

(RESEARCH ARTICLE)



ASSOCIATION OF MATERNAL HEAT EXPOSURE WITH PRETERM BIRTH AND MISCARRIAGE AMONG PREGNANT WOMEN IN YOPOUGON, CÔTE D'IVOIRE, 2014-2024: A RETROSPECTIVE STUDY

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ABSTRACT

Extreme heat events are increasing in frequency and intensity due to climate change, particularly in West Africa. Pregnant women and their fetuses are among the most vulnerable to heat exposure, yet evidence from African settings remains limited. In Abidjan, Côte d'Ivoire, both the frequency and intensity of heat episodes have increased in recent years. However, the effects of maternal heat exposure on adverse pregnancy outcomes have not yet been investigated in this context. This study assessed the relationship between heat exposure and maternal-fetal health outcomes. This retrospective ecological time-series analysis used hospital records from 2014 to 2024 from two maternity hospitals in Yopougon district. Pearson correlation analysis was used to examine associations between mean maximum temperature and preterm birth and miscarriage. A total of 36,376 deliveries were recorded at Wassakara maternity hospital, including 0.69% miscarriage and 0.90% preterm births. At Toit Rouge maternity, 22,294 deliveries were recorded, including 1.71% miscarriages and 1.18% preterm births. Annual and seasonal trends showed fluctuations in both outcomes. Pearson correlation analyses indicated broadly similar associations in both maternity hospitals, with weak positive associations between mean maximum temperature and the pregnancy outcomes studied, and a weak negative association for preterm birth in Wassakara maternity hospital. However, none of these associations were statistically significant. These findings suggest a potential association between heat exposure and adverse perinatal outcomes, including preterm birth and miscarriage, highlighting the need for further research considering more data and sources and targeted preventive strategies for pregnant women.

Keywords: Heat Exposure; Pregnancy; Preterm Birth; Miscarriage; Perinatal health; Abidjan

1 INTRODUCTION

Climate change has been identified as the greatest threat to global health in the 21st century, [1] with both immediate and long-term impacts on the most vulnerable populations, particularly those from low-income countries. Although the manifestations of climate change are diverse, they are all characterized by global warming, primarily driven by greenhouse gas emissions resulting from human activities. Moreover, the most direct and immediate effect of global climate change on human health is reflected in the continuous increase in mean global temperature, as well as the intensification and prolongation of extreme heat events.

According to the latest report by the Intergovernmental Panel on Climate Change (IPCC), global mean temperatures have increased by 1.1°C since the preindustrial era, with projected increases of 1.5 to 4°C by 2100, depending on emission scenarios. [2] Climate change represents a major challenge for Africa [3], particularly in sub-Saharan Africa, where observed increases in mean and extreme temperatures are already attributed to climate change and where several regions are experiencing warming at a rate exceeding the global average. [4] In West Africa, mean annual and seasonal temperatures have increased by approximately 1 to 3 °C since the mid-1970s, with more pronounced warming observed in the Sahara and the Sahel. [4] Under a global warming scenario of 1.6 °C, the number of days exceeding potentially lethal heat thresholds could reach 50 to 150 per year, posing a direct threat to human health and exacerbating associated risks, including heat-related illnesses, malnutrition, and mental health disorders. [5]

Data indicate that climate-related health risks disproportionately affect vulnerable and disadvantaged subgroups, such as the elderly, individuals with chronic diseases, and outdoor workers, particularly in low- and middle-income countries. In addition to these vulnerable groups, pregnant women also constitute a high-risk population. [6] However, pregnant women and the developing fetus were not initially considered vulnerable to extreme temperatures. Only recently have these two groups been recognized as susceptible to extreme heat. [7] For example, previous studies have shown that most heat response plans in European countries did not identify pregnant women as a high-risk group. [8,9] Furthermore, data on the impact of heat on pregnancy outcomes in Africa remain scarce, [10] despite numerous studies demonstrating the acute impact of high temperatures during the prenatal period on adverse pregnancy outcomes, such as preterm birth and miscarriage. [11]

