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# Protecting pregnant women from extreme heat: A content analysis of heat health action plans

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## ABSTRACT

Extreme heat exposure increases maternal vulnerability to adverse health outcomes. Heat Health Action Plans (HHAPs) are crucial to risk reduction and adaptive strategies for this vulnerable population. This study analyses the content of HHAPs to assess the extent to which they recognise pregnant women as a heat-vulnerable population, identify any maternal heat-health interventions, and develop recommendations to enhance HHAPs from a maternal health perspective. The grey literature search combined three strategies: 1) Google advanced searches for all HHAPs, 2) customised searches for country-specific HHAPs, and (3) targeted website searches for well-known HHAPs. The search included two phases: Phase 1 identified HHAPs published until August 2023; Phase 2 verified updates to the Phase 1 plans and identified newly released HHAPs from September 2023 to June 2025. Our analysis identified 36 HHAPs across thirteen countries that acknowledged the heightened vulnerability of pregnant women to extreme heat. Among these, 36 % (13/36) provided heat-health education interventions, 33 % (12/36) offered heat-risk communication interventions, 31 % (11/36) included support for health and social care and governance, while only 8 % (3/36) focused on indoor heat reduction for pregnant women. No plans included early warning systems, long-term plans or real-time surveillance targeting pregnant women. Our findings highlight the need to strengthen maternal health resilience in HHAPs through targeted communication, education, integrated health and social care, and indoor heat reduction strategies, along with governance frameworks for early warning systems, long-term heat-health interventions, and real-time surveillance.

## 1. Introduction

Climate change is intensifying extreme heat events, posing a serious threat to human health [1,2]. Pregnant women are increasingly recognised as vulnerable to extreme heat [3]. Exposure to extreme heat during pregnancy is strongly associated with adverse birth and pregnancy outcomes such as preterm birth ([PTB]; before 37 weeks of gestation) [3–7], low birth weight ([LBW]; less than 2500 g) [3, 8–10], congenital anomalies (structural or functional congenital disabilities) [11], stillbirth (foetal death before or during labour) [3,6, 12–16], neonatal deaths (within 28 days of live birth) [17], gestational diabetes [18,19], gestational hypertension [20–22],

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miscarriages [23] and emotional distress [24].

Research that links adverse birth and pregnancy outcomes with heat exposure has been conducted across diverse geographical locations. In North America (U.S.), a cohort of 53 million births reported a 2 % higher risk of PTB [25]; in Europe (Netherlands), a study of over two million births revealed increased risk of PTB (0.6 %) and LBW (0.7 %); In Asia (China and Taiwan), studies found a 3–19 % increased risk of congenital anomalies [26]; and a 3 % rise in gestational diabetes [19]; in Australia, heatwave exposure increased the risk of stillbirth by 50–75 %; and across 29 low-income countries (Africa, South Asia) heat was responsible for one-third of neonatal deaths [17]. Collectively, these findings highlight the global vulnerability of pregnant populations to heat-related health risks.

Epidemiological evidence emphasises the need for maternal-specific interventions to minimise these risks, as well as enhancing individual and community-level heat-health resilience [3,27]. Such strategies include heat alerts and early warning systems, heat-health education, behavioural interventions, and timely access to essential health and social services [27]. However, existing heat-health interventions are insufficient to address the unique needs of pregnant women [27,28]. Heat exposure, along with pregnancy-related anatomical changes and increased foetal demands, can reduce blood circulation, impair oxygen and nutrient delivery, and trigger dehydration, uterine contractions, and adverse birth and pregnancy outcomes [29–31]. Further, a recent review found that current interventions remain insufficient due to lack of empirical evidence evaluating their effectiveness for pregnant populations [27], highlighting a critical gap in maternal specific heat-health interventions. Evidence-based solutions can help policymakers address this gap by designing targeted interventions to protect this vulnerable group.

Adaptation responses to extreme heat have increasingly relied on Heat Health Action Plans (HHAPs) [32]. This study uses the term “Heat Health Action Plan” (HHAP) to represent all heat action plans, which may also be known as “heat action plans”, “heatwave action plans”, “heat alerts and response systems”, “extreme heat action plans”, “excessive heat emergency response plans”, “heatwave management plans” or “heat-health action guidelines” [32,33]. Such plans provide a framework for implementing preventive and adaptive strategies for the general population and heat-vulnerable groups [32,33]. When high-temperature thresholds are met, HHAPs trigger interventions to reduce heat-related illnesses among the public, including vulnerable groups such as older adults, children, individuals with pre-existing medical conditions, and outdoor workers [33–36]. Pregnant women are typically excluded despite evidence suggesting that they are vulnerable to heat due to reduced thermoregulation capacity and physiological changes [29].

