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Extreme weather events and maternal health in low-income and middle-income countries: a scoping review

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ABSTRACT

Background Despite global efforts to improve maternal health and healthcare, women throughout the world endure poor health during pregnancy. Extreme weather events (EWE) disrupt infrastructure and access to medical services, however little is known about their impact on the health of women during pregnancy in resource-poor settings.

Objectives This review aims to examine the current literature on the impact of EWE on maternal health to identify the pathways between EWE and maternal health in low-income and middle-income countries to identify gaps.

Eligibility criteria Studies were eligible for inclusion if they were published before 15 December 2022 and the population of the studies included pregnant and postpartum women (defined at up to 6 weeks postpartum) who were living in low-income and middle-income countries. The exposure of the included study must be related to EWE and the result to maternal health outcomes.

Sources of evidence We searched the literature using five databases, Medline, Global Health, Embase, Web of Science and CINAHL in December 2022. We assessed the results using predetermined criteria that defined the scope of the population, exposures and outcomes. In total, 15 studies were included.

Charting methods We identified studies that fit the criteria and extracted key themes. We extracted population demographics and sampling methodologies, assessed the quality of the studies and conducted a narrative synthesis to summarise the key findings.

Results Fifteen studies met the inclusion criteria. The quantitative studies (n=4) and qualitative (n=11) demonstrated an association between EWE and malnutrition, mental health, mortality and access to maternal health services.

Conclusion EWE negatively impact maternal health through various mechanisms including access to services, stress and mortality. The results have demonstrated concerning effects, but there is also limited evidence surrounding these broad topics in low-resource settings. Research is necessary to determine the mechanisms by which EWE affect maternal health.

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STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ First review to focus on all extreme weather events (not just disasters) and on a wider range of maternal health outcomes which include access to maternal health services which are a major determinant of maternal health. Demonstrates the need for further research more specific to the individual exposures and outcomes included in this broad review.
⇒ The review includes qualitative studies that explore the mechanisms by which extreme weather affects maternal health.
⇒ This review was limited by limited good quality studies on the topic.
⇒ The search strategy may exclude research in which extreme weather events are not the main exposure, but are still relevant to maternal health outcomes being studied.
⇒ Studies published in languages other than English were excluded, limiting the scope of the review.

INTRODUCTION

Maternal health is a broad subject that is defined by the WHO as referring to 'the health of women during pregnancy, childbirth and the postpartum period', inclusive of both physical and mental health.[1] The health of women during these periods is important for several reasons including the close link between the health of the mother and that of their child. Reducing maternal mortality is a target for the Sustainable Development Goal 3 (SDG3).[2] Maternal mortality however fails to encapsulate the full extent of the poor health that many women face during pregnancy. A significant number of women experience various forms of poor health that can be life altering for themselves and their children; the most common are infection, high blood pressure and obstructed labour.[1] Previous research has shown associations between maternal stress and spontaneous abortion, children born with a low birth weight and various developmental issues in the child.[3] Improving maternal health through access to affordable and reliable maternal health services (MHS) is an essential part of the global effort to reduce gendered health inequities.[1]

Maternal health can be impacted by determinants from several forces, each of which are deeply intertwined. Individual determinants of maternal health may classically be thought of as to the woman's diet or attendance of antenatal care (ANC) appointments. However, these seemingly personal decisions are profoundly entwined with social and structural determinants of health, such as the impact of poverty on diet or a nation's policies on access to affordable healthcare.[4] Environmental factors, such as extreme weather events (EWE), could also impact maternal health. EWE may include a variety of weather circumstances that vary from the norm, including, but not limited to heat waves, windstorms, flooding and droughts. EWE can be devastating to communities, especially those with limited resources as it can disrupt medical services, transportation and communications. The Intergovernmental Panel on Climate Change (IPCC) reports that flooding has resulted in an increase in physical health issues such as diarrhoeal diseases due to contaminated water supplies and lack of water for hygiene.[5] Additionally, increases in mental health issues including anxiety and stress have been observed following flood events.[5]

Previous reviews have analysed the evidence on the impact of floods and heat on maternal and child health in high-income, middle-income and low-income nations.[3 6–8] The reviews showed that floods and extreme heat exposure have an impact on maternal and child health.[3 6–8] Reviews of temperature effects on maternal health have largely focused on birth outcomes.[6 8] While the themes are similar, these previous reviews tend to focus on birth outcomes as the main outcome, rather than the health of the mother. Therefore, there is a notable gap in the current literature of reviews examining the impact and disruption to health services that are critical for women's health during pregnancy and childbirth. The inclusion of postpartum women in this review is also notable, as this population was not included in the previous reviews. Furthermore, there is an additional gap in the current literature assessing the impact of EWE (fires, hurricanes and extreme temperatures) on maternal health focusing on low-income settings. Therefore, research studying the impact of EWE in these settings is crucial to ensure that there is evidence for effective response measures. This scoping review aims to assess the effects EWE will have on pregnant and postpartum women's health in low-income and middle-income countries (LMICs).