According to the World Health Organization (WHO), the expulsion of an embryo or fetus weighing 500 g or less, corresponding to a gestational age of 20–22 weeks, is classified as a miscarriage, [12] and preterm infants are those born before 37 weeks of gestation. [13] Multiple studies have highlighted an association between heat exposure and an increased risk of preterm birth and miscarriage. For example, a study conducted in China reported that heat exposure during pregnancy was associated with a higher risk of preterm birth. [14] Similarly, a study conducted in Iran found that a 1°C increase in daily temperature exposure during pregnancy was associated with a 3 -15% higher risk of preterm birth. [15] Likewise, a study in Fuzhou, China, showed that a 1°C increase in mean temperature exposure during early pregnancy resulted in a 10% increase in adverse pregnancy outcomes. [16]

Although awareness of the impacts of heat on adverse pregnancy outcomes is increasing worldwide, no research has yet been conducted in Abidjan, the largest city in Côte d'Ivoire. Abidjan has experienced a significant increase in temperatures in recent years. [17] This study aims to fill this gap by examining the effect of heat exposure on the risks of preterm birth and miscarriage in two maternity hospitals in the Yopougon municipality of Abidjan.

2 METHOD

2.1 Study Site

The city of Abidjan is in the southern region of Côte d'Ivoire, between latitude 5°15'N and 5°26'N and longitude 4°5'W and 3°54'W. It is the country's largest urban center and the most populous in French-speaking West Africa, with a population of 6,351,086, representing 20% of the country's total population. As the economic capital, Abidjan covers an area of 422 km², with a population density of approximately 15,050 inhabitants per km². Furthermore, the city comprises over 280 neighborhoods. [18]

Abidjan experiences a humid tropical climate, characterized by four distinct seasons. From December to March, the long dry season occurs, followed by the long rainy season from April to July, peaking in June. The short dry season predominates from August to September, and finally, the short rainy season occurs from October to November, completing the annual cycle. [19]

Yopougon, the largest commune in Abidjan, serves as our study site. The population was 1,571,065 in 2021. [20] The commune is situated between Banco Forest and the Ébrié Lagoon, in the western part of Abidjan Nord.

Yopougon is situated within a tropical climate zone and demonstrates marked heterogeneity in living conditions owing to its large and diverse population. The commune includes both middle-and socioeconomically disadvantaged neighborhoods where access to air conditioning and/or fans is limited due to financial constraints and high electricity costs. In contrast, the area also contains more affluent residential sectors that benefit from a higher standard of living with improved access to resources.

Within Yopougon, there are 19 healthcare facilities equipped with maternity units. These facilities include one university hospital (CHU), one general hospital (HG), and 17 primary healthcare centers (ESPG), of which eight are urban healthcare facilities (FSU), six are urban health centers (CGU), and three are rural health centers (CSR), distributed across two health districts (Yopougon East and Yopougon West). [21]

This study focused on two community-based health centers (FSUCOM), namely Wassakara Attié and Toit Rouge. These facilities are located in the Yopougon East health district and are among the most frequently attended first-contact health facilities by pregnant women in the commune of Yopougon, due to their accessibility.