The World Health Organization (WHO) advocates for a systematic approach to implementing heat-health interventions for the public and vulnerable populations [32]. The WHO identifies eight core elements of a HHAP to prevent heat-related illnesses. These core elements include appointing a lead body to oversee the plan, accurate and timely alert systems, a plan for providing heat-related health information, reducing indoor heat exposure, long-term planning, real-time surveillance, healthcare and social systems, and caring for vulnerable populations (Supplementary File 1: Table S1) [32]. Many countries are adopting this framework in their HHAPs [36–39].

Most HHAPs included broad adaptation and prevention strategies for vulnerable populations, rather than tailored heat-health interventions, despite the WHO emphasising that HHAP preparedness should prioritise targeted advices and interventions to support pregnant women [40]. To our knowledge, no study has examined HHAPs from a maternal health perspective, despite the

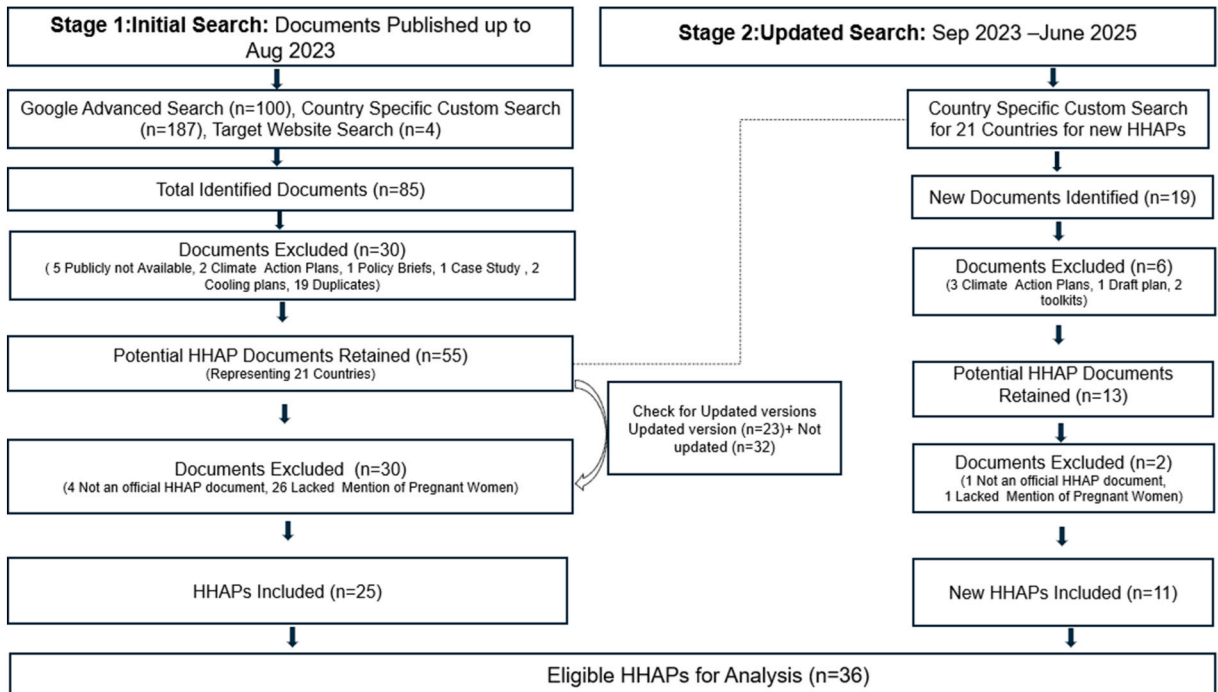


Fig. 1. Methodology for selection of heat health action plans.

increasing evidence of heat-related adverse birth and pregnancy outcomes worldwide.

