Climate change and potential impacts on birth outcome: A correlational study in Musina Hospital at Vhembe District, Limpopo Province

By

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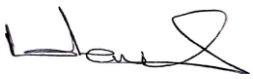
Declaration

The study titled, "*Climate Change and Potential Impact on Birth Outcomes in Musina Vhembe District, Limpopo Province,"* submitted by me (Mudau Rolivhuwa Sibongile Millet, student number 18010101), is an original work. It has not been submitted for any other degree, at any other school, department, or university. All information derived from other studies has been properly acknowledged.

I. I, Rolivhuwa Sibongile Millet Mudau, declare that this research is my original work, not someone's, and has not been submitted to any degree or faculty.
II. The dissertation has no graphs, tables, pie charts, or data copied from someone's research; the graphs in this dissertation were developed from the data I collected in Musina Hospital in Limpopo Province.
III. In this dissertation, information from various researchers has been used, and the original sources have been acknowledged.
IV. The supervisors played a crucial role in guiding me throughout the entire project, assisting with the design of the research, data analysis process, and interpretation of the results and findings.

Signature:  Date: 24/02/2025

Dedication

This study is dedicated to my late mother, Rambau Azwihangwisi Martha, who passed away while I was writing the study's proposal. To my older brother, Rambiyana Thendo, and my partner, Manzini Shaun, who were always by my side, supporting me every step of the way. To my sibling, Mudau Pandelani Prosper, my son, Manzini Lesedi Ndzalama, my uncle, Tharaga Shumani Patric, who constantly encouraged me with the words, "You can make it, I have faith in you," and my grandmother, Mavhungu Masindi, who made sure I lacked nothing while collecting data for this study.

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Abstract

Introduction: Climate change continues to pose a life-threatening risk to human health, particularly affecting pregnant mothers and the elderly. As a result, these groups are experiencing heightened harm. Climate change impacts both foetal and maternal health, leading to complications such as prematurity, low birth weight, stillbirth, neonatal jaundice, and hearing loss. On the maternal side, climate change contributes to pregnancy-induced hypertension, pre-eclampsia, and gestational diabetes. These are some of the complications that many studies dwell on regarding climate change and its impact on pregnancy outcomes.

Objectives: To determine climate change and its potential impact on birth outcomes in Musina Vhembe District, Limpopo Province, and to investigate the seasonal temperature changes and birth weight of infants.

Methods: Data were collected on patient medical records from 2019 to 2022 in the Musina Hospital in Vhembe District, Limpopo Province, using a checklist book to tick all information related to the study.

Results

Article 1: The study revealed that climate change significantly impacts pregnancy outcomes. Ambient temperature exposure was found to be associated with adverse pregnancy effects such as premature delivery, low birth weight, and stillborn. However, on the maternal side, pregnant mothers were found to be affected by various conditions such as pregnancy-induced hypertension, gestational diabetes, pré-eclampsia, and eclampsia. Neonates experience neonatal jaundice, cardiovascular diseases, developmental problems, hearing loss, etc.

Article 2: The study revealed a negative correlation with successive years. Throughout successive years, the results showed that the majority of mothers are suffering from pregnancy-induced hypertension compared to other maternal conditions. On the neonatal side, the high premature rate was noted compared to other neonatal conditions.

Article 3: The results show a negative and positive correlation between ambient seasonal temperature and birth weight. Birth weight was less affected in milder temperatures compared to harsher temperatures. Seasonal ambient temperature

showed an impact on pregnant women and the weight of their babies growing inside the uterus.

Recommendations and Conclusion: An awareness campaign should be launched that gathers all community members and educates them about the health risks associated with ambient temperature exposure during pregnancy. Healthcare providers should ensure that every healthcare facility has cooling resilience, such as air conditioners and fans. The Department of Health should ensure that expectant mothers receive education on the risks of high ambient temperatures on pregnancy outcomes and the strategies to mitigate these risks.

Climate change puts pregnant women at risk of experiencing heat-related illness, which in turn affects their pregnancy and unborn babies. Strategies that mitigate high temperature exposure will help the next generation of expectant mothers to carry their pregnancies to term without facing any complications.

Keywords: birth weight, climate change, high temperature, low birth weight, pregnancy outcomes, prematurity, stillborn

Abbreviations

AMA	Advanced Maternal Age
ASD	Arteria Septal Disorder
DOH	Department of Health
LMP	Last Menstrual Period
LWB	Low birth weight
MRR	Medical Record Review
MSB	Macerated Baby
ND	Neonatal Death
PAIA	Promotion of Access to Information Act
PICO	Population, Intervention, Comparison, and Outcome
PIH	Pregnancy-Induced Hypertension
PMR	Patient Medical Records
PTB	Premature Birth
RCR	Retrospective Chart Review
SPIDER	Sample, Phenomenon of interest, Design, Evaluation and Research type
UHDC	University Higher Degrees Committee
UREC	University Research Ethics Committee
US	United States
VSD	Ventricular Septal Disorder

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Section 1: Overview of the Study

This section presents the introduction and background of the study, problem statement, significance of the study, purpose of the study, objectives of the study, definitions of terms, theoretical framework, methodology, study designs and approaches, sampling methods, data collection and analysis, and ethical considerations.

Section 2: Articles

This study presents a systematic literature review, including findings, a conceptual framework, and correlational relationships represented in graphs.

- Article 1: Impact of Climate Change on Birth Outcomes Worldwide: A Systematic Review
- Article 2: Climate Change and Potential Impact on Birth Outcomes: A Correlational Study in Musina Hospital in Vhembe District, Limpopo Province
- Article 3: Impact of Ambient Temperature on Seasonal Variations in Birth Weight in Musina Hospital, Limpopo Province

Section 3: Study Results, Recommendations, Limitations, and Conclusions

This section will summarise the study results, findings, and recommendations, and state the study's limitations and conclusions.

Section 1: Overview of the Study

1.1 Introduction

Climate change is the cause of unexpected weather conditions in the country, such as extremely high temperatures (Seneviratne et al., 2021). High temperatures make pregnant women more vulnerable to environmental hazards that harm pregnancy or develop adverse outcomes (Wu et al., 2023; Sun et al., 2019) since their immune system is compromised (Khodadi et al., 2020). High temperature exposure is associated with placenta abruption and stillbirth delivery, especially in pregnant women with low socio-economic status, who spend most of their time in the hot weather or sun (Bonell,2023). Additionally, it is associated with pregnancy-induced hypertension, gestational diabetes, pre-eclampsia, eclampsia, and heat stress (Qian et al., 2023; Part et al., 2022; Teytone et al., 2023). High temperature exposure causes the release of oxytocin hormone inside the body, which induces labour (Samuels et al., 2022). Thus, pregnant women may be susceptible to delivering premature infants. A premature baby is an infant born before term or their time (before 37 weeks of pregnancy (Luiza et al., 2020). Prematurity is the leading cause of newborn fatalities, including a rise in the mortality rate for children under five years(Lincetto & Banerjee, 2020). Moreover, many surviving children face developmental challenges due to the exposure of pregnant women to extreme temperatures during pregnancy. Babies who survive birth complications are more likely to face challenges such as slow learning as a result of poor brain development, while some face vision problems (Park et al., 2020).

1.2 Background

Pregnant women are particularly vulnerable to environmental heat stress due to the added strain of pregnancy (Samuel et al., 2022). Exposure to high temperatures has been shown to cause prolonged delivery and labour. A study conducted with 14,880 records from 27 countries indicated that premature birth is more common in high temperatures compared to low temperatures (Cherish et al., 2020). At the same time, some women may avoid pregnancy because they are afraid of the negative impacts of heat exposure on pregnancy outcomes, leading to a decrease in the overall pregnancy rate (Hynkuk Cho, 2019).

A 2019 study conducted in the United States analyzed 31,921,046 singleton births, revealing that the majority of the participants were young pregnant women aged 25 to 35. Many of these women were unmarried, had limited educational backgrounds, and belonged to non-White demographics, with 77.7% identifying as White. The study found a higher occurrence of premature births among single mothers compared to those who were married (Son et al., 2019). As the effects of climate change—such as rising temperatures and extreme weather events—continue to escalate, these vulnerable populations face an even greater risk of adverse birth outcomes, including preterm delivery. This underscores the critical intersection between environmental stressors and existing social disparities.

Liang et al., (2019) found that pregnant women who carry male infants are at greater risk of giving birth to a premature infant compared to pregnant women who carry a female infant in their womb. When exposed to ambient temperature during the second and third trimesters, pregnant women are also at high risk of giving birth to low birth weight or premature infants (Yitshak-Sade, 2021). Most preterm births occur at 35 weeks of gestational age (Sun et al., 2019). During the thermoregulation process, the body releases antidiuretic hormones and oxytocin, which cause the contractions to start and lead to premature labour or premature delivery before term (Ilango et al., 2020; Samuels et al., 2022).

Exposure to high ambient temperatures causes harm, especially to disabled, elderly people, and pregnant women(Segal & Guidice,2022). For example, pregnant women who experience a body temperature of 39°C can hurt the growing baby in utero (Syed et al., 2022; Baby et al., 2023; Zihan & Teng Li, 2019). There is evidence that exposure of pregnant women to high ambient temperature has different consequences based on the socio-economic status of the women (McElroy et al., 2022; Son et al., 2019; Kehn & McCormick, 2017). High ambient temperatures in pregnant women harm placental development and function, resulting in a poor supply of nutrients to the fetus, also affecting the fetus, which is already growing inside the uterus. It results in an infant born with low birth weight as the fetus does not get adequate nutrients from the pregnant woman's body. Other studies indicate that heat exposure leads to placental abruption (Wang et al., 2022; He et al., 2018; Philippat et al., 2019). Exposure to ambient temperature also affects foetal development in utero (Shankar et al., 2023).

Most pregnant women affected by high ambient temperature are in the second trimester (Ha et al.,2017).

Heat exposure to obese pregnant women increases heat production and harms the developing baby (Dalugoda et al., 2022). Exposure to heat strains pregnancy hormones, contributing to the release of hormones such as prostaglandins and oxytocin, which induce labour (Samuels et al.,2022). This results in poor pregnancy outcomes. Additionally, heat exposure causes dehydration and constricts uterine flow, leading to antidiuretic secretions. These secretions can trigger labour-induced hormones, resulting in premature delivery (Lyndsay et al., 2019).

Studies have shown that high temperature exposure decreases birth and pregnancy rates. It increases the rate of premature delivery (babies born before 37 weeks of gestation) (Cho, 2020). A study done in Korea found that exposure to high ambient temperatures results in premature birth and low gestational age (Son et al., 2019; Kuehn & McCormick, 2017).

A study done in Guangzhou, China, in 2020 found that pregnant women at risk of giving birth prematurely, low birth weight, and stillbirth were those who experienced complications during pregnancy, including women who were no longer fit to give birth due to advanced maternal age (AMA) (Liu et al., 2020). Most of their infants were born with congenital abnormalities such as spinal bifida and cloudy eyes, for example, due to being exposed to high ambient temperatures (Mosalman et al., 2021).

A study in Drakenstein in Paarl (an urban area outside Cape Town) discovered that maternal health contributes to poor pregnancy outcomes or a harmful pregnancy depending on how long the pregnant woman has been exposed to extreme ambient temperature during pregnancy (Heather et al., 2019), especially for those living in a developing country as they lack many resources to protect them from exposure to high temperatures.

Weather changes also affect pregnancy outcomes. Ha (2020) highlights that various climate change factors affected pregnancy health, some of which include:

1. Direct impact (environmental factors such as floods, drought, and high ambient temperatures).

2. Indirect impact (social and physical environment, with a particular focus on pollution, food shortages, and water scarcity. The water is sometimes contaminated, which affects both pregnancy and the growing baby).
3. Physiological and biological changes (diet imbalance, leading to malnutrition, infections, and heat stress. This results in adverse effects such as low infant birth weight, neonatal mortality, foetal growth restrictions, and stillbirth.

Weather changes have negatively impacted direct, indirect, and physiological outcomes of pregnancy. These impacts indicate how they contribute to adverse pregnancy effects or pregnancy complications when exposed to extremely high temperatures during the pregnancy period, various pollutions during pregnancy, and heat stress. All these factors have been found to have an impact on pregnancy outcomes. However, most populations facing this challenge are pregnant women with low socio-economic status who cannot afford to maintain a healthy lifestyle. Many studies on climate change and its potential impact on birth outcomes have been conducted; however, there's a gap in understanding the pathophysiology in pregnant women after exposure to high ambient temperatures and pollution during their pregnancy period. These different exposures are associated with adverse pregnancy effects such as premature delivery, low birth weight, and stillbirth.

1.3 Problem Statement

The standard pregnancy period ranges from 38 to 40 weeks, counting from the pregnant woman's last menstrual period (LMP). Less than 28 weeks of gestation is regarded as extremely premature, from 28 weeks to less than 32 weeks is known as a very premature infant, and from 32 to 37 weeks is moderate prematurity; anything related to less than 38 weeks of gestation is a complicated pregnancy. Pregnant women thrive within a room/environmental temperature of 21-25°C and a body temperature of 35,5-37°C. Musina is one of the regions in Limpopo that experiences extremely high temperatures during the summer, ranging from 32-37°C and above (Ngwenya et al., 2019),There are various effects of extremely high temperature exposure, such as miscarriage, hypertension in pregnancy (PIH), premature delivery, stillbirth, low birth weight, intrauterine growth restriction, shorter gestational age, etc. (Wisley et al., 2024; Fan et al., 2023; Cushing et al., 2022; Ha et al., 2022).

Low birth weight accounted for 86%, premature births for 660, and 38 stillbirths were reported (South African Medical Research Council [SAMRC, 2020]; World Health Organisation [WHO, 2021]; South African Weather Service [SAWS, 2023]; University of Cape Town [UCT, 2022]).

The researcher was interested in investigating the correlation between extremely high temperatures and birth outcomes and how these variables impact each other in Musina Hospital, Vhembe District, Limpopo Province.

1.4 Rationale for the Study

Many studies related to climate change and birth outcomes have been conducted worldwide. Most pregnant women who face challenges of extreme high temperature exposure are pregnant women with low socio-economic status, not educated, mostly young age, unemployed, and Black who depend on farms for a living. They lack knowledge regarding extremely high temperatures and birth outcomes as the adverse pregnancy effects continue to increase yearly (Kim & Cil, 2022; Cho, 2020; Keivabu & Cozzani, 2022; Bonell et al., 2023). In South Africa, most studies conducted are related to climate change, newborns, maternal exposure, pregnancy, and people's health, and studies like temperature at conception and pregnancy loss in rural areas in KwaZulu-Natal province (Moodley et al., 2021). Extreme high temperature exposure harms maternal and newborn health (Cherish et al., 2022; Zar et al., 2019).

Other studies were conducted on significant climate change-induced risks to human health in South Africa (Wright et al., 2021). However, no study has been done on climate change and its potential impact on birth outcomes in the Musina region/district. A replication of this study needs to be done in other regions that also experience hot weather during the summer seasons in Limpopo Province, as pregnant women are facing pregnancy complications due to a lack of knowledge about climate change and its potential impact on birth outcomes. The researcher aimed to investigate the correlation between extremely high temperatures and birth outcomes in Musina Hospital, Vhembe District, Limpopo Province, to establish how these two variables influence each other.

1.5 Purpose of the Study

The purpose of this study was to determine the correlation between extremely high temperatures and birth outcomes and how these two variables influence each other in Musina Hospital in Vhembe District, Limpopo Province.

Objectives of the study

The objectives of the study were to:

- Assess the relationship between ambient temperature and birth outcomes in Musina Hospital in Vhembe District, Limpopo Province.
- Investigate climate change and its potential impacts on birth outcomes in Musina Hospital in Vhembe District, Limpopo Province.
- Describe climate change and its potential impacts on birth outcomes in Musina Hospital in Vhembe District, Limpopo Province.

Hypothesis

Pregnant women who are exposed to extremely high temperatures experience adverse pregnancy outcomes like premature delivery, stillbirth, and low birth weight, and when these temperatures are extremely high, pregnancy complications also increase.

1.6 Significance of the Study

This study will yield more information on this topic and other studies that are less studied because few studies have been conducted in Limpopo Province related to climate change but have not focused on climate change and birth outcomes in Musina, Vhembe District, Limpopo Province. This study aimed to determine the relationship between high ambient temperatures and birth outcomes in Musina, Vhembe District, Limpopo Province. The findings of this study may assist in developing strategies that can be used to fight the impact of climate change on birth outcomes and also address how climate change affects birth outcomes. For example, the birth outcomes were affected negatively or positively by extremely high temperature exposure. These will help to develop solutions to avoid extremely high temperatures by giving pregnant women health education on the strategies to mitigate the impact of climate change on

birth outcomes, such as drinking plenty of fluid to avoid dehydration, always avoiding working and walking in the sun, and avoiding heat stress and bathing with hot water during hot seasons.

Additionally, the findings of this study may assist policymakers in implementing a policy/programme that focuses on climate change and its potential impact on birth outcomes, whereby pregnant woman are taught about the effects of extremely high temperature exposure during their antenatal visit to healthcare facilities. This will reduce pregnancy complications and, in turn, increase term pregnancy. Community mobilisation, gatherings, and health education will be conducted to raise awareness about climate change and its potential impact on birth outcomes. The community will learn how to educate pregnant women on measures to reduce the impact of climate change during pregnancy, such as staying hydrated, seeking shelter to avoid exposure to high ambient temperatures, and contributing to the development of better infrastructure for pregnant women and their unborn babies. Additionally, community health nurses can begin training programmes to mitigate the effects of climate change on birth outcomes in Musina, Vhembe District, Limpopo Province. Nurses will be more alert when caring for pregnant women during antenatal visits as they will be aware of the risks of prematurity and other complications caused by extremely high temperature exposure. The researcher's recommendations and findings will encourage other researchers to conduct similar studies in provinces and districts experiencing extremely high temperatures during summer, such as Musina, Vhembe District, Limpopo Province.

1.7 Definition of Terms

Climate change

A temperature change that occurs over a long period (Benard et al., 2021). According to the study, climate change is referred to as extremely high temperatures that harm pregnant women and lead to adverse pregnancy outcomes like stillbirth, low birth weight, and prematurity.

High temperature

A high temperature refers to an elevated level of heat that cannot be tolerated by the human body (Cremar et al., 2022). In the current study, high temperature is defined

as environmental temperatures of 31°C and above, which are intolerable for humans, particularly pregnant women.

Pregnancy outcomes

A process whereby a sperm meets with a mature egg (ovum) in the fallopian tube to form a zygote, where the pregnant women start to show morning sickness as a sign of pregnancy (Almalik et al., 2017). In this study, pregnancy refers to the fertilisation period.

Stillborn

Heat exposure complications whereby the baby dies before the delivery process starts or during the delivery process (Muglu et al., 2019). Stillbirth in this study refers to a baby who dies a few hours before delivery.

Low birth weight

A baby is born in due time, but the baby's weight is too small to correspond with the gestational age (Hildalgo et al., 2019). The study's low birth weight refers to a fetus born after 37 weeks of pregnancy, but the fetus's weight is too small for gestational age.

Prematurity

A baby is born before the due date of delivery (before 37 weeks of gestation) (Hildago et al., 2019). In this study, premature or prematurity refers to a baby born before its time.

1.8 Conceptual Framework: Ecological Model

1.8.1 Origin of the ecological model

The ecological model is a framework used by psychologists to explain and describe human development, how the body reacts or responds to environmental stimuli (Ungar et al., 2013), and what the body encounters when it is exposed to high ambient temperature (Reed, 1996), which shows the relationship between human development and environmental factors such as extremely high temperatures (Phan, 2024). Psychologist Urie Bronfenbrenner developed this model in the late 1970s, as he

believed that people are affected by environmental interactions such as ambient temperature affecting the growing fetus in utero or high ambient temperatures affecting pregnancy outcomes, which lead to pregnancy complications such as premature and low birth weight. This later evolved into a theory in the 1980s, developed by Bronfenbrenner. The theory, which was demonstrated using various systems, highlighted how these systems place the individual in a challenging cycle. This system highlights the factors at the provincial, community, family, and individual levels that contribute to adverse pregnancy effects resulting from heat exposure, such as prematurity delivery, low birth weight, and stillbirth (Bronfenbrenner, 1977; Kilanowski et al., 2017).

Musina has experienced an extremely high temperature for the past few years, which impacts birth outcomes. Pregnant women are the most important people, according to Bronfenbrenner's model. This model plays an important role in influencing pregnant women regarding coping with high temperatures during summer seasons and how the body responds to heat stress. The family consists of support system resources and knowledge; the family and healthcare should have all of the above to help pregnant women deal with extremely high temperature exposure. Families that have the knowledge and are well-equipped can ensure that there is a cooling place, and that adequate fluid intake is taken, unlike families that do not have the knowledge. This puts pregnant women at risk. Community and healthcare facilities are associated with infrastructure, cultural practices that focus more on cooling measures (water distribution to communities and centers to mitigate the impact of high temperature exposure during pregnancy), and a lack of resources that result in many pregnancy complications due to high temperature exposure. Province levels include infrastructure and healthcare policies that must be used to reduce the impact of temperature exposure during summer.

Figure 1.1: The application of the ecological model (Bronfenbrenner, 1977; Kilanowski et al., 2017)

In this study, the ecological model was applied and aligned with a policy regarding climate change and its potential impact on birth outcomes. Pregnant women are governed by the Labour Guide of South Africa, which protects pregnant women from any environmental hazards, such as being exposed to high ambient temperatures, especially at the workplace, and not resting, standing, or sitting for a long time. The policy was developed to protect all pregnant workers and those who are breastfeeding so that they do not face any pregnancy complications. However, due to a lack of knowledge and poverty, most pregnant women faced adverse pregnancy effects as they depended on farms to meet their daily basic needs. High ambient temperatures affect a woman's pregnancy, which leads to complications such as the commencement of labour (Ha et al., 2017). Climate change exists because of burning fossil fuels, and air pollution affects the earth's temperature and causes extremely high temperatures (Kaur & Pandey, 2021), which harms human development, such as growing babies in utero.