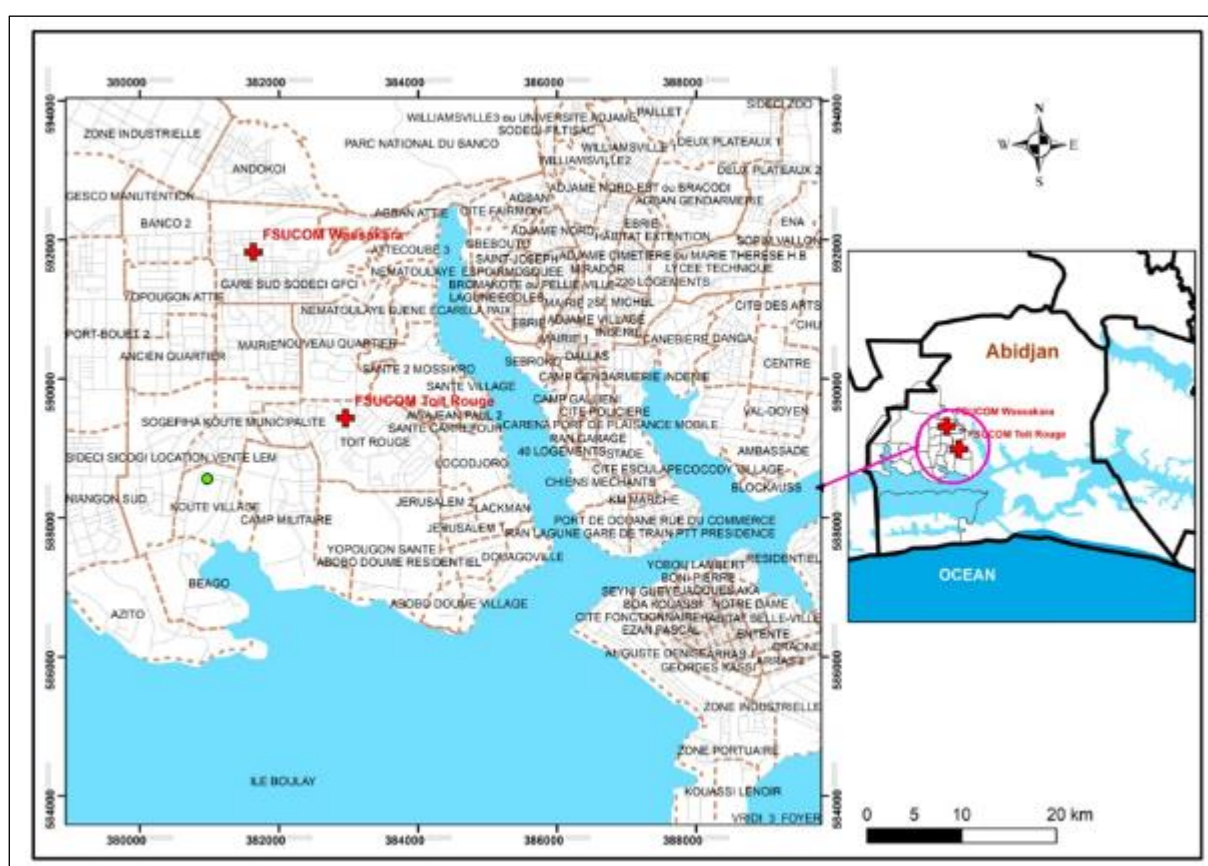


Figure 1: Location of the study area, in Yopougon, Abidjan, Côte d'Ivoire

2.2 Data

In this study, two primary data sources were utilized: meteorological data and health data

2.3 Meteorological Data

Meteorological data consisted of mean daily maximum temperatures recorded between 2014 and 2024, obtained from the Société d'Exploitation et de Développement Aéroportuaire, Aéronautique et Météorologique (SODEXAM), the national meteorological authority of Côte d'Ivoire. The use of mean daily maximum temperature as the sole exposure indicator was guided by data availability and its frequent use in studies on the health effects of heat. This indicator provides a standardized and comparable measure of heat exposure over the study period. However, it does not capture all aspects of heat stress, particularly humidity and extreme temperature variations.

2.4 Health Data

Health data were retrospectively collected from medical records, including delivery and antenatal care registers, covering the period from 2014 to 2024. These records included information on maternal age, available in aggregated form by age groups (8–14, 15–19, 20–24, 25–49, and ≥ 50 years). The ≥ 50 years category comprised three recorded cases. The analysis was based on monthly aggregated counts of preterm births and miscarriages during the study period. Preterm births were defined as any birth occurring before 37 completed weeks of gestation, whereas miscarriages were defined as the spontaneous loss of pregnancy before 22 weeks of gestation.

2.5 Analysis

All statistical analyses were performed using R software, version 4.5.2 (R Foundation for Statistical Computing, Vienna, Austria). Descriptive analyses and graphical visualizations were conducted using the *ggplot2* package.

First, descriptive statistics were used to characterize the distribution of miscarriages and preterm births within the study sample.

Subsequently, the association between mean daily maximum temperatures and miscarriage and preterm birth was assessed using Pearson's correlation coefficient, implemented through the *cor.test()* function in the *stats* package. This method allows the assessment of the strength and direction of linear relationships between two continuous variables. This was an exploratory analysis and does not account for potential confounding factors or lagged effects that may influence the observed associations.