This study aimed to fill these knowledge gaps by analysing the content of HHAPs worldwide to identify (a) to what extent they recognise pregnant women as a vulnerable group to heat, (ii) the inclusion of heat-health interventions focusing on pregnant women (iii) gaps and provide recommendations to enhance HHAPs from a maternal health perspective.

## 2. Method

### 2.1. Keyword selection and search strategies

A relevant HHAP search was conducted using three search strategies: (1) grey literature searched through Google Advanced Search with six keywords: “heat action plan”, “heat-health action plan”, “heatwave response plan”, “excessive heat emergency plan”, “extreme heat strategy plan”, and “heat early warning system”. These search terms were selected based on terminology commonly cited in WHO HHAP guidance and published literature on HHAPs [32,33]; (2) Customised Google searches for 183 countries to obtain relevant country-specific HHAPs (Supplementary File 2), with the country list sourced from the ND-GAIN (Notre Dame Global Adaptation Initiative) vulnerability index [41]; and 3) Targeted website searches to download well-known HHAPs (Supplementary File 2). These systematic approaches reduced the chance of missing relevant HHAPs.

### 2.2. HHAP identification and follow-up search process

Searches were conducted in two phases: Phase 1 (HHAPs published until August 2023): identified 55 potential HHAPs from 21 countries (Supplementary File 2). To ensure data relevance and up-to-date information, Phase 2 involved a two-step follow-up search (September 2023 to June 2025): first we verified whether the plans from Phase 1 had been updated. Second, we searched for any newly released plans within the same counties identified in Phase 1 (Fig. 1). We included only publicly available standalone HHAPs and excluded broader climate adaptation and disaster management frameworks due to the study time constraints. No restrictions were applied to time, language, or geographical region; however, the follow-up was limited to 21 countries identified in Phase 1, where HHAPs had already been located. These 21 countries account for the widely recognised HHAPs, while the remaining countries yielded



Fig. 2. Geographical distribution of HHAPs that identify pregnant women as a heat-vulnerable group. (N = national, S = subnational).

no HHAPs during Phase 1. Given the slow progress of developing targeted interventions for pregnant women [27,42], the probability of missing new plans with maternal-specific interventions was low. Conversely, widely recognised HHAPs were captured (Supplementary File 1: Table S2), ensuring relevance and coverage of key maternal heat-health interventions.

### 2.3. Selection criteria for maternal related HHAPs

HHAPs were selected for content analysis based on the following criteria: (i) the plan must be an officially recognised national or subnational document, and (ii) the plan must acknowledge pregnant women as a heat-vulnerable population. Non-English plans were translated using Google Translate and verified with native speakers to ensure content accuracy. (Fig. 1).

### 2.4. Content analysis

We created a list of themes and sub-themes to guide the extraction of heat-health information relevant to pregnant women. These themes were primarily derived from core elements outlined in WHO HHPA guidance [32] and incorporated insights from previously published literature [10,40,43] and discussions with co-authors. Content of the retrieved plans was read, and the relevant information was extracted into a spreadsheet. For the content analysis, scores were assigned as follows: 0 points if no heat-health intervention was described and 1 point if at least one intervention was described. Total scores and percentages of HHAPs addressing each theme, with a focus on maternal health, were calculated. The rationale for developing each theme is presented in the supplementary file (Supplementary File 1: Table S3).

Categories were primarily based on core elements from WHO HHPA guidance [32]. Coding was applied when at least one relevant strategy aligned with the subtheme’s focus.

## 3. Results

### 3.1. Extent of maternal focus across HHAPs

The study identified 68 potentially relevant HHAPs (Supplementary File 1: Table S2). Of these, 36 plans met the inclusion criteria by recognising pregnant women as vulnerable to heat. These 36 plans included national (n = 9) and sub-national (n = 27) HHAPs from 13 countries (Fig. 2).