2. Research Methodology

2.1 Introduction

The research methodology is a procedure used to generate knowledge and understanding for article readers and new researchers who are at the edge of developing their articles or studies (Mahajan, 2020). This section discusses the methods used to conduct this study.

2.2 Research Approach

A quantitative approach was used in this study, which is a research methodology that can be counted, as it can be expressed in numbers, not words (Grant et al., 2017), and correlational and non-experimental designs wherein the researcher will measure two variables and understand and assess the statistical relationship between them. The researcher chose this approach to gather more information about climate change and its potential impact on birth outcomes. The quantitative approach was used to provide an overall framework for this study and guidance on research methodology. In contrast, the research design was used to indicate all the procedures that were followed when collecting and analysing data to show the alignment between the study approach and research design.

2.3 Descriptive Design

A descriptive design was utilised in this study, which is a study type that identifies the population's behaviour, like how they behave (Siedlecki, 2020). This design explores and describes the phenomenon. Descriptive studies are commonly conducted with many participants in natural settings without manipulating the situation (Grove & Gray, 2019). This study helped the researcher to classify the information gathered from the pregnant women's records regarding climate change and its potential impact on birth outcomes in Musina Hospital in Vhembe District, Limpopo Province.

2.4 Correlational Design

A correlational design is the relationship between two variables and how one influences the other without manipulating them (Akhdan & Aminatum, 2022). A correlational design was also used in this study; it is a design that seeks the relationship between two variables to see if they influence each other (Siedlecki, 2020) and provides important information on how they work with each other (Brink, Walt &

Rensburg, 2018). The study used a correlational design to discern the relationship between temperature and birth outcomes. The study was focused on climate change and its potential impact on birth outcomes in the Musina Hospital in Vhembe District, Limpopo Province.

2.5 Characteristics of Non-Experimental Design

A non-experimental design refers to an observational design. The researcher observed that the assigned population did not experiment with anything (Jones, 2023). In a non-experimental design, everything happened a long time ago; thus, variables have no control, and there is no available study sample or participants who are ready for this method. Everything happened as it was intended to happen. The advantages of correlational studies in this research include flexibility. The cause of the phenomenon known as climate change and its potential impact on pregnancy will be investigated.

2.6 Retrospective Chart Review

Retrospective chart review (RCR), also known as reviewing of patient medical records (PMR) or medical records review (MRR), is a research design type that utilises existing records of the patient to answer one or more research questions (Saifee et al., 2019). Pregnant women's medical records were used as a useful method for the researcher to acquire information from the existing data (Kahane et al., 2021); using this design was quicker and more relevant as the data already existed from the pregnant women's records or medical charts. Additionally, it has a low cost compared to prospective trials and is accessible to the researcher (Suresh, 2018). This method was followed in nine steps and is displayed below in Figure 1.2 (Buxton, 2021).

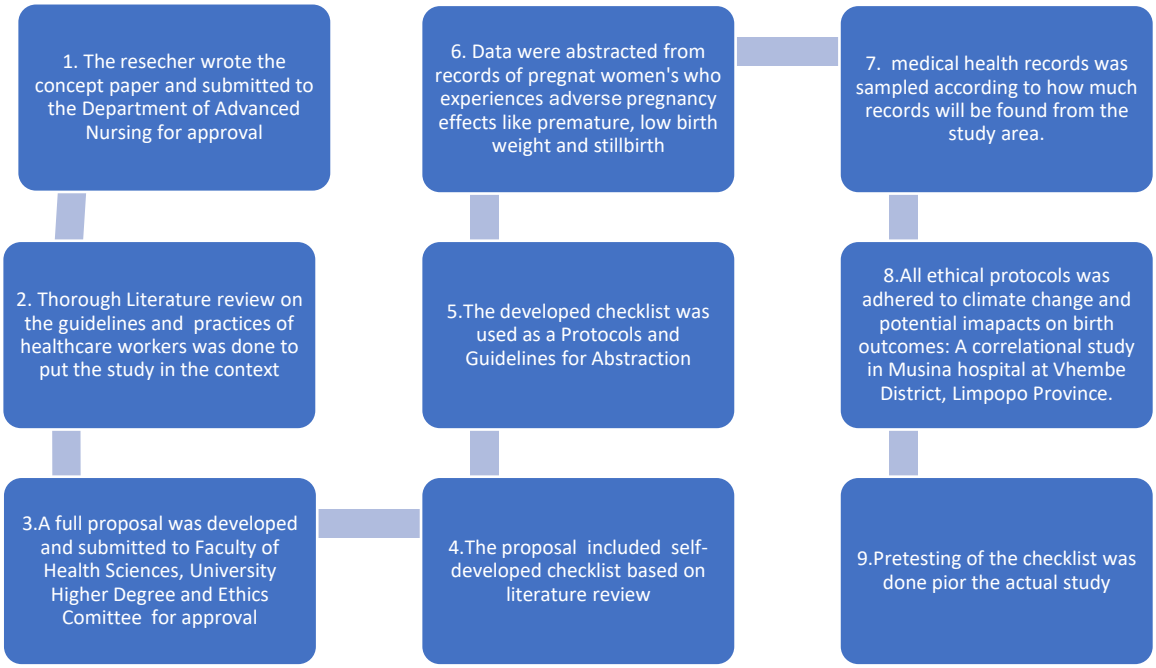

Figure 1.2: Retrospective chart review (Saifee et al., 2019)

2.7 Study Setting

The study setting refers to an area the researcher will research (Burn & Grove, 2015). This study was conducted in Musina Hospital, Vhembe District, Limpopo Province. Musina is located in the northern part of Limpopo and also shares borders with Zimbabwe, Botswana, and Mozambique. It has four local municipalities, namely Makhado, Musina, Thulamela, and Collins Chabane. The Vhembe District covers 21,407 km² with over 1,1 million population with 274,480 households. The Musina region (Figure 1.3) has a population of 20,000 to 40,000; it is also known as a place of wealth for its abundance of minerals, namely iron ore, magnetite, graphite, and diamonds. Musina is in a hot climate zone characterised by extreme seasonal temperature variations. In summer, the temperature rises above 40°C, making it vulnerable to the health impact, especially for pregnant women. Musina consists of Musina Hospital and various clinics to serve the community. However, rural and less accessible areas result in limited healthcare access, which affects birth outcomes

during the pregnancy period. Pregnant women in Musina are more prone to heat stress, dehydration, and heat-related complications such as premature birth, low birth weight, and stillbirth.

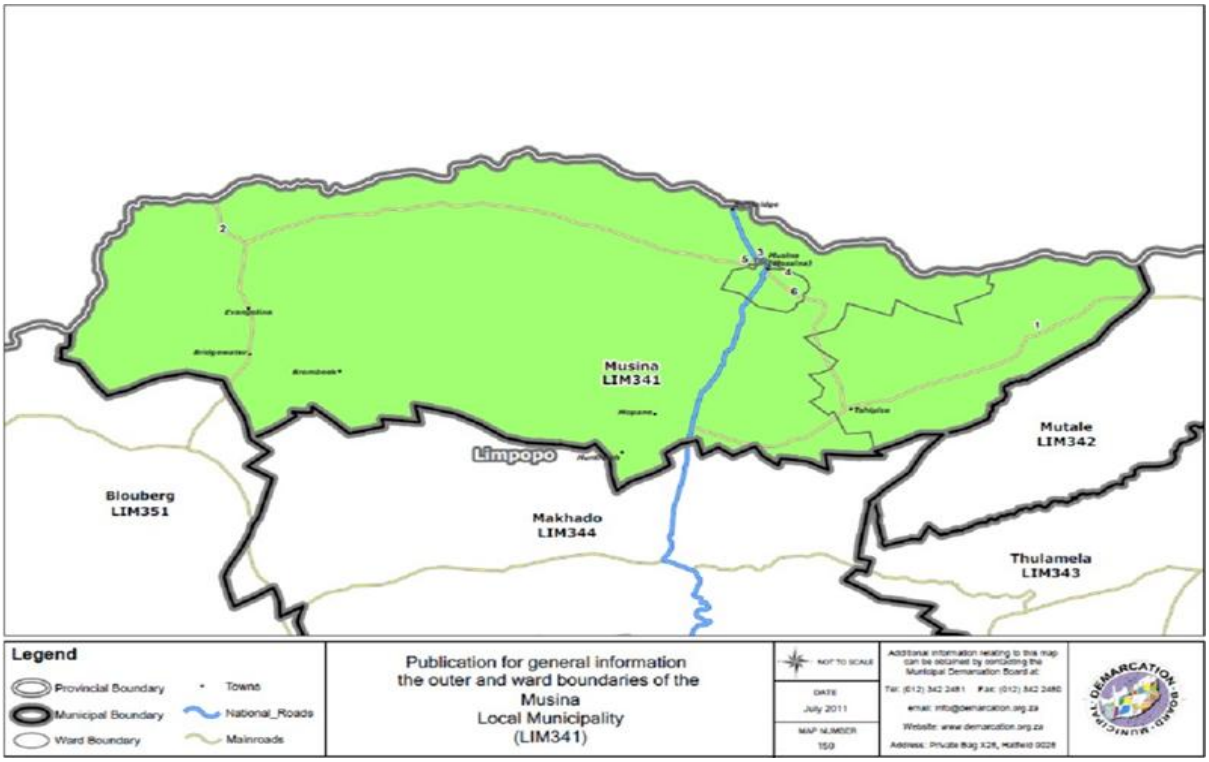

Figure 1.3: Musina map (Messner & Kahinda, 2011)

2.8 Study Population

The study population refers to the group of respondents that the researcher will focus on when conducting the study (Casteel et al., 2021). Conversely, the target group was the entire population that the researcher was focused on in this study and analysis (Suresh, 2018). The population of this study was the records of pregnant women ranging from 14-40 years of age who experienced adverse pregnancy effects from 1 January 2019 to 31 December 2022 in Musina Hospital in Vhembe District, Limpopo Province. The pregnant women's ages were checked using their date of birth, which was on the cover of their medical records. The research focused on climate change and its potential impact on birth outcomes regardless of age, educational status, socio-economic status, race, etc.

2.9 Sampling and Sampled

Sampling refers to a group of people from whom the researcher collected data (Bhardwaj, 2019). Musina Hospital was selected because it is located in an area that has experienced extremely high temperatures in recent years. Many residents, including pregnant women, rely on farming to meet their needs and appear to have limited knowledge and understanding of climate change and its potential impact on birth outcomes. The researcher chose Musina due to the region's climate and the increasing concerns about the adverse effects on pregnancy outcomes.

2.10 Sampling of the Mothers' Records

Sampling involves selecting a designated group that represents the entire population for a study (Gray & Grove, 2021). In this case, records of pregnant women who experienced adverse pregnancy outcomes in Musina Hospital were chosen using purposive sampling. For the retrospective chart review, the researcher focused on cases that were readily available in existing records. The researcher accessed pregnant women's records through an electronic healthcare record system, which requires credentials to ensure that only authorized personnel can retrieve the information. Patient files from 1 January 2019 to 31 December 2022 were selected, and an electronic tool was used to maintain the register. During this period, a total of 5,627 deliveries were documented.

The sample frame was all the records of the pregnant women who visited the healthcare facility experiencing pregnancy complications. The researcher employed purposive sampling as the study only focused on medical records that experienced adverse pregnancy outcomes (premature delivery, low birth weight, and stillbirth). The sample size was 357, according to Krejcie and Morgan's sample size table.

Permission to obtain pregnant women's records was granted to the researcher in line with protection laws in South Africa, such as the Protection of Personal Information Act (POPIA), and ethical considerations since the researcher focuses on confidential information that should only be accessible by authorized individuals. In each pregnant woman's medical record, relevant data such as demographic data were collected, namely the pregnant woman's age, relationship status, occupational status, gestational age at birth, complications during pregnancy, environmental temperature

exposed to during pregnancy, and neonatal outcomes. The researcher ensured that the sample size represented pregnant women who experience adverse outcomes in pregnancy, regardless of their socio-economic status. To avoid bias, incomplete records were not reviewed.

Table 1.1: Krejcie and Morgan's table (Chaun & Penyelidikon, 2006)

N	S	N	S	N	S	N	S	N	S
10	10	100	80	280	162	800	260	2800	338
15	14	110	86	290	165	850	265	3000	341
20	19	120	92	300	169	900	269	3500	346
25	24	130	97	320	175	950	274	4000	351
30	28	140	103	340	181	1000	278	4500	354
35	32	150	108	360	186	1100	285	5000	357
40	36	160	113	380	191	1200	291	6000	361
45	40	170	118	400	196	1300	297	7000	364
50	44	180	123	420	201	1400	302	8000	367
55	48	190	127	440	205	1500	306	9000	368
60	52	200	132	460	210	1600	310	10000	370
65	56	210	136	480	214	1700	313	15000	375
70	59	220	140	500	217	1800	317	20000	377
75	63	230	144	550	226	1900	320	30000	379
80	66	240	148	600	234	2000	322	40000	380
85	70	250	152	650	242	2200	327	50000	381
90	73	260	155	700	248	2400	331	75000	382
95	76	270	159	750	254	2600	335	1000000	384

2.11 Inclusive Criteria

Inclusive criteria refer to the population involved in the study to produce fruitful research outcomes (Connelly, 2020). The study included records of pregnant women aged 14-40 who delivered at Musina Hospital between 2019 and 2022 and experienced adverse pregnancy outcomes such as premature delivery, low birth weight, and stillbirth. The study focused on records of pregnant women who gave birth in Musina Hospital without any pre-existing conditions. Transfers were not considered since there was no patient information in the medical records. All records of mothers who gave birth to term babies and did not experience any pregnancy complications were excluded from this study.

2.12 Measurement Instrument

The self-constructed checklist was developed based on a literature review. A checklist was used in the study. The checklist consisted of closed-ended questions to reduce bias:

- Demographic data

- Climate-related variables that are determinants of pregnancy
- Maternal conditions related to climate change
- Neonatal outcomes related to climate change

2.13 Pre-testing of the Instruments

Pre-testing determines the validity of the tool used for the main data collection (Polit & Beck, 2017). The instrument was tested to determine if it would answer the research question/objectives. Data for the proposed study were collected in Musina Hospital in the Vhembe District of Limpopo Province. To complete the checklist, the researcher revisited the pregnant women's records and pre-tested the instrument in Musina Hospital in Vhembe District, Limpopo Province. The researcher selected 10% of the sample size (36 pregnant women's records) for pre-testing, which were surveyed using a self-developed checklist to assess whether the questions would bring the relevant information needed for the main study. The results of the pre-testing indicate that climate change affects birth outcomes. The data was accurate and not time-consuming, with all the information the researcher sought found within the pregnant women's records. The statistician and the supervisor reviewed the checklist for any errors.

2.14 Plan for Data Collection

Data collection is a method of gathering information needed for the study or questions that need to be answered by the study (Teasdale et al., 2023). The researcher got permission from the Limpopo DOH and met with the manager of Musina Hospital to plan the retrieval of pregnant women's records, which was then retrieved using the Promotion of Access to the Information Act (PAIA) Policy. The researcher was offered a private room for data collection since the information is more confidential and should not be accessible to third parties to avoid disturbance.

2.15 POPIA/PAIA Compliance

The POPIA outlines guidelines for the authorized processing of personal data about individuals (Malherbe, 2021). This law applies broadly to anyone or any entity maintaining personal data records. The primary goal of POPIA was to protect

individuals' private information and shield them from identity theft, fraud, and other similar breaches (Staunton et al., 2020).

According to the Act, personal information encompasses identifying an individual. This includes full names, addresses, details about a person's sexual life, political and religious beliefs, criminal histories, private correspondence, images, audio recordings, video footage, and more. Ntusi (2021) emphasises that "unique identifiers" were included in personal information.

While preserving anonymity in pregnant women's records can be difficult, the researcher ensures that no information from the files or records can be linked back to individuals. Instead, codes were used to identify records, such as Mus 1, Mus 2, etc. Additionally, the names on these records were redacted. The researcher guarantees that the information obtained from the records was accessible only to the investigator and university supervisors.

2.16 Plan for Management Data Analysis

For data management, all completed checklists were cleaned and stored in an Excel spreadsheet, as it facilitates organizing the data into a manageable size and simplifies the uploading process. The collected data were securely stored in the supervisor's locked office, on the researcher's computer, with access restricted to the researcher using a password-protected system. Data was analyzed using correlational analysis methods to determine the relationship between ambient temperatures and birth outcomes such as premature, low birth weight, and stillbirth in Musina Hospital, Vhembe District, Limpopo Province. Pearson's correlation coefficient was also used to prove whether climate change and birth outcomes have a positive or negative correlation. Data in quantitative research was presented in numerical forms or numbers, observations, surveys, and checklists, in the form of questionnaires. The researcher packages all the results according to complications and the years they have occurred, with the environmental temperatures for that year. Data were analyzed using Version 4.3.1 (R Development Core Team, 2023) and the Pearson correlational coefficient to check and measure the linear relationship between two variables, namely temperature and birth outcomes, which showed positive and negative correlations. Data was presented and interpreted in the form of graphs.

2.17 Validity and Reliability of the Study

2.17.1 Validity

Validity refers to the true findings concerning what the researcher has been researching, such as finding the related answer concerning the study (Surucu & Maslaka, 2020). The researcher selected 10% of the pregnant women's records and subjected them to scrutiny to develop a pilot study tool. The statistician and supervisor used the pilot study results to modify the instrument so that the researcher could find valid information on the proposed study.

2.17.2 Content validity

Content validity explains how the instrument is used and covers information on all the variables (Shrotryia & DHANDA, 2019). They conducted an extensive literature review to contextualise the study and gather enough variables to define the phenomenon under study. Then, the proper variables from the literature were used to construct a tool or checklist that explains all aspects of the relationship between climate change and neonatal outcomes in Musina Hospital in Vhembe District, Limpopo Province.

2.17.3 Reliability

Reality refers to the consistency of the results or how consistent one's results are (O'Connor & Joffe, 2020). To ensure reliability, the study tool was administered to a small sample of selected pregnant women's records to test the reliability of the results. The re-test reliability was done to ensure that the researcher gets the same results from the patient records.

2.18 Ethical Considerations

The approved proposal was sent to the University of Venda Research Ethics Committee (UREC) to request ethical clearance. The researcher was then given an ethical clearance certificate as proof that the university had approved the current study to be conducted (Ethical clearance No: FHS/24/NUT/08/208, as shown in Appendix [2]). The approved proposal and ethical clearance certificate were forwarded to the Limpopo Department of Health (DOH) to request permission to conduct this study in Musina Hospital, Vhembe District, Limpopo Province. The Limpopo DOH sent the approval letter to the Vhembe District, where the researcher focused. The Vhembe District provides a letter granting the researcher access to Musina Hospital. The

researcher then forwarded this approval letter to the Limpopo DOH and the letter from the Vhembe District to the Musina Hospital manager, requesting permission to access the medical records of pregnant women and to arrange data collection dates. A private room was provided to ensure privacy since participants' information should be confidential and not accessible to other people except the researcher. All the research questions related to the study were answered while looking at the self-developed checklist.

Permission

The researcher received permission to conduct the study from the Limpopo DOH and the Musina Hospital manager in the Vhembe District, Limpopo Province.

Informed consent

The researcher explained the procedure to the Musina Hospital manager to get full written consent.

Confidentiality

The researcher kept the pregnant women's records confidential so no one could access them.

Privacy

The pregnant women's records were kept private and locked whenever the researcher was using their records. The researcher implemented a clean desk policy, meaning that all sensitive information, including documents, notes, and electronic files, was kept safe after the session. In addition, documents were always locked away to prevent third parties from accessing them or attracting unwanted attention.

2.19 Delimitation of the Study

The population size was 40% of the total number of medical records from 1 January 2019 to 31 December 2022. Additionally, the study focused on one healthcare facility, Musina Hospital in Vhembe District, Limpopo Province. The variables of this study were birth outcomes (dependent variables) and temperature (independent variable).

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Section 2: Articles

Section 2: This section consists of three articles.

Article 2.1, which focuses on the impact of climate change, is an integrative literature review.

Article 2.2 is based on climate change and its potential impact on birth outcomes in Musina Hospital, Vhembe District, Limpopo Province.

Article 2.3 focuses on the effects of ambient temperature on seasonal changes in birth weight in Musina Hospital, Vhembe District, Limpopo Province.

Article 2.1: Impact of Climate Change on Birth Outcomes: An Integrated Literature Review

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Abstract

Background: Climate change is increasingly recognised as a critical factor influencing public health, particularly affecting vulnerable populations like pregnant women and newborns. Emerging evidence suggests that climate-related factors significantly impact birth outcomes. This integrated literature review synthesises existing studies to explore how temperature fluctuations affect maternal and neonatal health outcomes.

Aim: This review aims to investigate the impact of climate change on birth outcomes.

Methods: An integrative review method was utilised in this study. The search process for this review was conducted in an electronic database, namely Google Scholar and PubMed. Keywords such as high temperature, low birth weight, pregnancy outcomes, premature, and stillbirth were used to search for relevant studies related to the impact of climate change on birth outcomes. The study literature used is from 2020-2025. The study employed only English-written papers; those written in other languages were not considered. After the assessment, data were extracted, and 46 articles were selected as they were related to the study.

Conclusion: The review analysed findings from diverse global studies, identifying key patterns and risks associated with climate change. These risks included premature birth, low birth weight, stillbirth, and maternal complications such as pregnancy-

induced hypertension, gestational diabetes, and pre-eclampsia. The review also highlights gaps in current research and emphasises the need for further studies to identify the long-term effects and mechanisms linked to climate change and its impact on birth outcomes.