The use of Pearson's correlation is consistent with approaches commonly employed in the literature examining the links between climatic factors and reproductive health outcomes.[22]

3 RESULTS

3.1 Annual trend and seasonal variation at Toit Rouge maternity

Out of 22,294 deliveries recorded at the FSUCOM Toit Rouge maternity unit during the period 2014–2024, the miscarriage rate was 1.71%, and the preterm birth rate was 1.18%.

The annual rate of miscarriages showed a gradual decline between 2014 and 2017, followed by an increase from 2017 onward, with a peak in 2019, which recorded the highest number of cases. This increase was followed by a decline between 2019 and 2020. The number of cases remained stable from 2020 to 2021, followed by a gradual increase until 2024. The annual rate of preterm births showed an increase between 2014 and 2015, followed by stability from 2015 to 2016. A decline was observed between 2016 and 2019, followed by an increase between 2019 and 2020, after which the numbers stabilized at a lower level from 2020 to 2024.

Preterm birth showed a clear bimodal seasonal pattern, with peaks in February and September, and lower values between May and July. Miscarriage displayed a different pattern, with relatively lower levels in the first half of the year followed by a progressive increase from August onwards, reaching the highest levels in November and December. *Figure 2* present the annual and seasonal rate of miscarriages and preterm births at FSUCOM Toit Rouge during the study period.

Pearson correlation analysis between mean daily maximum temperatures and preterm births at FSU Toit Rouge showed a positive but very weak association ($r = 0,101$; 95% CI: -0,071 to 0,267; $p = 0,249$; $n = 132$). Similarly, the correlation between mean daily maximum temperatures and miscarriages was positive but negligible ($r = 0,022$; 95% CI: -0,150 to 0,192; $p = 0,804$; $n = 132$). The reported rates reflect only cases recorded in the two study hospitals and do not represent population-level incidence. See Table 1.