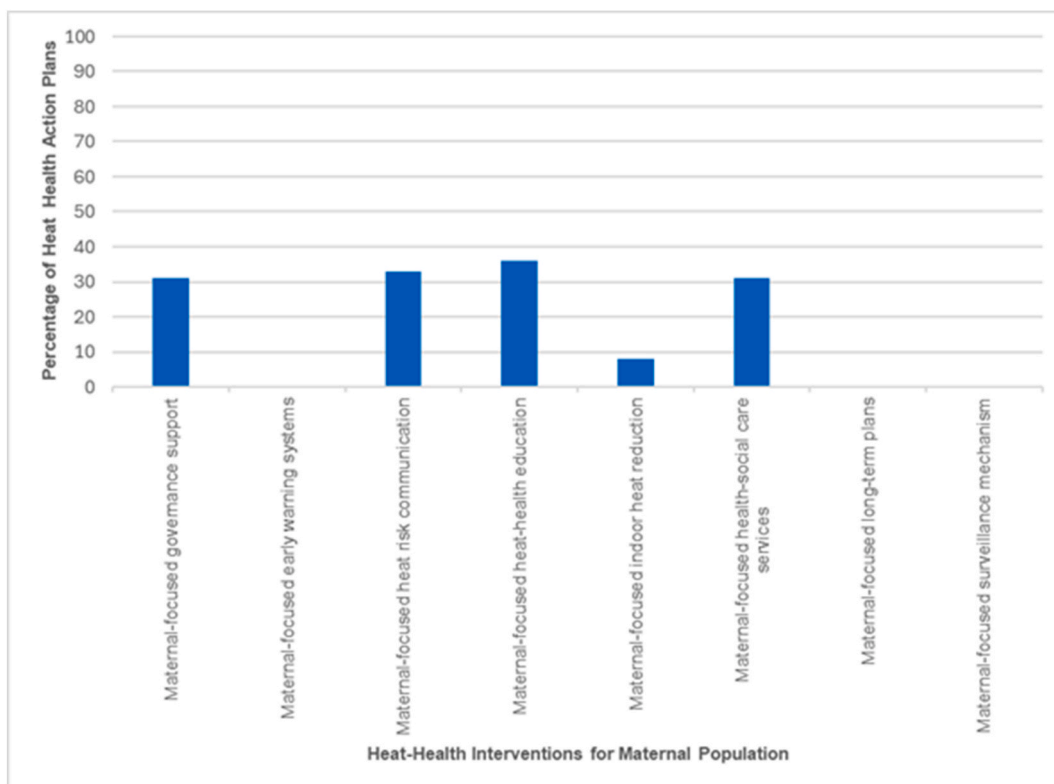


Fig. 3. Heat-health interventions targeting pregnant women.

Of the 36 HHAPs reviewed, 50 % (18/36) included at least one maternal-specific health intervention, while the remaining 50 % (18/36) acknowledged pregnant women as a heat-vulnerable group but did not outline target interventions (Supplementary File 1: Table S4).

### 3.2. Maternal heat-health interventions

The most common HHAP interventions targeting pregnant women were heat-health education (~36 % (13/36), followed by heat risk communication (~33 % (12/36) (see Table 1). Additionally, 31 % (11/36) outlined health-social care support interventions for the maternal population. Indoor heat reduction focusing on pregnant women was mentioned in only 8 % (3/36) of the HHAPs. Governance support for pregnant women was included in 31 % (11/36) of plans. None of the HHAPs provided long-term plans, real-time surveillance, or an early warning system for initiating actions aimed at protecting pregnant women (Fig. 3). Details of the heat-health interventions targeted towards pregnant women, as outlined in the HHAPs, are presented in Table 2.

#### 3.2.1. Heat risk communication interventions

Approximately one-third (33 %) of the HHAPs incorporated at least one heat risk communication strategy targeting the maternal population. Disseminating heat-health information is the most common maternal-focused intervention identified in the analysis. Multiple HHAPs in India included this strategy: disseminating IEC (Information, Education, Communication) materials aimed at raising maternal heat-health awareness and preventing dehydration [37,44,49,51]. Posters and pamphlets outlining the signs and symptoms of heat stress, along with recommended actions during heatwave periods, are also displayed in “village health walls”, maternity wards and Anganwadi centres (rural childcare and mother care centres) [37,49–51,61].

Behavioural adjustments through trusted healthcare practitioners are a central strategy in European HHAPs to mitigate maternal heat-health risks. These strategies include personalised behavioural advice via telephone calls or text messages [47], and individualised discussions with a general practitioner (GP) to address heat stress and dehydration [44,48]. Health authorities have also issued circulars encouraging pregnant women to consult GPs for heat-related illnesses [45]. Regular clinic visits make these strategies effective for pregnant women.

