.001)	-12.87 (<0.001)	-12.6 (<0.001)
Jamaica	-7.9 (<0.001)	-8.96 (<0.001)	-8.7 (<0.001)	-1.1 (0.001)	-8.2 (<0.001)	-7.9 (<0.001)
Seychelles	1.48 (<0.001)	1.62 (<0.001)	1.53 (<0.001)	1.62 (<0.001)	1.56 (<0.001)	1.40 (<0.001)
United States	-9.23 (<0.001)	-9.08 (<0.001)	-9.13 (<0.001)	-9.6 (<0.001)	-9.01 (<0.001)	-9.30 (<0.001)

Effect (p-value) Ghana= Country reference Males= Sex reference Hypertension N0= reference Employed No= reference

Ghana

Table 6a: Ghana's multivariable linear regression analysis adjusted for other variables.

Characteristics	Sleep onset Latency	Sleep Efficiency	WASO	Percent Wake	Average Wake Bout	Duration
Temperature	-0.01 (0.10)	0.01 (0.01)	0.001 (0.42)	-0.01 (0.02)	-0.45 (<0.001)	-0.0001 (0.83)
Age	0.003 (0.51)	0.003 (0.55)	0.005 (0.43)	0.003 (0.57)	0.006 (0.31)	0.003 (0.55)
BMI	0.003 (0.73)	0.004 (0.73)	0.004 (0.72)	0.004 (0.72)	0.004 (0.70)	0.004 (0.73)
Sex (Women)	0.28 (0.01)	0.25 (0.01)	0.25 (0.02)	0.24 (0.02)	0.29 (0.01)	0.24 (0.01)
Hypertension	0.05 (0.62)	0.08 (0.48)	0.07 (0.51)	0.81 (0.46)	0.07 (0.50)	0.07 (0.49)
Employed	0.23 (0.13)	0.30 (0.04)	0.27 (0.07)	0.31 (0.04)	0.37 (0.02)	0.26 (0.07)
Alcohol	-0.17 (0.11)	-0.17 (0.10)	-0.16 (0.14)	-0.17 (0.10)	-0.24 (0.02)	-0.16 (0.12)
Roof	-1.35 (<0.001)	-1.31 (<0.001)	-1.24 (<0.001)	-1.30 (<0.001)	-1.51 (<0.001)	-1.27 (<0.001)
Wall	0.12 (<0.001)	0.13 (<0.001)	0.13 (<0.001)	0.13 (<0.001)	0.14 (<0.001)	0.13 (<0.001)
House density	0.04 (0.004)	0.04 (0.005)	0.04 (0.01)	0.03 (0.01)	0.04 (0.003)	0.03 (0.01)

Effect size (p value)

South Africa

Table 6b: South Africa's multivariable linear regression analysis adjusted for other variables.

Characteristics	Sleep onset Latency	Sleep Efficiency	WASO	Percent Wake	Average Wake Bout	Duration
Temperature	0.09 (<0.001)	-0.23 (<0.001)	0.02 (<0.001)	0.22 (<0.001)	2.20 (<0.001)	-0.01 (0.002)
Age	0.001 (0.98)	-0.06 (<0.001)	-0.09 (<0.001)	-0.07 (<0.001)	-0.04 (0.03)	-0.02 (0.34)
BMI	-0.27 (<0.001)	-0.29 (<0.001)	-0.17 (<0.001)	-0.26 (<0.001)	-0.24 (<0.001)	-0.24 (<0.001)
Sex (Women)	2.86 (<0.001)	3.56 (<0.001)	2.57 (<0.001)	3.41 (<0.001)	2.67 (<0.001)	2.72 (<0.001)
Hypertension	-0.02 (0.98)	1.47 (0.002)	0.90 (0.08)	1.33 (0.01)	0.71 (0.16)	0.12 (0.81)
Employed	-1.00 (0.01)	-0.41 (0.21)	-0.61 (0.09)	-0.33 (0.33)	-0.92 (0.01)	-1.14 (0.003)
Alcohol	-2.37 (<0.001)	-2.14 (<0.001)	-2.04 (<0.001)	-2.10 (<0.001)	-2.60 (<0.001)	-1.92 (<0.001)
Roof	0.11 (0.45)	0.08 (0.53)	0.19 (0.19)	0.11 (0.41)	-0.02 (0.87)	0.28 (0.06)
Wall	0.22 (0.25)	0.03 (0.88)	0.42 (0.03)	0.07 (0.68)	0.004 (0.98)	0.35 (0.08)
House density	0.08 (0.17)	0.11 (0.05)	0.02 (0.73)	0.12 (0.04)	0.14 (<0.001)	0.10 (0.12)

Jamaica

Table 6c: Jamaica's multivariable linear regression analysis adjusted for other variables.

Characteristics	Sleep onset Latency	Sleep Efficiency	WASO	Percent Wake	Average Wake Bout	Duration
Temperature	0.03 (<0.001)	-0.12 (<0.001)	0.03 (<0.001)	0.13 (<0.001)	3.21 (<0.001)	-0.03 (0.002)
Age	0.04 (0.98)	-0.06 (<0.001)	-0.09 (<0.001)	-0.07 (<0.001)	-0.04 (0.03)	-0.02 (0.34)
BMI	-0.31 (<0.001)	-0.32 (<0.001)	-0.32 (<0.001)	-0.35 (<0.001)	-0.32 (<0.001)	-0.29 (<0.001)
Sex (Women)	2.86 (<0.001)	3.56 (<0.001)	2.57 (<0.001)	3.41 (<0.001)	2.67 (<0.001)	2.72 (<0.001)
Hypertension	-0.01 (0.98)	1.34 (0.002)	0.80 (0.08)	1.23 (0.01)	0.56 (0.16)	0.23 (0.81)
Employed	-0.32 (0.01)	-0.41 (0.21)	-0.61 (0.09)	-0.33 (0.33)	-0.92 (0.01)	-1.14 (0.003)
Alcohol	-1.56 (<0.001)	-1.14 (<0.001)	-1.04 (<0.001)	-1.10 (<0.001)	-1.60 (<0.001)	-2.92 (<0.001)

Seychelles

Table 6d: Seychelles' multivariable linear regression analysis adjusted for other variables

.

Characteristics	Sleep onset Latency	Sleep Efficiency	WASO	Percent Wake	Average Wake Bout	Duration
Temperature	0.01 (0.30)	-0.004 (0.59)	0.002 (0.07)	0.001 (0.89)	-0.05 (0.64)	<0.001 (0.93)
Age	-0.002 (0.72)	-0.002 (0.72)	-0.47 (0.4)	-0.002 (0.73)	-0.002 (0.80)	-0.002 (0.73)
BMI	0.01 (0.27)	-0.007 (0.21)	0.01 (0.20)	0.01 (0.19)	0.007 (0.18)	0.007 (0.19)
Sex (Women)	-0.48 (<0.001)	-0.48 (<0.001)	-0.47 (<0.001)	-0.48 (<0.001)	-0.48 (<0.001)	-0.48 (<0.001)
Hypertension	0.04 (0.58)	0.05 (0.52)	0.05 (0.50)	0.05 (0.50)	0.06 (0.48)	-0.06 (0.49)
Employed	-0.32 (0.29)	-0.31 (0.30)	-0.21 (0.49)	-0.33 (0.28)	0.35 (0.24)	-0.34 (0.26)
Alcohol	0.07 (0.27)	0.07 (0.30)	0.06 (0.33)	0.07 (0.28)	0.08 (0.25)	0.08 (0.27)
Roof	0.20 (0.15)	0.19 (0.18)	0.19 (0.17)	0.18 (0.19)	0.18 (0.20)	0.18 (0.21)
Wall	0.01 (0.87)	0.009 (0.87)	0.004 (0.93)	0.005 (0.93)	<0.001 (0.99)	0.003 (0.95)
House density	-0.02 (0.34)	-0.01 (0.37)	-0.02 (0.32)	-0.01 (0.36)	-0.02 (0.36)	-0.02 (0.33)

United States

Table 6e: United States' multivariable linear regression analysis adjusted for other variables.

Characteristics	Sleep onset Latency	Sleep Efficiency	WASO	Percent Wake	Average Wake Bout	Duration
Temperature	-0.003 (0.94)	0.13 (0.02)	-0.01 (0.26)	-0.13 (0.03	-0.32 (0.54)	0.009 (0.03)
Age	0.09 (0.06)	0.12 (0.02)	0.12 (0.04)	0.12 (0.02)	0.10 (0.05)	0.07 (0.17)
BMI	0.02 (0.530	0.03 (0.45)	0.02 (0.64)	0.02 (0.52)	0.03 (0.48)	0.03 (0.45)
Sex (Women)	-8.67 (<0.001)	-9.03 (<0.001)	-8.69 (<0.001)	-8.97 (<0.001)	-8.70 (<0.001)	-9.00 (<0.001
Hypertension	2.91 (<0.001)	3.07 (<0.001)	2.88 (<0.001)	3.05 (<0.001)	2.91 (<0.001)	3.17 (<0.001)
Employed	0.28 (0.64)	0.02 (0.97)	0.12 (0.84)	0.02 (0.98)	0.18 (0.77)	0.32 (0.59)
Alcohol	-2.32(<0.001)	-2.25 (<0.001)	-2.25 (<0.001)	-2.25 (<0.001)	-2.29 (<0.001)	-2.40 (<0.001)
Roof	-0.10 (0.83)	-0.02 (0.96)	-0.05 (0.90)	-0.01 (0.98)	-0.07 (0.88)	-0.07 (0.89)
Wall	0.001 (0.99)	-0.01 (0.95)	0.02 (0.93)	-0.01 (0.96)	0.01 (0.95)	0.03 (0.88)
House density	-0.56 (<0.001)	-0.58 (<0.001)	-0.50 (<0.001)	-0.56 (<0.001)	-0.58 (<0.001)	-0.60 (<0.001)

Table 7: Linear Multivariable Analysis of Sleep efficiency on bmi and glucose levels and adjusted for age, work status,sex and location.

Characteristics	BMI (kg/m^2)		Glucose (ml/dl)	
	Coefficient (95% CI)	**p-value**	**Coefficient (95% CI)**	**P -value**
Intercept	29.1 (21.6; 28.3)	<0.001	60.6 (41.1; 80.2)	<0.001
Efficiency (%)	0.02 (-0.19; 0.05)	0.16	0.43 ((0.22; 0.64)	<0.001
Age (years)	-0.05 (-0.09; -0.02)	<0.001	0.76 (0.60, 093)	<0.001
Country				
Ghana	___	____		
South Africa	-0.19 (-1.10; 0.72)	0.67	-31.7 (-36.1; -27.4)	<0.001
Jamaica	5.40 (4.19; 6.61)	<0.001	-18.48 (-23.2; -13.7)	<0.001
Seychelles	4.06 (3.39; 4.72)	<0.001	-1.61 (-5.03; 1.82)	0.36
United States	7.9 (7.15; 8.62)	<0.001	-16.07 (-19.8; -12.30	<0.001
Sex				
Males	___	___		
Females	3.16 (2.68; 3.63)	<0.001	-4.70 (-7.30; -2.36)	<0.001
Alcohol				
No	____	___		
Yes	-0.63 (-1.10; -0.19)	<0.001	3.01 (0.73; 5.30)	0.01
Work				
No	___	___		
Yes	0.06 (-0.60; 0.71)	0.86	-11.10 (-14.2; -7.96)	<0.001

Table 8 : Multivariable logistic regression for the three outcomes for the five countries adjusted for sex, age, work status, country and alcohol status. F=Female Work status, Alcohol status reference group =No Reference for countries Ghana CI =Confidence Interval Mins= Minutes

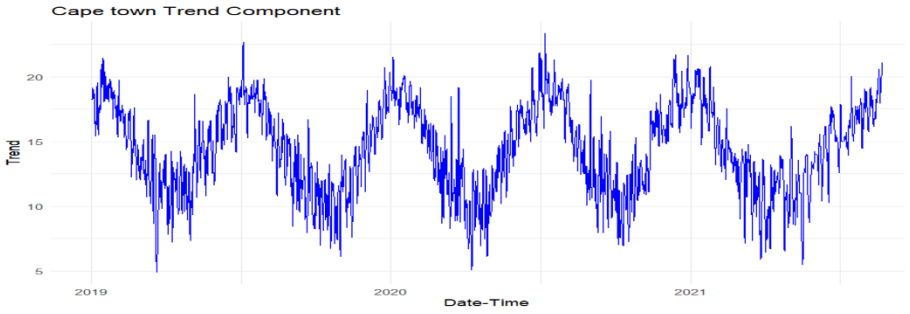
Characteristics	**Obesity**		**Hypertension**		**Diabetes**	
	OR (95% CI)	P-value	OR (95% CI)	P-value	OR (95% CI)	Pvalue
Age (years)	0.98 (0.97; 9.90)	<0.001	1.08 (1.07; 1.10)	<0.001	1.08 (1.06; 1.11)	<0.001
Sex (F)	3.04 (2.56; 3.51)	<0.001	0.93 (0.79; 1.11)	0.44	1.24 (0.94; 1.67)	0.13
Work (Yes)	0.81 (0.66; 1.01)	0.06	0.80 (0.64; 0.99)	0.04	0.50 (0.37; 0.68)	<0.001
Alcohol (Yes)	0.76 (0.66;0.89)	<0.001	0.86 (0.73; 1.01)	0.08	0.90 (0.69; 1.17)	0.44
South Africa	1.97 (1.42; 2.720	<0.001	1.56 (1.09; 2.26)	0.02	0.07 (0.02;0.28)	<0.001
Jamaica	4.29 (3.23; 6.04)	<0.001	0.74 (0.49; 1.11)	0.15	0.74 (0.40; 1.34)	0.34
Seychelles	3.81 (3.02; 4.92)	<0.001	2.01 (1.54; 2.63)	<0.001	1.44 (0.96;2.20)	0.08
United States	8.84 (6.79; 11.52)	<0.001	2.66 (2.02; 3.53)	<0.001	2.21(1.49; 3.37)	<0.001
Efficiency (%)	0.88 (0.82; 0.95)	0.001	0.88 (0.81; 0.94)	<0.001	0.45 (0.82; 1.05)	0.26
Duration (mins)	1.05 (1.01;1.09)	0.01	1.05 (1.01; 1.09)	0.01	1.18 (1.11; 1.24)	<0.001
Onset latency (mins)	1. 04 (0.99; 1.02)	0.65	0.99 (0.97; 1.00)	0.36	0.98 (0.95; 1.01)	0.28
WASO (mins)	0.92 (0.89; 0.96)	<0.001	0.93 (0.89;0.97	<0.001	0.84 (0.79; 9.00)	<0.001
Sleep time (mins)	0.96 (0.91; 0.99)	0.02	0.96 (0.91; 0.98)	<0.001	0.85 (0.80; 0.91)	<0.001

Table 9: Mediation analysis of temperature on the three outcomes.