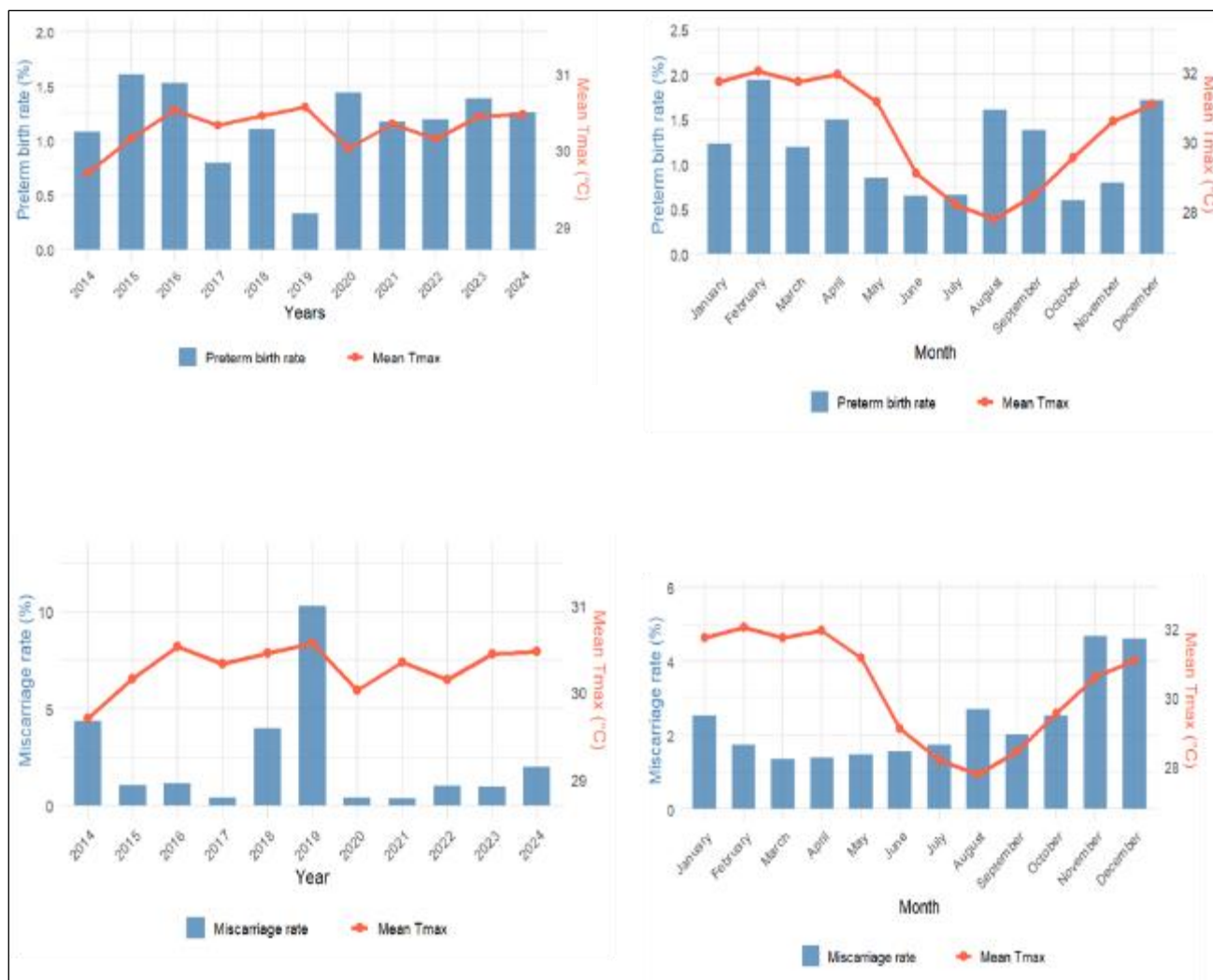


Figure 2 : Annual and seasonal trends in preterm births and miscarriage between 2014 and 2024 at the FSUCOM Toit-Rouge Maternity Ward, Yopougon, Côte d'Ivoire. (A) Annual trends in preterm births; (B) Seasonal trends in preterm births; (C) Annual trends in miscarriage; (D) Seasonal trends in miscarriage.

3.2 Annual trend and seasonal variation at Wassakara Attié

Among 36,376 deliveries at the FSUCOM Wassakara Attié maternity unit, the miscarriage rate was 0.69%, and the preterm birth rate was 0.90%.

The annual rate of miscarriages showed an increase between 2014 and 2016, followed by a decline through 2017. A slight rise occurred in 2018, followed by another decline in 2019. Values remained relatively stable between 2019 and 2021. A further decrease was observed in 2022, followed by an increase in 2023, before another decline between 2023 and 2024. Regarding preterm births, the rate remained negligible between 2014 and 2016. A modest increase was observed from 2017 to 2018, followed by a decline in 2019. Subsequently, the rate exhibited a gradual upward trend between 2021 and 2023, reaching its peak during the study period in 2023, before declining slightly in 2024.

Seasonal trends of miscarriages showed two marked peaks in March and August, whereas July recorded notable declines. For preterm births, one major peak was observed in June. Specifically, the number of cases increased from January to March, then decreased between March and May. A subsequent rise was recorded until the peak in June, followed by a gradual decline until November, and a slight increase between November and December. *Figure 3* presents the annual and seasonal trends of miscarriages and preterm births at FSUCOM Wassakara Attié during the study period.

Pearson correlation analysis between mean daily maximum temperatures and miscarriages at FSUCOM Wassakara Attié revealed a positive but extremely weak ($r = 0.006$; 95% CI: -0.175 to 0.186 ; $p = 0.949$; $n = 118$). Similarly, the correlation between mean daily maximum temperatures and preterm births showed a very weak negative association ($r = -0.091$; 95% CI: -0.268 to 0.091 ; $p = 0.325$; $n = 118$). The reported rates reflect only cases recorded in the two study hospitals and do not represent population-level incidence. See Table 1.