The objectives of this paper are as follows: (1) to assess the evidence for the health outcomes in pregnant women associated with EWE in LMICs, and (2) to identify pathways between EWE and maternal health across a variety of geographical locations.

METHODS

We conducted a scoping review to understand the impacts of EWE on maternal health. The definition of EWE for the purposes of this review has been adapted from the definition outlined by the IPCC as a variation in weather that is either above or below a region's typical threshold.[9] Our definition for maternal health aligns with that of the WHO as the health of women throughout three stages, pregnancy, labour and delivery and postpartum (defined as up to 6 weeks post delivery).[1]

The initial search was conducted in July 2022 and an additional search was completed in December 2022 to include any recently published studies. We searched five electronic databases: Medline, Global Health, Embase, Web of Science and CINAHL in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) guidelines.[10] Furthermore, we conducted a manual search of Google Scholar as well as a grey literature search of the websites of organisations including the International Federation of Red Cross and Red Crescent Societies, International Planned Parenthood Foundations, Action Aid, United Nations, WHO and International Centre for Research on Women.

The databases were searched using various terms for EWE, pregnancy and postpartum phases and maternal health (see online supplemental appendix A for detailed search terms). We used the Cochrane Effective Practice and Organisation of Care (EPOC) LMIC filter, based on the World Bank's 2021 country economic classifications.[11 12]The exposure was EWE, which has been defined as a weather event that varies from the expected average this includes, but is not limited to events such as floods, tropical storms, extreme heat or droughts.[5] The outcome of interest was maternal health, an umbrella term that included several health conditions such as pre-eclampsia, gestational diabetes or postpartum haemorrhage and access to care. The inclusion of outcomes that may not initially be considered as maternal health, such as access to MHS and malnutrition are justified to be included here as they are on the pathway to maternal health, as well as the impact experienced by pregnant and postpartum women within the studies. For example, access to skilled healthcare professionals during labour and delivery can prevent complications and death, while malnutrition during pregnancy can lead to anaemia, haemorrhage and death.[13]

The titles and abstracts of studies were screened by AP and MR and full texts were retrieved for studies that appeared to meet the inclusion/exclusion criteria (table 1)

Quality assessment

The quality of the included studies was primarily assessed using the Critical Appraisal Skills Programme (CASP) quality appraisal tools (see online supplemental appendix B).[14–16] The CASP appraisal tools were selected because of the wide range of study designs they cover, allowing for a more consistent quality appraisal. Qualitative, cohort and case–control studies were assessed using their respective CASP checklists.[14–16] Quantitative cross-sectional studies were assessed using the Joanna Briggs Institute (JBI) analytical cross-sectional studies assessment checklist.[17]

Table 1 Inclusion and exclusion criteria

	Inclusion	Exclusion
Population	► Pregnant and postpartum women, defined at up to 6 weeks postpartum	► Children or infants ► Healthcare workers who provide obstetrics and delivery care
Intervention or exposure	► Extreme weather event (see online supplemental appendix A)	► Geophysical events, such as earthquakes, volcanoes and tsunamis ► Temperature exposures not related to a specific heatwave event
Comparison	► Not applicable	► Not applicable
Outcome	► Maternal health (see online supplemental appendix A) ► Accessibility of antenatal and obstetrics/delivery care ► The exposure must be mapped to the outcome	► Child or infant health or development as the sole outcome
Timing	► Published before 15 December 2022	► Published after 15 December 2022
Study type	► Qualitative studies ► Quantitative studies ► Mixed-methods studies	► Commentaries ► Opinion pieces ► Policy papers ► Review articles
Source	► Peer-reviewed journals ► Research from international organisations	► Studies that either have not been peer-reviewed or are not from an international organisation
Geography	► Low-income and middle-income countries or territories	► High-income countries
Language	► Studies published in English	► Studies not published in English

For each study, the sum of the results was added and divided by the total number of questions. The score was given a classification of low, moderate or high quality.

Data synthesis

A narrative analysis of the results was conducted to allow the key findings of the studies to be organised in a way that facilitates comparison between the different study designs. Studies were separated based on the qualitative or quantitative study design and categorised by EWE type(s) and maternal health outcome(s). Key findings were extracted manually and organised using Microsoft Excel. The second author reviewed 10% of the articles and any discrepancies were resolved through discussion. The findings were then analysed to determine common themes relating to the aspects of maternal health that are most often impacted by extreme weather within the selected studies.

Patient and public involvement

No patients or members of the public were involved in this research.

RESULTS

Systematic search

Fifteen studies were found that met our criteria. The initial search of the five databases returned 1506 results (figure 1). Thirteen studies were selected for inclusion in the review. A grey literature search resulted in one additional study and a search of Google Scholar resulted in the inclusion of one more study.

Characteristics of included studies

The selected studies were published between 2011 and 2022. They were set in 10 countries in Bangladesh (n=5), Puerto Rico (n=2), Mozambique (n=1), Nigeria (n=1), Uganda (n=1), Pakistan (n=1), India (n=1), Philippines (n=1), Cambodia (n=1) and South Sudan (n=1). Figure 2 shows the geographic distribution of the included studies.