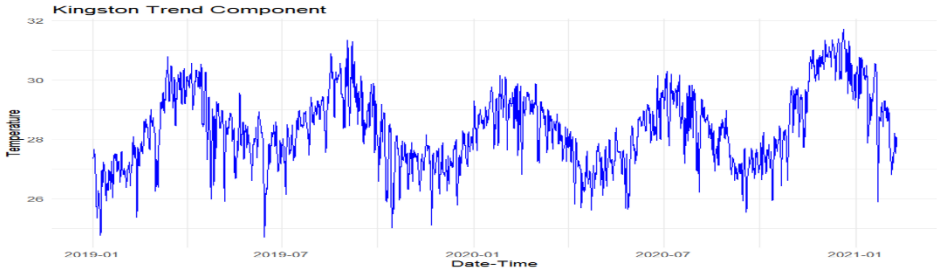
Characteristics	**Diabetes**		**Hypertension**		**Obese**	
	Estimate (95% CI)	P-value	Estimate (95% CI)	P-value	Estimate (95% CI)	P-value
ACME (control)	-0.000139 (-0.0006;0)	0.008	-0.0004 (-0.0007; 0)	<0.001	0.000007(0.00001; 0)	0.37
ACME (treated)	-0.00013 (-0.0006;0)	0.008	-0.0004 (-0.0007; 0)	<0.001	0.000007(0.00001; 0)	0.37
ADE (control)	-0.00001 (-0.00005,0)	0.992	-0.0009 (-0.004;0)	0.54	0.0008 (0.0003; 0)	<0.001
ADE (control)	-0.00001	0.992	-0.0009 (-0.004;0)	0.54	0.0008 (0.0003; 0)	<0.001
Total Effect	-0.00041 (-0.00005,0)	0.884	-0.0013(-0.004; 0)	0.39	0.0009 (0.0003; 0)	<0.001
Prop. Mediated (Control)	0.929 (-1.23;3.03)	0.884	0.32 (-3.01; 3.41)	0.39	0.009 (0.0003;0.3)	0.37
Prop. Mediated (treated)	0.928 (-1.23;3.03)	0.884	0.32 (-3.01; 3.41)	0.39	0.009 (0.0003;0.3)	0.37
ACME (Average)	-0.00013 (-0.0006;0)	0.008	-0.0004(-0.0007; 0)	<0.001	0.000007(0.00001; 0)	0.37
ADE (Average)	-0.00001 (-0.00521,0)	0.992	-0.000897 (-3.02;3.41)	0.54	0.0008 (0.0003; 0)	<0.001
Prop. Mediated (average)	0.929 (-1.23, 3)	0.884	0.32 (-3.01; 3.41)	0.39	0.009 (-0.01;0.03)	0.37

ACME = Average Casual Mediation Effect ADE= Average Direct Effect Prop= Proportion CI Confidence Interval

Figure 1:Nighttime temperature trends



1A



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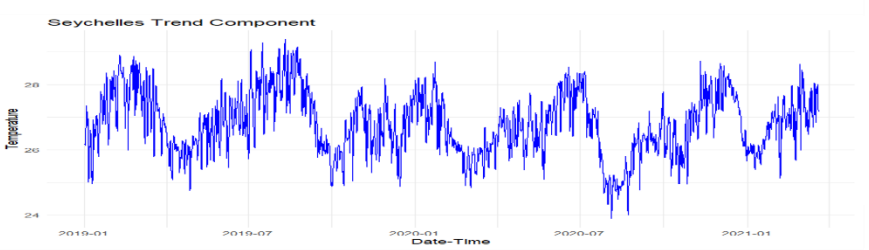

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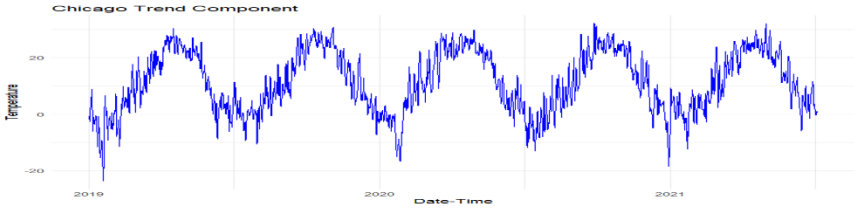


1D

Figure 2: Boxplot of sleep efficiency across the five sites.

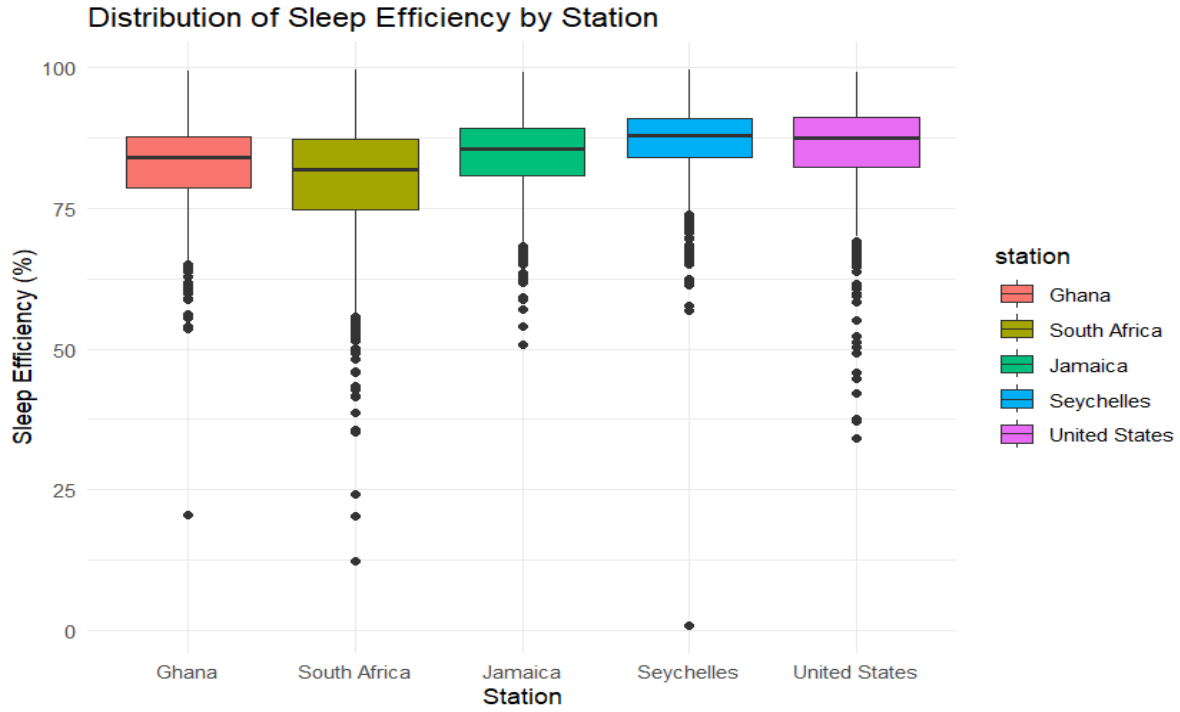


Figure 3: Boxplot comparing the distribution of sleep duration across the 5 sites.

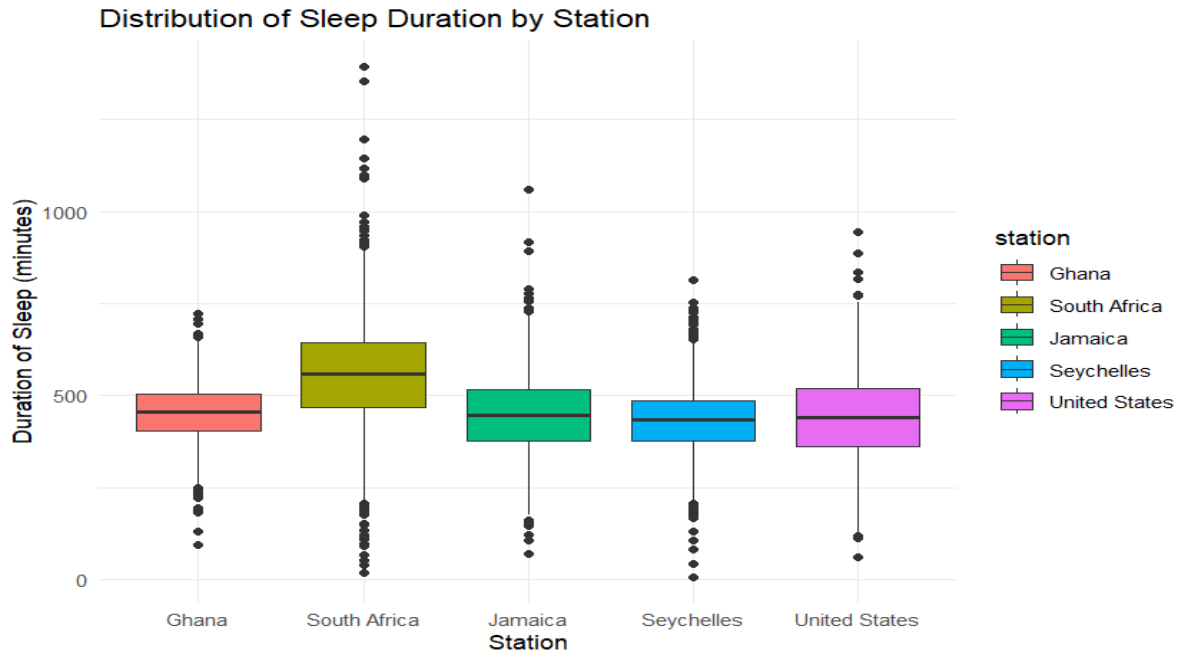


Figure 4: Boxplot showing the distribution of Wake Time by station

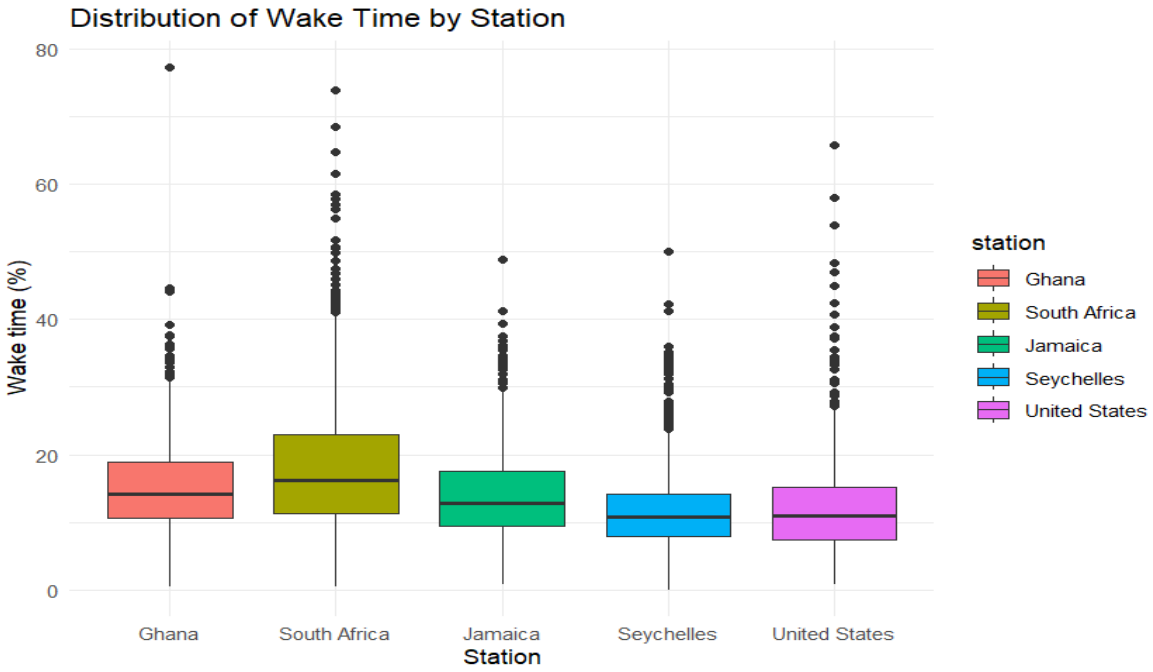


Figure 5: Bar plots comparing the Prevalence of outcomes by sex across the five sites.

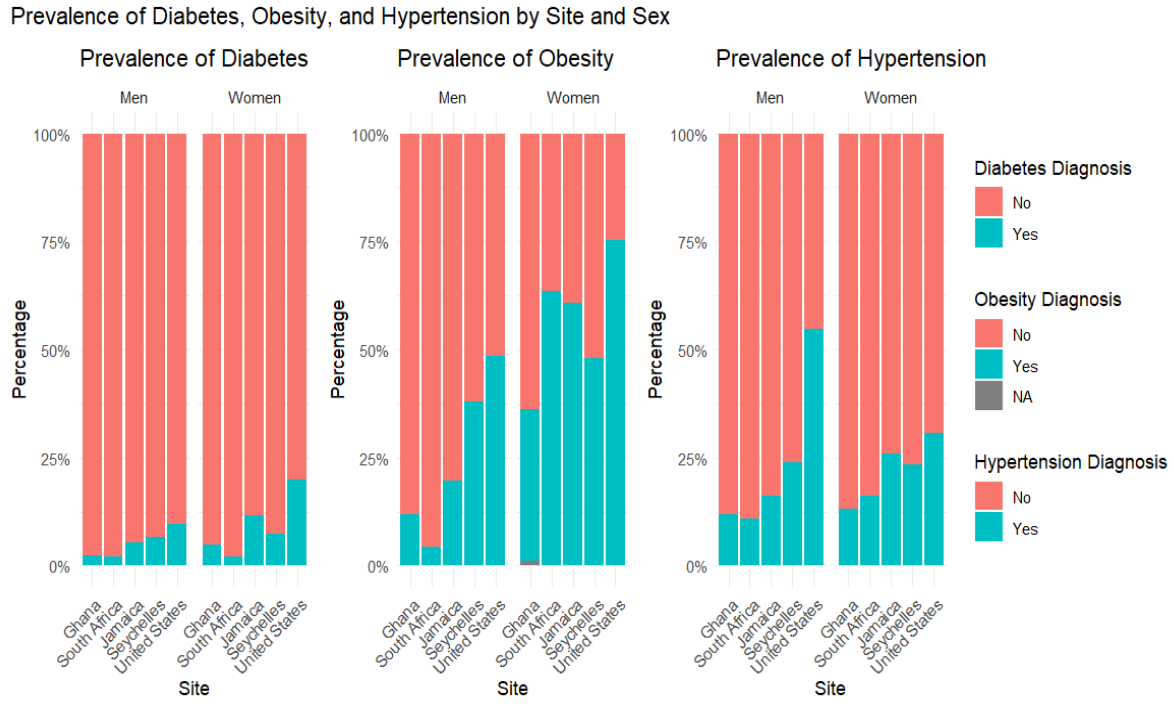


Figure 7: Correlation matrix of Temperature and Sleep variables across all sites.