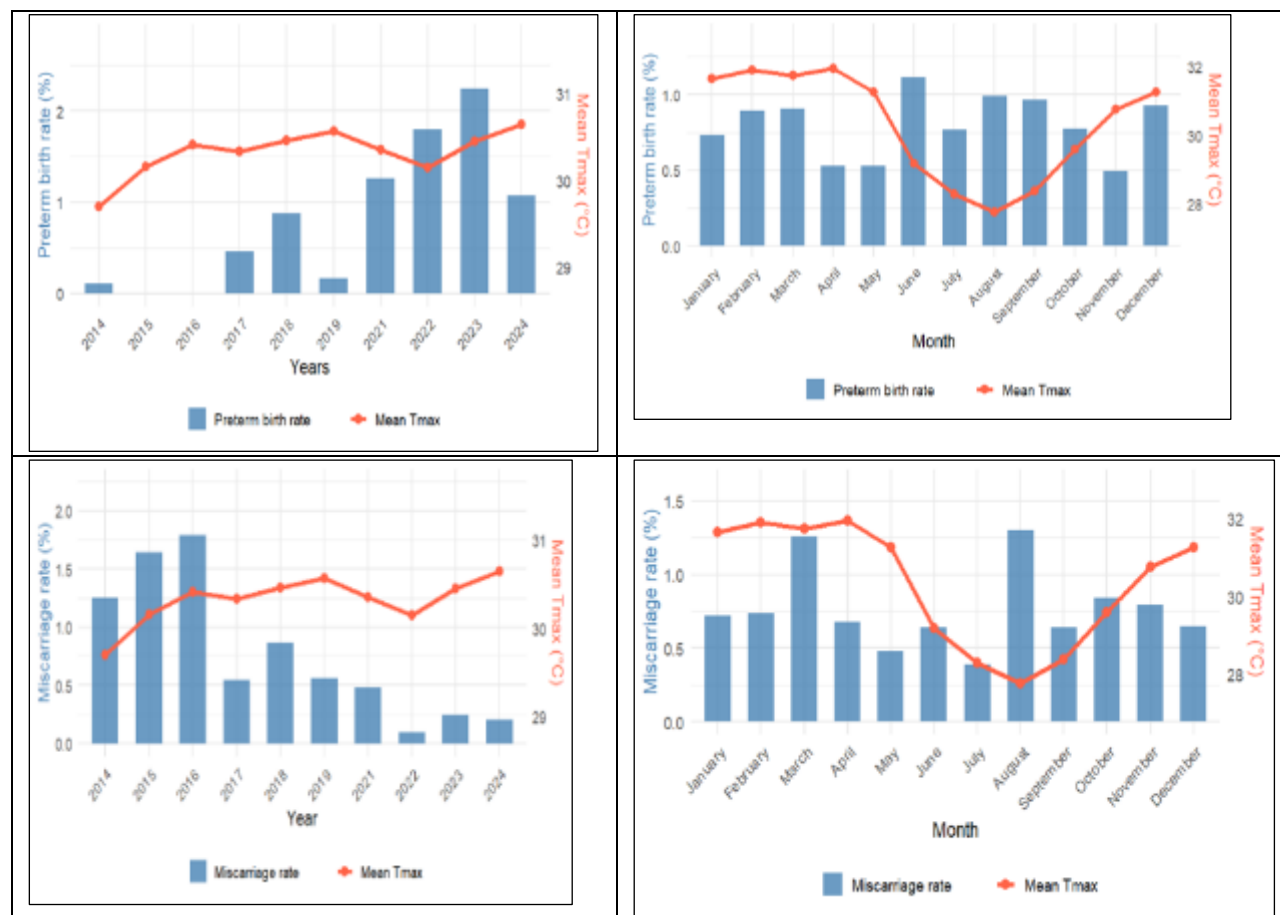


Figure 3: Annual and seasonal trends in preterm births and miscarriage between 2014 and 2024 at the FSUCOM Wassakara Attié Maternity Ward, Yopougon, Côte d'Ivoire. (A) Annual trends in preterm births; (B) Seasonal trends in preterm births; (C) Annual trends in miscarriage; (D) Seasonal trends in miscarriage.

4 DISCUSSION

Our study found weak and variable associations between mean daily maximum temperatures and adverse pregnancy outcomes, including miscarriages and preterm birth, across both study sites. These findings may suggest a potential association between heat exposure and adverse perinatal outcomes; however, the observed associations did not reach statistical significance.