The selected studies examined several different exposures and outcomes. Table 2 shows the different types of exposures and outcomes among the studies. No papers on heat waves were found.

Qualitative studies (n=11) were conducted using a range of methods: interviews, open-ended survey questions and focus group discussions.[18–28] One mixed-methods study was included in the review. However, only the qualitative aspects fit our inclusion criteria. Therefore, only the qualitative segment of this study has been included in this review. Epidemiological study designs included: cohort (n=2),[29 30] cross-sectional (n=1)[31] and case–control (n=1).[32]

Quantitative study findings

The selected quantitative studies each assessed the impact of flooding on access to MHS. Please see table 3 for a summary of the results.

Access to MHS

The quantitative studies assessed access to MHS and there were not any studies that considered direct measures of maternal outcomes. Several studies found that floods decreased pregnant women's ability to access MHS.[29–32]

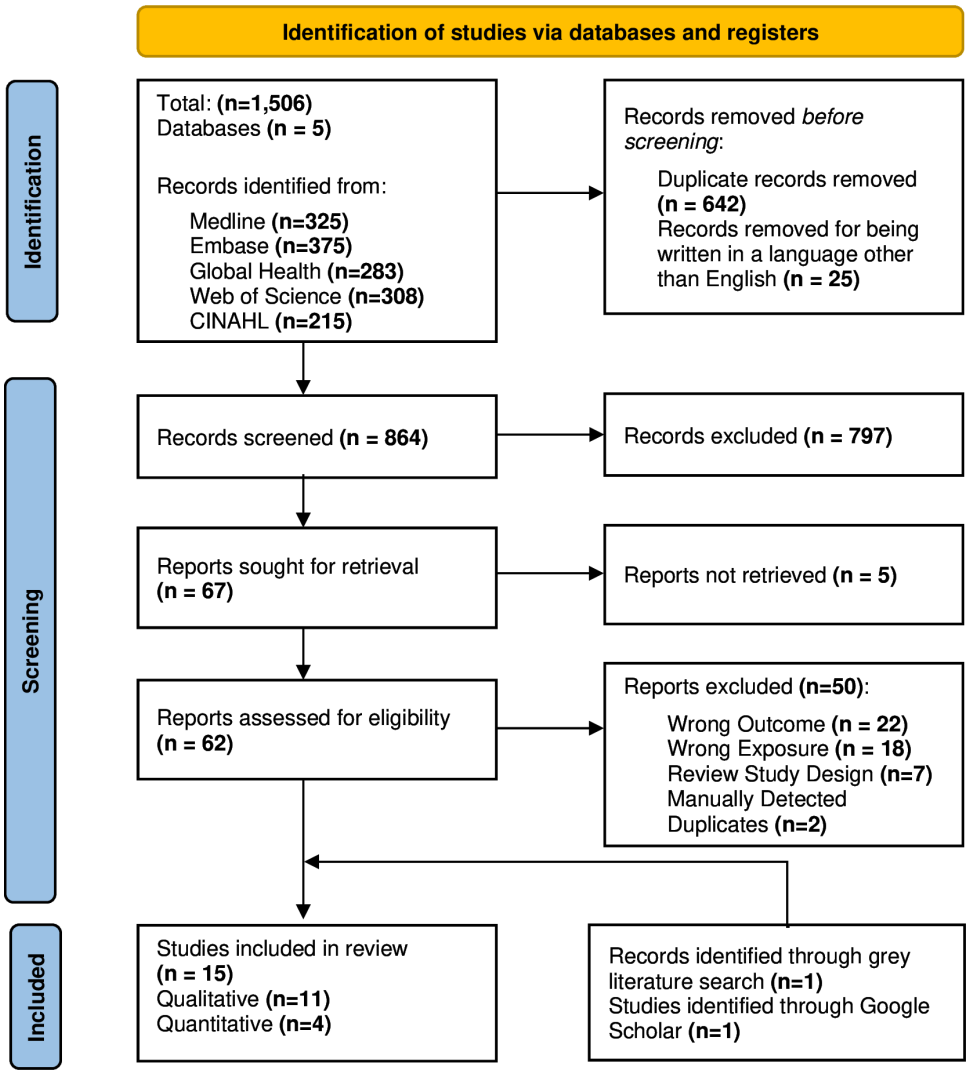

Figure 1 The study selection process which was conducted by two reviewers. Each step explains why studies were excluded and demonstrates how the studies that were included in the review were selected. PRISMA adapted from Page *et al*.[10] PRISMA, Preferred Reporting Items for Systematic reviews and Meta-Analyses.