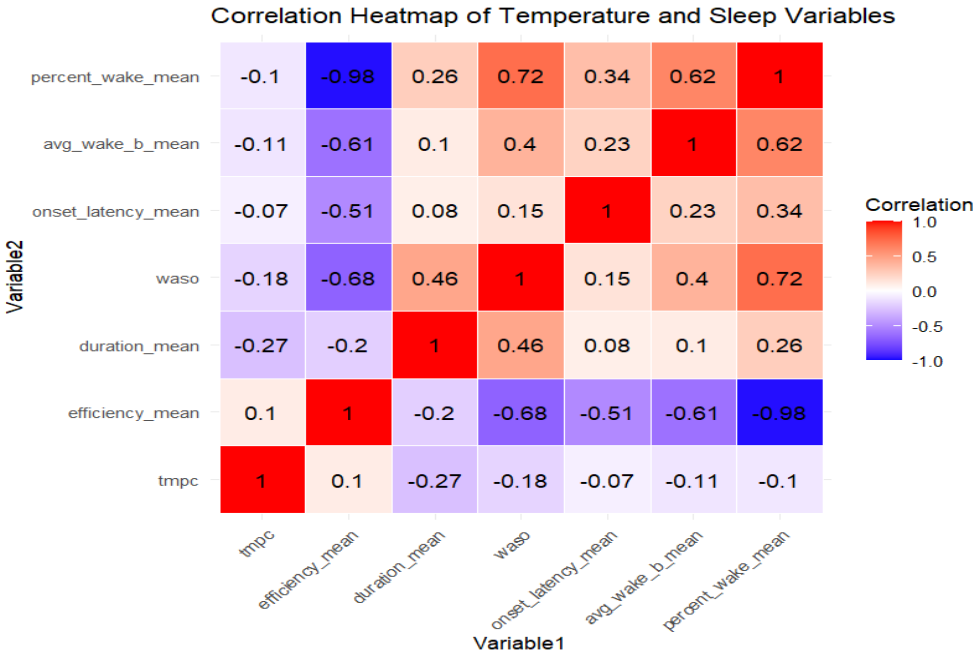


Figure7a: Correlations of temperature and Sleep variables for Ghana

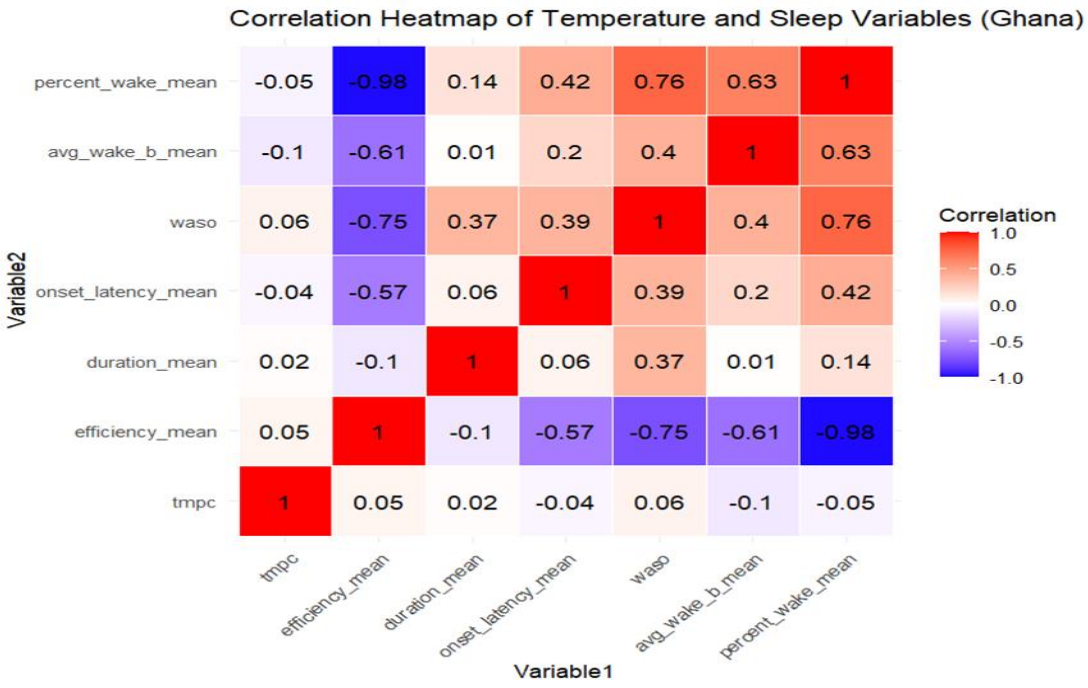


Figure 7b: Correlations of temperature and Sleep variables for South Africa

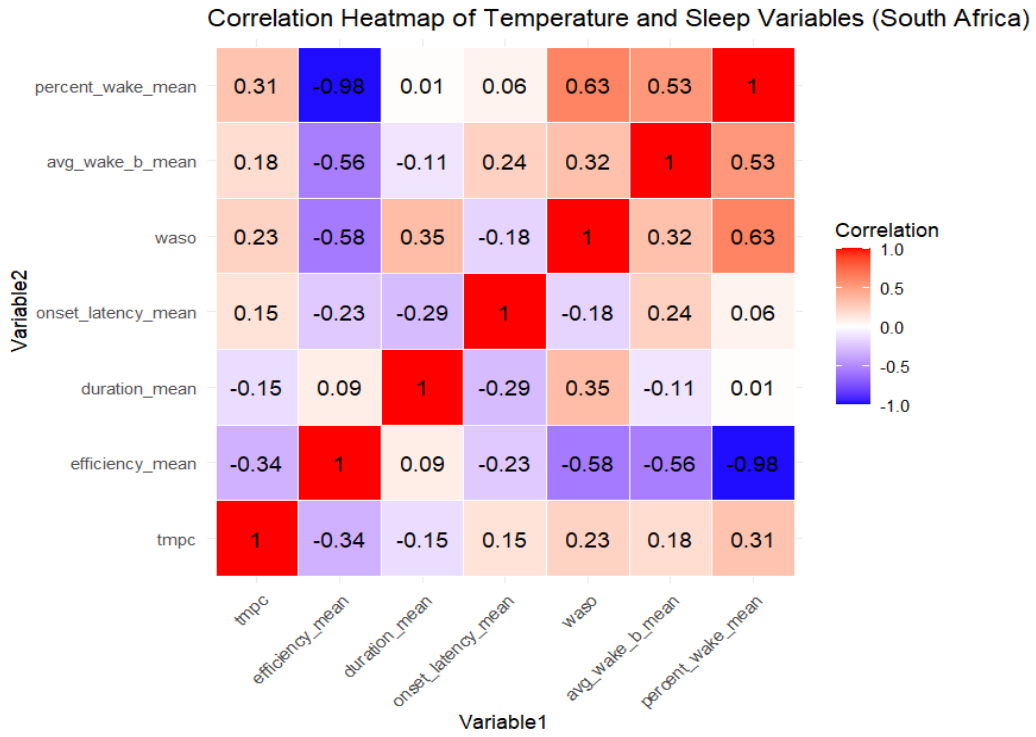


Figure 7c: Correlations of temperature and Sleep variables for Jamaica

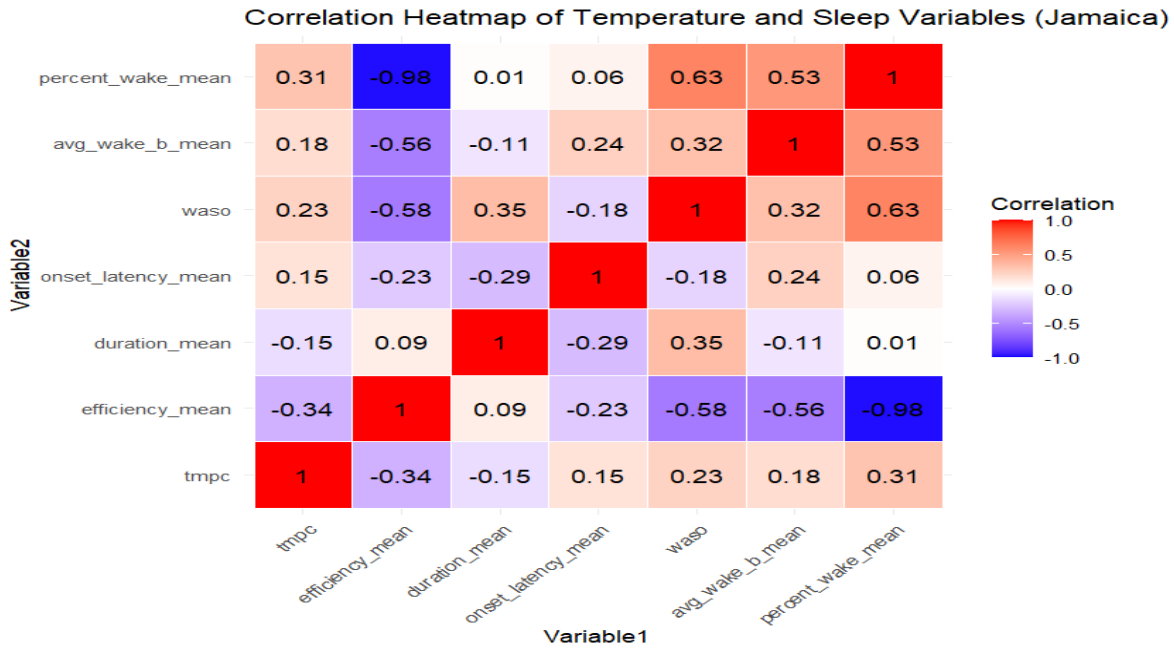


Figure 7d: Correlations of temperature and Sleep variables for Seychelles

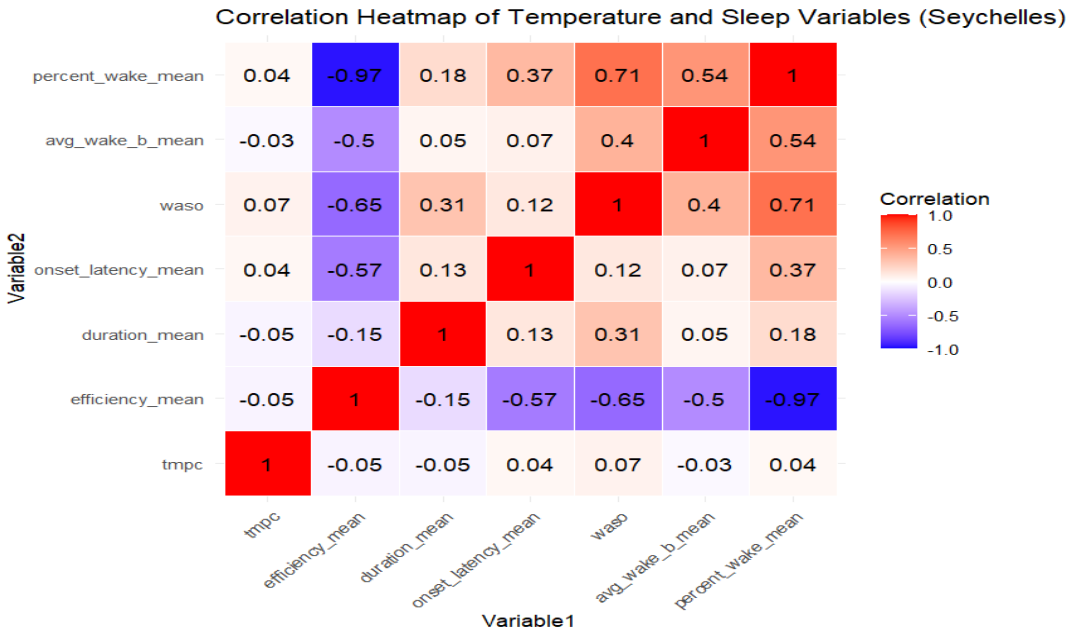


Figure7e: Correlations of temperature and Sleep variables for United States

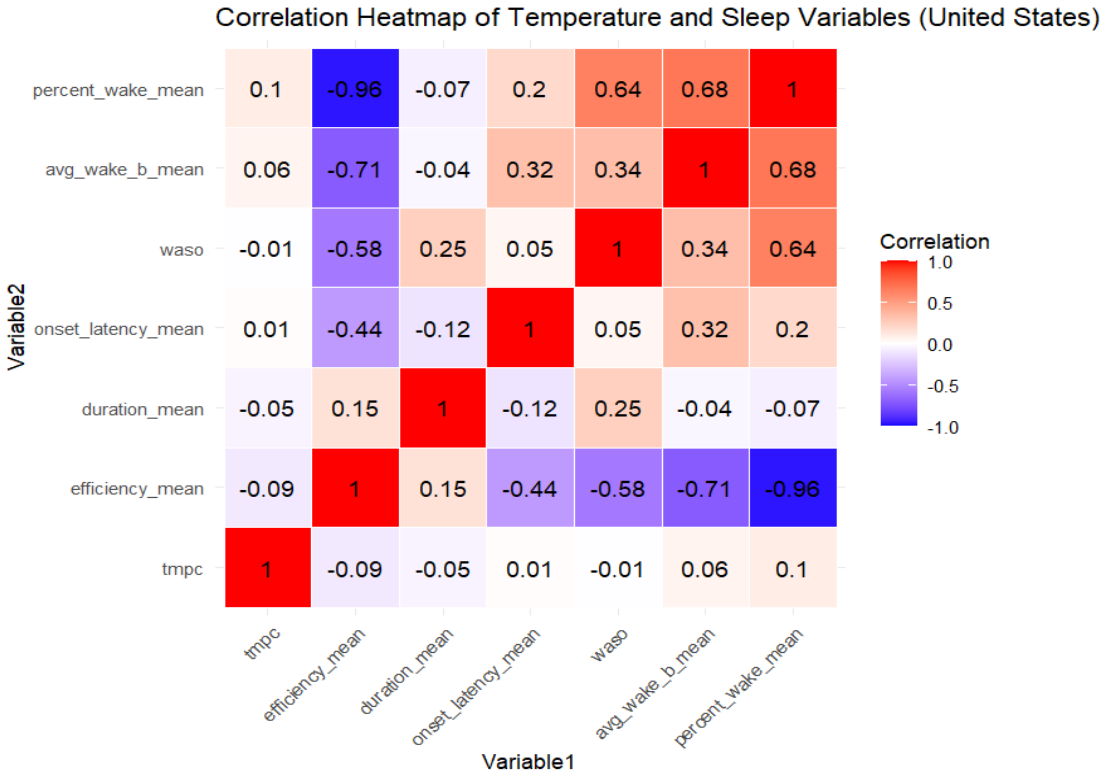
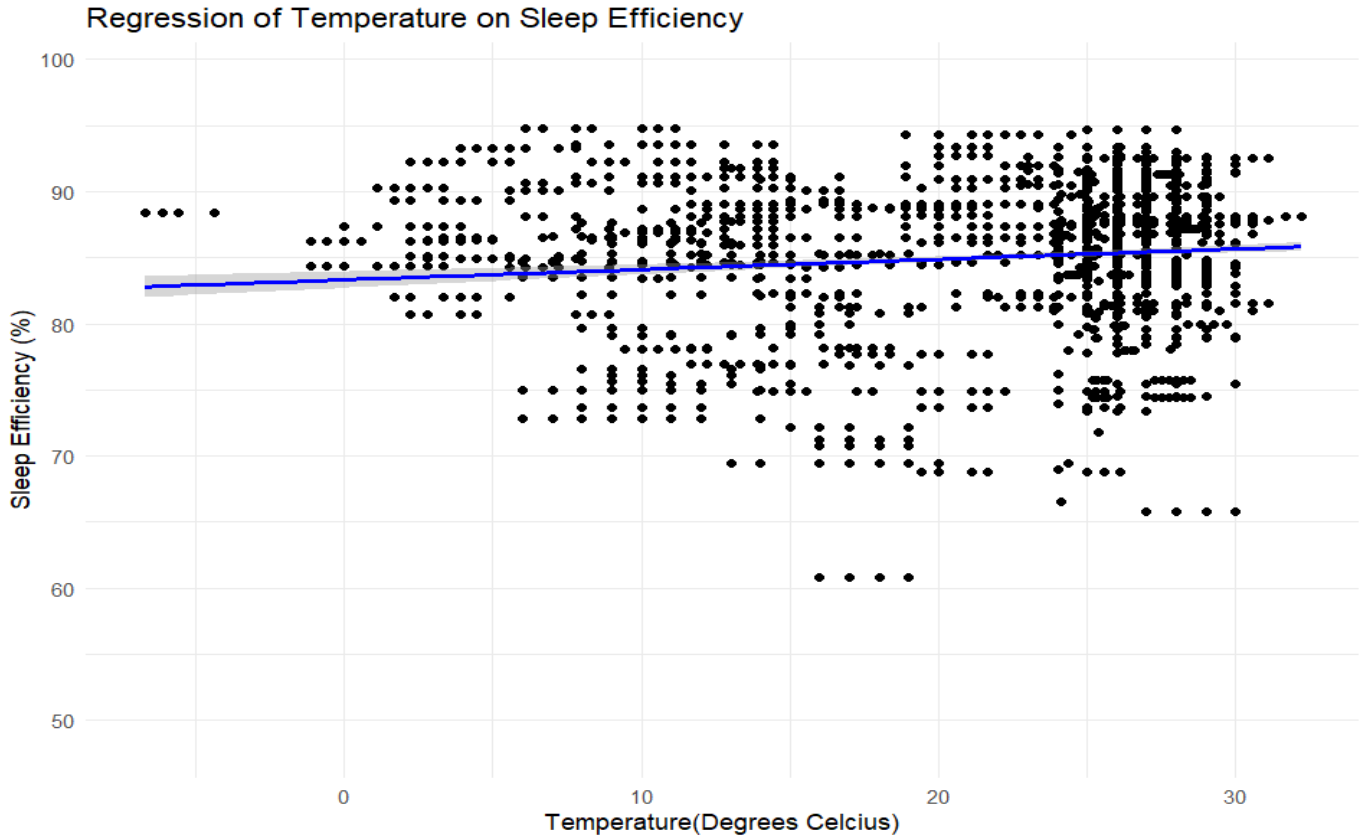


