

REVIEW

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As the planet warms, women pay the price: the climate change and reproductive health crisis

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Abstract

Climate change has emerged as a global environmental issue exacerbated by human activities. Specifically, greenhouse gas emissions and land-use changes have contributed to rising global surface temperatures and shifting weather patterns. These changes disrupt environmental and ecosystem balance, directly impacting human health. Worldwide, 3.6 billion people live in regions vulnerable to climate change, and it is projected that between 2030 and 2050, an additional 250,000 deaths annually will occur due to climate change-induced malnutrition, malaria, and diarrheal diseases. The health impacts of climate change vary between genders depending on biological, geographical, and socioeconomic factors, with women experiencing more severe negative effects. Reproductive health is significantly affected by rising temperatures, air pollution, extreme weather events, and changing meteorological conditions. Adverse reproductive outcomes (e.g., low birth weight, preterm birth, and congenital anomalies) are more frequently observed in women. Furthermore, climate change exacerbates hot flashes, increases the risk of cardiovascular diseases, and intensifies mental health disorders in postmenopausal women. Climate change has emerged as a global environmental issue exacerbated by human activities. Specifically, greenhouse gas emissions and land-use changes have contributed to rising global surface temperatures and shifting weather patterns. These changes disrupt environmental and ecosystem balance, directly impacting human health. Worldwide, 3.6 billion people live in regions vulnerable to climate change, and it is projected that between 2030 and 2050, an additional 250,000 deaths annually will occur due to climate change-induced malnutrition, malaria, and diarrheal diseases. The health impacts of climate change vary between genders depending on biological, geographical, and socioeconomic factors, with women experiencing more severe negative effects. Reproductive health is significantly affected by rising temperatures, air pollution, extreme weather events, and changing meteorological conditions. Adverse reproductive outcomes (e.g., low birth weight, preterm birth, and congenital anomalies) are more frequently observed in women. Furthermore, climate change exacerbates hot flashes, increases the risk of cardiovascular diseases, and intensifies mental health disorders in postmenopausal women. However, current literature remains limited in addressing the specific effects of climate change on women's health in low- and middle-income countries, as well as its influence during the menopausal period. Further research is needed to explore the intersection of climate change and socioeconomic disparities, particularly in vulnerable populations. Large-scale longitudinal studies focusing on region-specific risks and health outcomes are essential to develop targeted interventions and policies.

Keywords Climate change, Reproductive health, Women's health, Maternal and fetal health, Infertility and menopause

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1 Climate change

Climate change has far-reaching effects not only on the environment but also on human health. However, its impacts are not experienced equally by all populations. Women, due to their unique biological, reproductive, and social roles, are disproportionately affected by the health consequences of climate change. Women and girls bear the brunt of climate change's impacts, which amplify existing gender inequalities and pose unique threats to their livelihoods, health, and safety [1]. Studies show the effects of climate change on pregnant women's health due to extreme heat, air pollution, extreme weather events, and increasing adverse obstetric outcomes [1, 2].

During climate-related disasters, women suffer disproportionate mortality; female survivors suffer decreased life expectancy. Women and girls are at high risk of physical and sexual violence and are at higher risk for mood disorders such as depression and anxiety after disasters [1].

An estimated 80% of people displaced by climate change are women. When displaced, women face heightened risks of poverty, violence, unintended pregnancies, and insufficient reproductive healthcare [3]. Understanding how climate change intersects with gender is essential to addressing health inequalities and developing effective mitigation strategies.

Climate change refers to comprehensive and lasting shifts in environmental conditions, evaluated through components such as long-term temperature trends, precipitation patterns, atmospheric pressure, and humidity levels [4]. It is widely accepted that climate change is driven by human activities, particularly through greenhouse gas emissions and fine particles in the atmosphere, which damage the Earth's protective ozone layer, leading to global warming [5]. According to the National Oceanic and Atmospheric Administration's 2023 Annual Climate Report, the combined land and ocean temperature has increased three times faster since 1982 [6]. Irregular weather patterns, the retreat of global ice sheets, and the consequent rise in sea levels are among the most widespread and striking global impacts of climate change [2, 7].

Before the Industrial Revolution, natural events such as volcanoes, wildfires, and seismic activities were considered the primary sources of greenhouse gases like carbon dioxide, methane, nitrous oxide, and water vapor [8]. However, since the Industrial Revolution, the continuous increase in the volume of greenhouse gases released into the atmosphere, along with extensive deforestation and urbanization as part of land-use changes, has significantly raised global surface temperatures and altered meteorological parameters such as precipitation [7]. The increased concentration of greenhouse gases, combined

with a reduction in aerosol pollution, has led to rapid increases in anthropogenic radiative forcing, which has caused warming of the atmosphere, land, cryosphere, and oceans [9].