A HHAP in Italy explicitly references the *Safe Summer: How to Beat the Heat During Pregnancy* brochure as a part of its maternal heat-health communication and education, promoting behavioural changes to reduce heat risk during pregnancy [44,48]. The advice includes drinking plenty of water, at least 2 L per day, following the doctor’s instructions to avoid dehydration, limiting the intake of sugar-sweetened beverages and alcoholic beverages, consuming light meals rich in water, wearing loose-fitting clothes, and bathing frequently [44,48]. Such practical measures help equip pregnant women to minimise heat-health risks for themselves and their babies.

#### 3.2.2. Heat-health education interventions

Maternal-specific heat-health education interventions were identified in approximately 36 % of HHAPs. The most common strategies included educational outreach through IEC materials [36,37,44,49,50,52,53], pregnancy-focused heatwave awareness campaigns [44,48,52], and targeted educational sessions for health professionals [49,56].

These education efforts focus on promoting hydration and raising awareness within the maternal population of the dangers of heat waves. Particularly, Indian HHAPs recommended targeted awareness programmes using existing platforms, such as Urban Health and Nutrition Day, Village Health, Sanitation, and Nutrition Day, and Routine Immunisation Day, to raise heat-health awareness and promote the prevention of heat strokes and dehydration among pregnant women [49]. HHAPs also promote training front-line health

**Table 1**

Content analysis: Themes and sub-themes.

Core elements of HHAPs	Themes	Sub-themes	HHAPs addressing theme (%)
Agreement on a lead body	Governance Support	Identify at least one collaboration effort between the lead agency and stakeholders for planning or implementing maternal heat-health interventions, heat health policies, and/or resource allocation.	31 %
Accurate and timely alert systems	Early warning systems	Identify at least one warning at each heatwave severity level (low, medium, severe) or a threshold temperature that is relevant for pregnant women.	0 %
Heat-health information system	Heat risk communication	Outline at least one behavioural recommendation or one heat-health information dissemination strategy focused on pregnant women.	33 %
Care for vulnerable population	Heat-health education and training	Outline at least one heat-health education strategy for pregnant women or a training approach for healthcare professionals in maternal units.	36 %
Preparedness of health care and social services	Health care/social services support	Describe at least one health and social interventions that identifying high-risk pregnant individuals or, clinical follow up coordination or, symptom management, or access to emergency services.	31 %
Reduce indoor heat exposure	Reducing indoor heat	Describe at least one indoor heat reduction strategy at the household or healthcare facility level, targeting pregnant women.	8 %
Long-term planning	Long-term heat adaption and policy planning	Describe at least one long-term heat-health intervention or heat-health policy aimed at pregnant women.	0 %
Real-time surveillance	Real-time surveillance	Describe at least one systematic approach to tracking, monitoring, and evaluating pregnant women.	0 %

**Table 2**

Targeted heat-health interventions focusing on pregnant women covered in HHAPs.