Figure 8: Regression of temperature on sleep efficiency



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PART D: APPENDICES

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

FACULTY OF HEALTH SCIENCES
Human Research Ethics Committee

As Principal Investigator of this research **I am aware of a potential conflict of interest**. Please describe and provide a plan to manage the conflict of interest in the space below:	

8. Declarations and signatures

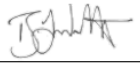
Note: Where the PI is also Head of

This application will not be processed unless all the required declarations and signatures are completed according to the Committee's Standard Operating Procedures. (see: SOP)

8.1 Head of Department or Division

My signature confirms that:

i. The researcher(s)/student(s)/supervisor(s) have the skills, training (including research ethics training), experience and time to undertake this research.
ii. There are adequate resources (e.g. equipment, space, support services) to perform this research.

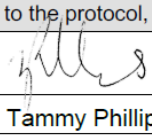
Signature of Head		Date	16-04-2024
Print name	Landon Myer		

Department, confirmation must be obtained from an authorised designee. PIs may not approve their own research.

8.2 Chairperson of the Departmental Research Committee (DRC)

My signature confirms that:

i. This research protocol has undergone peer review by a person(s) experienced in the field of study.
ii. This research is well-designed and scientifically sound.
iii. Where relevant, all methodological issues have been resolved to the satisfaction of the peer reviewer(s).
iv. If conducted according to the protocol, this research is expected to yield valid and useful findings.

Signature of Chairperson		Date	18April2024
Print name	Tammy Phillips		

Note: Where the PI is also the Chairperson of the DRC, confirmation must be obtained from an authorised designee. PIs

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

E52 Room 46 Old Main Building
Groote Schuur Hospital
Observatory 7925
Email: hrec-submissions@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

2 May 2024

HREC REF: 287/2024

Prof Lara Dugas
Division of Epidemiology and Biostatistics
School of Public Health
Faculty of Health Science
Email: lara.dugas@uct.ac.za
Student: mrkque001@uct.ac.za

Dear Prof Dugas

PROJECT TITLE: DOES TEMPERATURE ALTER THE RELATIONSHIP BETWEEN SLEEP BEHAVIOURS AND NON-COMMUNICABLE DISEASES IN FIVE DIFFERENT POPULATIONS? (MASTER DEGREE - MS QUEEN MARVELOUS MAREKERAH)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee (HREC) for review and approval.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study, subject to providing a DTA.

Approval is granted for one year until the 30 May 2025.

Please submit a progress report, using the standardised Annual Progress Report Forms (FHS016) **or** (FHS 017) if the study continues beyond the approval period. Please submit a Standard Closure form (FHS 010) when the study has been completed, this includes after publication or thesis submission and final completion.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval, where necessary, before the research may occur.

The HREC acknowledges that the following Master student will be involved in the study: Ms Queen Marvelous Marekerah.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the HREC reference number 287/2024 in all your correspondence.

Yours sincerely

PROFESSOR MARC BLOCKMAN
CHAIRPERSON, FACULTY OF HEALTH SCIENCES HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938
NHREC-registration number: REC-210208-007

This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use: Good Clinical Practice (ICH GCP), South African Good Clinical Practice Guidelines (DoH 2020), based on the Association of the British Pharmaceutical Industry Guidelines (ABPI), and Declaration of Helsinki (2013) guidelines. The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

DATA COLLECTION MATERIAL

METS-Microbiome Visit Checklist Baseline Visit:

Informed Consent _____

Form 1 – Demographics _____

_____

Form 2 - Anthropometrics

Form 3 – Biochemical measures

Urine _____

Blood _____

OGTT _____

Accelerometer Placement _____

Form 4 – GPAQ _____

Form 5 – FFQ _____

Form 6 – SES _____

Form 7 – Microbiome _____

Form 8 – Discrimination _____

Return Appointment _____

_____

Visit 2:

Was monitor returned? _____

Was stool collected? _____

Did participant receive reimbursement? _____

Did participant receive feedback forms? _____

Future appointments reminder _____

MAYWOOD, ILLINOIS
DEPARTMENT OF
INFORMED CONSENT

Participant's Name: _____
Medical Record Number: _____

PROJECT TITLE: Gut microbiota, short chain fatty acids, and adiposity across the epidemiologic transition.

THE APPROVAL FOR THIS PROJECT EXPIRES ON 01/16/2020.

Participant Information

PRINCIPLES CONCERNING RESEARCH: You are being asked to take part in a research project. It is important that you read and understand the principles that apply to all individuals who agree to participate in the research project described below:

1. Taking part in the research is entirely voluntary.
2. We do not know if you will benefit from taking part in the research but the knowledge obtained may help others.
3. You may withdraw from the study at any time without anyone objecting and without penalty or loss of any benefits to which you are otherwise entitled.
4. If during your participation in the research project new information becomes available which would affect your being in the research project, your doctor will discuss this new information with you and will help you make a decision about your continuing in the research.

The purpose of the research, how it is to be done, and what your part in the research will be is described below. Also described are the risks, inconveniences, discomforts and other important information which you need to make a decision about whether or not you wish to participate. You are urged to discuss any questions you have about this research with the staff members.

PURPOSE OF RESEARCH: You are being asked to participate in this study because we are investigating the relationship between the bacteria in your gut, short chain fatty acids and the risk for the development of obesity, diabetes and cardiovascular disease.

Document ID#: 209537am20.070919
Version Date: 07/09/2019

This research is sponsored by the Department of Public Health Sciences, Loyola University Chicago. Components of this project are also being conducted by researchers at the University of West Indies, Kingston, Jamaica; Kwame Nkrumah University of Science and Technology, Ghana; Minstry of Heatlth, Victoria, Seychelles, and the University of Cape Town, Cape Town, South Africa

Approximately 500 people will participate in this research.

The goal of this research is not to diagnose or treat any problems you may have. Therefore, participation in this study is not a substitute for the care you are receiving from your doctor. During the time you are in this study you should continue to see your doctor or if you have a problem contact your doctor.

DESCRIPTION AND EXPLANATION OF PROCEDURES: If you agree to participate in this study, you will complete the following research procedures outlined below.

Your initial participation in the study will last 8 days; you will be contacted for a follow-up visit each for two years from your initial visit. Your participation in the last year will also last 8 days.

Procedures for initial visit:

Time involved:
Day 1 - you will be at the clinic for about 2.5 hrs
Day 8 - you will be at the clinic for about 45 minutes
1 year later - you will be at the clinic for about 45 minutes 2 years later - Day 1; you will be at the clinic for about 1.5 hrs 2 years later - Day 8; you will be at the clinic for about 45 minutes.
3 years later – you will be at the clinic for about 45 minutes.
4 years later – you will be at the clinic for about 45 minutes.

During the initial visit:

1. We ask that you arrive at the clinic after not eating anything from 10pm in the evening before your visit.

2. We will ask you about foods you have eaten in the last 24 hours. We will do this twice, separated by 7 days. This information will allow us to calculate your daily food calories, the time at which you eat 50% of your calories, and the types of foods that you eat.

We will also ask you about your activity patterns, your health and sleep habits, as well as your personal wellbeing.

3. We will take the following body measurements: height, weight, blood pressure, waist, hip, and percent body fat. Body fat will be measured by bioimpendance analysis. With this method, we will place 4 electrodes on your hands and feet, and apply a small amount of electricity to measure the amount of water in the body. This test does not cause any pain or discomfort. If you have a pacemaker, you will be excluded from having your body fat measured and from the bone scan.

4. You will either have an IV catheter placed in your arm or you will undergo phlebotomy to provide blood samples. If you receive an IV catheter, it will be flushed with 0.9% normal saline following each blood draw.

5. Three tablespoons of blood will be drawn to measure substances in the blood that may be related to diabetes, nutritional status and cardiovascular disease.

6. You will be asked to provide a urine sample. We will use this urine sample to check your kidney function.

7. You will be given a stool collection kit and the clinic staff will detail the collection method. You will be instructed to provide the sample in the preceeding 24 hrs prior to your second clinic visit.

8. You will complete a standard oral glucose tolerance test. You will be given a sugar solution to drink and we will measure the sugar in your blood after 30, 60 and 120 mins. The total amount of blood is one table spoon.

9. An activity monitor will be strapped around your waist by a staff member. This monitor is the size of a watch and is attached to an elastic belt. The activity monitor measures physical activity patterns.

You will be instructed to wear the monitor at all times during the next 7 days, including during the night unless you are unable to sleep with it on. You will be asked to remove the monitor for bathing and swimming and to avoid completely submerging the monitor in water.

10. You may have two skin sensitivity tests to evaluate your risk for nerve damage from having prediabetes or diabetes. These tests will be performed by a study physician. The first test uses tiny wire filaments, which will individually be gently pressed on your hand until you feel the pressure from the wire filaments. During the second test, the physician will use a safety pin, and gently press both the sharp and dull side onto your hand to evaluate your skin sensation.

11. You may be asked to wear a sleep monitor around your wrist. This measurement may coincide with either first, second or third year follow-up. The monitor is the size of a watch and is attached by a velcro band. The sleep monitor will record your sleep patterns. You will be instructed to wear the sleep monitor at all times during the next 7 days, including at night.
You will be asked to remove the sleep monitor for bathing and swimming and to avoid completely submerging the monitor in water.

11. You will be given a light snack and may leave the clinic.

After the first visit:

After the first night, a staff member will call you at a phone number you provide to insure that you are comfortable with the monitor and to answer any questions you may have.

7 days later (Day 8): You will be asked to return to the clinic. You will bring the stool sample, collected in the preceding 24hrs with you. You will have the activity and sleep monitor removed, and you will be asked about the foods you have eaten the previous 24 hours.

1 year later (Day 1): You will be contacted and asked to return to the clinic. We will measure your weight, blood pressure, waist, hip and percent body fat and the bone mineral content as you had at the beginning of the study.

2 years later (Day 1): You will be contacted and asked to return to the clinic. We ask that you refrain from eating from 10pm in the evening before your clinic visit. We will measure your weight, blood pressure, waist, hip and percent body fat and bone mineral content. We wills strap a monitor to your waist, and a sleep monitor to your wrist and ask you some health, physical activity and dietary questions. You will have two tablespoons of blood drawn, and we will provide you with a stool collection kit. We will provide you with a snack, and you will be free to leave the clinic.

2 years later (Day 8): You will be asked to return to the clinic. You will bring the stool sample, collected in the preceding 24hrs with you. You will have the activity and sleep monitors removed, and you will be asked about the foods you have eaten the previous 24 hours.

3 years later (Day 1): You will be contacted and asked to return to the clinic. We will measure your weight, blood pressure, waist, hip and percent body fat as you had at the beginning of the study.

4 years later (Day 1): You will be contacted and asked to return to the clinic. We will measure your weight, blood pressure, waist, hip and percent body fat as you had at the beginning of the study.

RISKS/DISCOMFORTS: There are no risks with having your percent body fat measured. In addition, there are no risks from wearing an activity or sleep monitor. You may experience a minor and temporary discomfort and bruising at the site of the blood draw or IV catheter site. You may experience an infection at the site of the blood draw or IV catheter site. You may feel lightheaded during the OGTT test. If you participate in the skin sensitivity tests, you may experience some discomfort at the site where the wire filaments or safety pin is pressed onto your skin.

There is a small risk of loss of confidentiality.

REPRODUCTIVE AND SEXUAL ACTIVITY INFORMATION: The intervention in this study could affect a developing baby. Therefore, you cannot participate in this research project if you are pregnant at the time that you would start the study.
BENEFITS: Your participation will help us better understand the relationships between the composition of bacteria in your gut and your health, short chain fatty acids and the risk for obesity, diabetes and cardiovascular disease. It is unlikely that you will benefit directly from being in this research project. We will notify you if the blood test indicates high blood sugar or fat, or if your blood pressure is high. We will inform you if you have an increased risk of kidney disease based on results from your blood test and urine test. We will not provide any additional evaluations but would recommend that you see your doctor to discuss the results.

ALTERNATIVES: You do not have to participate in this project if you do not want to.

FINANCIAL INFORMATION: To compensate you for the time spent in the study, you will be given $75.00. Compensation will be provided at the clinic on Day 8. You will be compensated $20.00 for the time spent in the study for the 1-year follow-up study. You will be compensated $75.00 for the time spent in the study for the 2-year follow-up study. You will receive this payment at the clinic on Day 8. You will be compensated $20.00 for the visit during the 3rd year follow-up and $20.00 for the visit during the 4th year. If you participate in the skin sensitivity test, you will receive an additional $30.00. If you participate in the 7-day sleep monitoring activity, you will receive an additional $75.00. If you receive payment for participating in this research, personal information about you, including your name, address, and Social Security number, will be released to the Loyola University Chicago Accounting Office for the purpose of recording the payment and for tax reporting to the United States Internal Revenue Service (IRS). You will need to complete a W-9 form. This form will be provided to you. If you choose not to complete the W-9, you will not receive reimbursement.

You will not charged for any of the tests that are performed in this research project. In the event we recommend that you see your doctor for additional testing because of abnormal results obtained from the study tests, you will be financially responsible for the cost of care.

RESEARCH RELATED INJURY: In the event that you are injured or have side effects as a result of participating in this research project, there are no funds available from Loyola University Chicago to pay for the cost of care of the problem. You will be financially responsible for the cost of care of any problems. By signing this form, you are not giving up any legal rights to seek to obtain compensation of injury. .

INFORMATION COLLECTED AND WHAT WILL HAPPEN TO IT: In order to meet the goals of the research study (see Purpose of Research section of this consent), we will collect information on

you, and your research test results. The information will be collected by Lara Dugas, Ph.D., MPH, and the research staff.

Information about you will be provided to Loyola University Chicago; The National Institutes of Health (the research sponsor); data collection and study verification agencies.