Through geographic mapping and the use of precipitation records, Makanga *et al*[30] were able to determine that during normal times, 46% of women in southern Mozambique lived within a 1 hour walk to a primary health centre, a statistic that decreases to 37% during periods of floods.[30] On an average day, the longest commute to a primary health centre in this area was 7.9 hours.[30] Floods caused this travel time to increase substantially to 9.9 hours.[30] Although Makanga *et al* did not analyse the prevalence of MHS utilisation in their study sample, two other studies investigated medical usage during floods.[29–31] The results of two studies determined that floods impacted a pregnant woman's ability to access MHS.[29 31] Baten *et al*[29] found that women who lived in an area of Bangladesh that flooded four times between 2011 and 2014 have 0.66 decreased odds of having received ANC from a medical provider in comparison to women who lived in areas that only flooded once during the same time period.[29] Contrary to these results, in a study utilising Department of Health Services data in Bangladesh, Orderud *et al* (2022) initially determined that there was a negative correlation between flooding and MHS usage.[32] However, after controlling for several variables including flood duration, mother's age at birth, education and occupation, the researchers found no substantial effect, which they theorised was due to disaster mitigation efforts in communities that

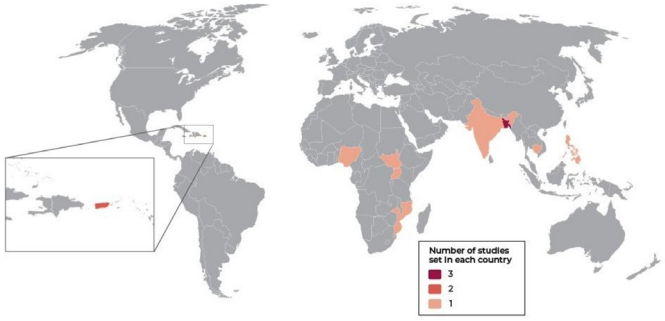

Figure 2 The geographical distribution of the selected studies which shows the frequency of each country's occurrence in the settings of the included studies.

Table 2 Types of exposures and outcomes in the selected quantitative and qualitative studies

	Flood	Windstorm	Drought
Maternal health services*	Baten *et al*[29], Haque *et al*[31], Makanga *et al*[30], Orderud *et al*[32], Abdullah *et al*[18], Ajibade *et al*[19], Ferdowsy *et al*[20], Maheen and Hoban[21], Wilunda *et al*[22], Saulnier *et al*[23]	Ferdowsy *et al*[20], Lafarga Previdi *et al*[24], Sato *et al*[25], Silva-Suarez[26]	Pardhi *et al*[27]
Malnutrition	Ferdowsy *et al*[20]	Ferdowsy *et al*[20], Sato *et al*[25]	Pardhi *et al*[27], Bryson *et al*[28]
Mental health	Saulnier *et al*[23]	Lafarga Previdi *et al*[24], Sato *et al*[25], Silva-Suarez *et al*[26]	Not applicable
Maternal mortality	Abdullah *et al*[18], Wilunda *et al*[22]	Not applicable	Not applicable

*Maternal health services is inclusive of health service accessibility and usage of antenatal and labour and delivery care.
N/A, not applicable.

frequently flood.[32] Furthermore, Haque *et al*[31] found that women who had been displaced because of floods had 0.18 decreased odds of having delivered their most recent child with medical providers in comparison to women who had not been displaced.[31] Only 16.2% of displaced mothers had delivered their most recent child in a health centre, in comparison to 59.8% of non-displaced mothers in the region.[31]

Qualitative study findings

We included 11 qualitative studies in this review, each of which used a cross-sectional design. The majority (n=10) were conducted via interviews and/or focus group discussions.[18–23 25–28] One study analysed the responses to an open-ended survey question.[24] Access to MHS, stress, malnutrition and maternal mortality were all common outcomes among the qualitative studies. Please see table 4 for a summary of the studies.

Access to MHS

During floods, accessibility and affordability of transportation to health centres and hospitals prevented people from seeking care.[18 21 23] In some regions, when floods occur, the only transportation available to take the women to the health facility is boats.[18 23] Some women paid for a ferry to transport them across the floods, while others had personal access to a boat.[21 23] However, during extreme conditions, access to boats was unreliable and could leave women stranded.[23] When asked about transportation access, one interviewee in Cambodia responded:

> Sometimes, (women) have the pain in the night. And there's no one to take them there because the flood was here all around, there's no boat or anything at all. It's risky (life threatening).[23]

Although in some situations hiring a boat may be an affordable option, it is not a feasible option everywhere. In Bangladesh, women reported not being able to hire someone to take them to seek emergency care in a boat because the boatmen were likely to charge inflated fares in emergency situations.[18] In Rumbek North County, South Sudan, boats were not a reliable option.[22] Pregnant women reported not having access to medical care because they would have to swim across the flooded areas.[22] One woman described the barriers to accessing healthcare during floods as illustrated by this quote:

> During the wet season, the land becomes flooded and the water can reach the shoulder level. If you are pregnant, you cannot swim in such a place, because your heart will get tired and your thighs will be exhausted[22]

Ajibade *et al*[19] found similar results in the aftermath of floods in Lagos, Nigeria.[19] In this setting, the husbands of women giving birth were required to abide by a compulsory spousal blood donation policy, which required the husband to donate blood before the woman could receive obstetrics care at the hospital.[19] As a result of her husband's refusal to donate blood, one woman reported giving birth at home instead. In this instance, the birth became dangerous because of floods especially regarding hygiene and infection and resulted in the death of the baby and complications with the mother's health.[19]