Keywords: climate change, pregnancy, birth outcomes, high temperatures

Introduction

Climate change is poised to be a major cause of adverse pregnancy effects worldwide, including preterm birth, low birth weight, stillbirth, autism, cleft palate, and heart problems. The most affected individuals are typically vulnerable populations, such as pregnant women and the elderly, particularly those with low socio-economic status (Dehdashti et al., 2020; Batiz et al., 2022; Hadju & Hadju, 2021; Keivabu & Cozzani, 2022; Kutz, 2023; Cabanez, 2024).

Exposure to high ambient temperatures has a significant impact on human health, especially among Black pregnant women than White pregnant women (Ha et al., 2024; Wooten, 2023; Kim & Cil, 2022; Cho, 2020; Brimicombe et al., 2025; Rocque et al., 2021). Research has shown that pregnant women who experience pregnancy complications are more likely to be exposed to high temperatures during the early weeks of pregnancy, which contributes to neonatal mortality in babies born with these complications (Keivabu & Cozzani, 2022; Sayed et al., 2022; Dalugoda et al., 2022).

Esser et al., (2024) found that exposure to high ambient temperatures is associated with increased head circumference in newborns. Pregnant women exposed to heat more frequently gave birth to babies with larger head circumferences compared to those exposed to cooler temperatures. Both hot and cold temperatures contribute to adverse effects during pregnancy, as noted by Khodadi et al., (2022), Shankar et al., (2023); Chen et al., (2021), Ren et al., (2022) and Yu et al., (2023). Head circumference was particularly linked to temperature ranges exceeding 30°C during the third trimester of pregnancy (Castro et al., 2022; Bont et al., 2022).

The highest incidence of complications occurred during the first trimester of pregnancy after exposure to high ambient temperatures, which also affected foetal weight (Rancière et al., 2024; Le & Nguyen, 2021; Basangana et al., 2021). According to McElroy et al. (2022), pregnancy complications do not occur only in the summer; they

can happen in every season. The difference lies in the incidence rate and how many pregnant women are affected in each season. Long-term exposure to high ambient temperatures has been linked to various health conditions, such as heart disease, mental illness, educational challenges, and respiratory problems (Brink et al., 2024). HIV-positive mothers appear to be particularly affected compared to those who are HIV-negative (Caniglia et al., 2021). When the body experiences high temperatures, it undergoes a cold thermoregulation process to combat the heat (Tansey et al., 2015; Osilla et al., 2018). If this process fails, the body may become dehydrated, reducing blood flow to the placenta (Ramirez et al., 2024).

The pathophysiology of high ambient temperature exposure and birth outcomes is not fully known. Only one study which was done in animals shows that high temperature exposure can cause dehydration (loss of body fluids due to excessive sweating), which is also considered to thicken blood, resulting in low blood flow to the placental side and thus triggering the release of oxytocin hormone responsible for the commencement of labour (Dadvand et al., 2011; Stan et al., 2013). Few studies found that all kinds of stress cause overactivation of the hypothalamic-pituitary-adrenal axis, thus also playing a vital role in triggering the release of corticotropin hormone and cortisol, which is responsible for early labour contraction, resulting in premature delivery (Costello et al., 2018). Weight gain during the pregnancy period makes the body face challenges when it's time for heat release to cool down (Wang et al., 2024). When it becomes too hot, they release extra heat into their pregnant women's bodies through metabolism, resulting in maternal heat stress (Limesand et al., 2018). Extremely high temperature exposure makes pregnant women more vulnerable to heat stress since their bodies fail to manage the amount of heat they receive, thus putting them at high risk of premature labour. Heat exposure can also cause pregnant women to reduce physical activity, start to lose their appetite, and sleep more (Batize et al., 2022; Bonell, 2023), which harms the developing foetus inside the uterus (Samuels et al., 2022), resulting in the high number of admissions to healthcare facilities due to neonatal complications (Bekkar et al., 2023). For pregnant women, it makes them to experience sleep disturbances, especially in the third trimester of pregnancy (Wang et al., 2024; Lo et al., 2023).

High temperatures do not significantly impact pregnant women from different backgrounds and characteristics (Cho et al., 2020). However, heat exposure is linked to reduced birth weight, especially during the second trimester of pregnancy (Le, 2024). Pregnancy complications such as newborn jaundice, hearing loss, and infections tend to be most common among pregnant women who are in their first trimester. These complications include reduced fertility and an increased risk of miscarriage. If these issues are not addressed, it may lead to future pregnancies resulting in unhealthy children and poor maternal health (Wang et al., 2024). Another complication may be oligohydramnios. Oligohydramnios is a marker of foetal compromise and elevated risk of injury (Seol et al., 2021). It can derive from both abnormalities (i.e., renal disease) and uteroplacental insufficiency and may be impacted by maternal hydration status (Luton et al., 2004; Seol et al., 2021).

Additionally, pregnant women may experience gestational diabetes, pregnancy-induced hypertension, pre-eclampsia, spontaneous abortion, and postpartum depression. Some studies have also reported impairments in neurodevelopment and a rise in waterborne diseases (Lin et al., 2023; Rekha et al., 2023; Papadiochou et al., 2024; Cherish et al., 2020; Lawrence et al., 2021; Lakho et al., 2024; Kim et al., 2021; Shankar et al., 2023; Veras et al., 2024; Dumbuya et al., 2024). As a result of these complications, many young women are becoming increasingly afraid of pregnancy and motherhood (Smith et al., 2023).

The study by Lakhani et al. (2024) focused on low- and middle-income countries (LMICs), finding that high ambient temperatures increase the risk of adverse pregnancy outcomes like preterm birth, low birth weight, and stillbirth. It does not support the claim that high-income countries (HICs) are more affected. HICs often have better healthcare systems and infrastructure to mitigate heat-related pregnancy risks.

Some studies have recorded an association between high temperatures and stillbirth delivery. Sexton et al. (2021) and Haghighi et al. (2021) state that exposure to high temperatures is linked to neonatal abnormalities. Dimitrova et al.,(2024) state that these complications are primarily observed during the third trimester of pregnancy.

Bonell et al., (2023) focused on singleton pregnant women who work on farms to meet their basic needs in villages that experience high temperatures during the hot season.

They found that pregnant women experienced adverse pregnancy outcomes, such as premature births, low birth weight, stillbirths, and small gestational age, which are often the result of foetal growth restrictions. This phenomenon is supported by findings from Nyandanu et al. (2024), Wang et al. (2024), Cushing et al. (2022), Son et al., (2022) and Ha et al., (2022).

Developing a framework

The researcher utilized a framework aligned with the topic of the review to ensure that the results are accurate and reliable (Snyder, 2019). This framework was commonly referenced in published literature, as described by Whittemore and Knafl (2005) and Aveyard and Jones et al. (2022). It consists of seven steps, which are as follows:

Step 1: Writing of review questions

Step 2: Determine the search strategy

Step 3: Critical appraisal of the search results

Step 4: Summarise the research results

Step 5: Data extraction and reduction

Step 6: Analysis

Step 7: Conclusion and implications

Step 1: Writing the review questions

Writing review questions is the starting point for an integrated literature review (Cronin, 2023). The review question regarding the impact of climate change on birth outcomes is relatively straightforward, as it focuses on the experiences of pregnant women exposed to various environmental conditions daily. The impact of heat-related illness is particularly significant for vulnerable populations, including the elderly, pregnant women, and children. It's crucial to recognize the heightened risks these groups face in extreme heat conditions. Formulating a strong review question is essential for covering all aspects of how climate change affects birth outcomes, making it a crucial step in writing an integrated literature review.

There are several tools that researchers can use while crafting review questions, such as PICOT and SPIDER. PICOT is responsible for investigating the impact of high

ambient temperature on birth outcomes, and SPIDER is responsible for exploring how temperature affects birth outcomes. These frameworks are effective for developing review questions and help break down research topics into answerable enquiries. Additionally, they guide the literature search process, including identifying relevant research databases and ensuring that all research concepts are addressed to achieve targeted results. In this study, the goal of the articles and reports is to investigate the impact of climate change on birth outcomes.

Step 2: Determine the search strategy

Table 2.1.1 compares the PICOT and SPIDER frameworks regarding the review questions.

Table 2.1.1: PICOT Template (Milner et al., 2024)

Population	Pregnant women who experience different types of pregnancy outcomes related to heat exposure
Intervention/ Interest	Provide information about the impact of climate change on birth outcomes to educate people about these risks
Comparison/ Context	The high temperature versus birth outcomes worldwide, context from 2020-2025
Outcomes	Prematurity, stillbirth, low birth weight, newborn abnormalities, newborn jaundice, spontaneous abortion, hearing loss, and neurodevelopment problems
Time	The publication dates from 2020-2025 confirm the comprehensive approach employed

Integrative: Both qualitative and quantitative studies. **Study design:** SPIDER Template	
Sample	No restriction on sample size
Phenomenon or Interest	Provision of information about the impact of climate on birth outcomes worldwide
Design	Integrative design
Evaluations	Every outcome that occurs as a result of ambient temperature exposure

Research Type	Integrative: Both qualitative and quantitative studies

The search process was conducted in the electronic database, including papers published from 2020-2025 in PubMed and Google Scholar, using the keywords *high temperature, birth outcomes, premature, stillbirth, low birth weight,* and a combination of them. The researcher considered cohort, cross-sectional, and case-control studies.

Table 2.1.1 presents the number of studies reviewed and those included and excluded from the review (Whittemore & Knafl, 2005).

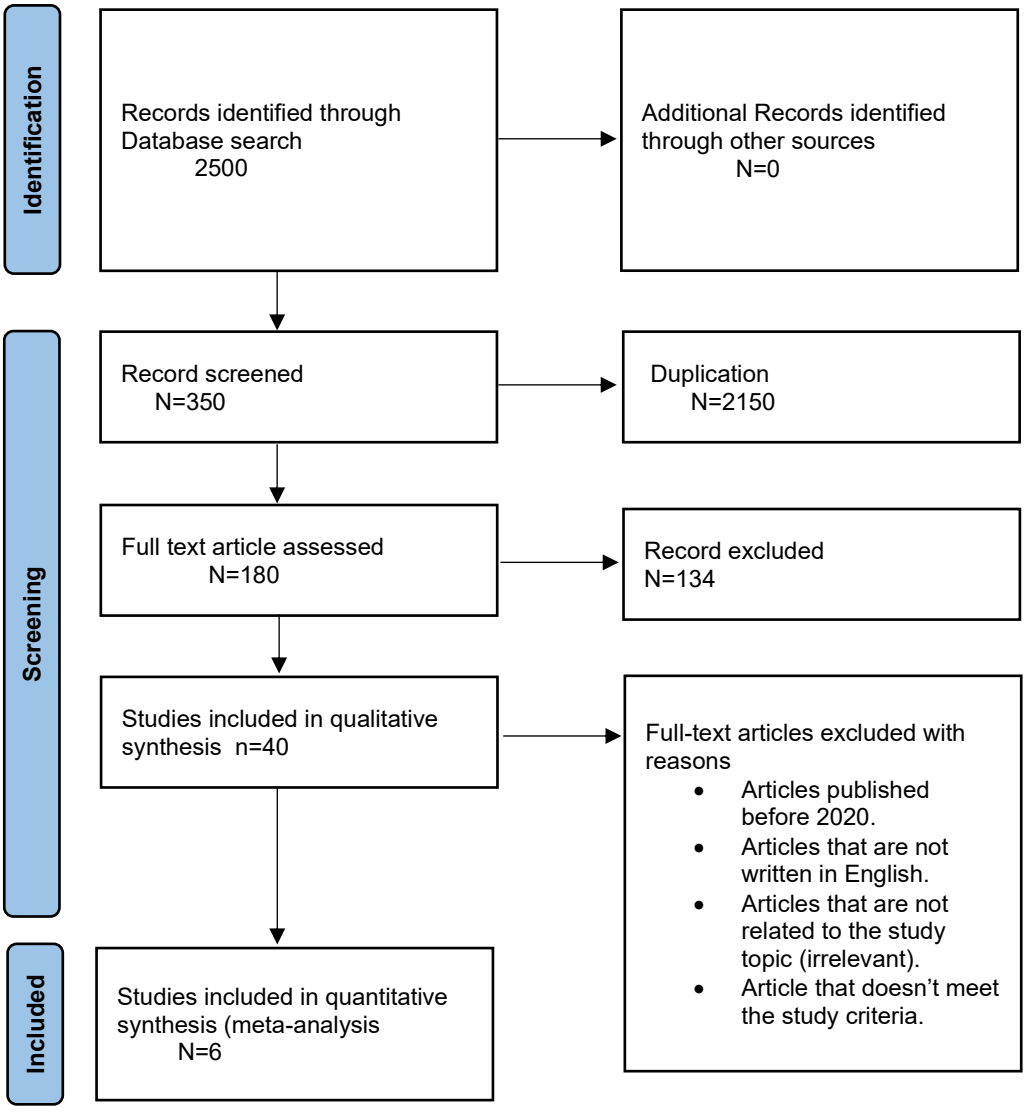

Figure 2.1.1: Prisma flow chart by (Page et al., 2021)

After removing 2,150 duplicate articles, 350 unique records remained for screening. After reviewing titles and abstracts, 180 articles were selected for full-text assessment to determine their eligibility. Following a detailed evaluation, 134 articles were excluded for not meeting the inclusion criteria, as outlined in the PRISMA flowchart. This process resulted in 46 studies that met the eligibility requirements and were included in the final review. Of these, 40 studies contributed to qualitative synthesis, offering insights through narrative or thematic analysis. The remaining six studies contained sufficient and compatible data for inclusion in quantitative synthesis (meta-analysis), ensuring a rigorous and focused evaluation of the available evidence.

Inclusion and exclusion criteria assist researchers in identifying relevant data related to their study while eliminating data or studies that do not align with their research topic. Researchers recognise that gathering more information does not necessarily mean it is all relevant; only pertinent data should be utilised in the study.

According to Whittemore et al. (2005), search strategies should include systematic reviews, meta-analyses, retrospective cohort studies, and other relevant methodologies. There were no restrictions on sample size when conducting this study; however, there were limitations on publication dates, as the reviewed literature was restricted to studies published between 2020-2025. Studies published before 2020, those written in languages other than English, studies discussing climate change without a connection to birth outcomes, and studies about birth outcomes that do not relate to climate change were excluded.

After implementing the search strategies, the researcher removed duplicate studies. Then, the remaining abstracts and titles were reviewed, and irrelevant studies were eliminated.

Step 3: Critical appraisal of search results

All articles related to the search strategies were critically appraised to ensure they were appropriate for the study and suitable for inclusion in the review. This review utilised a mixed methods approach, as described by (Gupta et al., 2024), to ensure the validity and reliability of the conducted research and to determine whether the results are valid and align with the study's context. This method helps the researcher articulate a clear statement regarding the research aim and investigate the impact of

climate change on birth outcomes worldwide, emphasising the significance of the study and its results.

Table 2.1.2: Critical Appraisal Results

Author/s and year	Design/Approach	Objective	Participants Age	Setting	Result	Limitations
Lin et al.,(2023	Descriptive design	The objective was to investigate the impact of ambient temperature on maternal complications, white blood cell count (WBC), newborn hearing, and neonatal jaundice.	18-50 years	Fuzhou Maternity and Child Healthcare Hospital	High ambient temperature affects neonatal jaundice and hearing loss, especially for mothers in their third trimester of pregnancy.	The study had several limitations: the small sample size necessitated cautious interpretation of the results, the study was conducted in only one city (Fuzhou), limiting the generalisability of the findings, and it relied solely on self-reported data.
Rekha et al.,(2023)	Systematic review and meta-analysis	To examine the impact of heat stress on maternal, foetal, and neonatal health.	No age limit	India	The study revealed that warmer temperatures have a greater potential impact on adverse pregnancy outcomes.	Studies only focused on India.
Papadiouchou et al.,(2024)	Systematic literature review	To assess the effects of climate change-driven environmental factors, such as air pollution and temperature extremes, on reproductive health outcomes, including fertility rate, miscarriage, preterm, and congenital abnormalities.	No age limit	The study was conducted in different geographical regions	The results reveal a clear and concerning link between climate change and adverse reproductive health outcomes. The evidence illustrated that environmental factors are associated with climate change, including air pollution and extreme temperatures, which impact fertility, pregnancy outcomes, and foetal development.	The study has several limits: the heterogeneity of the included studies in terms of their exposure assessment methods, outcome measures, and population characteristics. Findings may limit the ability to draw a firm conclusion about specific environmental exposure. There was potential publication bias, as the review included studies published in English and available as full-text articles. The study focused on mammalian species, meaning

						that other relevant research on non-mammalian models was not considered. Review reliance on studies up to a certain date may have missed more recent research development, particularly in the rapidly evolving field of climate change and health.
Cherish et al.,(2020)	Systematic literature review and meta-analysis	Assess whether exposure to high temperature in pregnancy is associated with an increased risk of preterm birth, low birth weight, and stillbirth.	Mapping review related to heat exposure(no age limit)	From different databases, namely Medline (PubMed), Science Citation Index Expanded, Social Science Citation Index, and Arts and Humanities Citation Index	Ambient heat temperatures were found to be more common in low socio-economic status groups.	How temperature and lag measures were used meant that the researchers had to develop decision rules for classifying temperature metrics and other variables. The study was of low quality, limiting analysis.
Ramirez et al.,(2024)	Systematic literature review	Examine the association between heat stress exposure and placental function, synthesising methodologies from the existing literature to inform future research approaches.	The study used both human and animal studies (no age limit).	Peer-reviewed articles	The study found the impact of heat stress on placental function, encompassing changes in weight, efficiency, blood flow, anatomy, and expression.	The study did not focus on informed, evidence-based strategies for maternal and foetal health in a changing climate.

McElroy et al.,(2022)	Global analysis	Examine the acute relationship between preterm birth and stillborn in 14 lower-middle-income countries.	15-49	Fourteen low-middle-income countries (Angola, Benin, Burundi, Ethiopia. Haiti, Malawi, Nepal, Nigeria, Philippines, South Africa, Tajikistan, Timor-Leste, Uganda, and Zimbabwe)	The study found a consistent and positive association between extreme heat beyond specific thresholds and risks of preterm birth and stillbirth in LMICs.	All exposures were assigned per globally gridded meteorological data that were previously validated.
Haghighi et al.,(2021)	Systematic literature review	Assess the exposure to high temperature and congenital abnormalities.	Electronic database search from 9 September 2018 to 23 September 2013(no age limit).	The study used the PubMed Science Citation Index Expanded, Social Science Citation Index, and Arts and Humanities Citation Index	Heat exposure has been found to increase the risks of some of the birth defects for cardiac lesions such as ASDs and VSDs.	Temperature measurements were operationalised in various ways, and multiple testing could lead to Types II errors. The study used outdoor or self-reported temperature measures as a proxy for the actual heat exposure, which depends largely on the heat resistance of the built environment.
Lakhani et al.,(2024)	Systematic literature review	Assess the impact of high environmental temperature on pregnancy outcomes (abortion, stillbirth, preterm, and low	Observational studies published between 2010 and 2023(no age limit).	The search was conducted on MEDLINE, Embase, CINAHL, Web of Science, and Scopus	The findings of this systematic review validate the hypothesis that high ambient temperature is associated with pregnancy adverse outcomes, namely preterm birth, low birth, and stillbirth in LMICs, which are	The limitation of this review is the inability to analyse the results.

		birth weight) in LMICs.			already highly vulnerable to those adverse outcomes.	
Lakho et al.,(2024)	Systematic literature review	Assess the impact of heat during pregnancy on maternal and neonatal outcomes.	The study used peer-reviewed epidemiology studies(no age limit).	Peer-reviewed epidemiology studies	Findings show that potential heat impacts non-reassuring foetal status and spontaneous abortion, which broadness the scope of enquiry into heat impact on foetal health and provides insight into an underlying causal pathway that mediates adverse outcomes.	The heterogeneity in exposure metrics and study design limits the findings.
Kim et al.,(2021)	Econometric approach	Temperature variation within narrowly defined geographic and demographic cells shows that exposure to extreme temperature increases the risks of maternal hospitalisation during pregnancy.	The study included all pregnant women(no age limit).	Washington and New York	Findings show that exposure to extreme temperatures harms women's pregnancy health and impacts maternal hospitalisation from exposure to unusually warm temperatures in both summer and non-summer.	The limitation of this study is that the researchers were unable to measure maternal health impacts, which were not captured by the hospitalisation data.
Shankar et al.,(2023)	Cohort	Growing evidence suggests that environmental heat stress negatively influences foetal growth and pregnancy outcomes.	The study used a global network and maternal and newborn health registry(no age limit).	India (Belgavi), (Nagpur) and Pakistan (Thatta)	The study findings suggest that greater temperature in pregnancy is associated with premature birth, pre-eclampsia, and low birth weight.	The present analysis only utilised daily maximal air temperature as the exposure to ambient heat stress.