In this way, we will learn about the relationships between the gut microbiota, short chain fatty acids and the risk for obesity, diabetes and cardiovascular disease.

The information we will collect and send includes:

X DEMOGRAPHIC AND QUESTIONNAIRE INFORMATION (e.g., name, address, phone number, physical activity patterns, health, sleep, wellbeing, and foods eaten)
X PHYSICAL AND SLEEP ACTIVITY MEASUREMENTS
X BODY MEASUREMENTS (e.g. blood pressure, weight, height, waist, hip, and percent body fat)
X URINE AND BLOOD SAMPLES
X SALIVA AND STOOL SAMPLES

We will collect and provide this information about you for as long as you are in the study which will be about 3 years.

It is possible that the sponsor, The National Institutes of Health, research nurses, data collection and/or study verification agencies, data administrators or staff. They may take notes or copy pages of the medical record. This is done to verify the accuracy of the information.

The results of this research study may be published in a journal for the purpose of advancing medical knowledge. You will not be identified by name or by any other identifying information in any publication or report about this research.

Consent for LUC to use and disclose your medical information is required in order for you to participate in the study.

A new Federal law, called the Genetic Information Nondiscrimination Act (GINA), generally makes it illegal for health insurance companies, group health plans, and most employers to discriminate against you based on your genetic information. This law generally will protect you in the following ways:

- Health insurance companies and group health plans may not request your genetic information that we get from this research.[2]
- Health insurance companies and group health plans may not use your genetic information when making decisions regarding your eligibility or premiums.
- Employers with 15 or more employees may not use your genetic information that we get from this research when making a decision to hire, promote, or fire you or when setting the terms of your employment.

All health insurance companies and group health plans must follow this law by May 21, 2010.
All employers with 15 or more employees must follow this law as of November 21, 2009.

Be aware that this new Federal law does not protect you against genetic discrimination by companies that sell life insurance, disability insurance, or long-term care insurance.

WITHDRAWAL OF CONSENT: Your consent to use and disclose your medical information for the purpose of this research study is completely voluntary. You can withdraw your consent for LUMC to use

and disclose your information and your consent to participate in this study at any time without affecting your ability to receive care and treatment at LUMC unrelated to the research study. Withdrawal means that all study procedures and follow-up will stop and we will not send any more information about you to the sponsor of this research or its designees. However, information already used and disclosed to the research sponsor prior to the time of your withdrawal from this study may continue to be used and disclosed by LUMC and the sponsor.

If you withdraw from the study, we will ask that you sign the form attached to this consent and send it to Lara Dugas, Ph.D., MPH or give it to the study staff. Your withdrawal from the study will not have any effect on any actions by LUC taken before the attached form is received by LUC.

Your study doctor, the Institutional Review Board, the regulatory authorities, or the sponsor, The National Institutes of Health, may terminate the study at any time with or without your consent.

CONSENT

I have fully explained to _____ the nature and purpose of the above-described procedure and the risks that are involved in its performance. I have answered and will answer all questions to the best of my ability. I may be reached at 708-327-9029.

_____Date:____/_____/____ Signature

Lara Dugas, Ph.D., MPH, the principal investigator for this study, or her associates will be available to answer any questions you may have. Dr. Dugas can be reached at: 708-327-9029.

If you ever feel that you have been injured by participating in this study or if you have any questions concerning your rights as a research participant, you may contact Kenneth Micetich, MD, Chair of the Institutional Review Board for the Protection of Human Subjects-Loyola University Chicago Health Sciences Division, at 708-216-4608.

Although you have the right to revoke this authorization, you accept that such revocation will not apply to any uses and disclosures of your information that are described in the Loyola University Health System Notice of Privacy Practices or otherwise allowable under any Federal or State laws.

 You will receive a signed copy of this informed consent document.

You have been fully informed of the above-described research program with its possible benefits and risks. Your signature below indicates that you are willing to participate in this research study and agree to the use and disclosure of information about you as described above. You do not give up any of your legal rights by signing this consent document.

_____Date:____/_____/____

Signature: Participant

FORM 1 **METS-MICROBIOME** **DEMOGRAPHICS FORM**

Participant ID: _____ **Exam date: _____/_____/_____** (MM/DD/YYYY)

□ Clinic visit □Home visit **Interviewer Initials _____**
New participant □ Yes □ No

CONTACT INFORMATION **Email _____**
Last name _____ First names _____ MI _____
Address _____
City _____ State _____ Zip_____
Home phone _____ Work phone _____ Alternate/cellular phone _____
Nearest intersection: _____

BASIC DEMOGRAPHICS
Age: _____ Birth date: _____ /_____/_____ (MM/DD/YYYY)
Birth place: _____
Country _____ State _____ City _____

1. **When did you move to your current residence?**
   - ☐ Less than 1 year ago □ 2-10 years ago □ 1-2 years ago
   - ☐ More than 10 years ago
2. **Have you travelled outside of the country in the past:**

Month □ Yes □ No
6 Months □ Yes □ No 1
year □ Yes □ No
□ I have not travelled outside my country in the past year.

3. What is your ethnic group?
- ☐ American Indian/Alaskan Native □ White Hispanic (USA)
- ☐ Asian (Chinese) □ Mixed (i.e. not predominantly in an other
- ☐ Asian (Indian) groups, e.g. Creole)
- ☐ Black or African American □ Other ethnic group
- ☐ Native Hawaiian or Pacific Islander □ Refused to answer
- ☐ White □ Don't know

BACKGROUND DEMOGRAPHICS

4. **Where were you born**
   - ☐ At home □ In a hospital: Name of hospital _____ □ Don't know
5. **Were you born via caesarean section (C-section):**
   - ☐ No □ Yes □ Don't know **6. Gender** □ Male □Female

7. Marital status:
- ☐ Married/living with a partner as married
- ☐ Living without a partner
- ☐ Refused to answer

8. **If you don't know the amount, can you give an estimate of the annual household income if I read some options to you? Is it** (READ OPTIONS)
   - ☐ ≤ $23 000
   - ☐ More than $23 000, ≤ $43 000
   - ☐ More than $43 000, ≤ $72 000
   - ☐ More than $72 000, ≤ $112 000
   - ☐ More than $112 000
   - ☐ Don't know
   - ☐ Refused

9. **On average, what is your gross personal income per year, including allowances, bonuses and other benefits?**
   - ☐ ≤ $15 000
   - ☐ More than $15 000, ≤ $30 000
   - ☐ More than $30 000, ≤ $46 000
   - ☐ More than $46 000, ≤ $75 000
   - ☐ More than $75 000
   - ☐ Don't know
   - ☐ Refused **For females only:**

10. **Are you pregnant?**
    - ☐ No
    - ☐ Yes. **You are not eligible to participate in this study now. Please come back 6months after giving birth.** ☐ Don't know

11. **Are you breastfeeding currently?**
    ☐ No ☐ Yes ☐ Refuse to answer

12. **Time since last pregnancy (years, if 6 months: 0.5) _____**
13. **Number of biological children _____**
14. **Are you currently menopausal?** ☐ No ☐ Yes

HEALTH HISTORY

15. **Have you seen a primary care physician in the last year?** ☐ No ☐ Yes

16. **If yes, what was the reason for the visit, select all that apply?**
    - ☐ Surgery/ accident
    - ☐ Simple short illness such as cold
    - ☐ Chronic condition such as diabetes or hypertension ☐ Other situation (if yes, which one: _____)

17. **How do you pay for routine health care?** ☐ Mostly cash/ out of pocket
    - ☐ Mostly covered by medical insurance
    - ☐ Medical insurance with some cash/out of pocket expenses
    - ☐ Public/government (Medicaid or universal health system with free or largely free provision of health care)

18. **Have you ever been told that you have:**
    - ☐ Heart attack or coronary heart disease, age _____
    - ☐ Rheumatic heart disease or other heart problem, age _____ ☐ Stroke, age _____
    - ☐ Cancer, age _____; type _____
    - ☐ High blood cholesterol, age _____
    - ☐ Diabetes/elevated blood sugar, age _____
      If yes to diabetes, do you take insulin now? ☐ Yes ☐ No
    - ☐ Osteoarthritis, age _____
    - ☐ Rheumatoid arthritis, age _____
    - ☐ Kidney failure, age _____
    - ☐ Mental health problems like depression, age _____
    - ☐ Any other chronic disease? If so, what _____
    - ☐ High blood pressure, age _____

19. **If you were told you have high blood pressure:**

Have you ever been told by a doctor or health care provider to:	Are you now:
☐ Take prescribed medicine for more than 1 month	☐ Taking prescribed medicine for >1 month

Control your weight or lose weight	Controlling or losing weight
Cut down on salt	Using less salt
Exercise more	Exercising more
☐ Reduce your alcohol intake ☐ Stop smoking	☐ Reducing your alcohol intake ☐ Trying to stop smoking

20. Medications

Did participant bring medications and supplements: No Yes Is participant taking any of the following prescription medications

☐ Glucocorticoids/Corticosteroids (e.g. Entocort, Prednisone, Prednisolone, Decadron)
☐ Anticonvulsants (e.g. Depakote, Diazepam, Dilantin, Tegretol)
☐ Loop or Thiazide Diuretics (e.g. Furosemide, Bumatanide, Hydrocholorthiazide)
Other medications for hypertension (ACEIs, ARB, BB, CCB, etc)) Metformin or another oral antidiabetic medicine Other:

Other currently prescribed medications	Reason for Taking Medication

FOR FEMALES ONLY

☐ Estrogens (e.g. Premarin, Climara, Vivelle, Estraderm, Cenestin) Oral contraceptive
☐ Injectable contraceptive (Depo-Provera)

21. Are you taking any nutritional/ herbal supplement?

☐ No
☐ Yes

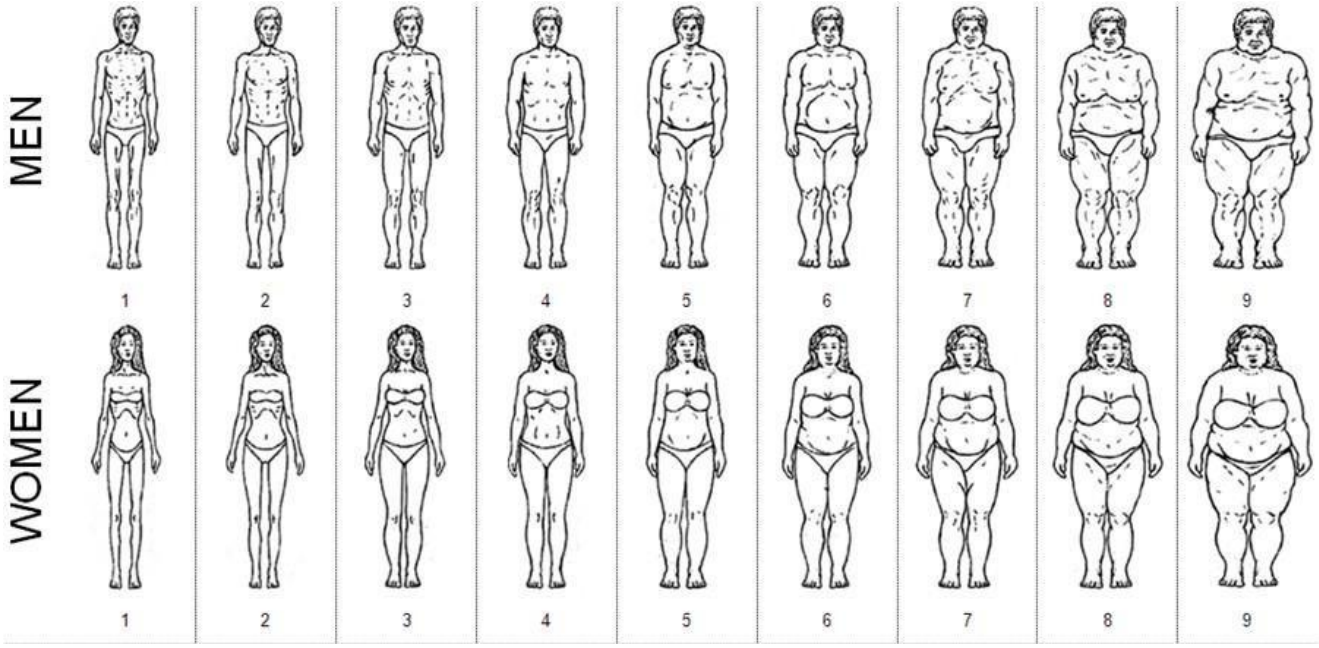
_____
__

RISK FACTORS

22. Approximately how many hours do you sleep each night? _____
23. Do you consider your current weight to be:

☐ Largely underweight
☐ Slightly underweight
☐ About right

☐ Slightly overweight ☐ Largely overweight
☐ Refused to answer



24. In the drawing, which figure best reflects how you think you look like with regards to your body shape? Answer (1-9): ____

25. In the drawing, which figure best represents how you would like to look like with regards to your body shape, ideally?
Answer (1-9): ____

26. Have you been intentionally trying to lose weight over the last year? ☐ No ☐ Yes
If yes, what method? ☐ Exercise ☐ Diet ☐ Other _____
If diet, what diet? _____

Smoking

27. Smoking (any tobacco use excluding e-cigarettes)

☐ Smoker: is currently smoking cigarettes (at least 1 per day). How many per day on average? _____ ☐ Occasional: Smokes, but not every day. How many per week on average? _____ ☐ Ex-smoker: Stopped smoking for at least 1 month.
☐ Non-user: Never smoked regularly

28. E-cigarettes usage

Do you ever use e-cigarettes: ☐ No ☐ Yes, occasionally ☐ Yes, regularly?
During the past 5 days, including today, on how many days did you smoke an e-cigarette? _____

Recreational Drug Use

29. Smoking (marijuana, hashish, pot)
☐ No ☐ Yes, Occasionally ☐ Yes, regularly Times per week _____

30. Cocaine, heroin, methamphetamine, amphetamines, ecstasy
☐ No ☐ Yes, Occasionally ☐ Yes, regularly Times per week _____

Alcohol

Note: 1 standard drink= 12 oz (350ml) beer= 5 oz (150 ml) glass of wine= 1.5 oz (44ml) glass of spirit (whiskey, gin, vodka)

31. Have you ever consumed any alcohol such as beer, wine, spirits or home-made alcohol?
☐ Yes
☐ No

32. Have you consumed any alcohol within the past 12 months?

- ☐ Yes
- ☐ No

33. If yes, during the past 12 months, how frequently have you had at least one standard alcoholic drink, on average?

- ☐ Daily ☐ 1-3 days per month
- ☐ 5-6 days per week ☐ Less than once a month
- ☐ 3-4 days per week
- ☐ 1-2 days per week

34. Have you consumed any alcohol within the past 30 days?

- ☐ Yes
- ☐ No

35. If yes, during the past 30 days, on how many occasions, approximately, did you have at least one standard alcoholic drink (standard drink: 1 bottle beer or 1 shot whisky or 1 glass wine)? _____

36. During the past 30 days, when you drank alcohol, how many standard drinks on average did you have during one drinking occasion? _____

37. During the past 30 days, what was the largest number of standard drinks you had on a single occasion on one single day/night, counting all types of alcoholic drinks together? _____ **38.** During the past 30 days, on how many days did you have six or more standard drinks in a single drinking occasion? _____

39. During each of the past 7 days, how many standard drinks did you have each day, on average?

Monday	_____		
Tuesday	_____	Friday	_____
Wednesday	_____	Saturday	_____
Thursday	_____	Sunday	_____

Life events

40. In the past year, have you experienced any of the following major life events:

- ☐ Death of a spouse
- ☐ Death of a family member or friend ☐ Imprisonment
- ☐ Divorce or separation ☐ Dismissal from work
- ☐ Major injury or ☐ Marriage illness ☐ Birth of a child
- ☐ Change in financial state

METS-MICROBIOME

FORM 2 **ANTHROPOMETRICS FORM**

Interviewer Initials: _____ **Exam Date: _____/_____/_____** (MM/DD/YYYY)

---

1. **Age: _____**
2. **Weight: _____ . _____** kilograms **SCALE ID** _____
3. **Height: _____. _____** m

Note: third measurements for all of the following are only required if first two differ by 0.5cm or more

4. **Waist circumference** _____. ___ cm
   _____. ___ cm
   _____. ___ cm

5. **Hip circumference** _____. ___ cm
   _____. ___ cm
   _____. ___ cm

6. **Upper mid-arm circumference** _____. ___ cm
   _____. ___ cm
   _____. ___ cm

BIOELECTRICAL IMPEDANCE ANALYSIS (BIA) **BIAID _____**

If participant has pacemaker or any other metal medical device, BIA cannot be done.
All piercings and jewelry must be removed before proceeding.