In the last 65 years, the observed and projected climate changes and global warming are among the most significant environmental changes, causing profound impacts on ecosystems and human societies by triggering major transformations in the climate system [4]. In this context, various international initiatives and strategies have been developed to manage the impacts of climate change. The United Nations Paris Climate Change Agreement, which remains in force today, came into effect on November 4, 2016 [4, 8]. Signed by parties under the United Nations Framework Convention on Climate Change (UNFCCC), the agreement provides a fundamental framework for tackling global climate change [8]. The main goal of the Paris Agreement is to limit global temperature increases to below 2 °C above pre-industrial levels and to strengthen international efforts to limit the increase to 1.5 °C [4]. The agreement is based on voluntary initiatives aimed at reducing greenhouse gas emissions as the primary means of halting climate change [4, 8]. Achieving global climate goals will depend on the effectiveness of actions to reduce greenhouse gas emissions and prevent dangerous temperature thresholds and irreversible climatic tipping points. In this regard, these initiatives are crucial to achieving the goals of limiting global temperature rise and mitigating the impacts of climate change [1, 4, 7, 8].

2 Methods

This review was conducted to examine the impact of climate change on women's reproductive health, with a focus on identifying the key risks and challenges. The following steps were taken to ensure a comprehensive and methodologically sound approach.

2.1 Data sources and search strategy

Relevant studies were identified through an extensive search of scientific databases, including *PubMed*, *Scopus*, and *Web of Science*, as well as reputable institutional and organizational websites such as the *World Health Organization (WHO)* and *United Nations Framework Convention on Climate Change (UNFCCC)*. The search was conducted in April 2024 and included peer-reviewed articles, systematic reviews, and reports published between 2014 and 2024. The following keywords and Boolean operators were used in the search: "Climate change" and "Reproductive health", "Women's health" or "Maternal health", "Environmental pollution" and "infertility", "Global warming", and "Pregnancy outcomes".

2.2 Inclusion and exclusion criteria

2.2.1 Inclusion criteria

- Studies published in English
- Articles focusing on the health effects of climate change on women, particularly reproductive health
- Publications providing quantitative or qualitative data relevant to the topic
- Systematic reviews and meta-analyses addressing related themes.

2.2.2 Exclusion criteria

- Studies not directly addressing climate change's effects on women's reproductive health
- Articles focused solely on men's health or general population health without gender-specific data.

The search was conducted in April 2024 and included peer-reviewed articles, systematic reviews, and reports published between 2014 and 2024.

2.3 Justification for the review

Previous reviews addressing the relationship between climate change and reproductive health were often limited in scope, typically focusing on specific reproductive outcomes such as fertility, pregnancy complications, or neonatal conditions. Most of these reviews drew primarily from studies conducted in developed countries, limiting their applicability to low- and middle-income contexts. Moreover, few reviews have considered the comprehensive life cycle of women, including menopause, within the framework of climate change. The most recent systematic reviews were published between 2022 and 2023, and while they provided valuable insights, they often failed to integrate gender-specific vulnerabilities with climate-related health threats in a holistic manner. There remains a significant gap in understanding how climate change affects women's reproductive health across different life stages and geographic regions. This review aims to fill that gap by offering an up-to-date and comprehensive synthesis of recent findings, highlighting global disparities, and identifying areas for future research.

3 Climate change and its impacts on health

In the report published by the World Health Organization (WHO) in 2023, assessing the health impacts of climate change, climate change is described as the greatest health threat humanity faces [10, 11]. It is stated that approximately 3.6 billion people globally live

in regions at high risk of climate change. Furthermore, it is projected that between 2030 and 2050, around 250,000 additional deaths per year will occur due to factors such as malnutrition, malaria, diarrhea, and heat stress caused by climate change [1, 11]. Climate change negatively affects health through multiple mechanisms, including rising temperatures, poor air quality, extreme weather events, altered vector-borne diseases, decreased water quality, and reduced food security [3]. The increase in extreme weather events (droughts, floods, extreme temperatures) and infectious diseases can lead to mass migrations due to economic hardships and resource shortages, making access to healthcare more difficult and increasing the risk of public infrastructure collapse [2, 3, 12].