In addition to floods, tropical cyclones have also been shown to influence access to MHS.[20 24–26] After Typhoon Haiyan in the Philippines, women did not have access to MHS for a month due the health centres being destroyed, and outreach workers being redirected to help at the medical centres.[25] Since the outreach workers were often the only form of maternal services that women in rural areas had access to, many women were left isolated during this time since they would have needed to travel to a health centre for care.[25] Similar impacts were seen in Puerto Rico after Hurricanes Maria and Irma.[24 26] Women in Puerto Rico faced delays in receiving access to MHS as most of the island's hospitals were without electricity.[26] Disruptions in access to healthcare services were reported by several women as a significant stressor during the aftermath of the hurricanes.[24] Despite the disruptions, the women in one study reported that they did eventually receive the care that they needed.[26]

Further issues were seen in cases where there was no option to access MHS. Two of the included studies that

Table 3 Quantitative studies (n=4) characteristics and key findings

Authors	Study sesign	Objective	Study population	Country (Income Index*)	Extreme weather events	Outcome	Exposure measurement	Key points
Baten *et al*[29]	Cohort	To provide more information on the impact that floods have on utilisation of MHS	Ever-married women on the Bangladesh Demographic and Health Survey who had given birth in the last 3 years (n=4620)	Bangladesh (lower middle income)	Flood	Use of antenatal care (ANC)	Emergency Events Database Historical Data	Women were less likely to use ANC in flooded areas. The number of women who ANC was lower in areas that are repeatedly affected by floods in comparison to areas that occasionally flood (OR: 0.66; 95% CI: (0.48 to 0.90); p<0.05)
Haque *et al*[31]	Cross-sectional	To determine the differences in usage of maternal health care services based on flood impact	Households with children under the age of 15 that had experienced displacement in the last 10 years (n=2125)	Bangladesh (lower middle income)	Flood	Delivery at a health facility	Proximity of villages to flood and riverbank erosion prone regions	16.2% of displaced mothers delivered their child at a health centre, compared to 59.8% of non-displaced mothers, affordability and accessibility are cited as reasons (AOR= 0.18, 95% CI: (0.09 to 0.36), p<0.01)
Makanga *et al*[30]	Cohort	To adapt maternal health services access models for low-income settings	Households with women of reproductive age as reported on a census. Sample size varies based on exposures and outcomes	Mozambique (low income)	Flood	ANC accessibility	Precipitation and flood data mapped using GPS	Mapping of a community preflood and postflood revealed that the number of pregnant women within a one-hour walk of a healthcare centre falls by 11% after floods
Orderud *et al*[32]	Case–control	To evaluate the impact that precipitation levels can have on access to maternal health services	Ever-married women of reproductive age listed on Bangladesh's Demographic and Health Survey who responded to all of the questions (n=19 519)	Bangladesh (lower middle income)	Flood	Use of antenatal care (ANC)	Emergency Events Database and Geocoded Disasters	Duration of flood exposure is negatively associated with access to maternal health services; 0–9 months exposure coefficient: 0.008, 95% CI (−0.011 to 0.027); 10–24 months exposure coefficient: −0.012, 95% CI (−0.033 to 0.009); 25–36 months exposure coefficient: −0.021, 95% CI (−0.042 to −0.001)

*Income Index is based on the World Bank's 2024 country economic classification.
†Refer to Appendix B for the quality assessment of each study.
AOR, adjusted OR; MHS, maternal health services.

Table 4 Qualitative study (n=11) characteristics and key findings

Authors	Study design	Objectives	Study population	Country (Income Index)*	Extreme weather events	Health outcome	Other outcomes	Key findings
Abdullah *et al*[18]	Cross-sectional; focus group discussions and interviews	To assess how the community adapts to provide emergency care to pregnant women during floods	Community members who knew the details of recent maternal deaths; focus group (n=3) and interviews (n=8)	Bangladesh (lower middle income)	Seasonal flooding	Maternal mortality	Access to maternal health services	Maternal deaths increased in the region due to the difficulty in accessing MHS as the duration and strength of the floods increases
Ajibade *et al*[19]	Cross-sectional; focus group discussions, survey and interviews	To determine the impact of flooding in Lagos, Nigeria on women's lives and health	Random sample of women who lived in three regions (n=36)	Nigeria (lower middle income)	Flash floods	Not applicable	Access to labour and delivery care	Flooding in conjunction with discriminatory health policies resulted in women giving birth in unsafe and unsanitary conditions at home, often resulting in infection
Bryson *et al*[28]	Cross-sectional; focus group discussions	To highlight the unstable food supply for pregnant women and to provide a platform for women to share their experiences about situations where food is limited	Women in the Kanungu District who were pregnant or who had previously been pregnant (n=46)	Uganda (low income)	Drought	Malnutrition	N/A	Women report a lack of food during the dry season due to drought and difficult pregnancies as a result
Ferdowsy *et al*[20]	Cross-sectional; focus group discussions and interviews	To evaluate the efficiency of the Bangladesh Red Crescent Society's emergency responses to flooding and Cyclone Amphan	People who benefitted from the organisation's interventions including shelter and food security (n=350)	Bangladesh (lower middle income)	Tropical cyclone and flood	Malnutrition	Access to maternal health services	The maternal health centre was destroyed during the events, limiting access to services. Women reported that emergency food distribution did not account for the dietary needs of pregnant women