Theme	Sub-theme	Implementation Level	Maternal focus intervention	Example	Reference HHAP		
Heat-risk communication	Behavioural adjustments	Individual	Advice via healthcare professionals	“Avoid excessive weight gain during pregnancy; drink 2.5 L daily ... reduce activities in hottest hours, use air conditioner, dress in light clothing.” “Wear loose, stay hydrated, limit sun exposure during the hottest part of the day (between 11 a.m. and 5 p. m., avoid exercise during hot days”	Italy HHAP (pp. 53) [44] Portuguese HHAP- Circular No. 25/DA/DSR [45,46]		
			Establishment of a “heat line”	“Pregnant women .... receive a call or an SMS or app message combining a personal heat alert and behavioural advice ....”	Vienna HHAP (pp. 42) [47]		
			Food hygiene precautions	“During extreme heat, consuming improperly preserved foods can increase the risk of gastroenteritis, which is particularly harmful during pregnancy” ... ..” During extreme heat pregnant women should avoid high-risk foods, .... must be accompanied by special attention to how permitted foods are stored.”	Italy HHAP– <i>How to Beat the Heat During Pregnancy</i> brochure [44,48], France HHAP (pp. 207) [35]		
	Dissemination heat health information	Individual/Community Health Facilities	Tailored messaging for pregnant women on heat safety Ministry of Health circular to all health establishments outlining risks and actions for pregnant women.	“Heat information messages tailored to pregnant women” “If you are in the presence of a pregnant woman, assess heat stress signs such as dizziness, fatigue, irregular heartbeat, blood pressure, body temperature ... ..move the pregnant woman to a cool room ....”	South Africa HHAP (pp. 20) [36] Portuguese HHAP -Circular. No. 25/DA/DSR [45, 46]		
Heat-risk communication/education	Dissemination heat health information	Community	Distribution of IEC materials	“Display IEC materials at Anganwadi centres” .... “ICDS workers disseminate Heat Wave related information with special focus on pregnant and lactating mothers to protect them from dehydration” “Heat information messages tailored to pregnant women”	India HHAPs - Odisha (pp. 52) [37], Telangana (pp. 61) [49], Bhubaneswar (pp. 42) [50], Ahmedabad (pp. 20) [51], Angul pp.29) [52], Bihar (pp. 34) [53], Gujarat (pp. 28,37) [54], Haryana (pp. 13) [55], Rajasthan (pp. 61) [56], Uttar Pradesh (pp. 57, 58) [57], South Africa HHAP (pp. 20)		
			Preventive education	Individual Community	Educational brochures for pregnant women Education sessions and campaigns	<i>Safe Summer: How to Beat the Heat During Pregnancy.</i> - covering hydration, signs and symptoms of heat stress and heat prevention measures. “Heat-health education through designated community health days (e.g., Urban Health and Nutrition Day, Village Health, Sanitation and Nutrition Day, Routine Immunization Day) for pregnant women regarding heat stroke management and dehydration prevention	Italy HHAP- <i>How to Beat the Heat During Pregnancy</i> brochure [44,48] India HHAPs - Odisha (pp. 52) [37], Bhubaneswar (pp. 37,42) [50], Ahmedabad (pp. 20) [51], Telangana (pp. 61) [49], Angul (pp.19) [52], Bihar (pp. 34) [53], Haryana (pp. 13) [55], Rajasthan (pp. 61) [56], Uttar Pradesh (pp. 57,58) [57],
			Heat-risk detection	Individual (health professionals)	Workforce education and training	“Training ASHAs and ANMs, and ICDS staff to recognise heat stress symptoms in pregnant women and children and take action” “HIV councillors and other lay health workers be trained to provide heat interventions”	India HHAPs - Telangana (pp. 54) [49], Rajasthan (pp. 61) [56] South Africa HHAP (pp. 20) [36]
Health and social support services	Access emergency services Clinical follow-up coordination	Individual	Child and women-specific 24/7 hotline during heatwave season Medical referral and home visits based on alert calls	“Child and Women specific Hot Line numbers activate 24/7”. “... during calls, the staff of the “heat line” watches out for signs of health issues. If necessary, they inform the competent GP for follow-up home visits”	India HHAPs-Telangana (pp. 61) [49] Vienna HHAP (pp. 42) [47]		

(continued on next page)

Table 2 (continued)