The impacts on morbidity and mortality include deaths due to heat stroke, injuries caused by extreme weather events, depression, the effects of poor air quality on respiratory and cardiovascular diseases, diseases like diarrhea caused by poor water quality, and the negative effects of climate-induced migration on mental health [11, 13, 14]. Additionally, rising carbon dioxide levels lead to food insecurity, decreasing food quality and causing malnutrition, while the spread of mosquitoes and other vectors increases diseases such as malaria and dengue fever [2].

The impacts of climate change on health vary between men and women due to biological, geographical, socio-economic, and sociocultural factors [3, 15]. As a result of these differences, climate change exacerbates existing gender-based health inequalities, especially in low- and middle-income countries [3]. According to the United Nations Framework Convention on Climate Change (UNFCCC), climate change has more negative health effects, particularly on poor women [15]. Women are reported to be physiologically and socially more vulnerable to climate impacts concerning reproductive health, with prolonged exposure to high temperatures being associated with stillbirth, congenital anomalies, and preterm birth [16]. Moreover, women are at higher risk of adverse health outcomes throughout their life stages (postpartum, menopause, and old age) compared to men [15–17].

4 The impact of climate change on women's reproductive health

Climate change poses a significant risk to overall health and well-being by adversely affecting reproductive health [18]. Rising seasonal average temperatures, increased frequency of heat waves, poor air quality, more intense and frequent natural disasters, and shifting rainfall and temperature patterns negatively impact reproductive health [19]. Global trends over the past 50 years show a decline

in fertility rates, an increase in cases of gestational diabetes and congenital anomalies, more widespread infertility, and higher rates of abortion and preterm birth [18, 20]. Elevated ambient temperatures due to climate change are known to affect the secretion of gonadotropins (LH and FSH) and gonadotropin-releasing hormone (GnRH), impairing oocyte development and maturation, early embryonic development, and fetal and placental growth and negatively influencing the postpartum breastfeeding process [21]. It is reported that procedures aimed at protecting women's reproductive health and mitigating and adapting to climate threats need to be implemented at both the global and national levels [1, 17].

4.1 The impact of climate change on maternal and fetal health

Pregnant women are particularly vulnerable to climatic changes such as rising temperatures and heat waves [19, 22]. This vulnerability is attributed to physiological changes in the maternal cardiovascular and respiratory systems, as well as adaptations in the endocrine and immune systems [19, 23]. Prolonged heat exposure triggers heat stress, which activates inflammatory and oxidative stress responses. This can promote endothelial dysfunction and increase blood viscosity, leading to serious health issues and heat-related illnesses such as heat cramps, collapse, or stroke [23, 24]. Studies have shown that prolonged elevated ambient temperatures during pregnancy are associated with gestational hypertension and preeclampsia in pregnant women, as well as congenital anomalies in newborns, such as autism spectrum disorder, hypospadias, orofacial clefts, and congenital heart defects [17, 25–27]. Increased heat production of vasoactive substances, elevated blood viscosity, impaired endothelial cell function, and reduced placental blood flow are reported to increase the risk of intrauterine fetal death [17, 25]. Additionally, disproportionate heat exposure reduces progesterone concentration, triggers maternal antidiuretic hormone and oxytocin secretion, and is linked to increased rates of preterm birth and abortion [23–25]. One review has reported that elevated environmental temperatures during pregnancy may be associated with increased risk of beta cell dysfunction and gestational diabetes mellitus [25].

Climate change is particularly seen as a major health issue in low-income countries, and this is associated with difficulties in accessing healthcare during pregnancy [25, 26]. These access difficulties are often linked to natural disasters and environmental factors in the region, and they are considered one of the contributing factors to fetal growth disorders during pregnancy [25, 28]. A study reported that prenatal hypertensive disorders and cesarean delivery rates increased among pregnant women

exposed to natural disasters such as hurricanes, with preterm birth and low birth weight risks rising [28]. Natural events like wildfires, which cause air pollution, can negatively impact pregnancy. Physiological changes during pregnancy lead to a 20% increase in oxygen consumption, a 40–50% increase in ventilation, and a 40% increase in cardiac output, making pregnant women particularly vulnerable to air pollution [26, 29]. Exposure to air pollution during pregnancy can trigger adverse pregnancy outcomes such as low birth weight and intrauterine fetal death and negatively impact fetal neurodevelopment [29]. A systematic review of the effects of wildfire exposure during pregnancy reported a strong association between wildfire exposure and decreased birth weight [30]. Furthermore, exposure to negative climate change near oil and gas well sites is associated with an increased risk of spontaneous preterm birth, and air pollution is linked to a higher risk of neurodevelopmental delays and autism [31, 32]. Additionally, air pollution is reported to increase the risk of hypertensive disorders during pregnancy, leading to maternal morbidity and mortality [17, 33]. To prevent the negative effects of climate change on pregnancy, it is crucial to monitor and improve air quality, implement measures to mitigate the effects of temperature fluctuations, strengthen healthcare services, and develop strategies to minimize exposure to environmental pollutants.