In this regard, our findings are consistent with those of a study conducted in Ghana, which examined the association between exposure to the Wet Bulb Globe Temperature (WBGT) index and the risk of spontaneous abortion. The authors reported an approximately 15% increase in risk for each one-degree rise in WBGT (OR = 1.15; 95% CI: 0.92–1.42), although the association was not statistically significant.[23]

Furthermore, a systematic review and meta-analysis, which included multiple international studies, some specifically examining preterm birth, reported a positive association between ambient heat exposure and the risk of preterm birth. The analysis indicated that a 1°C increase in temperature was associated with an approximately 5% increase in risk (OR = 1.05; 95% CI: 1.03–1.07), while heatwaves were linked to a more pronounced increase (OR = 1.16; 95% CI: 1.10–1.23). In addition, overall heat exposure during pregnancy was associated with a moderate increase in preterm birth risk (OR = 1.14; 95% CI: 1.11–1.16), although substantial heterogeneity across studies was noted. [11]

In addition, in an exploratory review, 23 of the 75 included studies reported a significant association between high ambient temperatures and an increased risk of preterm birth.[24] More specifically, a time-series study conducted in Iran found a significant increase in preterm birth risk during heatwave days defined as a mean daily maximum temperature above the 90th percentile for at least two consecutive days compared with non-heatwave days (RR = 1.21; 95% CI: 1.08–1.37).[25] Similarly, in Guangzhou, China, exposure to extreme heat (31.9°C) was associated with a 10.0% increase in the risk of preterm birth.[26]

Similarly, a systematic review reported mixed findings regarding the association between ambient heat exposure and preterm birth. [27] Most included studies (15 of 17) identified a positive association between heat exposure and an

increased risk of preterm birth. However, some studies conducted in Montreal [28] and Germany [29] did not find a statistically significant association, while a study conducted in Shenzhen [30] reported an unexpected protective effect. The differences observed between our findings and those reported in the literature may be attributed to a range of methodological and contextual factors.

Firstly, the absence of significant associations may be related to limitations in the analytical approach employed. Pearson's correlation assumes a linear relationship between temperature and pregnancy outcomes; however, evidence suggests that this relationship is not always linear and may follow a U-shaped pattern, with increased risk at both low and high temperature extremes. [31] In such cases, linear methods may fail to adequately capture the true association. Moreover, the effects of temperature exposure on pregnancy outcomes may occur with a delay of several days, which is not accounted for by simple correlation analyses. More advanced approaches, such as distributed lag non-linear models (DLNM), are better suited to capturing both non-linear and delayed effects over time. [32]

Secondly, this study used mean daily maximum temperatures as the exposure indicator, which may represent a limitation. A review highlighted that heat stress is a multidimensional phenomenon that cannot be adequately captured by ambient temperature alone [33]. The authors further note that heat indices vary across studies and often incorporate multiple parameters, including humidity and extreme temperatures. Therefore, relying on a single indicator such as average temperature may not accurately reflect actual heat exposure, which could have influenced the observed associations.

The differences observed between our results and those reported in other studies may also be explained by contextual and population-specific factors. As highlighted in this study, the municipality of Yopougon is characterized by diverse housing and living conditions, ranging from deprived areas with limited ventilation to more affluent areas with better access to ventilation and air conditioning. Such heterogeneity may mask effects at the aggregate level.

In this context, the two maternity hospitals included in the study also reflect this diversity. The Wassakara maternity hospital, which records a higher number of deliveries, is located in a generally more socioeconomically disadvantaged environment, whereas Toit Rouge maternity hospital presents a more diverse and potentially more advantaged patient profile. Furthermore, the mobility of patients between the two facilities may contribute to reducing the expected contrasts. Women residing in more affluent areas of the Yopougon district may attend Wassakara, while others from more disadvantaged neighborhoods may attend Toit Rouge, depending on proximity or personal preference. This mixing of populations reduces the socioeconomic specificity of each site and may contribute to masking the effect of exposure. Thus, these factors suggest that the observed results may be partly explained by heterogeneity in exposure and by attenuation of associations within the study population. Moreover, several potential confounding factors were not accounted for in the analysis, including socio-economic status and housing conditions, access to and quality of antenatal care, and maternal comorbidities. The omission of these variables may introduce bias into the estimates and contribute to the absence of statistically significant associations. These factors play a key role in maternal and perinatal health outcomes, and their exclusion may mask or attenuate true underlying effects. For instance, a review highlighted that socio-economic inequalities, living conditions, and access to healthcare significantly influence maternal and neonatal outcomes, particularly the risk of obstetric complications, preterm birth, and low birth weight. [34] The authors further emphasize that these social determinants may act as important confounders in epidemiological studies. Therefore, incorporating these variables into future analyses is essential to obtain more accurate estimates and to improve the interpretation of observed associations.