Veras et al.,(2024)	Systematic literature review	Bedside socio-economic factors, environmental pollution, and climate change are central and temporary threats to health.	No age limits; the author used recent data from the systematic literature review.	Systematic literature review retrieved from PubMed five years ago	Foetal development and postnatal health are also impaired by health exposure. Low birth weight is found to be more common worldwide.	The authors only focused on studies published five years ago by PubMed.
Dumbuya et al.,(2024)	Systematic literature review	The review examined how climate change adversely affects maternal health and pregnancy outcomes in Africa.	There was no age limit in studies involving pregnant women or medical health outcomes in the African region.	Africa	The study found that most African nations struggle to effectively adapt and mitigate the adverse impact of climate change due to limited resources, particularly women. It also reveals that the number of maternal deaths continues to rise, along with an increase in low birth weight, premature births, and stillbirths.	The study only focused on maternal health and pregnancy outcomes in Africa.
Smith et al.,(2023)	Thematic analysis approach	To explore how climate change impacts the pregnancy intention of young women and their perspective towards childbearing.	18-25	Canada	Findings revealed that the young generation is afraid of childbearing due to the impact of climate change, contributing to a reduced pregnancy rate.	Participants were a geographically restricted sample of seven CIS-gender women.
Bonell et al.,(2023)	Observational cohort studies	To evaluate the use of Ambi flow in the field setting to assess the impact of heat stress on the umbilical artery resistance index.	Women at 28 weeks of pregnancy with a singleton fetus (no age limit).	West Kiang, the Gambian, West Africa	The study findings show low blood flow to the placental side due to heat exposure.	The study has several limitations: the sample size was reduced due to the COVID-19 pandemic, limiting the scope of analysis. The maternal core temperature could not be measured in the field; therefore,

						less accurate and less precise tympanic temperature was measured.
Nyandanu et al.,(2024)	Systematic and meta-analysis	Review an ambient temperature to summarise and appraise the evidence with recommendations.	The review was done up to December 2023(no age limit).	Databases such as PubMed, CINAHL, Scopus, Medline/Ovid, Embase, and Ovid, Web of Science	The study findings show a positive association, which was mostly consistent for PTB and stillbirth, particularly elevated during the late pregnancy period.	One limitation of the umbrella review is the multiple inclusion of primary studies, which suggests possible duplications of SRMAs using largely the same primary studies with almost consistent findings.
Cushing et al.,(2022)	Correlational study	To test the hypothesis that acute exposure to extreme heat was associated with a higher risk of live spontaneous preterm birth and that risks were high among people of colour and neighbourhoods with heat-trapping land cover.	No age limit	Texas Department of State Health Services	The study's findings reveal that maximum ambient temperature is associated with a 15% increase in the risk of spontaneous birth.	Lack of information on stillborn or miscarriage. The researchers could not address this issue directly in the analysis; a recent simulation study suggested that live birth bias can lead to an underestimation of the effects of hazardous environmental exposure on pregnancy.
Son et al.,(2022)	Stratified analysis	To investigate the association between exposure to heat/heatwave during the last week of gestation and preterm birth in Carolina and	No age limit	North Carolina	Findings suggest that exposure to heat during pregnancy increases the risk of PTB and suggests disparities in these risks.	The study focused only on North Carolina.

		evaluate effects modification by residential greenness, urbanicity, and socio-economic status.				
Ha ,(2022)	Analytic methods and assessment strategies	To review the summarised literature regarding the impact of climate change and related environmental disasters on pregnancy health and provide recommendations to inform future adaptation and mitigation efforts.	No age limit	The population that has less access to resources worldwide	The findings show that pregnant women and growing babies with fewer resources are vulnerable to direct and indirect climate change impacts.	The study did not target healthcare professionals who provide for patients.
Samuels et al.,(2022)	Exploratory review of the literature search	The aim is to build a consensus on how high temperatures impact women and fetuses during pregnancy and childbearing based on scientific evidence.	No age limit	Review paper	The study found that exposure to high ambient temperatures is associated with adverse pregnancy outcomes.	There is a lack of specific advice on defining a dangerously hot ambient temperature, whether there is a length of safe exposure time or vulnerable time points during pregnancy when women should be particularly alert to the danger of heat exposure.
Lo et al.,(2023)	Scopus review	To synthesise the existing evidence of heat-related health impacts in the	No age limit	Western Pacific region	The results show a strong association between heat exposure dehydration and heat stroke.	Morbidity has been studied less, and its association with heat is less robust.

		Western Pacific region.				
Brink et al.,(2024)	Meta-analysis	To systematically assess the evidence on the long-term impact of heat exposure on the fetus in utero.	Study conducted in August 2019 and April 2023(no age limit).	In Medline (PubMed)	Heath exposure in utero is associated with a possibility of wide-ranging long-term impacts on socio-economic and health outcomes, with a significant cost associated with increasing global temperature.	No studies have used widely accepted heat exposure indices that consider important environmental modifying factors like humidity and wind speed.
Caniglia et al.,(2024)	Correlational design	To examine the association between seasonality and adverse birth outcomes among women with HIV in a large geographical representative birth outcomes surveillance study in Botswana from 2015-2018.	No age limit, provided that the mothers are at 29 weeks of pregnancy(no age limit).	Botswana	The study found variation in the overall number of deliveries and the risks of adverse birth outcomes by birth during wet seasons.	The researcher summarised complex seasonal patterns across several years into four categories, which may not fully account for specific weather-related factors and cannot be disentangled from agricultural practice or other activities specific to these four seasons. They could not evaluate the seasonality of pregnancy loss occurring before 24 weeks of gestation. Measurement error pattern for preterm delivery and small for gestational age is possible, but not likely to be differential.
Cho et al.,(2020)	Cohort	Examine the effects of temperature on birth rate and birth outcomes.	Data obtained between 2009-2013(no age limit).	South Korea	The study found that the effect of temperature bins did not vary according to mothers' characteristics, such as educational background and age.	The study did not examine the temperature birth rate based on behaviour.

Esser et al.,(2024)	Cohort	To evaluate the association between temperature exposure during pregnancy and foetal size and growth in three European birth cohorts.	Women with life singleton birth from week 1-32 of pregnancy(no age limit).	Asturias, Gipuzkoa, Sabadell, and Valencia	The findings show that cumulative exposure to colder and hotter temperatures was associated with changes in head circumference size and growth during gestation.	The researchers could not account for factors that may modify the individual levels of exposure (e.g., air conditioning or heating use, behavioural, and activity patterns).
Khodadi et al.,(2022)	Systematic literature review	To investigate the relationship between the universal thermal climate index and adverse pregnancy outcomes, including stillborn, low birth, preterm labour, spontaneous abortion, pre-eclampsia, and hypertension in Ahvaz, Iran.	No age limit	Ahvaz, Iran	The results show that hot thermal stress in the UTCI index increases the risk of stillbirth.	The researchers did not observe any significant relationship between UTCI and other adverse pregnancy outcomes.
Ranciere et al.,(2024)	Linear and logistic regression (cohort studies)	To investigate associations between heat waves during pregnancy and birth weight outcomes in term newborns from the Paris birth cohort and to explore meteorological conditions and air	Newborn babies born between February 2003 and June 2006(no age limit).	Paris	The results show that exposure to heat waves, particularly during the first trimester, was associated with lower birth weight at term and a higher likelihood of small gestational age at term.	The researchers could not control maternal height and weight as the data were not collected at birth in the Paris cohort.

		pollution as possible intermediate factors.				
Le and Nguyen,(2021)	Explorative design	To investigate the extent to which in-utero exposure to temperature shocks affects birth weight outcomes in Vietnam.	No age limitation	Vietnam	The results revealed that exposure to ambient temperature during the first trimester affects birth weight.	The study only focused on Vietnam.
Basangana et al.,(2021)	Nonlinear model framework	To evaluate, in a national retrospective cohort, critical windows of susceptibility during pregnancy to extreme temperatures (low and high) and foetal growth among 624940 singleton term births in Israel during the period 2010-2014.	Singleton term birth (no age limit)	Israel	The findings show that exposure to extreme temperatures, especially heat, during a specific time window may result in reduced foetal growth restriction.	The researchers could not assess residential mobility in their population. They did not account for humidity or other climatological variables and intend to incorporate them in their future studies.
Dehdshti et al.,(2020)	Systematic literature review	To review the impact of climate change around the world on the incidence of emerging and non-communicable diseases in sensitive and vulnerable individuals, such as	Focused on review from 2018-2020(no age limit).	Scopus, PubMed, Web of Science, and Google Scholar	The review findings show that climate change affects birth weight, gestational diabetes, etc.	The study did not focus on the effect of climate-related environmental exposure on pregnancy.

		pregnant women and newborns.				
Batiz et al.,(2022)	Narrative review	The study identifies seven impacts of climate change, namely temperature, precipitation, air quality, food insecurity, displacement, range of vector-borne diseases, and socio-economic inequality, that jointly and individually have the potential to convey an elevated risk of adverse pregnancy outcomes and preterm.	No age limits: the study included all pregnant women.	Narrative literature review	The study concluded that an adaptation plan should be developed to help vulnerable populations, such as pregnant women.	Many of the region's most likely to experience the worst climate extremes are also those that have already reported high rates of prematurity.
Hadju and Hadju,(2021)	Correlational design	The study analyses the impact of in-utero temperature exposure on birth weight and an indicator for low birth weight using administrative.	Singleton live birth(no age limit)	Hungary	The study found that high ambient temperature exposure is associated with birth weight, especially during the first trimester.	The study only focused on Hungary's singleton live births.
Kutz,(2023)	Systematic literature review	To investigate how in-utero exposure to weather events, such as heat and cold waves or rainfall,	No age limit	United States of America	Results revealed that babies born to black, Mexican, and low-educated mothers are disproportionately prone to climate-related health risks.	The researchers only observed effects on live births in their data. The researchers cannot control mothers' mobility and actual temperature exposure.

		impacts infant health at birth.				
Cabanez,(2024)	Cohort	Determine the causal moderating effects of energy prices on the relationship between extreme temperature and birth outcomes.	The author uses a different birth cohort.	Spain	The results show that extremely high temperatures affect birth weight, especially in the third trimester of pregnancy.	The study focused predominantly on energy prices as a moderating factor, leaving unexplored possible contributions from other moderating variables that could enrich the understanding of the relationship between extreme temperature and birth outcomes.
Brimicombe et al.,(2025)	Time series regression analysis	To explore the association of heat with seven perinatal and maternal health outcomes.	No age limit	Mombasa Hospital, Kenya	Results show that different risks are attributed to different heat exposure metrics for all parental and maternal health outcomes.	The Mombasa Hospital dataset is small, so it may be that the researchers would see significance in other outcomes with a larger dataset.
Rocque et al.,(2021)	Systematic literature review	To develop a systematic synthesis of a systematic review of the health impacts of climate change by synthesising study characteristics, climate impact, health outcomes, and key findings.	No age limitation	Cohort studies	Climate change is associated with infectious diseases, mortality rates, respiration, and cardiovascular outcomes.	The limitation of this study is that the researcher could not access some full texts; therefore, some studies were excluded, even though they were deemed potentially relevant after title and abstract inspection. Another limitation is that the researcher couldn't conduct a meta-meta-analysis of the findings across reviews due to the heterogeneity of the included systematic reviews. The date of the systematic search is a limitation, as they searched in June 2019.
Castro et al.,(2022)	Cohort	To investigate whether pregnancy	No age limit pregnancy	Kilimanjaro Christian	The study showed that adverse weather conditions are	The study did not examine the precise biological mechanism

		exposure to weather conditions affects neonatal birth weight, length, head circumference, and Apgar score and to evaluate changes in weather conditions across the study period.	women were assessed through their postpartum period.	Medical Centre in Tanzania	associated with more negative birth outcomes, which have a lasting unfavourable health impact.	linking pregnancy and birth outcomes to different weather conditions.
Keivabu and Cozzani,(2022)	Descriptive design	To investigate the effects of extreme heat on birth-on-birth outcomes and whether the effect is heterogeneous among socio-economic strata.	Newborn	Spanish provincial capital	The study observed negative effects of exposure to temperature above 32°C on birth outcomes, such as low birth weight and very low birth weight, particularly when extreme temperatures occurred in early pregnancy. The study also found that males are more affected than females.	The study focused on differences among socio-economic groups, but inequality may also change over time. The study did not investigate the mechanism explaining heterogenies between SES groups and the prevalence of negative outcomes among SES mothers.
Sayed et al.,(2022)	Gestational window of sensitivity	To identify the major adverse pregnancy outcomes examined in the context of ambient gestational heat exposure, with emphasis on study design, gestational window of sensitivity, and characterisation of environmental temperatures.	No age limit	Cohort studies	The results show that high ambient temperatures have an impact on the health of pregnant women.	The researchers did not assess the methodological quality of the included papers, and they discuss only general, albeit limited, findings regarding gestational heat exposure and adverse pregnancy outcomes.

Dalugoda et al.,(2022)	Scoping review	An overview of the published literature identifies research gaps and summarises the current evidence of the association between elevated ambient temperature exposure during pregnancy and adverse maternal, foetal, and neonatal outcomes.	Articles from 2015-2020(no age limit)	Electronic database searches using PubMed, CINAHL, and Embase, including original articles published in English between 2015-2020	Elevated temperatures show an impact on foetal outcomes such as congenital abnormalities, namely congenital heart defects.	The researchers limited their search to published articles from 2015 to 2020. The study did not include hand-search articles or grey literature such as government reports, conference papers, etc. The scoping review did not perform a quality appraisal for the included articles. The study did not examine the impact of cold temperature on adverse maternal, foetal, and neonatal outcomes.
Cheng et al.,(2021)	Stratified analysis	To investigate the association between extreme ambient temperature and the risk of preterm birth in Xuzhou, China.	Singleton deliveries(no age limit)	Xuzhou China	Low ambient temperature was found to be associated with risks.	The study only focused on Xuzhou, China.
Ren et al.,(2022)	Meta-analysis and meta-regression	To evaluate the effects of maternal exposure to extreme temperature on PTB and its clinical subtype in China and to identify the effect modification of regional factors in the dimensions of population, economy, medical resources,	Singleton live birth(no age limit)	China	The study found that exposure to extreme heat during the entire pregnancy was associated with the risks of preterm birth.	The study could only clarify an association between extreme temperature and preterm birth but could not prove casualty.

		and environmental factors.				
Yu et al.,(2023)	Stratified analysis	To investigate the associations of extreme climate events with the risk of preterm birth and its subtype, discerning possible modifiers.	Singleton deliveries with no age limit(no age limit).	China, including all secondary and tertiary hospitals	The study findings revealed that exposure to extreme cold temperatures during pregnancy increased the preterm birth risk.	Using air conditioning and heating may mitigate the associations of extreme temperature exposure with preterm birth. Although the researchers assumed that most Chinese pregnant women choose the nearest hospital for childbirth, measurement errors may arise when assigning temperature based on the hospital location. Errors in the gestational age may have influenced the incidence of PTB and led to inaccurate effect estimation.
Sexton et al.,(2021)	Systematic literature review	To systematically review published methods, data sources, and data linkage practice to characterise associations between ambient temperature and stillborn to inform stillbirth prevention and risk management strategies.	No age limit	Cohort studies	Exposure to hot and cold temperatures is associated with stillbirth delivery.	Most studies used routine, retrospective data and would be less likely to be published if no significant effects were found. Published study protocols were not found for any of the included studies, and no pre-specified cut-points were described in any methods section.

Yang et al.,(2022)	Time-series analysis	To assess the impact of extreme temperature on the stillbirth rate.	No age limit	Taiwan	The results show that the rate of stillbirths in Taiwan continues to rise.	The study shows that hot temperatures have a more significant overall effect on stillbirths than cold temperatures, and Taiwan, located in a subtropical region, predominantly experiences warm temperatures. The study did not discuss medication, maternal infection, or congenital abnormalities. Heat adaption and resilience could reduce the thermal hazard, but this study did not collect these effect modifiers at an individual level.
Dimitrova et al.,(2024)	Time-stratified case-crossover design	To assess the relative contribution of observed climate change to the burden of temperature-related neonatal death in LMICs over the period 2001-2019.	15-49 years	Sub-Saharan Africa	Findings indicate that both high and low ambient temperatures pose a risk to neonatal health in LMICs, with 4.3% of neonatal deaths during the study period.	DHS data may not fully capture neonatal deaths due to social stigma in reporting, omissions, and misrecording by the interviewer or misclassification between very early neonatal deaths and stillbirth.

Step 4: Summarise the research results

This study aimed to investigate the impact of climate change on birth outcomes worldwide. A total of 46 studies were included; this review consisted of 26 cohort studies, 14 cross-sectional studies, and six case-control studies. The impact of climate change on birth outcomes was associated with increases in premature and low birth rates.

The systematic review provided vital information related to the impact of climate change on birth outcomes. A limitation of this study is that it focused solely on literature published between 2020 and 2025 that met the inclusion criteria, excluding earlier studies. As a result, the researcher may have missed valuable information regarding the impact of climate change on birth outcomes. The study did not dwell much on the high ambient temperature and neonatal death; thus, further studies should focus on the mechanism behind neonatal death due to heat exposure.

Step 5: Data extraction and reduction

A data collection form was developed using the PICOT and SPIDER frameworks to collect data on the impact of climate change on birth outcomes. The following information was excluded from the articles: author/s, year, design, objectives, participant age, settings, results, and limitations. The results from the included articles that met the inclusion criteria were coded and analysed thematically to investigate the impact of climate change on birth outcomes worldwide.

Step 6: Analysis

The study developed the themes and sub-themes in Table 2.1.3.

Table 2.1.3: Theme and sub-theme

Theme	Sub-Theme
Climate change affects birth outcomes and newborn and maternal health.	➢ **Sub-theme 1:** Ambient temperature and birth outcomes and maternal health ➢ **Sub-theme 2**: Climate change and newborn health

Theme: Climate change affects birth outcomes and newborn and maternal health

Studies found that climate change has a significant impact on maternal health and newborn health (Castro et al., 2022), which in turn leads to adverse pregnancy effects/outcomes such as premature delivery, low birth weight, and stillbirth. This climate change has been found to harm pregnant women with low socio-economic status (Cherish et al., 2020) and those living in lower to middle-income countries (McElory et al., 2022). This makes the younger generation afraid of getting pregnant due to the fear of facing pregnancy complications due to high ambient temperature exposure (Smith et al., 2023). Environmental factors such as air pollution are associated with adverse reproductive health, such as fertility, miscarriage, and preterm and congenital abnormalities (Papadiouchou et al., 2024). Dumbuya et al., (2024) found that African nations are struggling the most because they cannot adapt or mitigate the impact of climate change due to a lack of resources, which is resulting in a high maternal death rate in Africa.

Sub-theme 1: Ambient temperature on birth outcomes and maternal health

High temperature exposure has a greater impact on birth outcomes (Samuels et al., 2022); it increases heat-related complications such as premature delivery, low birth weight, and stillbirth (Rekha et al., 2023). However, there are disparities in these risks (Son et al., 2022). A systematic review revealed that high ambient temperature is associated with adverse pregnancy outcomes such as preterm, low birth weight, and stillborn in lower-middle-income countries (Lakhani et al., 2024). Heat exposure affects foetal development in utero and impairs postnatal health worldwide (Veras et al., 2024).

Pregnancy complications mostly occurred in pregnant women who were affected by high ambient temperature during their last stage of pregnancy (Nyandanu et al., 2024); high temperature exposure was found to be associated with low blood flow to the placental side during pregnancy (Bonell et al., 2023). Pregnant women mostly suffer from pre-eclampsia as a result of heat stress due to high temperature exposure (Shankar et al., 2023) and increased hospitalisation rates (Kim et al., 2021). A systematic review illustrated that heat exposure has an impact on the non-reassuring foetal status and spontaneous abortion (Lakho et al., 2024), maximum ambient

temperature is associated with a 15% increase in risks of spontaneous abortions (Chusing et al., 2022), and risks of stillbirth delivery due to hot thermal stress in the universal thermal climate index (UTCI) (Khodadi et al., 2022). It has been found that pregnant women and their growing babies with less access to resources to help them mitigate the impact of climate change are more vulnerable to the indirect and direct effects of climate change (Ha, 2022b).

High ambient temperature significantly correlates with dehydration and heat stroke (Lo, 2023). Seasonal temperature exposure contributes to the risks of affecting birth weight in wet seasons (Caninglia et al., 2024), regardless of the pregnant woman's background (Cho,2020). Head circumferences were affected by both hot and cold temperatures; when there is high temperature, foetal head circumference was reduced compared to cold temperature (Esser et al., 2024).

Pregnant women exposed to heat during their first trimesters were likely to deliver low birth weight infants with smaller gestational age due to foetal growth restriction (Basangana et al., 2021; Ranciere et al., 2024; Le & Nguyen, 2021; Hadju & Hadju, 2021). During the first trimester of pregnancy, critical developmental processes occur, including the formation of the placenta and organogenesis. Exposure to heat stress during this period can impair placental development, which in turn reduces the transport of nutrients and oxygen to the fetus throughout gestation. This may lead to fetal growth restriction and low birth weight (Basagana et al., 2021; Rancière et al., 2024).

In the second trimester, the fetus enters a period of growth and organ maturation. Prolonged exposure to high ambient temperatures during this time may disrupt maternal thermoregulation, decrease uteroplacental blood flow, and compromise nutrient delivery. This can lead to intrauterine growth restriction, a condition associated with low birth weight (Le & Nguyen, 2021; Hadju & Hadju, 2021). The third trimester is characterized by rapid fetal weight gain, with up to 50% of birth weight acquired in the final eight weeks. Exposure to extreme heat during this stage is more directly linked to reduced birth weight, premature delivery, and compromised fetal development (Cabanez, 2024). Additionally, gestational diabetes typically worsens in the third trimester, depending on maternal glucose control (Dehdshit et al., 2020).

Babies born to black Mexican women who are uneducated were also more prone to climate change impacts (Kutz,2023). Temperatures above 32°C were associated with very low birth; males were more affected than female infants (Keivabu & Cozzani, 2022), and exposure to cold temperatures is associated with stillborn delivery (Sexton et., 2021; Yang et al., 2022).

Sub-theme 2: Climate change and newborn health

Dimitrova et al., (2024) found that heat exposure increases the risks of neonatal mortality in lower-middle-income countries by 4.3%. The high ambient temperature was associated with neonatal jaundice and hearing loss (Lin et al., 2023), increasing the risk of birth defects for cardiac lesions such as ASDs and VSDs. This contributed to mortality, respiratory and cardiovascular outcomes (Rocque et al., 2021; Haghighi et al., 2021), and congenital heart defects (Dalugoda et al., 2022).