7. **During the BIA measurement, the participant was:** Lying down _____
8. **Resistance measure: _____**
9. **Reactance measure: _____**

BLOOD PRESSURE **OMRON ID _____**

Time of day ____: _____ (hh:mm, e.g. 14.23, 24 hour time)

10. **Have you had any food, alcohol, coffee or cigarettes within the last 30 minutes?** ☐ Food
    - ☐ Alcohol
    - ☐ Coffee
    - ☐ Cigarette
    - ☐ Recreational drugs

11. **Arm Circumference _____. ____cm**

12. **Cuff size selected**

Adult Arm Circumference	Recommended Cuff Size
22-26cm	12x 22cm (small adult)
27- 34cm	16x 30cm (adult)
35-44cm	16x 36cm (large adult)
45- 52cm	16x 42cm (adult thigh)

BIOCHEMICAL MEASURES FORM

FORM 3 **METS-MICROBIOME**

13. **Arm selected** ☐ Right ☐ Left. Specify reason: _____

Participant ID: _____ V1_01/03/2018

FORM 2 **ANTHROPOMETRICS FORM**

14. **Blood Pressure measure refused?** ☐ No ☐ Yes

15. **First Blood Pressure Measurement**
SBP _____
DBP _____
60-second pulse rate _____

16. **Second Blood Pressure Measurement**
SBP _____
DBP _____
60-second pulse rate _____

17. **Third Blood Pressure Measurement**
SBP _____
DBP _____
60-second pulse rate _____

A second set of blood pressure measures follows the placement of the Actical.

18. **Repeat Blood Pressure measure refused?** ☐ No ☐ Yes

19. **First Repeat Blood Pressure Measurement**
SBP _____
DBP _____
60-second pulse rate _____

20. **Second Repeat Blood Pressure Measurement**
SBP _____
DBP _____
60-second pulse rate _____

21. **Third Repeat Blood Pressure Measurement**
SBP _____
DBP _____
60-second pulse rate _____

BIOCHEMICAL MEASURES FORM

Participant ID: _____ V1_01/03/2018 **Interviewer Initials: _____**
Exam Date: _____/_____/_____ (MM/DD/YYYY)

FOR FEMALES ONLY:

1. **Date of Last Menstrual Period: _____ /_____/_____** (MM/DD/YYYY)
2. **If greater than four weeks, is participant on Depo provera? Or other device (IUD); which one**;
_____

Phlebotomist Initials: _____

When was the last time you had something to eat or drink?

3. Date last ate _____ /_____/_____ (MM/DD/YYYY)
4. Time last ate _____ **:**_____ (hh:min, Record in 24-hour time)

Glucose Check (Accuchek)

5. ☐ No ☐ Yes 6. **Result _____ (mg/dL) or _____(mmol/l) If the glucose check is ≥ 125 mg/dL (7.0 mmol/L), participant may not participate in the oral glucose tolerance test.**

Baseline blood draw (timepoint 0:00)

6. Time of blood draw _____ **:**_____ (hh:min, Record in 24-hour time) Baseline BLOOD COLLECTION TUBES

2 tubes of 6 ml with K2EDTA

☐ No
☐ Yes

3 tubes of 6ml with no EDTA

☐ No
☐ Yes

Glucose drink:

7. Time at which entire 75 gram glucose drink was completed ____ **:**____ (hh:min, Record in 24-hour time)

2nd blood draw (timepoint **30min** after drink was completed)

8. Time of blood draw _____ **:**_____ (hh:min, Record in 24-hour time)
1 BLOOD COLLECTION TUBE

1 tube of 6 ml with no EDTA

☐ No
☐ Yes

3rd blood draw (timepoint **60min** after drink was completed)

9. Time of blood draw _____ **:**_____ (hh:min, Record in 24-hour time)
1 BLOOD COLLECTION TUBE

1 tube of 6 ml with no EDTA

☐ No
☐ Yes

BIOCHEMICAL MEASURES FORM

4th blood draw (timepoint **120min** after drink was completed)

10. Time of blood draw _____ **:**_____ (hh:min, Record in 24-hour time)
1 BLOOD COLLECTION TUBES

1 tube of 6 ml with no EDTA

☐ No
☐ Yes

Worksheet for Phlebotomist	
Time of drink	
Time for 2nd blood draw (30min)	
Time for 3rd blood draw (60min)	
Time for 4th blood draw (120min)	

URINE

11. **Spot urine**

☐ No ☐ Yes

ACCELEROMETER 12. **Serial Number** _____

13. **Was accelerometer placed on right hip?** ☐ Yes ☐ No Reason for using left hip: _____

14. **Start date** _____ /_____/_____ (MM/DD/YYYY)
15. **Start time** ___ ___ **:**___ ___ (hh:min, Record in 24-hour time)
16. **Epoch period** 60 seconds ☐ No ☐ Yes
17. **Mode** Record steps ☐ No ☐ Yes

☐ *Retrieve Anthropometrics (Form 2) and record second set of blood pressure measures*

Check date ___ ___ /___ ___/_____ (MM/DD/YY)

Participant ID: _____

Comments: _____

BIOCHEMICAL MEASURES FORM

FOLLOW UP

Interviewer initials: _____

18. **Was monitor returned?** ☐ No ☐ Yes
19. **End date ___ ___ /_____/_____** (MM/DD/YYYY)
20. **End time ___ ___ :___ ___** (hh:min, Record in 24-hour time)
21. **Would you say this period represents your usual activity level?**
    ☐ No ☐ Yes
    If no, what was different about this period? _____
    _____

STOOL SAMPLE

22. **Date that stool was passed: _____/ _____/_____** (MM/DD/YYYY)
23. **Approximate time that stool was passed: ____: _____** (hh:mm, e.g. 14.23, 24 hour time)
24. **Date that stool was received: _____/_____/_____** (MM/DD/YYYY)
25. **Approximate time that stool was received and stored at -80: ____: _____** (hh:mm, e.g. 14:23, 24 hour time)
26. How has stool been stored since it was passed:
    - ☐ Refrigerated
    - ☐ On ice
    - ☐ At room temperature ☐ Other _____
27. Occult blood test result:
    - ☐ Positive
    - ☐ Negative

FORM 4 **METS-MICROBIOME** **GPAQ**

Interviewer Initials: _____

Physical Activity			
Next I am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these questions even if you do not consider yourself to be a physically active person. Think first about the time you spend doing work. Think of work as the things that you have to do such as paid or unpaid work, study/training, household chores, harvesting food/crops, fishing or hunting for food, seeking employment. *[Insert other examples if needed].* In answering the following questions 'vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate, 'moderate-intensity activities' are activities that require moderate physical effort and cause small increases in breathing or heart rate.			
Questions		**Response**	**Code**
Activity at work			
1	Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like *[carrying or lifting heavy loads, digging or construction work*] for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 4*	P1
2	In a typical week, on how many days do you do vigorous- intensity activities as part of your work?	Number of days ⌊__⌋	P2
3	How much time do you spend doing vigorousintensity activities at work on a typical day?	⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ Hours : minutes hrs mins	P3 (a-b)
4	Does your work involve moderate-intensity activity that causes small increases in breathing or heart rate such as brisk walking *[or carrying light loads*] for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 7*	P4
5	In a typical week, on how many days do you do moderate- intensity activities as part of your work?	Number of days ⌊__⌋	P5
6	How much time do you spend doing moderateintensity activities at work on a typical day?	Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋ hrs mins	P6 (a-b)
Travel to and from places			
The next questions exclude the physical activities at work that you have already mentioned. Now I would like to ask you about the usual way you travel to and from places. For example to work, for shopping, to worship. [insert other examples if needed]			
7	Do you walk or use a bicycle (*pedal cycle*) for at least 10 minutes continuously to get to and from places?	Yes 1 No 2 *If No, go to P 10*	P7
8	In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?	Number of days ⌊__⌋	P8

9	How much time do you spend walking or bicycling for travel on a typical day?	Hours : minutes ⌊_⌊_⌋ : ⌊_⌊_⌋ hrs mins	P9 (a-b)
Recreational activities			
The next questions exclude the work and transport activities that you have already mentioned. Now I would like to ask you about sports, fitness and recreational activities (leisure), [insert relevant terms].			
10	Do you do any vigorous-intensity sports, fitness or recreational (*leisure*) activities that cause large increases in breathing or heart rate like [*running or football,]* for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P 13*	P10
11	In a typical week, on how many days do you do vigorous- intensity sports, fitness or recreational (*leisure*) activities?	Number of days ⌊_⌋	P11
12	How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day?	Hours : minutes ⌊_⌊_⌋ : ⌊_⌊_⌋ hrs mins	P12 (a-b)

Participant ID: _____

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FORM 4 **METS-MICROBIOME** **GPAQ**

Physical Activity (recreational activities) contd.			
Questions		**Response**	**Code**
13	Do you do any moderate-intensity sports, fitness or recreational *(leisure*) activities that causes a small increase in breathing or heart rate such as brisk walking,(*cycling, swimming, volleyball*)for at least 10 minutes continuously? *[INSERT EXAMPLES] (USE SHOWCARD)*	Yes 1 No 2 *If No, go to P16*	P13
14	In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational (*leisure*) activities?	Number of days ⌊_⌋	P14
15	How much time do you spend doing moderate-intensity sports, fitness or recreational (*leisure*) activities on a typical day?	Hours : minutes ⌊_⌊_⌋ : ⌊_⌊_⌋ hrs mins	P15 (a-b)
Sedentary behaviour			

The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television], but do not include time spent sleeping. *[INSERT EXAMPLES] (USE SHOWCARD)*			
16	How much time do you usually spend sitting or reclining on a typical day?	Hours : minutes └─┴─┘ : └─┴─┘ hrs min s	P16 (a-b)

Participant ID: _____

1. Food frequency questionnaire

	In a typical week, on <u>how</u> <u>many days</u> do you have the following on average:	**On these days, <u>how many</u> <u>servings</u> of the same do you take on average?**
Water (bottled, tap water)		(200-300ml glass)
Tea		(200ml cup) :
Coffee		(200ml cup):
Do you generally add milk in coffee or tea (powder or liquid)	Yes/No :	
Do you generally add sugar in coffee or tea (powder or liquid)	tea spoons/cup: 0,1,2, 3:	
Commercial soft drink (Cola, Fanta, etc) (3dl ~1 small bottle)		(300mll serving):
Commercial diet drink (Diet coke, etc) (3dl ~1 small bottle)		(300ml small bottle):
Fresh fruit juice (pressed, 1-2dl ~1 glass)		(200-300mll serving):
Fruit juice canned/packet (1 small packet ~2.5dl~1 serving)		(200-300mll serving):
Milk in glass (fresh, reconstituted, etc)		(200-300ml serving):
Soup (homemade, packet, etc)		(1,2,3 meals/day)
Beer		(300mll bottle or equivalent):
Wine or liquor (Porto, Irish coffee, etc)		(200mll glass):
Spirit (whisky, rum, gin, vodka, etc)		(20mll peg):
Locally made alcohol (moonshine)		(300-500ml glass):
Rice (white polished or brown unpolished)		Meals per day 1,2 3
Corn/maize (grits,hominy, crude, cooked, roasted, etc)		Meals per day 1,2 3
Potato (boiled, cooked, fries, hashbrown, fries)		Meals per day 1,2 3
Yam, taro, cassava, sweet potato (roots)		Meals per day 1,2 3
Bread (white or brown; buns, muffin, biscuit, bagel, sandwich, crackers, hamburger)		Slices or equivalent/d

Pasta (macaroni, spaghetti, ramen noodles)		Meals per day 1,2 3
Grains, beans and legumes		Meals per day 1,2 3
Raw vegetables (fresh, green, tomato, carrots, lettuce, avocado, guacamole, etc)		(1,2,3 meals/d)
Cooked Vegetables -canned, frozen, stirred e.g. cabbage, pumpkin, (but not salad, not roots):		(1,2,3 meals/d)
Cereals "for breakfast" (oatmeal, cornflakes, porridge)		(1,2,3 meals/d)
Local/commercial savory snacks (e.g. chips, peanuts, etc)		(servings per day)
Fruit (fresh, canned, frozen, etc, but not counting juice)		(portions/d)
Fast food (McDonalds, fried chicken, pizza, taco)		(1,2,3 meals/d)
Chicken (roasted, grilled, cooked, curry, etc)		(1,2,3 meals/day)

Meat (beef, pork, goat cooked, grilled, curry, etc but not processed)		(1,2,3 meals/day)
Meat processed (sausage, bacon, ham, bologna, burger, hot dog, etc)		(1,2,3 meals/day)
Fish (fresh, frozen, fried, cooked, grilled, can [tuna])		(1,2,3 meals/day)
Eggs (boiled, poached, omelet, etc)		(1,2,3 meals/day)
Cheese (processed, piece)		(1,2,3 meals/d)
Dessert, chocolate, cake, ice cream, shake, candy, cookie, donut		(1,2,3 meals/d)

General pattern of meals:

2. On a typical week day (Monday to Friday), do you usually eat for:
Breakfast (Y/N) _____ Lunch (Y/N) _____ Dinner (Y/N) _____

3. On a typical week day (Monday to Friday), do you usually take a solid snack (not just a drink): Between breakfast & lunch Y/N) _____; between lunch & dinner Y/N) _____; after dinner Y/N) _____

4. In a typical week, how many times do you buy food, for lunch or for dinner, from a take away business, vendor or food truck? (1-5) _____

5. In a typical week, on how many days do you usually eat food from a workplace canteen? (1-5) _____

6. In a typical month, how many times do you eat in a restaurant/from a fast food vendor/ street food vendor? _____

7. In a typical week, how often do you buy a salty or sugary snack (not as main meal, not drink) from a vendor? 1) Not every week 3) 3-5 times per week
2) 1-2 times /week 4) Every day or almost every day
5) More than once on most day of week

8. Do you substitute artificial sweetener for sugar (in your tea, coffee, etc) ? 1) Never or nearly never 2) Sometimes
3) Regulary (every day)

9. How often do you drink water from the tap ?
1) Never or virtually never 3) Often, at least once every week
2) Occasionally (not every week) 4) Often, every day or nearly every day

10. In a typical week, do you usually use water from a water dispenser at home Y/N) ___ ; at work Y/N) ___

FORM 6 **METS-MICROBIOME** **SES**

Interviewer Initials: _____

Section A: General household characteristics

1. How many people are part of this household, including yourself, and what gender are they? [The household is defined as people who normally live and eat together in the household, sleeping at least 4 nights per week in the household on a regular basis]

males _____ females _____

2. How many of the household members are in the following age ranges. Include yourself.

0-2 years old _____ 40-65 _____ 3-15 _____ over 65 _____

16-40 _____

3. How many of the household members contribute to the household income. Include yourself. _____
4. How many of the household members are currently enrolled in school, including up to university degree? _____

Section B: Subject's socioeconomic characteristics

5. Can you read and write? ☐ No ☐ Yes

6. What is the highest grade you completed, or how many years of formal education (including primary, secondary, tertiary/university but excluding pre-school/creche) do you have? _____
7. Do you have any of the following degrees? [Choose only the highest degree]

☒ No formal education or less than primary school

☐ Primary School (i.e. school between 3-5 and 15-16, often considered "obligatory school" in some countries)

☐ Some High School (i.e beyond age of 15-16, generally beyond what is considered "obligatory school"

☐ Completed High School

☐ Vocational degree or certification (e.g., electrician's license, auto repair certificate) ☐ Bachelor's degree (college or university undergraduate,BA, BS, BArch, BEng, etc.)