In addition, the relatively low number of preterm births observed in this study may have reduced statistical power and limited the detection of significant associations. Indeed, the study sites are first-contact health facilities that lack neonatal care services. Thus, high-risk pregnancies are generally referred to higher-level facilities, which may have led to under-ascertainment of preterm births and an underestimation of the true number of cases. Furthermore, data for the year 2020 were unavailable, likely due to disruptions in health services and routine data collection associated with the COVID-19 pandemic, which may have affected the completeness and robustness of the dataset.

Finally, populations living in hot climates may develop a degree of adaptation to heat exposure, which could contribute to the weaker or non-significant associations observed in our study. For instance, a Canadian study reported an increased risk of congenital anomalies during hot months, as pregnant women in temperate climates are not necessarily adapted to heat and are therefore more vulnerable to extreme heat events. [35] In contrast, in Israel, where the climate is generally hot, pregnant women may exhibit a higher degree of adaptation to heat. [36] Overall, these findings suggest that thermal adaptation may differ according to climatic context, with individuals in temperate regions being more vulnerable to heat exposure compared with those habitually exposed to warmer climates. [24]

Although this study has certain limitations, particularly related to the methodology employed and the consideration of some socioeconomic factors, it provides an original contribution to a field that remains poorly documented in Africa. Indeed, studies on the effects of ambient heat on perinatal health are still scarce on the African continent and, to our

knowledge, no study has been conducted on this topic in Côte d'Ivoire. This study therefore represents an important first step in generating evidence on the relationship between heat exposure and perinatal health in the Ivorian context and helps to fill a significant gap in the African scientific literature. It also provides a reference basis for future research in this field. Overall, this study should be considered as a first exploratory analysis in Côte d'Ivoire, providing preliminary evidence on heat-related risks in pregnancy. Future research using more robust, non-linear and multivariable models is required to confirm and refine these findings.

Furthermore, the findings also have important implications for public health. Although the observed positive correlations are relatively weak, they suggest that exposure to high temperatures may have adverse consequences for maternal and fetal health, particularly by contributing to the occurrence of miscarriages and preterm birth. In the context of increasing heat episodes linked to climate change, these results highlight the need for further studies to better characterize the magnitude and mechanisms underlying these associations. They also underscore the urgency of integrating maternal and fetal health considerations into climate change adaptation strategies and heat-related risk prevention plans. A better recognition of this particularly vulnerable population is essential to strengthen public health policies and to mitigate the health impacts of global warming.

5 CONCLUSION

Our study suggests a potential association between mean daily maximum temperature and the occurrence of pre-term birth and miscarriages. Although no statistically significant linear association was observed, the findings, from a first exploratory study in these settings, indicate that heat exposure may be associated with these pregnancy outcomes. The limited number of recorded data, the observed seasonal patterns, together with methodological limitations and the lack of adjustment for certain confounding factors, suggest that the relationship between heat exposure and pregnancy outcomes may not have been fully captured by the analytical approach used. Future steps of our research will employ non-linear models with distributed lag effects, incorporate more comprehensive measures of heat exposure, and account for relevant contextual and individual-level factors to better characterize the relationship between heat exposure and pregnancy outcomes.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflicts of interest.

Statement of ethical approval

This study was a retrospective analysis of anonymized medical records and did not involve direct contact with patients. Therefore, informed consent was not required. However, administrative authorization to access the data was obtained from the Ministry of Health and Universal Health Coverage (MSHPCMU) and the National Ethics Committee for Life and Health Sciences (CNESVS), under reference number 216-23/MSHPCMU/CNESVS-km.

Statement of informed consent

All data were anonymized before analysis to ensure patient confidentiality and data protection.

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