Step 7: Conclusions and implications

Conclusion

Ambient temperature on birth outcomes and maternal health

Rising temperatures have led to more health outcomes and challenges for vulnerable populations, such as pregnant women and their newborn babies. Exposure to high temperature has been associated with maternal and pregnancy complications such as premature delivery, low birth weight delivery, stillborn, pre-eclampsia, and gestational diabetes.

Health implications

When exposed to high ambient temperatures, pregnant women experience dehydration, heat stress, and other heat-related diseases, which affect pregnancy outcomes.

Climate change and newborn health

Climate change affects women during pregnancy, and the heat also impacts the baby, causing symptoms to manifest when the baby is born. Extreme temperatures can lead to developmental delays in newborns, causing growth to occur at an abnormal pace. This is often a result of prolonged exposure to climate change.

These two themes illustrated the link between climate change and birth outcomes by showing how high temperatures and long-term exposure to ambient temperature affect maternal and newborn health.

In summary, these themes show that temperature increases are linked to adverse pregnancy outcomes and newborn health. Further studies are needed to find strategies to mitigate this impact so that our future generation can carry their pregnancy to term without complications.

Declaration of conflict of interest

There was no conflict of interest.

Ethics

The article did not require approval from an ethics committee.

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Article 2.2: The Association Between Climate Change and Birth Outcomes: A Correlational Study at Musina Hospital in Vhembe District, Limpopo Province

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Abstract

Background: Ambient temperature is a significant cause of adverse health outcomes, especially for pregnant women with low socioeconomic status. In Musina, temperatures have shown considerable variation over the years. The rate of premature births was notably high compared to other pregnancy complications, which could be attributed to exposure to high temperatures. This study aimed to determine the correlation between ambient temperature and birth outcomes in Musina Hospital in the Vhembe District of Limpopo Province.

Methodology: This study employed a quantitative approach with a descriptive and correlational design. Data was collected from antenatal records of pregnant women, aged 14 to 40 years, who experienced pregnancy complications at Musina Hospital between January 2019 and December 2022. Purposive sampling was utilized to select the records of those mothers who faced complications during their pregnancies at Musina Hospital in the Vhembe District of Limpopo Province. The sample size was determined using the Krejcie and Morgan table (2006). A self-developed checklist consisting of multiple-choice questions was used to extract data from the records of pregnant women. The data were analyzed using R, Version 4.3.1 (R Development Core Team, 2023), and the results were presented in graphical format.

Findings: The findings revealed a consistent decrease in ambient temperature over the four years, with 2019 recorded as the warmest year. Despite this downward trend, high ambient temperatures, particularly during hotter seasons, were associated with negative birth outcomes. A significant number of pregnant women were affected by pregnancy-induced hypertension, while a high rate of premature births was recorded among neonates. These results indicate a clear relationship between elevated ambient temperatures and adverse maternal and neonatal health outcomes.

Conclusion: The study concludes that precautionary measures are essential to address the effects of climate variability. Educating pregnant women, especially those in high-risk areas, about heat exposure and strategies to mitigate its effects is critical in reducing temperature-related health risks.

Keywords: climate change, high ambient temperatures, foetal outcomes, maternal outcomes

Introduction

Extreme high temperature exposure can cause pregnant women to sweat profusely, leading to dehydration during pregnancy and causing a decrease in blood flow to the placenta, triggering the elevation of antidiuretic hormone and oxytocin, which is responsible for the commencement of labour (Dadvand et al., 2011; Stan et al., 2013). Some researchers found that various stress levels led to the elevation of corticotropin hormones and cortisol, which are responsible for contraction and early labour (Costella et al., 2018). Other researchers have found that pregnant women who are obese have difficulty releasing heat trapped in their bodies, which can negatively affect the growing fetus in utero (Wang et al., 2024). The fetus can also increase maternal heat stress through the metabolic process during warm seasons (Limesand et al., 2018).

The thermoregulation process, meant to cool the body, can fail, leading to overheating. This particularly concerns premature infants and those with low birth weights, as their bodies are less equipped to handle extreme temperatures. As a result, there is an increase in neonatal mortality rates, as well as incidents of sudden infant death, neonatal hypoxia, asphyxia, and potential brain damage (Nakstad et al., 2022; Ozten et al., 2024; Roos et al., 2021; Dimitrova et al., 2024).

Physiological changes due to climate change can significantly impact maternal and newborn health, including anatomical changes that reduce the body's ability to regulate temperature. Thermoregulation is crucial for everyone, especially pregnant women, as it involves sweating to cool the body. When temperatures become excessively high, it can lead to dehydration and heat stress.

Numerous studies indicate that high ambient temperatures during pregnancy can lead to premature delivery, stillbirth, and low birth weight in infants (Zhang et al., 2017; Samuel et al., 2022; Guo et al., 2018; Zhong et al., 2018). These outcomes may be associated with the early release of oxytocin, a hormone that stimulates uterine contractions and can prematurely trigger labor (Roos et al., 2021; Dadvand et al., 2011; Wang et al., 2024; Stan et al., 2013). Extremely high temperatures can also contribute to serious conditions such as pre-eclampsia, eclampsia, pregnancy-induced hypertension (PIH), and gestational diabetes (Part et al., 2022; Beltran et al., 2014; Zhang et al., 2020). Furthermore, elevated temperatures can reduce blood flow to the placenta (Cowell et al., 2023; Limesand et al., 2018; Samuels et al., 2022), which can negatively impact the developing fetus in the uterus. Consequently, the risks of maternal mortality increase due to complications associated with extreme heat exposure during pregnancy.

The WHO (2024) explains that climate change significantly affects vulnerable populations, particularly the elderly and pregnant women. For elderly individuals, increased temperatures can lead to dehydration and a weakened immune system. In pregnant women, exposure to high temperatures can contribute to premature deliveries, low birth weight, stillbirths, and gestational hypertension. Research indicates that a 1% increase in temperature correlates with a 22.4% rise in mortality rates. The year 2023 was noted as exceptionally hot, marking a critical point in the 170-year record of climate emergencies, which include extreme heat and flooding. Some studies suggest that extreme heat exposure, particularly for pregnant women, can adversely affect foetal development, potentially leading to brain damage (WHO, 2023).

A study by Cherish et al.,(2020) found that increasing temperatures negatively affected foetal weight in the womb. Specifically, as temperatures rise, foetal weight tends to decrease more significantly in pregnant women from low socio-economic backgrounds

compared to those from higher socio-economic statuses. Furthermore, research indicates that exposure to extremely high temperatures during pregnancy is associated with stillbirths, perhaps because pregnant women's immune systems are compromised (Hajdu & Hajdu., 2021; McElroy et al., 2021; Chen et al., 2020; Davenport et al., 2020). Additionally, pregnant women often give birth earlier than expected, and some experience shorter gestations, resulting in less developed fetuses. This is attributed to exposure to ambient temperatures during pregnancy (Barreca & Schaller, 2020; Wad et al., 2019). Notably, Black pregnant women are disproportionately likely to experience these adverse effects during pregnancy (Bekkar et al., 2020).

The human body, including that of a pregnant woman, maintains a normal temperature range between 35-37°C. When temperatures exceed this range, it poses potential risks, such as miscarriage, stillbirth, and other bodily harm (Asamoah et al., 2018). Adverse effects during pregnancy, such as preterm delivery, are more common in warmer seasons compared to winter (Min et al., 2024; Mohammed et al., 2019). Pregnant women are particularly vulnerable to environmental temperature extremes, leading to negative pregnancy outcomes. These outcomes may include damage to the endocrine system, infertility, intrauterine growth restriction, low birth weight infants, and premature births. Such conditions can result in hormonal dysregulation and various health complications for newborns (Yuzen et al., 2023; Ha et al., 2022).

A study by Dehdashit et al., (2020) highlights the negative impact of exposure to high ambient temperatures on pregnant women and the elderly. This exposure is linked to adverse pregnancy outcomes, such as autism, low birth weight, neonatal mortality, cleft palate, heat disorders (Pandipati et al., 2023; Smith et al., 202; Olson et al., 2020), and neonatal jaundice in newborns (Lin et al., 2023). Additionally, research focusing on Gambian women farmers reveals that those who rely on farming for their livelihood face significant challenges during hot seasons. Many report symptoms such as dizziness, dehydration, nausea, placenta previa, eclampsia (uncontrollable high blood pressure), and general body weakness due to extreme heat exposure (Spencer et al., 2022; Mohammed et al., 2023).

Pregnant women living in developing countries are particularly vulnerable to high temperatures, especially during the first and second trimesters of their pregnancy.

Research by Hu and Li(2019) found that high temperatures are associated with lower foetal weight, while studies by He et al., (2018) indicate that the third trimester is linked to an increased risk of placental abruption.

Many pregnant women facing these challenges are teenagers who lack education and live unhealthy lifestyles due to poverty. This situation increases the likelihood of decreased birth rates and deterioration of female reproductive health, as well as a higher incidence of heat-related diseases, such as heat stroke. In contrast, educated pregnant women who can afford resources are better equipped to enjoy a healthy lifestyle. They possess the knowledge necessary to take precautionary measures, enabling them to carry their pregnancies to term with fewer complications (Sorensen et al., 2018; Cho et al., 2020; Barreca et al., 2018).

The researchers are of the view that climate change refers to variations in environmental temperatures, which can be high or low depending on the season. Birth outcomes refer to pregnancies influenced by exposure to these environmental temperatures. Studies conducted in other countries have shown that exposure to high temperatures can lead to adverse pregnancy outcomes, such as premature delivery, stillbirth, and low birth weight. Those years were among the warmest recorded in Africa, leading to an increased number of hospital admissions for pregnancy-related issues such as premature births, stillbirths, low birth weight, neonatal deaths, and macerated babies. Additionally, high temperatures are a leading cause of neonatal mortality in South Africa (Nakstad et al.,2022).

To address these challenges, implementing policies, distributing pamphlets, and providing health education regarding climate change and its potential impact on birth outcomes will help mitigate these risks. Pregnancy complications can arise from exposure to high ambient temperatures, particularly for pregnant women at high risk, such as those living in Matwale Village and Nancefield, which are the hottest areas in Musina. Many reproductive women from these regions experience significant complications during pregnancy.

In the Limpopo Province, many studies related to climate change have been conducted; however, none have specifically examined the potential impact of climate change on birth outcomes. The researcher determined the relationship between

ambient temperature and birth outcomes, highlighting how these two variables are interconnected.

Material and methods

The study used a quantitative methodology, incorporating both descriptive and correlational designs to explore the relationship between climate change and its potential impact on birth outcomes in Musina Hospital in the Vhembe District of Limpopo Province. This approach aimed to deepen our understanding of how climate change may correlate with birth outcomes. Specifically, the study examined the records of pregnant women who experienced adverse effects such as premature delivery, low birth weight, and stillbirth from 2019-2022.

Purposive sampling was used to select the specific records required for this study. The sample size was determined using the Krejcie and Morgan table (2006). 121 records were found in the Musina database. The inclusion criteria for this study were the records of pregnant women who experienced adverse pregnancy outcomes and delivered in Musina Hospital, aged between 14 and 40 years, from 2019 to 2022. Data were collected using a self-developed checklist.

Data collection took place in a quiet office accessible only to the researcher, ensuring privacy at all times. The researcher was the sole person with access to the office keys, as the patient records were confidential and restricted from access by others.

The checklist consisted of multiple-choice questions about climate change and its potential impact on birth outcomes. The questionnaire consisted of the following sections: Section A (demographic data), Section B (climate-related variables that are determinant to pregnancy), Section C (maternal conditions related to climate change), and Section D (neonatal outcomes related to climate change). Each patient's information was recorded on a questionnaire, and every paper was labelled MUS 1, MUS 2, etc., to avoid using patient file numbers or names.

Ethical considerations

The research committee of the DOH in Limpopo Province, Vhembe District, along with the university's ethics committee, approved the conduct of the study. Approval letters were issued, permitting data collection for the research (Ethical Clearance No:

FHS/24/NUT/08/208). This study focused on patient records from 1 January 2019 to 31 December 2022.

To maintain anonymity, only the hospital's name and a unique identifier (e.g., Mus 1) were used to reference each patient. The patient records were provided to the researcher by the registry staff, with both the researcher and the registry personnel signing a record to confirm the transaction. The same procedure was followed when the patient records were returned. The researcher emailed the requested documents to the Musina Hospital, namely the Limpopo DOH approval letter and district letter, to prepare everything that was needed to collect data. To ensure privacy, the researcher was given an empty room with a table and a chair to review the patient records. For confidentiality, the room had a key and was accessible only to the researcher, with no other person allowed access. A clean desk policy was implemented, documents were securely locked, and never left on the table to prevent unauthorized access or attract unwanted attention.

Data analysis

The collected data were stored on an Excel spreadsheet. The temperature data were tested for normality using the Shapiro-Wilk normality test (Souza et al., 2023). A linear regression model was used to analyse the temperature, and data were analysed using R, Version 4.3.1(R Development Core Team, 2023). Data was presented using graphs.

Results

The results show a negative correlation between average ambient temperature and successive years (Figure 2.2.1). Temperature decreased with successive years, which was not significant (R= - 0.16; p >0.065). Throughout the successive years, the results show that the most pronounced maternal condition was pregnancy-induced hypertension compared to other maternal conditions (Figure 2.2.2); however, on the neonatal side, the most pronounced neonatal outcome is premature compared to other neonatal outcomes (Figure 2.2.3).

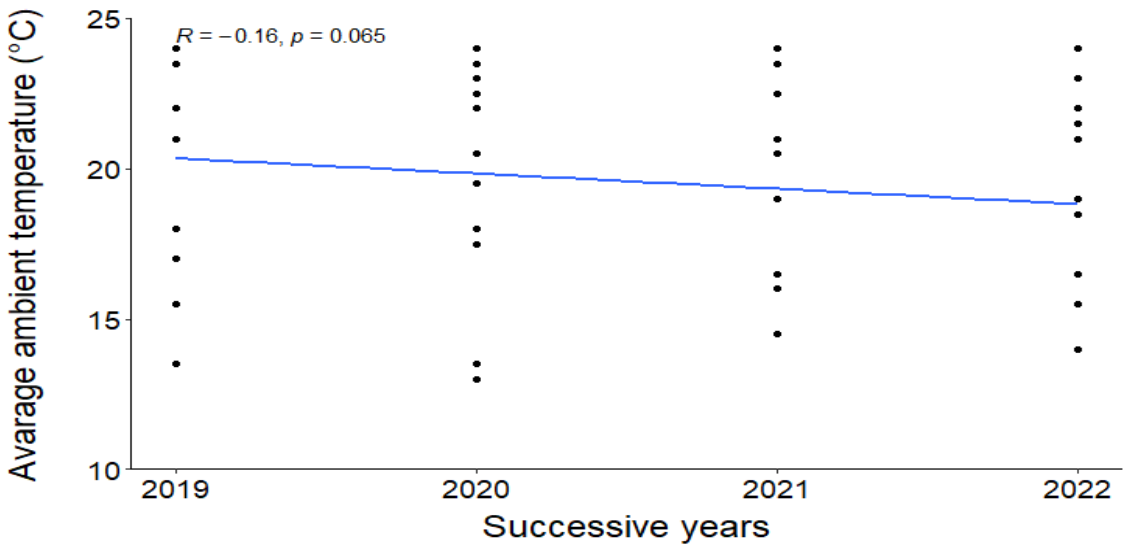

Figure 2.2.1: Variation in temperatures over successive years

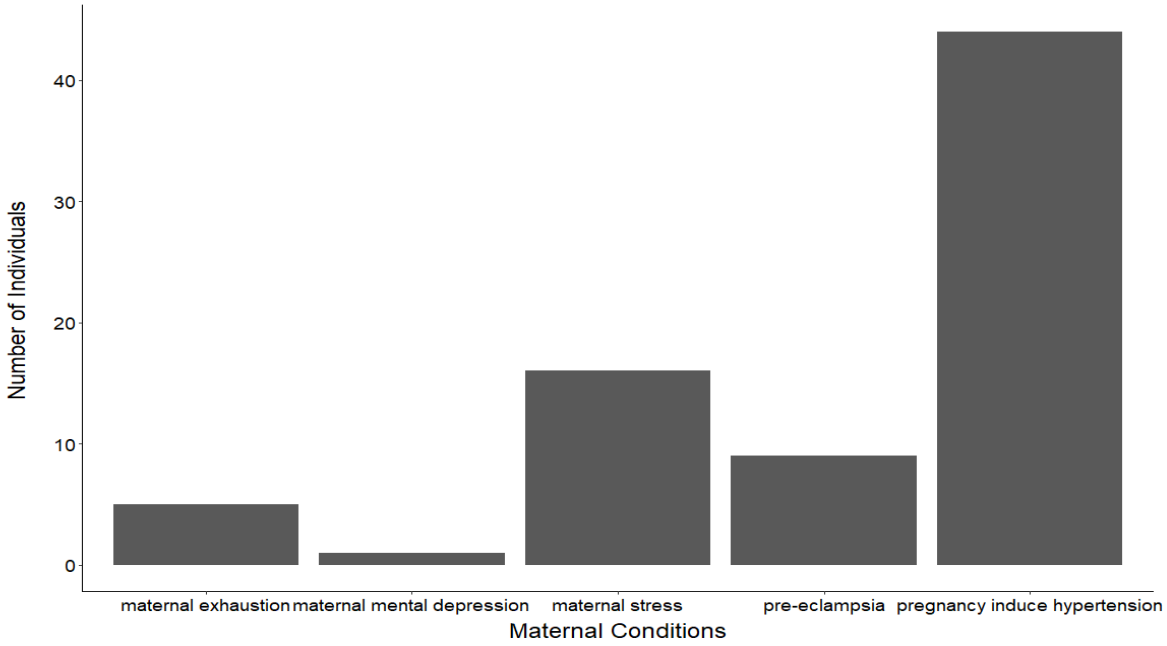

Figure 2.2.2: Number of individuals who faced adverse pregnancy outcomes and their maternal conditions

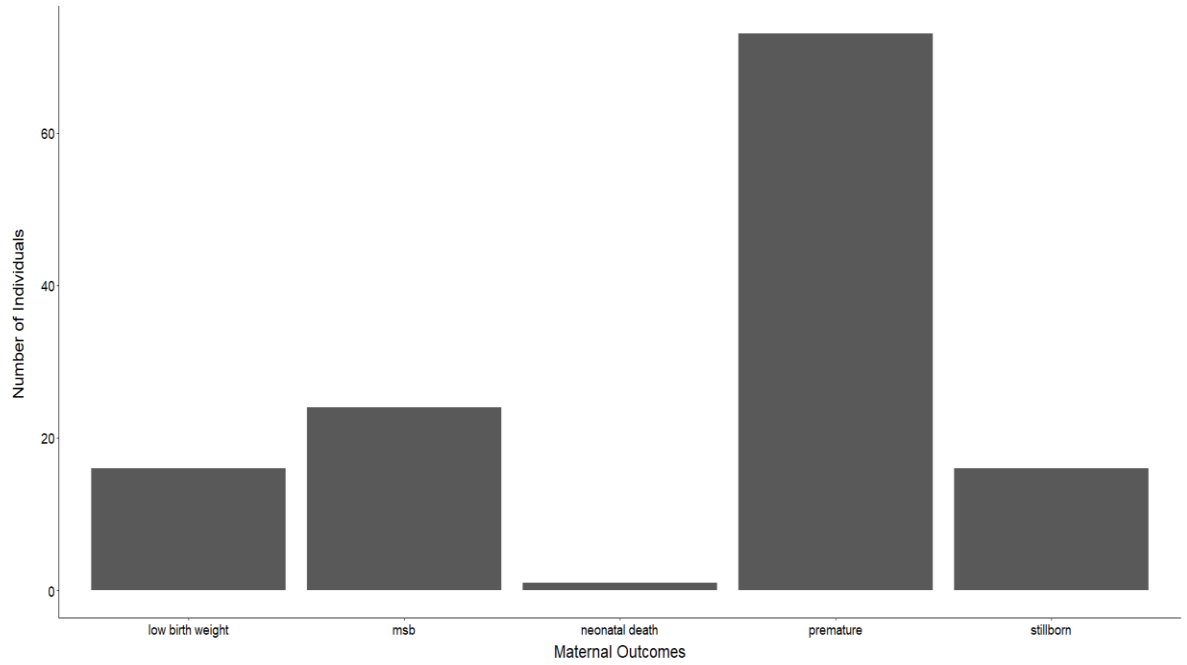

Figure 2.2.3: Number of infants born prematurely, with low birth weight, and stillborn, who experienced neonatal death

Discussion

The study determines the correlation between ambient temperature and birth outcomes in Musina, Vhembe District, Limpopo Province. The findings revealed a negative correlation, indicating that as temperature increase there is a corresponding decline in favourable birth outcomes. The study demonstrated that pregnant women exposed to higher temperatures are more likely to experience various complications during pregnancy ,highlighting the significant impact of environmental heat stress on maternal and neonatal health.

In East Asia countries as China, Japan, and Korea, significant temperature decreases have been observed in association with the passage of a cold front. For instance, (Zhou et al., (2020) documented a sharp drop in temperature up to -27,6°c in the United States, highlighting the intensity of these cold air outbreaks. Similarly,(Ha et al.,2017)noted that such temperature drops occur seasonally, typically when the strong cold fronts advance into the region. This study revealed a notable downward trend in ambient temperature in Musina, Vhembe District, Limpopo Province, over the period 2019–2022, with a strong negative correlation between temperature and

successive years. The year 2019 recorded the highest temperatures, aligning with national and global reports, including Blunden et al. (2024), who cited 2019 as South Africa's warmest year. According to the National Center for Environmental Information (2019), global average temperatures increased by +0.95°C, with Southern Hemisphere regions like Africa, Australia, and Madagascar among the most affected.