☐ Graduate or advanced professional degree (MBA, PhD, JD, MD, etc.)

8. How many days of work did you miss in the past 12 months due to sickness, illness, or injury? ☐ none, but did work last year ☐ 1 week or less ☐ 1-2 weeks ☐ more than 2 weeks ☐ did not work last year
9a. Did you do any type of work for pay in the last month? ☐ No ☐ Yes

9b. If you did not work in the last month, what was the main reason you did not work? ☐ No work available ☐ Seasonal inactivity

☐ Student

☐ Household/family duties ☐ Too old or too young to work

☐ Infirmity/sickness

☐ Other (Write in "Other" reason_____)

10. How were you paid for your work?

☐ Regular Wages or salary

☐ Payment in kind

☐ Casual labor (hourly/daily) ☐ Unpaid contributing worker ☐ Self-employed or own my own business

11. What is the main industry or activity at your primary job? (If currently unemployed, please use your last job)

☐ Agriculture ☐ Mining/quarrying ☐ Manufacturing/ processing ☐ Construction ☐ Transport

☐ Trade/selling

☐ Services (e.g.: restaurant, beauty salon, lodging)

- ☐ Education/health ☐ Administration
- ☐ Other (Write in "Other" industry_____)

12. What is the main occupation at your primary job? (If currently unemployed, please use your last job)

☐ Senior managers or administrators (finance manager - chief executive)
☐ Traditional professional occupations (accountant - solicitor/lawyer - physician - scientist/engineer) ☐ Modern professional occupations (teacher - nurse - social worker - artist - police officer sergeant+)) ☐ Middle or junior managers (office manager - bank manager - restaurant manager)
☐ Clerical and intermediate occupations (secretary - clerical worker - call center agent - nursing aid)
☐ Technical and craft occupations (car mechanic - inspector - plumber - printer - electrician) ☐ Semi-routine manual and service occupations (postal worker - machine operator - security guard) ☐ Routine manual and service occupations (driver - cleaner - porter - laborer – waiter)
☐ Farming or agricultural occupations (farmer, herder)
☐ Fishing
☐ Other occupation (Write in occupation here: _____)

13. How many other people work in your workplace? (if currently unemployed, answer for your last job) ☐ 0 (I work alone or freelance)
    - ☐ 1 ☐ 2-9 ☐ 10-24
    - ☐ 25 or more

14. How many employees do you supervise? (if currently unemployed, answer for your last job) ☐ 0 (I do not supervise anyone)
    - ☐ 1 ☐ 2-9
    - ☐ 10-24 ☐ 25 or more

15. In the course of your work, do you make management decisions, such as how many people to hire? (if currently unemployed, answer for your last job) ☐ No ☐ Yes
16. Not counting the place where you currently stay (and whether you own it or rent it), do you own a house, an apartment or another building that you rent to others? ☐ No ☐ Yes

Section C: Significant other's information

17. Does your significant other have any of the following degrees? [Pick only one, the highest degree obtained]
    - ☐ No formal education or less than primary school
    - ☐ Primary School ☐ Some High School ☐ Completed High School
    - ☐ Vocational degree or certification (e.g., electrician's license, auto repair certificate) ☐ Bachelor's (college or university undergraduate) degree (BA, BS, BArch, BEng, etc.) ☐ Graduate or advanced professional degree (MBA, PhD, JD, MD, etc.) ☐ Don't Know
    - ☐ Not applicable. Not living with a significant other

Section D: Household assets and amenities

19. Does the household or a household member own the dwelling you live in?
    - ☐ Owns the dwelling
    - Rents the dwelling
    - Uses without paying rent
    - Nomadic or temporary dwelling

21. Does the household use land it does not own? ☐ No ☐ Yes

22. Does the household own any cattle or other livestock, like cows, horses, donkeys, pigs, goats, sheep, (even 1-2) ? ☐ No ☐ Yes

23. Does the household have electricity? ☐ No ☐ Yes

24. Does the household or any member of the household (including yourself) own or have any of the following? (Include only if they are in working condition)

☐ Electric iron ☐ Sprayer (Jamaica, Ghana only)

☐ Refrigerator ☐ Radio or CD player

☐ Television ☐ Telephone (land line)

☐ Satellite Dish or Cable Television ☐ Cell phone

☐ DVD player or VCR ☐ Fan

☐ Computer (only include a computer purchased ☐ Air conditioner by you or a member of your household) ☐ Mattress or bed ☐ Bicycle

☐ Sofa ☐ Motorcycle

☐ Car or truck

25. Do you personally own any of the following? (Include only if they are in working condition; include any items that were listed above)
    - ☐ Cell phone
    - ☐ Bicycle
    - ☐ Motorcycle
    - ☐ Car or truck

26. In the past year, did your household have problems satisfying the food needs of the household members? ☐ Never
    - ☐ Seldom
    - ☐ Sometimes
    - ☐ Often
    - ☐ Always

27. How do you compare the overall economic situation of your household compared with other households in your local area? ☐ Much worse now
    - ☐ A little worse now
    - ☐ Same
    - ☐ A little better now ☐ Much better now
    - ☐ Don't know

28. What is the material of the roof of the house?
    - ☐ Mud
    - ☐ Thatch
    - ☐ Wood

    Iron/ Aluminum sheets Cement/ concrete
    Roofing tiles
    - ☐ Asbestos
    - ☐ Other (please name other roofing material:_____)

29. What is the material of the walls of the house?
    - ☐ Mud/ mud brick
    - ☐ Stone
    - ☐ Burnt bricks
    - ☐ Iron/ Aluminum sheets ☐ Cement/ sandcrete
    - ☐ Wood/Bamboo
    - ☐ Cardboard ☐ Dry Wall
    - ☐ Other (please name other material :_____)

30. What is the main source of drinking water?

- ☐ Public piped into dwelling or compound
- ☐ Public outdoor tap or borehole
- ☐ Protected well
- ☐ Unprotected well or rain water
- ☐ River, lake, or pond
- ☐ Vendor, truck, or bottled
- ☐ Other (name other source :_____)

31. What type of toilet facility does your household have?

- ☐ None
- ☐ Flush
- ☐ Pan/bucket
- ☐ Covered pit latrine
- ☐ Uncovered pit latrine
- ☐ Ventilation improved pit latrine
- ☐ Other (please name other type:_____)

32. What is the main fuel used for cooking?

- ☐ Firewood
- ☐ Charcoal
- ☐ Kerosene/oil
- ☐ Gas
- ☐ Electricity
- ☐ Crop residue/ saw dust
- ☐ Animal waste
- ☐ Other (please name other fuel:_____)

33- 38. How many minutes does it take from your home to reach the nearest …? (circle one)

	0-14	15-29	30-44	45-59	60+
33. Supply of drinking water:	1	2	3	4	5
34. Food market:	1	2	3	4	5
35. Public transportation: 1	2	3	4	5	
36. Pharmacy:	1	2	3	4	5
37. Health clinic or hospital:	1	2	3	4	5
38. Primary School:	1	2	3	4	5

FORM 6 **METS-MICROBIOME SES**

Interviewer Initials: _____

FORM 7 **METS-MICROBIOME** **MICROBIOME FORM**
Interviewer Initials: _____ **Exam Date:**
____/_____/_____(MM/DD/YYYY)

General Lifestyle and Hygiene Information

1. Do you bite your fingernails? ☐ Yes ☐ No

2. How often do you swim in a river/lake/swimming pool/hot tub?
   - ☐ Daily
   - ☐ Regularly (3-5 times/week)
   - ☐ Occasionally (1-2 times/week)
   - ☐ Rarely (few times/month)
   - ☐ Never

3. Do you have any animals inside your home?
   - ☐ Dog ☐ None
   - ☐ Cat ☐ Other _____

4. Do you have daily or weekly contact with some kind of animal that may be kept outside
   - ☐ Dog ☐ Chicken ☐ Sheep
   - ☐ Cat ☐ Goat ☐ Cow
   - ☐ Other _____

General Health Information

5. How many times do you have a bowel movement in an average day?
   - ☐ Less than one ☐ Two ☐ Four
   - ☐ One ☐ Three ☐ Five or more

6. Have you had diarrhea in the last 3 months? ☐ No ☐ Yes

7. Describe the quality of your bowel movements:
   - ☐ I tend to be constipated (have difficulty passing stool) – Type 1 and 2; ☐ I tend to have diarrhea (watery stool) – Type 5, 6 and 7; ☐ I tend to have normal formed stool – Type 3 and 4.

   Use the chart below as a reference:

8. I have taken <u>antibiotics</u> in the last _____.
   - ☐ Week (Name of antibiotic)
     _____
   - ☐ Month (Name of antibiotic)
     _____ ☐ 6 months ☐ Year
   - ☐ I have not taken antibiotics in the past year.

9. I have received a <u>flu vaccine</u> in the last _____.

☐ Week ☐ 6 months ☐ I have not gotten the flu vaccine in the past year.
☐ Month ☐ Year

10. My weight has _____ within the last 6 months.

Participant ID: _____ V1_01/03/2018

FORM 7 METS-MICROBIOME MICROBIOME FORM

☐ Increased more than 10 pounds/6kg.
☐ Decreased more than 10 pounds/6kg.
☐ Remained stable

11. Have you had your tonsils removed?
☐ No ☐ Yes ☐ Not sure

12. Have you had you appendix removed?
☐ No ☐ Yes ☐ Not sure

13. Have you had chickenpox?
☐ No ☐ Yes ☐ Not sure

14. How were you fed as an infant?
☐ Primarily breast milk ☐ A mixture of breast milk and formula ☐ Primarily infant formula ☐ Not sure

15. Do you have seasonal allergies? ☐ No ☐Yes

16. Do you have any of the following non-food allergies? (check all that apply)
☐ Drug (e.g. Penicillin) ☐ Beestings ☐Sun
☐ Pet dander ☐ Poison ivy/oak

17. Are you intolerant to milk (lactose intolerant)? ☐ No ☐ Yes

18. Are you gluten intolerant?
☐ I was diagnosed with celiac disease
☐ I was diagnosed with gluten allergy (anti-gluten IgG), but not celiac disease ☐ I do not eat gluten because it makes me feel bad
☐ No

19. I am allergic to _____ (mark all that apply)
☐ Peanuts ☐ Shellfish
☐ Tree nuts ☐Other _____ ☐ I have no food allergies that I know of.

Participant ID: _____ V1_01/03/2018

FORM 8 METS-MICROBIOME DISCRIMINATION FORM
Interviewer Initials: _____ Exam Date: _____/_____/_____ (MM/DD/YYYY)

In your day-to-day life, how often do any of the following things happen to you?

1. You are treated with less courtesy than other people are.
☐ Almost every day
☐ At least once a week

- ☐ A few times a month
- ☐ A few times a year
- ☐ Less than once a year
- ☐ Never

2. You are treated with less respect than other people are.
   - ☐ Almost every day
   - ☐ At least once a week
   - ☐ A few times a month
   - ☐ A few times a year
   - ☐ Less than once a year
   - ☐ Never

3. You receive poorer service than other people at restaurants or stores. ☐ Almost every day ☐ At least once a week
   - ☐ A few times a month
   - ☐ A few times a year
   - ☐ Less than once a year
   - ☐ Never

4. People act as if they think you are not smart.
   - ☐ Almost every day
   - ☐ At least once a week
   - ☐ A few times a month
   - ☐ A few times a year
   - ☐ Less than once a year
   - ☐ Never

5. People act as if they are afraid of you.
   - ☐ Almost every day
   - ☐ At least once a week
   - ☐ A few times a month
   - ☐ A few times a year
   - ☐ Less than once a year
   - ☐ Never

6. People act as if they think you are dishonest.
   - ☐ Almost every day
   - ☐ At least once a week
   - ☐ A few times a month
   - ☐ A few times a year

   - ☐ Less than once a year
   - ☐ Never

7. People act as if they're better than you.
   - ☐ Almost every day
   - ☐ At least once a week
   - ☐ A few times a month
   - ☐ A few times a year
   - ☐ Less than once a year
   - ☐ Never

8. You are called names or insulted.
   - ☐ Almost every day
   - ☐ At least once a week
   - ☐ A few times a month
   - ☐ A few times a year
   - ☐ Less than once a year
   - ☐ Never

9. You are threatened or harassed.
   - ☐ Almost every day
   - ☐ At least once a week
   - ☐ A few times a month
   - ☐ A few times a year
   - ☐ Less than once a year
   - ☐ Never

Follow-up Question (Asked only of those answering, "A few times a year" or more frequently to at least one question): (Check more than one options if participant indicates)

What do you think is the main reason for these experiences?

- ☐ Your ancestry or national origins
- ☐ Your gender
- ☐ Your race
- ☐ Your religion
- ☐ Your height
- ☐ Your weight
- ☐ Some other aspect of your physical appearance
- ☐ Your education or income level

Participant ID: _____
v1_05/25/2018

Loyola University Chicago
METS – Microbiome Study Results Form

Name: _____ **Date:** _____
Height: _____ft._____in._ **Weight:** _____lbs._
Age: _____
Body Mass Index (BMI): _____

Underweight	Below 18.5
Normal	18.5 – 24.9
Overweight	25.0 – 29.9
Obese	30.0 or Higher

National Heart, Lung, and Blood Institute (NHLBI), NIH

Blood Pressure #1: _____/_____ _____/_____
_____/_____ **Blood Pressure #2:** _____/_____ _____/_____
_____/_____

	Systolic (Top Number)		**Diastolic (Bottom Number)**
Normal	Below 120 mmHg	And	Below 80 mmHg
Pre - Hypertension	120 – 139 mmHg	Or	80 – 89 mmHg
Hypertension	140 or Higher	Or	90 or Higher

American Heart Association (AHA)

Blood Glucose Results: _____ mg/dL

Normal FASTING glucose	70 – 99 mg/dL
Normal glucose 2hrs after eating	70 – 145 mg/dL
Impaired fasting glucose (pre-diabetes)	100 – 125 mg/dL
Indicates diabetes	126 mg/dL & above on more than one occasion

National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), NIH

Fecal Occult Blood Test: _____

Negative	No blood was detected in your stool sample.
Positive	Blood was detected in your stool sample. You may need additional testing such as a colonoscopy to locate the source of the bleeding and rule out colon cancer, ulcers or hemorrhoids.