Continued

Table 4 Continued

Authors	Study design	Objectives	Study population	Country (Income Index)*	Extreme weather events	Health outcome	Other outcomes	Key findings
Lafarga Previdi *et al*[24]	Cross-sectional; open-ended survey	To highlight the experiences of pregnant women after hurricanes Irma and Maria and to determine the factors that influence these experiences	Women who were participants in the PROTECT programme who were pregnant during or shortly after hurricanes Irma or Maria (n=76)	Puerto Rico (higher-middle income)	Tropical cyclone	Mental health	Access to maternal health services	Pregnant women report dealing with many different stressors after the hurricanes regarding access to health services, housing, work, their health and their children. Community support helped to ease the stress in some women
Maheen and Hoban[21]	Cross-sectional; interviews	To understand the experiences of pregnant women in relief camps as so that access to maternal healthcare can be improved in the future	Women who gave birth during floods between July 2011 and September 2011 who lived in one of five villages along the Indus River (n=15)	Pakistan (lower middle income)	Flood	N/A	Access to maternal health services	There is a lack of MHS in relief camps. Women often must travel long distances outside of the camps to seek care
Pardhi *et al*[27]	Cross-sectional; interviews	To understand the experiences of pregnant women living in relief camps because of extreme weather events in India	Women who were pregnant or with a child less than 2 years old who were forced migrants in Mumbai (n=15)	India (lower middle income)	Persistent drought	Malnutrition	Access to maternal health services	Women report that MHS in camps are secondary to other health issues, and they cannot access care. Financial constraints poorly influence the women's nutritional status
Sato *et al*[25]	Cross-sectional; focus group discussion	To determine the barriers impacting access to maternal healthcare after typhoon Haiyan	Women from four communities affected by typhoon Haiyan who were pregnant at the time of the storm (n=53)	Philippines (lower middle income)	Tropical cyclone	Malnutrition, mental health	Access to maternal health services	Pregnant women report expecting miscarriage, lack of food and no access to MHS for a month after the typhoon

Continued

Table 4 Continued

Authors	Study design	Objectives	Study population	Country (Income Index)*	Extreme weather events	Health outcome	Other outcomes	Key findings
Saulnier *et al*[23]	Cross-sectional; focus group discussions and interviews	To determine how pregnancy and delivery are managed during floods	Women who were pregnant or experienced childbirth during recent flooding or their partners (n=41)	Cambodia (lower middle income)	Seasonal and occasional flooding	Mental health	Access to labour and delivery care	Women report needing to be self-reliant during floods and stress over lack of access to care during delivery
Silva-Suarez *et al*[26]	Cross-sectional; interviews	To highlight the experience of pregnant women during Hurricane Maria	Women who were pregnant and in an area impacted by Hurricane Maria (n=10)	Puerto Rico (higher-middle income)	Tropical cyclone	Mental health	Access to maternal health services	Several stressors reported by pregnant women after the hurricane including concern for their baby's health and delayed access to healthcare
Wilunda *et al*[22]	Cross-sectional; focus group discussions; interviews	To understand why women do not use maternal health services in Rumbek North County, South Sudan	Women who had recently given birth, their husbands, community leaders and healthcare professionals (n=226)	South Sudan (low income)	Seasonal flooding	Maternal mortality	Access to labour and delivery care	Floods were found to be an important barrier to labour and delivery care, causing roads to be inaccessible, medication shortages at the health facilities and transportation issues, resulting in maternal deaths

*Income Index is based on the World Bank's 2024 country economic classification.[41]
†Refer to online supplemental appendix B for the Quality Assessment of each study.
MHS, maternal health services; N/A, not applicable.

assessed the health of mothers in relief camps after an EWE found that antenatal and delivery care was nearly impossible to access.[21 27] In part, this was because the doctors had more urgent health issues to address, but in some cases, there was no obstetrics care offered within the camps.[21 27] In a relief camp in Pakistan, women were referred to the nearest health centre which could be as far as 20 kilometres away.[21] This led to women being isolated due to lack of funds for transportation.[21]

Access to MHS in the aftermath of an EWE is not always related to the patients' transportation issues. In some cases, EWE can prevent the health centres from receiving the supplies they need.[22] Women impacted by floods in South Sudan reported choosing to avoid health centres even when access was convenient because the floods prevented delivery of medicines and supplies.[22] However, these disruptions in delivery were not an issue for the staff at hospital in a flood-prone area in Cambodia.[33] Hospital staff reported that their facility prepared effectively for supply-chain issues following EWE and stockpiled supplies in anticipation of disasters.[33]

There are no epidemiological studies of the impact of extreme weather on maternal mortality. Maternal mortality was only examined in one qualitative study.[18 24 25] Abdullah *et al*[18] stated that during floods in Bangladesh, community members reported an increase in maternal death due to the necessity of boats to reach the hospital or for healthcare workers to reach the pregnant women.[18] A village doctor provided their insight into maternal mortality during floods:

> Maternal deaths occur due to excessive bleeding after delivery and difficult to reach at hospital as boat is the only mode of transportation. Sometimes the mother died within the boat. This is most common during the flood period.[18]

Abdullah *et al*[18] claimed that while access to healthcare played a large role in maternal mortality during floods, one must also acknowledge the other factors such as malnutrition and infectious diseases that caused pregnancy complications.[18] These difficult births often led to emergency situations that forced women to seek alternative forms of transportation to the hospital during floods.[18]

Stress

Reported stress following tropical cyclones and floods was a common outcome among several papers.[23–26] Across multiple studies, women reported concerns about access to healthcare during labour.[23 24 26] One woman described feeling stressed during a caesarean section due to unreliable electricity at the hospital after Hurricanes Irma and María.[24]

Outside of the stress surrounding access to healthcare, women also reported an increase in stress in daily life.[23 24] One study on the impact of floods on women in Cambodia described the stress pregnant women felt after the disaster as a result of their tendency to be self-reliant when others in the community were struggling.[23] Further interviewees reported stress over access to essential goods and prenatal vitamins and concerns about the risk of miscarriage as a result.[24]

Maternal nutrition

Malnutrition in the aftermath of EWE was another recurring theme among studies. After Typhoon Haiyan in the Philippines, women spoke about the lack of access to food they experienced immediately after the storm.[25] Especially in settings where rations were being provided, pregnant women reported a disregard for their condition such as having queued for hours for food which was often not enough to meet their increased dietary needs.[20 21 24] Ferdowsy *et al*[20] reported that when distributing rations, their organisation (Bangladesh Red Crescent Society) provided equal rations to everyone.[20] The evaluation of their response to floods and cyclones in Bangladesh concluded that future emergency responses need to acknowledge the additional nutritional needs of pregnant women.[20]

Similar outcomes were reported among pregnant women who lived through floods and droughts. Maheen and Hoban[21] found that in flood relief camps in an area of Pakistan with already high rates of malnutrition, pregnant women were not given enough food or supplements to meet their nutritional needs.[21] In instances where emergency rations were not provided within a drought relief camp, pregnant women reported not being able to afford enough food to feed themselves and their families.[27] During a drought in Uganda, women stated that malnutrition was the most significant determinant of poor health during and after their pregnancies.[28] In this region, access to ANC had improved substantially, yet women still reported that there was not an improvement in overall health throughout the perinatal period due to malnutrition.[28]

DISCUSSION

This review offers evidence that supports the claim that EWE negatively affects maternal health outcomes. The findings of the five quantitative studies provided evidence on the effects of EWE on maternal health, particularly the adverse consequences of inconsistent access to MHS. The 11 qualitative results were complementary to the quantitative results, revealing the lived experiences and perceptions among women during and after EWE and how this impacted their health. Only one of the 15 included studies, Orderud *et al*[32] found no impact to maternal health outcomes in the aftermath of EWE.

Four common outcomes were identified among the 15 studies, including stress, access to MHS, malnutrition and maternal mortality. While each of these outcomes are notable by themselves, one must also acknowledge the limited evidence available on the intersection between EWE and maternal health outcomes, especially in low-income settings. For example, several studies have been

conducted on stress in pregnant women living in high-income settings following hurricanes.[33–35] However, the results of these studies conducted in high-income settings are not entirely transferrable to low-income or middle-income populations due to the differences in institutional structures and support for postdisaster recovery. As none of the studies included in this review analysed stress as the primary outcome, this is a notable gap in the research.

The necessity of access to maternal healthcare has been acknowledged by the international community and the minimum care necessary at all times has been determined through the Minimal Initial Service Package (MISP) for Sexual and Reproductive Health.[36] This plan outlines the minimum sexual and reproductive health interventions that are necessary to prevent loss of life in a crisis setting. While the MISP serves as a necessary baseline for care provided in humanitarian settings, as evidenced by the results of this review, there is a need to progress from this minimum. For example, in several of the included studies, there was a continuation of care following the EWE, however ease of accessibility of health centres remained a key determinant in the number of women who sought care.[18 21 23 29–32] Furthermore, the participants of several included studies reported an increase in stress following EWE due to the uncertainty whether they would be able to access obstetrics care.[23–26] Therefore, transitioning from the minimum standards outlined by MISP to more comprehensive access to care is necessary for preventing long-term health complications in pregnant women. However, as highlighted in this review, the determinants that influence maternal health outcomes following EWE in low-income settings are complex. The pathway between EWE and maternal health is characterised by the exacerbation of systemic vulnerabilities in the aftermath of the events. EWE disrupt healthcare facilities and infrastructure and interrupt medical supply chains, directly limiting access to maternal health services. Reduced access to skilled birth attendants and emergency obstetric care can result in increases in sexually transmitted infections, unwanted pregnancies and maternal and neonatal death. Addressing these issues would require improvements across various dimensions, including socioeconomic factors, infrastructural development and the availability of healthcare services. Understanding the issues and preparing for them through disaster action plans may help to alleviate some of the burden that pregnant women face in accessing obstetrics and delivery care during and after EWE.