From 2020 to 2022, the study observed a progressive decline in temperature, averaging below 20°C, marking a shift toward colder climatic patterns. The Annual Global Report (2022) also identified 2022 as a year of significantly lower temperatures. Despite this cooling trend, both extreme heat and cold temperatures were associated with adverse maternal and neonatal outcomes, supporting findings from Bonell et al. (2023) and Bekkar et al. (2020). One of the key findings of this study is that pregnant women are highly vulnerable to extreme temperatures, particularly during the first trimester. High ambient temperature exposure was significantly linked to maternal stress, with 18 women in the study reporting heat-induced stress. While a few cases of stress were attributed to family or social issues, environmental temperature was the predominant stressor, reinforcing conclusions from Baharav et al. (2023) and Lin et al. (2017b).

Furthermore, this study recorded increased rates of pregnancy-induced hypertension, more than any other maternal condition. This supports previous research indicating that extreme heat exposure increases the risk of pre-eclampsia and eclampsia, especially in early pregnancy (Xiong et al., 2020; Quan et al., 2023; Part et al., 2022b). Comparable studies in China also confirm that high temperature exposure during early pregnancy is strongly associated with hypertensive disorders (Zeng et al., 2024; Mao et al., 2023).

In terms of birth outcomes, this study revealed a high rate of premature deliveries, making it one of the most prevalent neonatal complications linked to temperature extremes in Musina. While neonatal death was rare, high ambient temperature remains a contributing factor, as also noted in global studies (Nakstad et al., 2022; Lakho et al., 2022). Premature neonates were frequently reported to suffer from developmental issues, including impaired brain function, hearing loss, and visual deficits, in line with WHO (2023) findings. Additionally, this study affirms that heat exposure negatively affects fetal development, particularly in early pregnancy,

corroborating the findings of Kuehn et al. (2017) and Rylander et al. (2013). Adverse outcomes such as low birth weight, stillbirth, and delayed conception were frequently observed, echoing prior studies by Korsa et al. (2021), Demarco et al. (2021), and Zhang & Yu (2017).

Importantly, the study also suggests that climatic patterns may influence birth trends in the long term. Cho (2019) and Dimitrova et al. (2024) reported associations between high temperature exposure and decreased birth rates, a pattern which may be emerging in regions like Musina due to persistent climate extremes.

Interestingly ,the study observes that pregnant women most affected by these conditions tended to share socio-economic characteristics;+, most were unemployed, of unknown occupational status, single ,living in rural or border Areas(such as Beitbridge),and age between 14 and 40 years. These findings highlight the vulnerability low socio-economic groups to climate related health challenges. Both extremely hot and cold temperatures were noted to negatively affect pregnancy outcomes (Ren et al., 2021).

Despite challenges in data retrieval due to missing records, incomplete entries, and the transfers of high-risk pregnant women to other healthcare facilities, the study still uncovered the critical patterns. Although Musina Hospital recorded fewer complications between 2019-2022, anecdotal and registry-based evidence suggest that complications began to increase in 2023. The data gaps underscore the need for improved health information systems and record-keeping in rural health facilities.

The study focused on one district in Limpopo; thus, the study should be replicated in various regions that experience extremely high temperatures during the summer season. Future studies should examine the factors linked to maternal and neonatal health due to long-term temperature exposure during pregnancy.

The findings of this study underscore the impact of extremely high temperatures on birth outcomes and public health, urging the need for urgent actions to mitigate the effects of climate change, particularly for pregnant women from low socio-economic backgrounds. Additionally, the study will raise community awareness about the risks of extreme temperature exposure and guide measures to support pregnant women at risk.

Recommendations

It was found that high ambient temperature is indeed associated with negative birth outcomes, namely premature birth, low birth weight, stillborn, etc., including maternal conditions such as pregnancy-induced hypertension, pre-eclampsia, eclampsia, and so on. We must develop strategies to protect pregnant women against the impact of high ambient temperature exposure. The healthcare system should develop a programme to guide pregnant women on the risk of high ambient temperature exposure, including a monitoring section for those who are at risk of adverse pregnancy effects. An awareness campaign should be developed to teach community members about the impact of high ambient temperature exposure and coping strategies during hot seasons. The government should build a climate-resilient infrastructure to protect pregnant women against heat exposure during warm seasons. A policy consisting of regulations and legislation to reduce all kinds of environmental exposure must be developed, while attention should be paid to pregnant women of low socio-economic status and those who are unemployed. Finally, future studies should examine various factors linked to maternal and neonatal health due to long-term temperature exposure during pregnancy.

Conclusion

Numerous studies worldwide indicate that ambient temperatures negatively impact birth outcomes (Zhang et al., 2017; Samuel et al., 2022; Guo et al., 2018; Zhong et al., 2018). High temperatures can lead to premature deliveries, stillbirths, and low birth weights, as well as maternal complications such as eclampsia, pre-eclampsia, and increased maternal stress. A recent study highlights that the temperature varies from year to year, and it finds a significant association between ambient temperatures and adverse maternal conditions and pregnancy outcomes from 2019-2022. The rate of premature births was notably high compared to other birth outcomes, and incidents of pregnancy-induced hypertension were elevated to other maternal conditions.

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Article 2.3: Impact of Ambient Temperature on Seasonal Variations in Birth Weight in Musina Hospital, Limpopo Province

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Abstract

Background: Seasonal fluctuation in ambient temperature, particularly elevated heat exposure during pregnancy, has been increasingly associated with adverse birth outcomes, including intrauterine growth restriction and reduced infant birth weight. This climatic stress not only compromises fetal development but also contributes to a surge in healthcare facility deliveries, highlighting a pressing public health concern amidst ongoing global climate change. The study aims to determine the relationship between seasonal temperature changes and infant birth weight in Musina Hospital in the Vhembe District, Limpopo Province.

Methodology: This study employed a quantitative research approach, utilizing a descriptive and correlational research design to examine the relationships between variables. The population of this study was the records of pregnant women who only delivered low birth weight infants in Musina Hospital, Vhembe District, Limpopo Province. The sample size of this study was 121 patient records. Additionally, the sample size was determined using the Krejcie and Morgan table. Data were collected using a self-developed checklist comprised of yes/no questions. The data were analyzed using R, Version 4.3.1 (R Development Core Team, 2023). The results were presented through graphs.

Results: The results indicate negative and positive correlations between seasonal temperatures and infant birth weight. Specifically, birth weight tends to decrease as temperatures increase during summer. Conversely, birth weight tends to increase

when temperatures are milder, such as in spring, autumn, and winter. Exposure to high ambient temperatures was notably greater during the summer compared to other seasons. There was insufficient information regarding trimester data because many mothers did not attend antenatal appointments consistently throughout all three trimesters. Most mothers did not attend during the first trimester; some began attending in the second, while others started only in the third trimester. This lack of attendance made it difficult for the researchers to gather adequate data on the impact of seasonal temperature and trimester weight.

Conclusion: Seasonal temperatures were associated with foetal growth restrictions, particularly during summer when the heat was more intense compared to other seasons.

Keywords: pregnancy outcomes, heat stress, seasonal temperature, foetal growth restrictions, birth weight

Introduction

A study conducted in Hungary between 2000 and 2016 shows that an increase in temperature results in a decrease in infant birth weight, particularly when examining singleton births during the first trimester, which is considered the most sensitive period (Hadju & Hadju,2021). Birth weight tends to be positively affected in cooler or colder temperatures, while higher temperatures are associated with lower birth weights (Hadju & Hadju, 2021b). The mechanism behind exposure to high ambient temperatures is its potential impact on birth weight (Grace et al., 2015), particularly during the third trimester of pregnancy. High temperatures reduce nutrient and oxygen supply to the placenta, which may result in low birth weight at delivery (Zhang et al., 2015; Limesand et al., 2018b). This issue can arise from decreased uterine blood flow, increased hormonal stress production, and placental damage due to heat stress (Cowell et al., 2023).

Additionally, low temperatures can negatively affect foetal development in utero (Limesand et al., 2018c). As a result, altered blood flow and heightened metabolic demands on the fetus can also occur. However, Ding et al., (2023) found that high ambient temperatures significantly affect birth outcomes during the second trimester, while the first trimester is particularly important for foetal development, including

weight. Both hot and cold weather temperatures can affect birth weight by influencing the placenta, which plays a crucial role in foetal health and growth, leading to potential growth restrictions and other complications (Coswell et al., 2023b; Wulayin et al., 2023). Alterman et al., (2024) noted that exposure to ambient temperatures during early to mid-pregnancy, as well as the first few months postnatally, is linked to changes in infant weight gain. Conversely, Esser et al., (2024b) found that exposure to high ambient temperatures impacts foetal head circumference in utero, depending on whether the mother was exposed to hot or cold temperatures during pregnancy, as noted by Du et al., (2022).

Chen et al., (2020) and Hadju and Hadju, (2021c) noted that male infants are more affected than females in this context. Additionally, Yitshak et al., (2019) concluded that exposure to high ambient temperatures negatively impacts the weight of the developing fetus, leading to low birth weight, as supported by findings from Ha et al., (2017b) and Basu et al., (2018b). Birth weight varies between winter and summer seasons. However, high summer temperatures also impact pregnant women during their second trimester of pregnancy (Ha et al., 2022b). Exposure to high ambient temperatures has been found to affect human fertility, leading to a decrease in birth weight (Thiede et al., 2022; Jakpor et al., 2020). According to Le and Nguyen (2021), when pregnant women are exposed to elevated temperatures in the summer, foetal growth is adversely affected, particularly during the first trimester.

Cold temperatures are indeed associated with increased infant or birth weight, as noted by Basangane et al. (2021). However, only a few studies have explored this issue within specific trimesters and their effects on birth weight, such as research conducted by Cherish et al., (2020), Lawrence et al., (2021), and Yistshak et al., (2020b). In contrast, studies by Ha et al., (2017c), Kloog et al., (2018), Sun et al., (2019), and Yistshak et al., (2020c) examined all pregnancy trimesters but did not specify temperature exposure during the individual trimesters. Low birth weight is one of the root causes of neonatal mortality, morbidity, and abnormalities (Tadesse et al., 2021). A study conducted by Rashid et al., (2017) found that temperature has a more significant impact on infants born in the summer than those born in other seasons, which also affects their length.

Additionally, there is a reduction in birth weight for infants born at exactly 40 weeks of gestation (Sun et al., 2019b). Various weather conditions and seasons are associated with birth outcomes (Grace et al., 2021b). Studies have shown that ambient temperatures can fluctuate with the seasons, negatively impacting the growing fetus in utero.The researcher was motivated to conduct this study to educate the community and provide strategies for managing the effects of ambient temperature exposure, particularly for pregnant women at higher risk. This study aimed to determine the relationship between seasonal ambient temperatures and birth weight in Musina Hospital in the Vhembe District, Limpopo Province.

Material and method

The study employed a quantitative methodology with descriptive and correlational designs to investigate the relationship between seasonal temperature exposure and the birth weight of infants in Musina Hospital in the Vhembe District, Limpopo Province.

The population consisted of 121 medical records indicating the birth weight of all infants among pregnant women who experienced adverse effects during pregnancy from 1 January 2019 to 31 December 2022. Non-probability purposive sampling was utilised to select 121 records of pregnant women who delivered low birth weight infants in Musina Hospital, Vhembe District, Limpopo Province. Data were collected from these records using a checklist consisting of yes/no questions. The self-developed checklist had four sections, namely Sections A to D. Section A consisted of demographic data, Section B focused on climate-related variables that are determinant to pregnancy, Section C focused on maternal conditions related to climate change, and Section D focused on neonatal outcomes related to climate change. The researcher was provided with an empty office containing a chair and a table to review these records. This arrangement ensured confidentiality and privacy, as access was granted only to the researcher who had permission to examine the records. The promoters served as guides to assist the researcher in navigating the study discussion, ensuring alignment with the research topic. All questions were answered by reviewing the patient's medical records, and no questions were left unanswered.

Ethical considerations

The research committee of the DOH in Limpopo Province, Vhembe District, along with the university's ethics committee, approved the conduct of the study. Approval letters were issued, permitting data collection for the research (Ethical Clearance No: FHS/24/NUT/08/208). This study focused on patient records from January 1, 2019, to December 31, 2022.

To maintain anonymity, only the hospital's name and a unique identifier (e.g., Mus 1) were used to reference each patient. The patient records were provided to the researcher by the registry staff, with both the researcher and the registry personnel signing a record to confirm the transaction. The same procedure was followed when the patient records were returned. The researcher emailed the requested documents to the Musina Hospital, namely the Limpopo DOH approval letter and district letter, to prepare everything that was needed to collect data. To ensure privacy, the researcher was given an empty room with a table and a chair to review the patient records. For confidentiality, the room had a key and was accessible only to the researcher, with no other person allowed access. A clean desk policy was implemented, documents were securely locked, and never left on the table to prevent unauthorized access or attract unwanted attention.

Data analysis

The data collected was organized using Excel spreadsheets. The normality of seasonal temperature data was assessed using the Shapiro-Wilk test (Souza et al.,2023). A linear regression model was employed to analyze the relationship between seasonal temperature and birth weight. All statistical analyses were conducted using R, Version 4.3.1 (Developmental Core Team,2023), and the results were presented in graph form.

Results

Demographic Profile

A total of 121 patient records were included in the study.

Table 2.3.1a: Demographic profile

patient	year	seasons(lpm)	minimum temp	maximum temp	weight in trimester 1 (g)	weight in trimester 2 (g)	weight in trimester 3 (g)	birth season
Mus 1	2020	autumn	13	33	0	680	0	spring
Mus 2	2019	summer	13	34	0	680	0	winter
Mus 3	2019	summer	13	34	0	400	680	autumn
Mus 4	2019	spring	5	31	0	595	1497	autumn
Mus 5	2019	summer	15	33	4	0	0	spring
Mus 6	2021	summer	14	31	0	230	1300	spring
Mus 6	2021	summer	14	31	0	230	1300	spring
Mus 7	2019	summer	12	32	0	595	0	spring
Mus 8	2021	winter	1	26	0	680	1760	autumn
Mus 9	2021	summer	14	33	23	0	0	winter
Mus 10	2020	summer	16	32	0	400	1300	winter
Mus 11	2020	summer	16	32	0	400	1300	winter
Mus 12	2019	summer	15	33	0	0	1900	spring
Mus 13	2021	summer	12	32	0	0	1600	spring
Mus 14	2022	summer	13	33	0	386	1760	spring
Mus 15	2021	autumn	13	32	0	530	1300	spring
Mus 16	2020	spring	6	35	0	530	0	autumn
Mus 17	2022	autumn	8	29	0	595	1400	winter
Mus 18	2020	spring	10	34	4	530	0	autumn
Mus 19	2020	spring	10	34	0	0	1500	winter
Mus 20	2020	spring	6	35	0	530	1300	autumn

Mus 21	2021	spring	4	28	0	530	1760	autumn
Mus 22	2021	autumn	4	28	40	680	1050	summer
Mus 23	2021	spring	7	34	0	530	1800	summer
Mus 24	2019	winter	4	27	14	680	1050	spring
Mus 25	2021	spring	13	35	0	530	0	autumn
Mus 26	2019	summer	15	33	0	1000	1966	spring
Mus 27	2018	winter	5	26	0	530	0	summer
Mus 28	2018	spring	10	34	0	300	2333	winter
Mus 29	2018	spring	10	34	0	760	2350	winter
Mus 30	2018	summer	13	35	0	530	1300	winter
Mus 31	2021	winter	3	26	0	530	1300	summer
Mus 32	2019	summer	15	33	0	300	2000	winter
Mus 33	2020	spring	6	35	40	530	1100	summer
Mus 34	2019	winter	4	25	0	530	680	summer
Mus 35	2020	winter	2	25	0	560	1660	summer
Mus 36	2020	winter	0	26	0	530	0	summer
Mus 37	2020	winter	0	26	0	530	0	summer
Mus 38	2019	autumn	6	29	0	530	1700	summer
Mus 39	2022	winter	6	25	14	680	1060	autumn
Mus 40	2021	spring	13	35	0	760	0	winter
Mus 41	2021	summer	14	31	14	680	1600	spring
Mus 42	2018	summer	13	35	0	300	1900	spring
Mus 43	2018	spring	8	34	43	530	1300	autumn
Mus 44	2021	autumn	8	30	0	900	2600	summer
Mus 45	2022	summer	13	33	0	0	1900	winter
Mus 46	2020	spring	6	35	0	0	1945	winter
Mus 47	2018	summer	13	35	23	530	1750	spring
Mus 48	2018	autumn	14	33	0	595	1700	summer
Mus 49	2019	spring	5	31	0	530	1050	summer
Mus 50	2019	spring	14	34	23	0	0	winter

Mus 51	2019	winter	4	27	0	530	1300	summer
Mus 52	2018	winter	5	26	14	530	1500	summer
Mus 53	2022	spring	13	31	0	530	800	winter
Mus 54	2021	spring	7	34	0	530	1922	winter
Mus 55	2018	summer	13	35	0	530	1300	winter
Mus 56	2021	summer	14	31	0	875	0	winter
Mus 57	2022	autumn	2	25	0	530	1700	autumn
Mus 58	2021	autumn	7	26	0	0	2405	summer
Mus 59	2021	winter	1	26	0	0	1300	summer
Mus 60	2021	autumn	7	26	0	530	1800	summer
Mus 61	2021	winter	1	26	0	530	1000	summer
Mus 62	2021	spring	13	35	0	430	2000	winter
Mus 63	2021	winter	4	28	0	430	0	autumn
Mus 64	2018	winter	3	25	0	416	1700	autumn
Mus 65	2019	autumn	11	31	0	0	2370	summer
Mus 66	2018	autumn	9	27	0	760	1910	summer
Mus 67	2018	winter	5	26	0	0	1200	summer
Mus 68	2018	winter	5	26	14	530	1900	autumn
Mus 69	2018	spring	14	31	0	400	1200	summer
Mus 70	2018	winter	5	26	0	443	1300	summer
Mus 71	2018	winter	6	30	0	600	0	autumn
Mus 72	2020	autumn	2	25	0	500	0	summer
Mus 73	2018	winter	3	25	0	367	1600	autumn
Mus 74	2020	summer	13	35	14	530	1750	autumn
Mus 75	2021	spring	4	28	0	710	1300	autumn
Mus 76	2021	spring	7	34	0	530	1700	winter
Mus 77	2022	summer	13	30	0	0	300	winter
Mus 78	2022	autumn	5	26	0	1200	0	spring
Mus 79	2018	spring	8	34	0	1000	0	winter
Mus 80	2019	spring	14	34	0	386	1600	winter

Mus 81	2018	autumn	14	33	0	830	1900	summer
Mus 82	2018	winter	5	35	0	7	300	autumn
Mus 83	2021	autumn	8	30	0	760	1766	summer
Mus 84	2021	autumn	13	32	0	0	2604	summer
Mus 85	2019	summer	15	33	0	1200	0	spring
Mus 86	2019	spring	14	34	0	530	1300	winter
Mus 87	2018	autumn	14	33	0	800	1420	summer
Mus 88	2019	summer	12	32	0	830	0	winter
Mus 89	2019	spring	14	34	0	530	1505	winter
Mus 90	2019	autumn	11	31	0	530	1325	summer
Mus 91	2019	winter	4	27	0	530	1953	autumn
Mus 92	2019	winter	5	31	0	0	2000	winter
Mus 93	2019	spring	14	34	0	660	1300	winter
Mus 94	2019	summer	13	34	0	680	1500	winter
Mus 95	2019	summer	13	34	0	530	1806	spring
Mus 96	2020	autumn	13	32	0	660	1300	spring
Mus 97	2020	autumn	13	32	0	595	2000	summer
Mus 98	2019	spring	5	31	0	530	900	autumn
Mus 99	2020	spring	10	34	0	560	1375	winter
Mus 100	2020	autumn	2	25	0	560	2205	summer
Mus 101	2020	winter	0	26	0	680	1300	autumn
Mus 102	2020	winter	5	30	0	530	1983	summer
Mus 103	2020	autumn	2	25	0	760	2000	summer
Mus 104	2019	spring	14	34	0	449	1270	winter
Mus 105	2019	spring	5	31	0	0	2100	winter
Mus 106	2019	summer	13	34	0	530	0	winter
Mus 107	2020	winter	5	30	0	660	1375	autumn
Mus 108	2021	summer	12	32	0	530	1700	spring
Mus 109	2020	summer	13	32	0	530	2000	spring
Mus 110	2021	spring	6	32	0	595	1380	autumn

Mus 111	2021	autumn	13	32	0	600	0	spring
Mus 112	2019	spring	5	31	14	530	1970	autumn
Mus 113	2021	spring	6	32	14	300	1300	winter
Mus 114	2021	winter	2	26	0	530	1300	spring
Mus 115	2021	autumn	8	30	0	300	1830	summer
Mus 116	2019	summer	12	32	0	530	1570	spring
Mus 117	2019	spring	10	37	0	575	2225	winter
Mus 118	2019	spring	14	34	14	595	1700	winter
Mus 119	2019	winter	1	26	0	530	1700	autumn
Mus 120	2018	winter	5	26	0	530	1575	autumn
Mus 121	2018	winter	3	25	0	386	0	summer