Mayo Clinic

METS Referral Program

As a participant of our study, you are eligible to participate in the METS referral program. **For every person you refer to the METS research study, you may receive $20**. In order to receive payment the person you refer must complete both initial appointments and agree to participate in the follow-up appointments after one year and two years. **For every five participants referred who complete both initial visits, you will receive an extra $50.** Call 708-216-7881 or email metsbiome@luc.edu.

- **Participants must be African American and between 35-55 years old.**

Date: _____ Your Name:

_____

Your Phone Number(s):

_____

#1

Name of Person

You are Referring: _____ Phone #: _____

How do you know this person? _____ Alternate #: _____

#2

Name of Person You are Referring: _____ Phone #: _____

How do you know this person? _____ Alternate #: _____

#3

Name of Person You are Referring: _____ Phone #: _____

How do you know this person? _____ Alternate #: _____

#4

Name of Person You are Referring: _____ Phone #: _____

How do you know this person? _____ Alternate #: _____

#5

Name of Person You are Referring: _____ Phone #: _____

How do you know this person? _____ Alternate #: _____

#6

Name of Person You

are Referring: _____ Phone #: _____
How do you know

this person? _____ Alternate #: _____

#7

Name of Person
You

are Referring: _____ Phone #: _____
How do you know

this person? _____ Alternate #: _____

#8

Name of Person
You

are Referring: _____ Phone #: _____

How do you know this person? _____ Alternate #: _____

PART E: POLICY BRIEF

Instructions for Authors

Shortcuts

- Artwork Guidelines
- Authors' Contributions
- Author Statement Form
- Conflict of Interest
- COPE's Guidelines
- Formatting Guidelines
- Formatting Guidelines for Text, Tables and Figures
- Policy on Correction of Errors
- SAGA Guidelines Checklist
- Sex and Gender Equity in Research (SAGER) Guidelines

Manuscript Submission Overview

Submission Process
The Lancet Global Health publishes high-quality original research, commentary, and correspondences on various health subjects in low and middle-income countries. Manuscripts must be solely the work of the author(s) stated and must not have been previously published elsewhere or be under consideration by another journal. Inclusion of illustrations (eg, photographs, graphs, diagrams) is a prerequisite for many publication types. Digital photography files should have a resolution of at least 300 dpi and be at least 107 mm wide. Figures, videos and good quality photographs in colour or black and white can be used to supplement and to enhance the text where possible. *The Lancet Global Health* follows the COPE's Guidelines.
Covering letter
Use a covering letter to explain why your paper should be published in *The Lancet Global Health* rather than elsewhere. Upload your covering letter at the "Enter Comments" stage of the online submission process.
Statements, permissions, and signatures

a. Authors and contributors

Designated authors should meet all four criteria for authorship in the ICMJE Recommendations. All authors, and all contributors (including medical writers and editors), should specify their individual contributions at the end of the text. More than one author should have directly accessed and verified the underlying data reported in the manuscript and be from the academic team for research articles arising from academic and commercial partnership. The contributor's statement should state who those authors are. All authors should confirm that they had full access to all the data in the study and accept responsibility to submit for publication. Collaboration and coauthorship with colleagues in the locations where the research is conducted is encouraged for diversity. Authors of papers focused on minoritised populations to include authors from those populations and describe whether and how people with lived experience of minoritisation were involved in or led their research. *The Lancet Global Health* will not publish any Only paper with the signatures of all authors will be published.

b. Reporting sex-based and gender-based analyses

For research involving or pertaining to humans, animals, model organisms, or eukaryotic cells, investigators should integrate sex-based and gender-based analyses into their research design according to evolving funder/sponsor requirements and best practices within a field. Authors should address their research's sex and/or gender dimensions in their manuscript. In cases where they cannot, they should discuss this as a limitation to their research's generalisability. With research involving cells and model organisms, researchers should use the term "sex". With research involving humans, researchers should consider which terms best describe their data. Authors can refer to the Sex and Gender Equity in

Research (SAGER) Guidelines and the SAGA Guidelines Checklist. The author statement form should be used and upload the signed copy with the submission.

c. Reporting on race and ethnicity

Researchers to include people from minoritised racial or ethnic populations as participants, and to plan to report and analyse data by race, ethnicity, or both as disaggregating these data can help to uncover health inequities.

d. Use of AI and AI-assisted technologies in scientific writing

Where authors use generative AI or AI-assisted technologies in the writing process, these technologies should only be used to improve readability and language of the work and not used to replace researcher tasks such as producing scientific insights, analysing and interpreting data, or drawing scientific conclusions. Such writing assistance should be disclosed in a statement at the end of the article in the acknowledgment section. In the Blue section content, generative AI should only be used to assist with writing in English, for example with grammar and spelling.

e. Forms and signatures

Forms should be uploaded on submission for Comments and Correspondence, but for original research (Articles), forms will be requested after peer review. The following signed statements are required:

• Authors' Contributions
• Conflict of Interest ICMJE forms)
• Statements of role, if any, of medical writer or editor
• Acknowledgments—written consent of cited individual
• Personal communications—written consent of cited individual
• Use of copyright-protected material—signed permission statements from author and publisher

f. Declaration of interests

All submissions must include disclosure of all relationships in which there is a potential or actual conflict of interest, even if it not directly relevant to the submitted work. Intentional non-disclosure of conflicts is a form of misconduct. All authors must disclose any financial and personal relationships with other people or organisations, even if it does not directly relate to the submitted work. All authors are required to provide a Conflict-of-Interest Statement and should complete a standard form, which is available.

g. Role of the funding source

All sources of funding should be declared as an acknowledgment at the end of the text. At the end of the Methods section, under a subheading "Role of the funding source", authors must describe the role of the study sponsor(s), if any, in study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the paper for publication. If there is no Methods section, the role of the funding source should be stated as an acknowledgment. If the funding source had no such involvement, the authors should state this.

h. Role of medical writer or editor

In the event of the involvement of a medical writer or editor in the creation of the manuscript, we need a signed statement from the corresponding author include their name and information about funding of this person should be submitted and added to the Acknowledgments or Contributors section. Signed statements from any medical writers or editors declaring that they have given permission to be named as an author, as a contributor, or in the Acknowledgments section are required.

i. Patient and other consents

Appropriate written consents, permissions, and releases must be obtained where any case details, personal information, and/or images of patients or other individuals is to be included. Studies on patients or volunteers need approval from an Ethics Committee and informed consent from participants and these should be documented in the paper. For publication in the journal, a consent, permission, or release should include, without limitation, publication in all formats (including print, electronic, and websites), in sublicensed and reprinted versions (including translations), and in other works and products.

Types of article and manuscript requirements

Anything submitted to The Lancet Global Health should follow the guidelines provided for each article type. For instruction on how to format the text of your paper, including tables, figures, panels, and references, please see Formatting Guidelines. The main article types are as follows:

Red section (Articles) Articles

The Lancet Global Health prioritises reports of original research and invite submission of all clinical trials to enhance clinical practice and thinking. All articles should have a main text of 3500 words at a maximum (4500 for randomised controlled trials) with 30 references. They must include an abstract (semi structured summary), with five paragraphs (Background, Methods, Findings, Interpretation, and Funding), not exceeding 250 words.

a. Putting research into context

All research papers (including systematic reviews/meta-analyses) submitted to any journal in *The Lancet* family must include a panel putting their research into context with previous work. This panel should not contain references.

The Discussion section should contain a full description and discussion of the context. Authors are also invited to either report their own, up-to-date systematic review or cite a recent systematic review of other trials, putting their trial into context of the review

b. Data sharing

From September 21, 2020, all submitted research Articles must contain a data sharing statement, to be included at the end of the manuscript.

Blue section (Comment, Correspondence) Editorial

Editorials are the voice of *The Lancet Global Health* and are written in-house by the journal's editorial-writing team and signed "*The Lancet Global Health*". They are normally in the following forms:

a. Comment

The comment section contains commentaries that accompany papers published in *The Lancet Global Health* or on issues of wide-reaching concern in global health. Comments which may be peer reviewed should not exceed 750 words, have ten references, and one figure, panel, or small table may be peer reviewed.

b. Correspondence

Letters for publication in response to previous content publication should be submitted within 4 weeks of publication of the original item and should be no longer than 400 words. Letters of general interest, unlinked to items published in the journal, can be up to 400 words. Correspondence letters are not usually peer reviewed, but replies may be requested from the authors of the original publication. Only one table or figure is permitted, and there should be no more than five references and five authors.

c. Corrections

The *Lancet* journals have a Policy for types of errors can or cannot be corrected. Any error affecting a non-proprietory drug name, dose, or unit, any numerical error in the results, or any factual error in the interpretation of results will be corrected. Authorship format changes after publication to facilitate a different visualisation in MEDLINE/PubMed will not be done.

Green section (Reviews, Viewpoints, Health Policy, Commissions, Series)

a. Reviews

Reviews are either a definitive overview of a major topic connected with global health or an update of knowledge in a somewhat narrower field of current interest. Manuscripts are assessed and suitable will be peer reviewed before an editorial decision is made. Reviews should be no more than 4500 words, with a maximum of 75 references and A 150 word an unstructured summary of up to 150 words. All Reviews should include a brief section entitled "Search strategy and selection criteria" stating the sources of the material covered, and the criteria used to include or exclude studies.

b. Viewpoint

Viewpoints are opinion pieces that use the best evidence to develop a robust argument on a topic of immediate relevance to global health. They should have a novel and clear point to make, with the aim of provoking transformational thinking at a high level. Length guidelines are up to 2500 words and a maximum of 30 references.

c. Health Policy

Health Policy papers should cover developments in global health related to policy, guideline development, health systems, or economics. A mix of original research, narrative review, and advocacy

can be included, as long as these elements are clearly identified. Health Policy papers are longer than Original Research Articles at up to 4500 words and a maximum of 75 references, with a 150-word unstructured summary.

Formatting guidelines

a. Language

Manuscripts should be submitted in English. Authors writing in Chinese, Portuguese, or Spanish may wish to use the Webshop to provide an English translation of their manuscript for submission.

b. Title page

A brief title, author name(s), preferred degree (one only), affiliation(s), and full address(es) of the authors must be included. The name and address of the corresponding author should be separately and clearly indicated with email and telephone details.

c. Formatting of text

Type a single space at the end of each sentence. Do not use bold face for emphasis within text. We use a comma before the final "and" or "or" in a list of items. Type decimal points midline (ie, 23·4, not 23.4). To create a midline decimal on a PC: hold down ALT key and type 0183 on the number pad, or on a Mac: ALT shift 9. Numbers one to ten are written out in words unless they are used as a unit of measurement, except in figures and tables. Use single hard-returns to separate paragraphs. Do not use tabs or indents to start a paragraph. Do not use the automated features of your software, such as hyphenation, endnotes, headers, or footers (especially for references). Please use page numbering. Guidelines on formatting tables are available in the Artwork Guidelines.

d. References

Cite references in the text sequentially in the Vancouver numbering style, as a superscripted number after any punctuation mark references are cited separated by a comma, with no space. Three or more consecutive references are given as a range with an en rule. References in tables, figures, and panels should be in numerical order according to where the item is cited in the text. If there are six authors or fewer, give all six in the form: surname space initials comma. If there are seven or more give the first three in the same way, followed by et al. For a book, give any editors and the publisher, the city of publication, and year of publication. For a chapter or section of a book, also give the authors and title of the section, and the page numbers. For online material, please cite the URL, together with the date you accessed the website. Online journal articles can be cited using the DOI number.

References that are in press can be cited in the reference list with "(in press)" added after the journal name. For personal communications and unpublished work, please cite in-text rather than in the reference list in the format "(unpublished)" or "(Smith R, unpublished)" if it is your own observation, or "(Jones E, institution, personal communication)" if it is someone else's observation.

Preprints should be clearly marked as such, for example by including [preprint] before the reference, and specifically referred to as a preprint in the main text. Where a preprint has subsequently become available as a peer-reviewed article, the formal publication should be used as the reference.

e. Figures

Our in-house illustrators redraw most figures into *Lancet* style. The quality of the files we receive from authors has a direct effect on the accuracy and time taken to prepare figures that are suitable for publication. We have different criteria for photographic and illustrative files, the following notes are a summary of our ideal requirements, but a detailed description is in the Artwork Guidelines.

Guidelines for supplementary material

Describe any supplementary material published online alongside the manuscript (figure, tables, video, spreadsheets, etc.). Please indicate the name and title of each element as follows Figure S1: title, Table S1: title, etc. All material should be submitted as one PDF (with a table of contents and numbered pages) with the paper and will be peer reviewed. Material will be published at the discretion of *The Lancet* journals' editors. For clinical trials, authors to include a copy of the study protocol. All material should be provided in English.

a. Text

Main heading for the web extra material should be in 12 point Times New Roman font **BOLD.** Text should be in 10 point Times New Roman font, single spaced. Headings should be in 10 point **BOLD.**

b. Tables

Main table heading should be in 10 point Times New Roman font **BOLD.** Legends should be in 10 point, single spaced. Tables should be in 8 point Times New Roman font, single spaced. Headings within tables should be in 8 point **BOLD.**

c. Data

Numbers in text and tables should always be provided if % is shown. Means should be accompanied by SDs, and medians by IQR. P values should be given to two significant figures, unless p<0·0001

Front Matter

These sections should appear in all manuscript types:

a. Title

The title of your manuscript should be concise, specific and relevant. A brief title, author name(s), preferred degree (one only), affiliation(s), and full address(es) of the authors must be included. The name and address of the corresponding author should be separately and clearly indicated with email and telephone details. Please read the criteria to qualify for authorship.

b. Abstract

The abstract should be a total of about 250 words maximum. The abstract should be a single paragraph and should follow the style of structured abstracts, but without headings: 1) Background: Place the question addressed in a broad context and highlight the purpose of the study; 2) Methods: Describe briefly the main methods used. Include any relevant preregistration numbers, and species and strains of any animals used. 3) Results: and 4) Conclusion: Indicate the main conclusions or interpretations. The abstract should be an objective representation of the article: it must not contain results which are not presented and substantiated in the main text and should not exaggerate the main conclusions.

c. Keywords

Three to ten pertinent keywords need to be added after the abstract. We recommend that the keywords are specific to the article, yet reasonably common within the subject discipline.

Research Manuscript Sections

a. Introduction:

The introduction should briefly place the study in a broad context and highlight why it is important. It should define the purpose of the work and its significance, including specific hypotheses being tested. The current state of the research field should be reviewed carefully and key publications cited. Please highlight controversial and diverging hypotheses when necessary. Finally, briefly mention the main aim of the work and highlight the main conclusions. Keep the introduction comprehensible to scientists working outside the topic of the paper.

b. Materials and Methods

They should be described with sufficient detail to allow others to replicate and build on published results. New methods and protocols should be described in detail while well-established methods can be briefly described and appropriately cited. Give the name and version of any software used and make clear whether computer code used is available. Include any pre-registration codes.

c. Results:

Provide a concise and precise description of the results, their interpretation as well as the conclusions that can be drawn.

d. Discussion

Authors should discuss the results and how they can be interpreted in perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible and limitations of the work highlighted. Future research directions may also be mentioned. This section may be combined with Results.

e. Conclusions

This section is mandatory and should provide readers with a summary of the main conclusions.

f. Patents

This section is not mandatory but may be added if there are patents resulting from the work reported in this manuscript.