4.2 Climate change and infertility

It is well known that reproductive physiology is particularly sensitive to thermal stresses, such as high temperatures [9]. Fertility rates in early industrialized regions decreased in the 1900s, and these issues were linked to increased climate change and exposure to harmful chemicals [34]. The growing need for medically assisted reproduction worldwide, especially in industrialized countries, supports the view that chemicals and air pollution, contributing to climate change, negatively affect reproductive health [35]. Studies have also shown that climate change disrupts hormonal balance, reducing women's fertility rates and endangering reproductive health [18, 35]. A systematic review examining the effects of ambient temperature stress on pregnancy outcomes reported a strong association between global warming and miscarriage, fetal death, and infertility [36]. Another review investigating the effects of climate change on fertility found that meteorological changes affect women's menstrual cycles, with increased temperatures altering follicle size, ovulation frequency, and cycle length, and that women exposed to air pollution had reduced chances of conception and increased pregnancy loss. It has also been noted that climate change-induced body heat primarily affects spermatogenesis, leading to low sperm

count, poor sperm motility, and abnormal sperm morphology in the ejaculate, all of which are associated with infertility [5, 37, 38]. According to the study results, climate change and its consequences directly or indirectly negatively impact the reproductive health of both men and women [37]. Therefore, it is important for healthcare professionals to be knowledgeable about climate change and its effects on reproductive health and to organize educational programs aimed at helping individuals cope with these effects.

5 The impact of climate change on the menopausal period

In recent years, while the effects of climate change on reproductive health and pregnancy outcomes have been a focus, the potential effects on women's health and well-being during menopause and beyond have been less studied [36, 37]. However, climate change significantly affects the menopausal period, and this interaction deepens the clinical course of menopause and its negative impacts on women's health [36, 38]. Climate change may contribute to early ovarian reserve depletion and an increased risk of early menopause in women. Rising temperatures and environmental stressors significantly increase menopausal symptoms worldwide, thereby increasing the burden on women's quality of life and overall health [36].

It is known that hot flashes and night sweats, observed in more than half of menopausal women, negatively affect sleep quality and mood, potentially impacting daily activities and work productivity [38]. A study investigating the potential impact of climate change on hot flashes during menopause reported that high ambient temperatures increase the frequency and severity of hot flashes [37]. Climate change is linked not only to estrogen levels in the premenopausal period but also to an increased risk of cardiovascular disease and mental health changes during menopause, conditions that are expected to worsen due to the climate crisis [37, 38]. A systematic review of the impact of climate change on menopause found that climatic factors directly affect women's menopause experiences, potentially through their effects on the body's thermoregulatory systems. It is also suggested that not only rising temperatures but also oxygen levels may play a role in the onset of symptoms [38]. Literature reviews highlight the need for further research into the interactions between climate change and menopause.

6 Discussion and conclusion

This review highlights the significant impacts of climate change on women's reproductive health and overall well-being. The reviewed literature indicates that climate change adversely affects pregnancy outcomes, fertility rates, and menopausal experiences. Elevated

temperatures are associated with risks such as low birth weight, preterm birth, and reduced fertility while also exacerbating menopausal symptoms, thereby negatively impacting women's quality of life.

However, critical gaps in the current literature have been identified. Specifically, there is insufficient data on the effects of climate change on women's health in low- and middle-income countries. Furthermore, research addressing the menopausal period remains limited, and the influence of socioeconomic factors requires further exploration.

In light of these findings, it is crucial to develop awareness programs aimed at mitigating climate-related health risks for women, strengthen health systems to become more resilient to climate change, and implement policies to reduce environmental risks. Future research should focus on large-scale studies that examine the interplay between climate change, socioeconomic factors, and regional disparities to provide a more comprehensive understanding of its impact on women's health.

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All authors reviewed the manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

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Not applicable.

Consent for publication

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Competing interests

The authors declare no competing interests.

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