Table 2.3.1b: Demographic profile

patient	patient age	marital status	gestational age	infant weight	infant sex	mini temp	maxi temp	average temp	maternal condition	Current pregnancy outcome	employment status
Mus 1	15	unknown	38	1980	female	13	33	23	pre-eclampsia	low birth weight	employed
Mus 2	19	single	38	1720	female	13	34	23,5	Pregnancy-induced hypertension	stillborn	unknown
Mus 3	18	single	40	2380	male	5	31	18	maternal stress	low birth weight	unemployed
Mus 4	20	singe	38	2280	female	15	33	24	none	stillborn	unemployed
Mus 5	19	stable relationship	38	2320	male	14	31	22,5	pre-eclampsia	stillborn	unknown
Mus 6	16	single	38	2260	female	14	31	22,5	none	low birth weight	student
Mus 7	26	single	39	2160	male	12	32	22	maternal exhaustion	stillborn	unemployed
Mus 8	25	single	39	1600	female	1	26	13,5	maternal stress	stillborn	employed
Mus 9	22	single	40	2100	female	14	33	23,5	Pregnancy-induced hypertension	low birth weight	unemployed
Mus 10	20	single	40	2500	male	16	32	24	Pregnancy-induced hypertension	low birth weight	employed
Mus 11	37	married	38	2390	male	16	32	24	Pregnancy-induced hypertension	stillborn	unemployed
Mus 12	24	single	33	1450	male	16	32	24	Pregnancy-induced hypertension	premature	employed

Mus 13	38	married	38	2180	female	15	33	24	Pregnancy-induced hypertension	stillborn	unemployed
Mus 14	22	married	38	2290	male	12	32	22	Pregnancy-induced hypertension	low birth weight	unknown
Mus 15	21	stable relationship	38	1570	female	13	33	23	Pregnancy-induced hypertension	low birth weight	unemployed
Mus 16	34	married	38	2300	female	13	32	22,5	Pregnancy-induced hypertension	low birth weight	unemployed
Mus 17	31	single	38	2100	male	6	35	20,5	Pregnancy-induced hypertension	stillborn	unemployed
Mus 18	18	stable relationship	38	2300	male	8	29	18,5	Pregnancy-induced hypertension	stillborn	unknown
Mus 19	40	stable relationship	39	2020	male	10	34	22	none	low birth weight	unemployed
Mus 20	15	single	32	1497	female	10	34	22	none	premature	employed
Mus 21	18	single	28	1670	female	6	35	20,5	Pregnancy-induced hypertension	premature	unemployed
Mus 22	20	unknown	26	900	male	4	28	16	maternal stress	premature	unemployed
Mus 23	23	single	32	1340	female	4	28	16	Maternal stress	premature	employed
Mus 24	30	Stable relationship	35	1500	male	4	28	16	Pregnancy-induced hypertension	premature	employed
Mus 25	15	single	28	980	female	15	33	24	none	msb	student
Mus 26	21	single	30	1300	female	15	33	24	maternal stress	premature	employed
Mus 27	38	married	38	2500	male	15	33	24	Pregnancy-induced hypertension	stillborn	employed

Mus 28	18	single	31	1400	male	10	34	22	Pregnancy-induced hypertension	msb	unemployed
Mus 29	30	married	30	1966	male	10	34	22	none	premature	unknown
Mus 30	40	stable relationship	30	2350	male	13	35	24	maternal stress	msb	employed
Mus 31	31	stable relationship	28	1600	femal e	3	26	14,5	maternal stress	premature	employed
Mus 32	14	unknown	35	2506	femal e	15	33	24	maternal stress	premature	student
Mus 33	18	single	37	2025	male	15	33	24	Pregnancy-induced hypertension	Low birth weight	unemployed
Mus 34	21	Stable relationship	36	1900	male	2	25	13,5	Pregnancy-induced hypertension	premature	unknown
Mus 35	16	unknown	34	1945	femal e	2	25	13,5	Pregnancy-induced hypertension	premature	student
Mus 36	18	single	32	1922	femal e	0	26	13	Pregnancy-induced hypertension	premature	unemployed
Mus 37	22	single	30	1400	male	0	26	13	none	msb	employed
Mus 38	28	married	29	1350	male	6	29	17,5	pre-eclampsia	msb	employed
Mus 39	16	single	32	1050	femal e	6	29	17,5	Pre-eclampsia	msb	student
Mus 40	17	stable relationship	28	1500	femal e	13	35	24	pre-eclampsia	premature	unemployed
Mus 41	35	Stable relationship	38	2550	male	13	35	24	Pregnancy-induced hypertension	Low birth weight	employed
Mus 42	15	single	32	1650	femal e	13	35	24	Pregnancy-induce hypertension	stillborn	student

Mus 43	19	stable relationship	30	1400	male	8	34	21	Pregnancy-induced hypertension	premature	unknown
Mus 44	19	stable relationship	34	1550	male	8	30	19	maternal stress	premature	unknown
Mus 45	21	single	33	1450	male	13	33	23	maternal stress	stillborn	unknown
Mus 46	20	unknown	39	2430	female	6	35	20,5	maternal stress	stillborn	unemployed
Mus 47	19	single	35	1305	male	6	35	20,5	Pregnancy-induced hypertension	premature	unemployed
Mus 48	18	unknown	40	2607	male	14	33	23,5	none	low birth weight	employed
Mus 49	20	single	32	1005	female	14	34	24	Pre-eclampsia	msb	unemployment
Mus 50	16	unknown	38	2500	female	14	34	24	none	low birth weight	student
Mus 51	31	married	36	1570	female	4	27	15,5	pre-eclampsia	premature	unemployed
Mus 52	32	married	37	2300	male	5	26	15,5	Pregnancy-induced hypertension	msb	employed
Mus 53	30	married	39	2507	male	13	31	22	none	low birth weight	employed
Mus 54	21	stable relationship	36	1500	female	7	34	20,5	maternal exhaustion	stillborn	unemployed
Mus 55	18	stable relationship	37	2200	female	13	35	24	none	premature	unemployed
Mus 56	15	unknown	34	1350	female	14	31	22,5	Pregnancy-induced hypertension	premature	unemployed
Mus 57	16	unknown	36	1600	male	2	25	13,5	maternal stress	msb	student

Mus 58	18	unknown	35	1580	female	7	26	16,5	none	premature	unemployed
Mus 59	38	unknown	28	1100	female	1	26	13,5	Pregnancy-induced hypertension	msb	employed
Mus 60	32	stable relationship	30	1235	male	7	26	16,5	maternal stress	premature	employed
Mus 61	14	single	31	1230	male	1	26	13,5	Pregnancy-induced hypertension	premature	student
Mus 62	16	single	31	1350	female	13	35	24	none	msb	student
Mus 63	28	married	29	1300	male	4	28	16	Pregnancy-induced hypertension	msb	employed
Mus 64	17	single	38	1690	female	3	25	14	Pregnancy-induced hypertension	low birth weight	unemployed
Mus 65	15	unknown	38	1700	male	11	31	21	none	low birth weight	student
Mus 66	19	unknown	39	2250	male	9	27	18	none	low birth weight	unknown
Mus 67	19	unknown	40	2340	female	5	26	15,5	Pregnancy-induced hypertension	low birth weight	unknown
Mus 68	21	single	38	2505	female	5	26	15,5	maternal stress	msb	unknown
Mus 69	18	Stable relationship	34	1050	male	5	26	15,5	Pregnancy-induced hypertension	premature	unemployment
Mus 70	20	stable relationship	37	2350	female	5	26	15,5	Pregnancy-induced hypertension	msb	unemployed
Mus 71	18	stable relationship	37	2300	female	6	30	18	maternal stress	premature	unemployed

Mus 72	16	single	36	2100	male	2	25	13,5	pregnancy induce hypertension	stillborn	student
Mus 73	31	unknown	35	2050	femal e	3	25	14	pre-eclampsia	premature	employed
Mus 74	15	single	30	1100	femal e	4	28	16	eclampsia	msb	student
Mus 75	32	married	35	1900	male	4	28	16	pre-eclampsia	premature	employed
Mus 76	30	married	33	1460	male	7	34	20,5	pre-eclampsia	stillborn	employed
Mus 77	21	stable relationship	34	1450	male	13	30	21,5	none	stillborn	unemployed
Mus 78	15	single	34	1236	femal e	5	26	15,5	none	premature	student
Mus 79	19	stable relationship	36	1750	male	8	34	21	Pregnancy-induced hypertension	premature	unemployed
Mus 80	18	stable relationship	35	1560	male	14	34	24	Pregnancy-induced hypertension	premature	unemployed
Mus 81	14	single	31	1150	femal e	5	35	20	none	premature	student
Mus 82	20	stable relationship	35	1432	femal e	5	35	20	none	neonatal death	unemployed
Mus 83	19	single	33	1405	femal e	8	30	19	Pregnancy-induced hypertension	stillborn	unemployed
Mus 84	16	unknown	32	1450	femal e	13	32	22,5	Pregnancy-induced hypertension	stillborn	student
Mus 85	26	unknown	30	1350	femal e	15	33	24	none	low birth weight	employed
Mus 86	25	unknown	30	1350	femal e	14	34	24	maternal exhaustion	stillborn	employed

Mus 87	22	unknown	32	1205	male	14	33	23,5	maternal exhaustion	premature	employed
Mus 88	20	unknown	31	1345	male	12	32	22	maternal exhaustion	premature	employed
Mus 89	35	Stable relationship	29	1050	female	12	32	23,5	Pregnancy-induced hypertension	premature	unemployment
Mus 90	37	married	31	1350	male	11	31	21	none	premature	employed
Mus 91	38	married	38	1850	female	4	27	15,5	none	low birth weight	employed
Mus 92	22	stable relationship	38	1780	male	5	31	18	Pregnancy-induced hypertension	low birth weight	unknown
Mus 93	21	single	38	1890	male	14	34	24	Pregnancy-induced hypertension	low birth weight	unemployed
Mus 94	34	single	37	1765	male	13	34	23,5	none	msb	unemployed
Mus 95	31	stable relationship	37	1740	male	13	34	23,5	maternal stress	premature	unemployed
Mus 96	18	stable relationship	35	1320	female	13	32	22,5	pre-eclampsia	premature	unemployed
Mus 97	40	married	35	1500	male	13	32	22,5	Pregnancy-induced hypertension	premature	unemployed
Mus 98	15	single	34	1250	female	5	31	18	Pregnancy-induced hypertension	premature	student
Mus 99	18	single	30	1180	male	10	34	22	none	premature	unknown
Mus 100	20	single	39	2245	female	2	25	13,5	Pregnancy-induced hypertension	low birth weight	unknown
Mus 101	21	single	38	2435	female	0	26	13	none	low birth weight	unknown

Mus 102	18	single	38	2343	male	5	30	17,5	Pregnancy-induced hypertension	low birth weight	unknown
Mus 103	30	stable relationship	40	2600	male	2	25	13,5	Pregnancy-induced hypertension	low birth weight	unknown
Mus 104	40	stable relationship	39	2390	male	14	34	24	Pregnancy-induced hypertension	low birth weight	unemployed
Mus 105	31	stable relationship	38	2360	femal e	5	31	18	maternal stress	stillborn	unemployed
Mus 106	14	unknown	36	2100	male	13	34	23,5	Pregnancy-induced hypertension	msb	student
Mus 107	16	unknown	37	2240	femal e	5	30	17,5	maternal stress	low birth weight	student
Mus 108	18	unknown	37	2050	male	12	32	22	maternal stress	stillborn	unemployed
Mus 109	22	married	36	1908	male	13	32	22,5	Pregnancy-induced hypertension	stillborn	unknown
Mus 110	28	married	34	1900	male	6	32	19	Pregnancy-induced hypertension	stillborn	unemployed
Mus 111	17	single	33	1870	femal e	13	32	22,5	maternal stress	stillborn	unknown
Mus 112	15	single	30	1934	male	5	31	18	maternal stress	msb	student
Mus 113	19	single	29	1798	male	6	32	19	maternal exhaustion	premature	unemployed
Mus 114	19	single	30	1980	male	2	26	14	Pregnancy-induced hypertension	premature	unemployed
Mus 115	21	stable relationship	28	1080	femal e	8	30	19	Pregnancy-induced hypertension	premature	unemployed
Mus 116	20	stable relationship	27	982	male	12	32	22	Pregnancy-induced hypertension	premature	unknown

Mus 117	18	unknown	30	1120	male	10	37	23,5	Pregnancy-induced hypertension	premature	unemployed
Mus 118	16	unknown	34	1230	male	14	34	24	maternal exhaustion	premature	unknown
Mus 119	16	single	39	2350	male	1	26	13,5	Pregnancy-induced hypertension	msb	unknown
Mus 120	18	stable relationship	38	2250	femal e	5	26	15,5	Pregnancy-induced hypertension	msb	unemployed
Mus 121	22	stable relationship	38	2130	femal e	3	25	14	Pregnancy-induced hypertension	msb	employed

The results reveal a negative correlation between average ambient temperature and neonatal weight (Figure 2.3.1). Birth weight decreases with increased temperature, which was not significant (R=-0.014, P>0,88). A negative and positive correlation was noted between seasonal ambient temperature changes and birth weight. A decrease in temperature showed less impact on birth weight during winter seasons, which was not significant (R=0.11; P>0.95; Figure 2.3.2a), while an increase in temperature showed a greater impact on birth weight during summer seasons and was significant (R=0.26; P>14; Figure 2.3.2b). A positive correlation was noted between spring (Figure 2.3.3a) and autumn (Figure 2.3.3b) on both temperatures with less impact on birth weight, which was not significant (Figure 2.3.3a [R=012; P>0.50] and Figure 2.3.3b [R=0.28; P>0.88]).

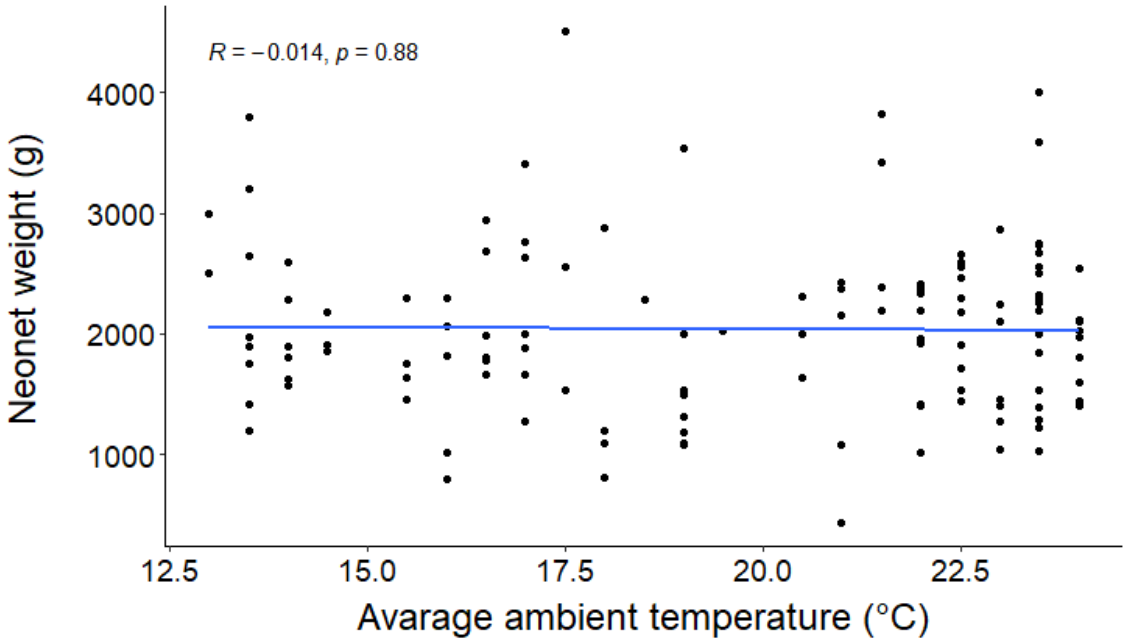

Figure 2.3.1: Ambient temperature exposure with birth weight

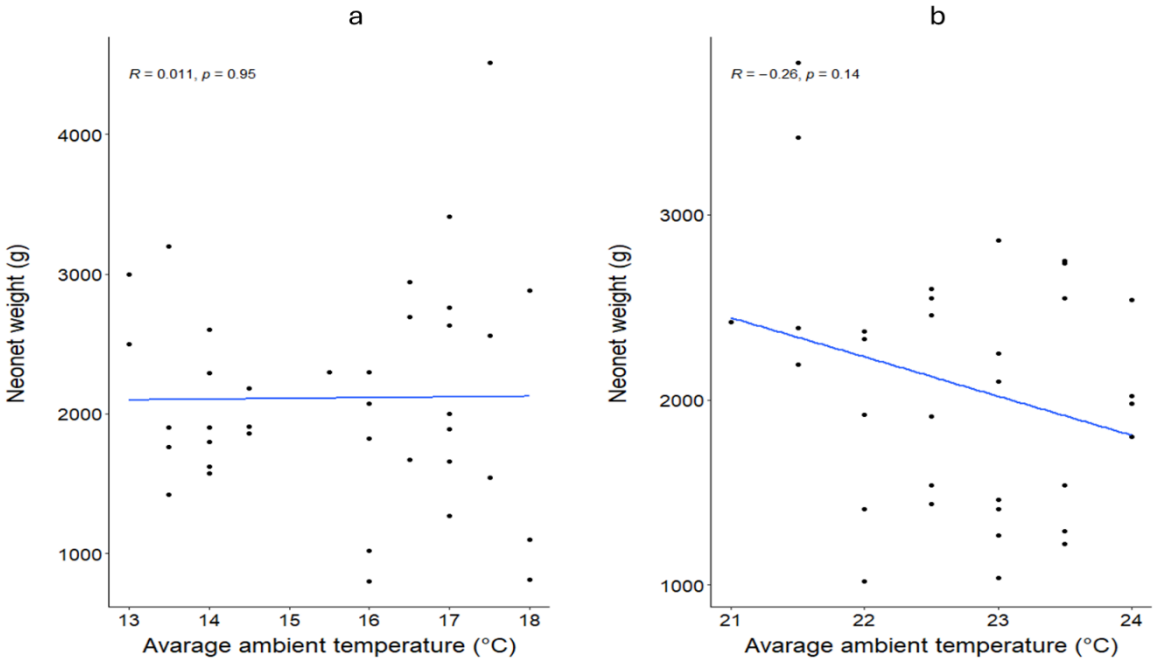

Figure 2.3.2: Seasonal ambient temperature changes with birth weight (a, winter and b, summer)

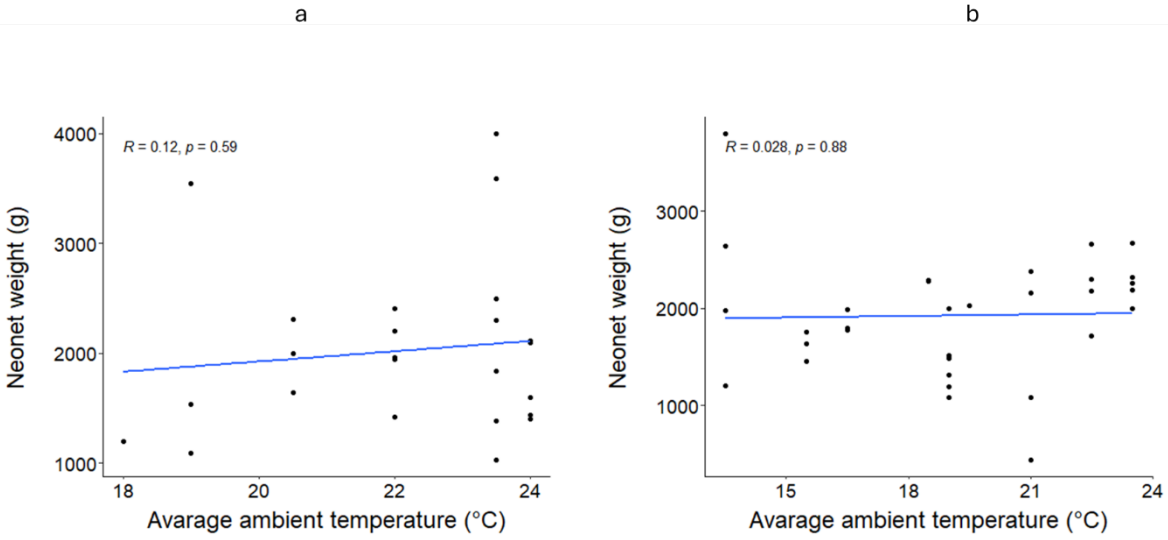

Figure 2.3.3: Seasonal ambient temperature changes with birth outcomes (a, spring and b, autumn)

Discussion

The study determines the relationship between ambient temperature change and birth weight in Musina Hospital, Vhembe District, Limpopo Province. The study revealed a significant association between ambient seasonal temperature changes and birth weight among infants delivered at Musina Hospital, Vhembe District, Limpopo Province, from 2019 to 2022. Specifically, a negative correlation was observed during summer, where higher ambient temperatures were associated with lower birth weights. Conversely, a positive correlation was found during the cooler seasons — spring, autumn, and winter — where moderate or low temperatures were associated with increased birth weights.

These findings align with previous studies, including Basangana et al. (2021b), who reported that exposure to high ambient temperatures reduces infant birth weight, and Cowell et al. (2023c), who linked harsh temperature exposure to small gestational age and low birth weight. Similarly, Bonell et al. (2023b) and Leung et al. (2023) found that high heat exposure may restrict placental blood flow, reducing oxygen and nutrient delivery to the fetus, thereby contributing to fetal growth restriction and low birth weight.

According to the World Health Organization (WHO, 2019), low birth weight is defined as less than 2,500g at birth. The findings of this study reaffirm that temperature extremes, particularly during the summer, significantly increase the risk of low birth weight, with the first trimester being a critical period for fetal weight development (Cherish et al., 2022). Other literature supports that high temperature exposure during the second and third trimesters also poses a risk (Baharami et al., 2012; Ha et al., 2022c).

Moreover, Hemati et al. (2021) noted that infants born in colder seasons like winter often experienced greater weight gain and higher BMI, which is consistent with this study's findings. Interestingly, the data also suggest sex-based vulnerability, with male infants more adversely affected by extreme heat exposure (Bonell et al., 2023c; Chen et al., 2020). Infants born in autumn also tended to have lower birth weights, reinforcing the sensitivity of fetal growth to seasonal changes. While spring, autumn, and winter showed no statistically significant differences, the summer season presented a significant negative impact on birth weight, especially in areas where temperatures are

particularly extreme, and cooling resources are scarce. These outcomes were particularly pronounced among pregnant women from low socio-economic backgrounds, who often lack access to adequate cooling facilities.