The concept of preventing poor maternal health outcomes through disaster action plans at health centres was addressed in two studies that appeared in our systematic search, but were excluded due to variations in the studies' population or outcome from our predetermined inclusion criteria.[37 38] The first of these studies, van Loenhouet *et al*, analysed obstetrics admissions at two hospitals in the Philippines after Typhoon Haiyan. One of the hospitals had a pre-emptive disaster action plan, while the other did not. The hospital with the plan saw no significant change in obstetrics admissions (OR: 1.05, 95% CI (0.81 to 1.36), p=0.713), while the hospital without the plan had a large decrease in obstetrics admissions (OR 0.38, 95% CI (0.26 to 0.56), p<0.01) following the typhoon.[37] The second excluded study, Saulnier *et al*,[38] had similar results.[38] This qualitative study, in which researchers interviewed staff at a hospital in Cambodia, revealed that flooding had little impact on access to MHS at the facility due to the comprehensive contingency plan in place.[38] These studies suggest that an effective means of mitigating the impact of EWE on pregnant women is by training healthcare personnel to effectively manage health centres during and after challenging weather circumstances. By equipping healthcare staff with the necessary knowledge and skills to navigate management of the health centre in a disaster setting, healthcare facilities can provide undisrupted care to pregnant women. While these studies were not eligible for inclusion in this review, the results are still relevant to the discussion surrounding EWE and maternal health. Understanding the barriers preventing women from accessing MHS as outlined in these studies is crucial for mitigation of this problem in the future.

The necessity of research regarding the impact of EWE on maternal health will become increasingly more valuable over the coming years as the IPCC forecasts EWE will increase in duration, severity and frequency as a result of anthropogenic climate change.[5] The type of EWE will vary by region, but as a result, an increase in disasters and climate-related humanitarian crises are already occurring and expected in the future.[5] Many of the consequences of climate change are no longer preventable, therefore adaptation to the new normal will become even more valuable. This could include a variety of actions such as restoring mangroves to protect against coastal surges, changing agriculture to adapt to new weather patterns or building homes that are designed to stay cool even in extreme heat.[5] Adaptation will be a means of preventing excess morbidity and mortality in the face of EWE.

Recent calls for action have highlighted a lack of understanding of how maternal health will be impacted by climate change.[39 40] As evidenced by this review, there is limited research analysing the impact of EWE on maternal health in low-income settings. Regarding maternal health, more research in low-income settings needs to focus on the impact of EWE on miscarriages, infectious diseases, haemorrhages, difficult labour and postpartum depression. Some of these subjects have been studied in high-income settings, but the results are not entirely transferable to women living in LMIC settings due to socioeconomic differences. It is critically important that more research is conducted in low-income settings as they are predicted to be the most prominently impacted by climate change and the resulting EWE.[5] Though there is an urgent need for more research surrounding these subjects, conducting research in the aftermath of a disaster can be difficult, particularly in regions that have poor infrastructure. This is a challenge that has been

overcome in the past as evidenced by the studies included in this review. Using previous studies as a blueprint for how to conduct a successful research study in a postdisaster setting, as well as developing community led solutions and building networks with local researchers could allow for more efficient and impactful research in the aftermath of EWE.

Limitations

The lack of research on this subject has limited the expanse of this review. The wide nature of the topic was necessary. Ideally in the future, when more research on the subject is published, future reviews can individually assess each of the outcomes as a means of scrutinising the impact of EWE more thoroughly. Furthermore, the search method was designed to identify studies in which the main exposure was EWE. However, this may be excluding research in which the impacts of EWE are reported despite this not being the main focus of the research. Additionally, the reviewers' positionality must be noted as a potential influence on the review. Studies that were published in languages other than English were excluded. Discussions of decolonising global health emphasise that often when English is the sole language used in academia, the voices of non-English speaking researchers and experts may be neglected. As these individuals likely would have valuable insight into the issues surrounding EWE and maternal health in their communities, their lack of inclusion in this review is a limitation.

Over time, this review has changed slightly from the original intention. The review was originally registered on PROSPERO as a systematic review. However, with the addition of a third author, discussion moved to labelling the work a scoping review, rather than a systematic review. This change was enacted in part because of the limited studies available on this subject. Therefore, the need for a scoping review became evident so that it could highlight the need for more research on the subject and guide future reviews to conduct more intensive dives into certain subjects included in this review.

CONCLUSION

Overall, the available research suggests that in the aftermath of EWE, pregnant women are vulnerable to negative health outcomes such as malnutrition, stress and mortality. However, more research is necessary on each of these subjects to fully understand the impact of EWE on maternal health. The SDG3 seeks to reduce maternal mortality rates and addressing the morbidity and mortality associated with pregnant and postpartum women following EWE is an important step of advancing this goal.[2] A recurring theme among studies in this review was that pregnant women often felt that their needs were overlooked in the aftermath of EWE.[20 21 25 27] This review provides a platform for the voices and negative health outcomes of pregnant women to be recognised so that efforts can be made in research, policy and practice to address these issues in the context of more frequent and severe EWE.

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