This study focused on monthly average temperatures, which may have overlooked the more acute effects of daily temperature spikes. Further studies are recommended to include broader geographic regions and consider both high- and low-income settings for a more comprehensive understanding.

Recommendations

Based on the findings of this study, which revealed both positive and negative correlations between ambient seasonal temperatures and birth weight at Musina Hospital in the Vhembe District, several key recommendations are proposed: The healthcare system should implement targeted maternal care interventions that prioritize pregnant women, particularly during periods of extreme seasonal temperatures. This includes routine monitoring of both maternal and fetal health throughout all trimesters. Pregnant women should receive structured health education about the risks associated with exposure to extreme ambient temperatures, especially during the summer season. Educational programs should include guidance on coping mechanisms, hydration, rest, and appropriate environmental adaptations. Public health authorities must create accessible cooling shelters or designated rest areas within communities, particularly for pregnant women from low socio-economic backgrounds who are most vulnerable to heat exposure. These centers would serve as protective environments during heat waves or high-temperature periods. Policymakers should incorporate maternal heat-exposure risks into national and local health strategies. This includes integrating environmental health into antenatal care services, community outreach programs, and maternal risk assessment tools. Additional studies are needed to explore the long-term effects of ambient seasonal temperature exposure on child development and health outcomes post-birth. Research should also investigate region-specific mitigation strategies, considering both socio-economic and climatic differences.

By adopting these recommendations, the healthcare system can mitigate the adverse effects of ambient temperature exposure on maternal and infant health, thereby

reducing temperature-related hospital admissions and improving birth outcomes in vulnerable regions.

Conclusion

This study established a clear relationship between seasonal ambient temperatures and fetal birth weight. Findings indicated that high temperatures during summer are significantly associated with low birth weight, while moderate temperatures in spring, autumn, and winter are associated with healthier birth weights. These results underscore the sensitivity of fetal development to environmental conditions, particularly in regions like Musina that experience extreme seasonal heat. Healthcare providers play a critical role in addressing these challenges by counselling pregnant women on the dangers of heat exposure and implementing preventive measures throughout the pregnancy. The findings of this study contribute valuable insight into the intersection of climate and maternal health and emphasize the need for collaborative action from health professionals, policymakers, and communities. By proactively addressing temperature-related health risks, we can protect vulnerable populations and promote healthier pregnancy outcomes, especially in regions prone to extreme climate variability.

Acknowledgement

The researcher would like to express gratitude to the matron of Musina Hospital and the Musina maternity manager for facilitating access to patient records and providing all the necessary resources to conduct this research.

Funding

None

Disclosure

The was no conflict of interest.

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Section 3: Study Results, Conclusion, Recommendations, Limitations, and Conclusions

This section's conclusion was obtained from the findings of the studies on the records of pregnant women who experienced adverse pregnancy effects and delivered in Musina Hospital, Vhembe District, Limpopo Province. This study aimed to determine the relationship between high ambient temperature and birth outcomes in Musina Hospital, Vhembe District, Limpopo Province.

Article 2.1 examines the effects of climate change on birth outcomes globally through an integrative literature review. The methods used in the study involved developing clear research questions, employing research searching strategies, and conducting data extraction. The findings were carefully analyzed to ensure the reliability and validity of the investigation into the impact of climate change on birth outcomes worldwide.

The study found that climate change is a threat to human health, particularly vulnerable individuals like pregnant women, as it results in adverse outcomes such as premature delivery, low birth weight, etc. However, no strategies have been implemented to mitigate the impact of climate change on birth outcomes. Further studies should focus on long-term temperature exposure and mechanisms linked to the impact of climate change on birth outcomes.

Article 2.2 investigates the potential impact of climate change on birth outcomes in Musina, Vhembe District, Limpopo Province. A descriptive and correlational design was utilised in this study. This study employed a quantitative approach focusing on records of pregnant women who experienced adverse pregnancy outcomes or pregnancy complications and only those who delivered in Musina Hospital, Vhembe District, Limpopo Province, from 2019-2022. The results show the temperature variation over successive years. A high number of pregnant women face pregnancy-induced hypertension than other maternal conditions. On the neonatal side, prematurity was the most common outcome compared to other neonatal conditions. The study suggests that future research should focus on daily temperature exposure to pregnant women and its direct impact on birth outcomes, investigating whether the effects are immediate or take time to manifest.

Article 2.3 explores the effects of ambient seasonal temperature on birth weight in Musina Hospital in Vhembe District, Limpopo Province. The study utilized a correlation and descriptive design with a quantitative approach. It focused on the records of pregnant women who gave birth to low-birth-weight infants between 2019 and 2022 in Musina Hospital. The findings indicated that both high and low temperatures are associated with birth weight. Specifically, higher temperatures were linked to a decrease in birth weight, while lower temperatures were associated with an increase in birth weight. The study suggests that future research should investigate the pathophysiology behind the effects of ambient seasonal temperature on birth weight and explore strategies to mitigate these impacts.

Recommendations

Pregnant Women and Families

- Pregnant women and family members should be educated about the impact of climate change on birth outcomes, ensuring they stay alert and know what to do if they find themselves in such situations.
- Pregnant women should be advised to avoid heat exposure, stay hydrated, and live a healthy lifestyle.
- They should be advised to visit the nearest healthcare facilities if they experience labour pains during the early weeks of their pregnancy or if they have been exposed to high ambient temperatures during warm seasons.
- Families should support pregnant women during warm seasons and ensure they avoid outdoor activities and stay hydrated.

Community

- An awareness campaign should be developed where all community members are gathered in one place and educated about the impact of ambient temperature exposure. The aim of this would be to protect vulnerable individuals, like pregnant mothers, during warm seasons.
- Community leaders should designate community halls as cooling centres for pregnant women, particularly during warm seasons, to mitigate the impact of high ambient temperatures and ensure that all pregnant women have access to cooling resources, especially those with low socio-economic status.

- They should also distribute pamphlets to every household explaining the impact of high ambient temperature exposure, the population most vulnerable to it, and how to reduce it.
- Community leaders should ensure that water is distributed to the population in areas experiencing water shortages during warm seasons to help them stay hydrated and reduce the impact of high ambient temperature exposure.
- Community leaders should select volunteers and train them to assess the well-being of pregnant women during warm seasons.

Midwives and Health Facilities

- Midwives should closely monitor pregnant women to assess hydration or dehydration, weight gain, and the well-being of pregnant women during warm seasons.
- Midwives should ensure that pregnant women visit healthcare facilities regularly to detect any risks early before they become severe. During warm seasons, midwives should check pregnant women at least once a week to ensure no symptoms are overlooked.
- Midwives should provide pregnant women with health education on the impact of high ambient temperature exposure and strategies to reduce the impact.
- Healthcare providers should ensure that health facilities are well-equipped with cooling resources, such as air conditioners and fans, so that every pregnant woman who visits a healthcare facility has full access to cooling resources during their visit.
- Midwives should routinely monitor maternal signs of heat exposure, such as the development of high blood pressure during pregnancy, and monitor foetal well-being, including the weight of the fetus, during warm seasons. A healthy diet and lifestyle should be recommended during pregnancy.
- Healthcare providers should develop a protocol linked to the impact of high ambient temperature exposure, consisting of emergency assistance for heat-related illnesses to any vulnerable person during hot seasons.

Department of Health

- Develop a guideline focused on the impact of high temperature exposure and outline steps to mitigate risks and manage complications during warm seasons. Additionally, a guideline for midwives should be created to ensure that pregnant women are not exposed to any risks throughout their pregnancy.
- Collaborate with the media department to launch an awareness campaign on the impact of high ambient temperature exposure and strategies to mitigate the risks, particularly during warm seasons.
- Invest in additional mobile clinics by providing funding and extending working hours, allowing mothers facing issues to consult with healthcare providers telephonically.
- Collaborate with the South African Weather Services to provide early warnings about temperature changes, enabling people to prepare and implement coping strategies in advance.

Policymakers

- Develop a policy addressing the impact of ambient temperature exposure in pregnancy and precautionary measures to improve maternal and foetal well-being.
- Develop a warning system that advises healthcare providers to assess and monitor the risk to pregnant women during each healthcare visit.
- Establish guidelines on managing the impact of high ambient temperature exposure.

Limitations

This study has several limitations. Firstly, the study focused only on Musina Hospital in Vhembe District, Limpopo Province. Secondly, the required sample size was not met for patient records, as some records were not recorded on the system, making it difficult for the researcher to retrieve them. Of the 357 records that were needed for this study, only 121 records were retrieved, and the remaining records were not found in the system. Thirdly, the researcher could not get adequate data on seasonal ambient temperature changes and birth weight because there was not much information about antenatal visits in the patient records. Another limitation is that the study focused on patient records from 2019-2022 and omitted

records from 2018 and earlier, including only those from 2023 and later, which may present useful information for the researcher. Lastly, the study focused on medical records of pregnant women who experienced adverse effects due to temperature exposure, such as premature births, low birth weight, and stillbirth; records of those who gave birth to term babies were not considered.

Conclusions

Article 2.1 highlights the significant impact of climate change on pregnant women and newborns, with male infants being particularly affected by heat exposure. The article suggests that climate change may contribute to a future decline in pregnancy rates, as many young people are increasingly hesitant to become pregnant due to the global effects of heat exposure on pregnancy.

Article 2.2 concludes that ambient temperature negatively impacts pregnancy outcomes, including maternal outcomes. High ambient temperature is associated with high risks of pregnancy-induced hypertension in exposed pregnant mothers during their pregnancy, resulting in a high rate.

Article 2.3 discusses how ambient seasonal temperature changes impact birth weight, particularly for pregnant women during their first trimester, as it is associated with foetal development. Low and high temperatures have been found to impact growing babies inside the uterus.

Exposure to both high and low ambient temperatures has been detrimental to pregnant mothers and their developing babies. Preterm delivery, low birth weight, and stillborn can occur as a result of exposure to high or low temperatures. Most studies agree that climate change impacts pregnant women and their growing babies, depending on how much heat they have been exposed to during their pregnancy.

Annexures

Appendix 1: UNIVEN Standard Informed Consent

RESEARCH ETHICS COMMITTEE

UNIVEN Informed Consent

LETTER OF INFORMATION

Title of the Research Study: Climate Change and Potential Impact on Birth Outcomes: A Correlational Study in Musina Hospital at Vhembe District, Limpopo Province.

Principal Investigator/s/ researcher : Mudau Rolivhuwa Sibongile Millet, Master of Nursing

Co-Investigator/s/supervisor/s : Dr T. Malwela
Prof. M.S. Maputle

Brief Introduction and Purpose of the Study:

Outline of the Procedures: The researcher will use a checklist to collect data through a retrospective chart review. The hospital manager will assist in retrieving the necessary files for the researcher. This study will focus on the records of mothers who experienced adverse pregnancy outcomes, such as premature birth, low birth weight, and stillbirth, between 1 January 2019 and 31 December 2022. The researcher will review these records in a private room to ensure confidentiality. The primary objective of this study is to determine the correlation between temperature and birth outcomes, specifically how these two variables may influence each other.

Risks or Discomforts to the Participant : None

Benefits : None

Remuneration : No remuneration
Costs of the Study : None, the researcher will be the sole participant in this study, utilising patient records for data collection.
Confidentiality : Patient records will be reviewed in a free room to ensure confidentiality
Research-related Injury : None

Persons to Contact in the Event of Any Problems or Queries:

Please contact the researcher, my supervisor (0827572013 or email thivhulawi.malwela@univen.ac.za) or the University Research Ethics Committee Secretariat on 015 962 9058. Complaints can be reported to the Director: Research and Innovation, Prof GE Ekosse on 015 962 8313 or Georges Ivo.Ekosse@univen.ac.za.

General:
Potential participants must be assured that participation is voluntary, and the approximate number of participants to be included should be disclosed. A copy of the information letter should be issued to participants. The information letter and consent form must be translated and provided in the primary spoken language of the research population.

CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, (*name of researcher*), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: _.
- I have also received, read and understood the above-written information (*Participant Letter of Information*) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and occupation, will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research, which may relate to my participation, will be made available to me.

Full Name of Participant Date Time Signature

I, …… …… …… ……

(*Name of researcher*) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

Full Name of Researcher

…… Date…… Signature……

Full Name of Witness (If applicable)

..... Date ..... Signature.....

Full Name of Legal Guardian (If applicable)

..... Date..... Signature.....

Appendix 2: Proposal Approval

University of Venda

Faculty of Health Sciences

Research and Postgraduate Studies

Executive Faculty Higher Degree Committee

To : Mudau RSM

Masters in Nursing

From : Prof L Makhado

Deputy Dean: Research and Postgraduate Studies

Date : 2024/04/08

The decision of the Executive Faculty of Health Sciences Higher Degree Committee on 2024/04/08

Application for approval of a dissertation proposal report in the Department of Nursing Sciences: **Student Name:** Mudau RSM (18010101)

Title: Climate change and potential impacts on birth outcome: A correlational study in Musina Hospital at Vhembe district, Limpopo

Province.

Supervisor : Dr Malwela

Co-supervisor: Prof Maputle

EFHDC is recommended for approval by the UHDC.

Prof L Makhado
Deputy Dean: Research and Postgraduate Studies (Chairperson of EFHDC)
Faculty of Health Sciences

Appendix 3: Ethical Clearance Certificate

ETHICS APPROVAL CERTIFICATE

RESEARCH AND INNOVATION
OFFICE OF THE DIRECTOR

NAME OF RESEARCHER/INVESTIGATOR:
Ms RSM Mudau

STUDENT NO:
18010101

PROJECT TITLE: Climate Change and potential impact on birth outcome: A Correlational Study in Musina Hospital at Vhembe District, Limpopo province.

ETHICAL CLEARANCE NO: FHS/24/NUT/08/1208

SUPERVISORS/ CO-RESEARCHERS/ CO-INVESTIGATORS

NAME	INSTITUTION & DEPARTMENT	ROLE
Dr T Malwela	UNIVEN, ADVANCED NURSING SCIENCE	Supervisor
Prof MS Mapulle	UNIVEN, ADVANCED NURSING SCIENCE	Co-Supervisor
Ms RSM Mudau	UNIVEN, ADVANCED NURSING SCIENCE	Investigator– Student

Type: Masters Research
Risk: *Minimal risk to humans, animals, or environment* (Category 2)
Approval Period: August 2024 – August 2025

The Human and Clinical Trials Research Ethics Committee (HCTREC) hereby approves your project as indicated above.

General Conditions
While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following.

- The project leader (principal investigator) must report in the prescribed format to the REC:
  - Annually (or as otherwise requested) on the progress of the project, and upon completion of the project.
  - Within 48hrs in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.
  - Annually a number of projects may be randomly selected for an external audit.
- The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of those changes at the REC. Would there be deviated from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.
- The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date; a new application must be made to the REC and new approval received before or on the expiry date.
- In the interest of ethical responsibility, the REC retains the right to:
  - Request access to any information or data at any time during the course or after completion of the project,
  - To ask further questions; Seek additional information; Require further modification or monitor the conduct of your research or the informed consent process.
  - withdraw or postpone approval if:
  - Any unethical principles or practices of the project are revealed or suspected,
  - It becomes apparent that any relevant information was withheld from the REC or that information has been false or misrepresented,
  - The required annual report and reporting of adverse events was not done timely and accurately,
  - New institutional rules, national legislation or international conventions deem it necessary..

ISSUED BY:
UNIVERSITY OF VENDA, RESEARCH ETHICS COMMITTEE
Date Considered: August 2024

Name of the HCTREC Chairperson of the Committee: Prof NS Mashau

Signature:

UNIVERSITY OF VENDA
OFFICE OF THE DIRECTOR
RESEARCH AND INNOVATION
2024 -08- 12
Private Bag X5050
Thohoyandou 0950

Appendix 4: Request to The Department of Health to Conduct Research

P.O. Box 1952
Nzhelele
0993
17 June 2023

Limpopo Province
Department of Health
Private Bag X9302
Polokwane
0700

Dear Sir/Madam

Request for permission to conduct research

I, Mudau Rolivhuwa Sibongile Millet, a postgraduate student doing a master's degree in nursing at the University of Venda, hereby request permission to conduct a study in Musina, Vhembe District of Limpopo Province, South Africa. The study topic is Climate change and potential impacts on birth outcomes in Musina Hospital in Vhembe District, Limpopo Province, South Africa. This study aims to determine the correlation between two variables, namely temperature and birth outcomes, and how these variables correlate or influence each other. The information extracted from patient files or records will be securely stored to ensure confidentiality. It will only be used for the purposes of this study, and no one other than the researcher will have access to the data. In this study, the researcher will serve as the primary data collector. Data will be gathered from the patient records using a checklist to achieve the research objectives.

Contact details: 0725893834 or email sibongilemillet64@gmail.com

I would greatly appreciate your approval of my request.

Yours faithfully,

Mudau R.

Appendix 5: Department of Health Approval Letter

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF
HEALTH

Ref : LP_2024-08-014
Enquires : Legodi P
Tel : 015-293 6028/6410
Email : Malesela.Legodi@dhsd.limpopo.gov.za

MUDAU RSM

CC: UNIVERSITY TO ENSURE COMPLIANCE WITH CLAUSE 2d OF THIS APPROVAL LETTER

PERMISSION TO CONDUCT RESEARCH IN DEPARTMENTAL FACILITIES

Your Study Topic as indicated below;

CLIMATE CHANGE AND POTENTIAL IMPACTS ON BIRTH OUTCOME: A CORRELATIONAL STUDY IN MUSINA HOSPITAL AT VHEMBE DISTRICT, LIMPOPO PROVINCE

1. Permission to conduct research study as per your research proposal is hereby Granted.
2. Kindly note the following:
    a. Present this letter of permission to the office of District Executive Manager a week before the study is conducted.
    b. This permission is **ONLY** for Messina Hospital
    c. In the course of your study, there should be no action that disrupts the routine services or incur any cost on the Department.
    d. After completion of study, it is mandatory that the findings should be submitted to the Department to serve as a resource.
    e. The researcher should be prepared to assist in the interpretation and implementation of the study recommendation where possible.
    f. **The approval is only valid for a 1-year period.**
    g. If the proposal has been amended, a new approval should be sought from the Department of Health
    h. Kindly note that, the Department can withdraw the approval at any time.

Your cooperation will be highly appreciated.

7/10/2024

Head of Department **Date**

pp

Private Bag X9302, Polokwane 0700
Fidel Castro Ruz House, 18 College Street, Polokwane 0700
Tel: 015 293 6000. Fax: 015 293 6211. Website: www.doh.limpopo.gov.za

The heartland of Southern Africa - *development is about people!*

Appendix 6: Request to The Vhembe District to Conduct Research

P.O. Box 1952
Nzhelele
0993
17 June 2023

P.O. Box 4006
Musina
0900
Cnr. N1 & Whyte Rd

Dear Sir/Madam,

Request for permission to conduct research.

I, Mudau Rolivhuwa Sibongile Millet, a postgraduate student doing a master's degree in nursing at the University of Venda, hereby request permission to conduct a study in Musina, Vhembe District of Limpopo Province, South Africa. The study topic is Climate change and potential impacts on birth outcomes in Musina Hospital in Vhembe District, Limpopo Province, South Africa. This study aims to determine the correlation between two variables, namely temperature and birth outcomes, and how these variables correlate or influence each other. The information extracted from patient files or records will be securely stored to ensure confidentiality. It will only be used for the purposes of this study, and no one other than the researcher will have access to the data. In this study, the researcher will serve as the primary data collector. Data will be gathered from the patient records using a checklist to achieve the research objectives.

Contact details: 0725893834 or email sibongilemillet64@gmail.com

I would greatly appreciate your approval of my request.

Yours faithfully,

Mudau R.

Appendix 7: Vhembe District Approval Letter

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF
HEALTH

Ref: S5/4/2/3 (LP_2024-08-014)
Enq: Chauke H.S
Cell: 015 962 1001

From: Vhembe HRD

To: DIRECTOR HOSPITAL SERVICES ,(PHC)

PERMISSION TO CONDUCT RESEARCH IN DEPARTMENTAL FACILITIES

1. **The above matters refer:**
2. The office of the HOD has granted: Mudau R.S.M permission to conduct research on (Climate Change and potential impacts on birth outcome) A correlation study in Musina Hospital (Vhembe District): Approval Ref: LP_2024-08-014).
3. As per the approval ref no: **LP_2024-08-014** from the province the permission is only for Musina Hospital within Vhembe District.
4. The approval is only valid for a 1-year period.
5. In that regard the above mentioned facility is requested to welcome Mudau R.S.M to do their Research without disrupting our day to day service or incur any cost on the Department.
6. Hope you find the above in order.

DISTRICT EXECUTIVE MANAGER: HEALTH SERVICES 14/10/2024 **DATE**

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Old Parliamentary Building Tel:(015) 962 1848, (015) 962 1852, (015) 962 1754, (015) 962 1001/2/3/4/5/6 Fax(015) 962 2373,(015) 962 2274,(015) 962 4623

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Annexure 8: Proof Of Editing

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Editorial Certificate

To Whom It May Concern,

This certificate confirms that the dissertation entitled **"Climate change and potential impacts on birth outcome: A correlational study in Musina Hospital at Vhembe District, Limpopo Province"** by **Mudau Rolivhuwa Sibongile Millet** was edited by an expert English editor with a PhD. The following issues were corrected: grammar, spelling, punctuation, sentence structure, phrasing, and formatting.

Signed on behalf of NIM Editorial by:

.....

Dr N.I. Mabidi

Founder & Chief Editor