Theme	Sub-theme	Implementation Level	Maternal focus intervention	Example	Reference HHAP
	Symptom management	Community	Alert system for rapid response to maternal heat stroke cases	“Considerations for identifying patients (including pregnant women) at risk in your practice. “Mobile base alert systems for ASHAs and ANMs provide effective and immediate assessment of heat stroke cases.”	Australian HHAPs-Queensland (pp. 36) [58], South Australia (pp. 45) [59] India HHAPs - Odisha (pp.,41) [37], Bhubaneswar (pp. 40) [50], Angul (pp.20) [52]
	Maternal outreach and care	Community	Neighbourhood community support services	“... neighbourhood and local facilities .... act as multipliers and provide useful tips and local outreach ... .. domestic support, meals on wheels, can be used to establish direct contacts.	Vienna HHAP (pp. 42) [47]
		Individual Community	Mobilise community health workers and assist pregnant women	“Community health workers identify and assist pregnant women during heat waves particularly those who are in high-risk areas.”	South Africa HHAP (pp. 20) [36]
		Community	Pre-position safe drinking water, rehydration supplies, before heatwaves to reduce maternal dehydration risks	“Provision for sufficient safe drinking water may be made in all Anganwadi centres- “... .. “prepare stock of oral rehydration solution, buttermilk, and other rehydration methods well in advance at all Anganwadi centres.”	India HHAPs - Telangana (pp 61) [49], Odisha (pp., 52) [37], Ahmedabad (pp. 20) [51], Angul (pp. 29) [52], Gujarat (pp. 28) [54], Rajasthan (pp. 62) [56], Uttar Pradesh (pp. 57,58) [57]
Indoor heat reduction strategies	Household-level adaptation	Individual	Reduce indoor heat exposure for pregnant women	“Improve the microclimate at home by darkening the windows ... use curtains, shutters, blinds, ... .. Close windows during the daytime .... Spend the hottest hours in the coolest room in the house ... use air conditioner” ... .. “Rest in air-conditioned places. reduce the room temperature by placing bottles of cold water in the room”	Italy HHAP <i>How to Beat the Heat During Pregnancy</i> brochure [44,48] Portuguese HHAP Circular No. 25/DA/DSR [45,46]
		community	Improve thermal comfort in antenatal and childbirth facilities	“Indoor temperature monitoring, heat resilient antenatal and childbirth environment, natural ventilation, fans.	South Africa HHAP (pp. 20) [36]
Governance support	Resource allocation	Government	Readiness of health facilities for heat-affected maternal cases	“Deputy Commissioner for Health and Sanitation ensures availability of beds, staff, inventories, and ambulances” with priority to high-risk groups including pregnant women	India HHAPs - Bhubaneswar (pp. 39) [50]
	Labour protection		Work exemptions and adjustments for pregnant women during heatwaves	“Government of North Macedonia and Ministry of Health recommend flexible hours, remote work, or reassignment to lighter duties for pregnant women in heat-affected areas”	North Macedonia ((pp 29,30,50) [60]
	Stakeholder Coordination		Stakeholder collaboration for maternal heat-health interventions	Most Indian HHAPs assign roles to departments like Health & Family Welfare, Women & Child Development, and ICDS to coordinate IEC, outreach, and service delivery for pregnant and lactating women during heatwaves.	India HHAPs - Telangana (pp 61,67) [49], Odisha (pp. 41) [37], Bihar (pp. 34) [53], Bhubaneswar (pp. 39,42) [50] Angul (pp. 19) [52], Ahmedabad (pp. 20) [51] Gujarat (pp. 37) [54], Rajasthan (pp. 50,52, 61) [56], Uttar Pradesh (pp. 57,58) [57]

Notes: Information, Education, Communication (IEC), Auxiliary Nurse Midwives (ANMs), Accredited Social Health Activists (ASHAs), Anganwadi workers (AWWs), and Integrated Child Development Scheme staff (ICDS), Anganwadi centres (rural childcare and mother care centres).

workers, including Auxiliary Nurse Midwives (ANMs), Accredited Social Health Activists (ASHAs), Anganwadi workers (AWWs), and Integrated Child Development Scheme staff (ICDS), to support early recognition and management of maternal heat-health issues [49, 56].

These heat-health education interventions enhance maternal understanding of heat-related risks, while targeted training for obstetric and maternal care staff improves interdisciplinary collaboration to identify high-risk pregnant individuals in extreme heat.

### 3.2.3. Health-social services support interventions

Approximately 31 % of HHAPs indicated health-social care for pregnant women. These strategies include localised maternal outreach care, clinical coordination and follow-ups, emergency, and symptom management services [36,37,47,49–52,54,56,57].

In Austria, the Vienna HHAP established maternal outreach care through neighbourhood community programs designed to identify pregnant individuals at risk during heatwaves, offering domestic support, meals, and arranging GP follow-ups when needed [47]. Indian HHAPs encourage Anganwadi centres to ensure uninterrupted nutrition services and pre-position safe drinking water, and rehydration supplies (including oral rehydration solutions and buttermilk), to protect pregnant women, lactating mothers, and babies during heatwaves [37,49,51,52,54,56,57].

Support services for symptom management during heatwaves include guidance from ASHAs and ANMs on safe delivery, breastfeeding, and heat stroke management [37,50,52]. The Telangana HHAP (India) recommended implementing a 24/7 child and women-specific hotline to ensure timely access to emergency care for maternal and child needs during heatwaves [49]. These health-social care services provide timely assistance to pregnant women, thereby reducing health risks for both them and their fetuses.

### 3.2.4. Indoor heat reduction interventions

Indoor heat reduction interventions have received little attention, with only 8 % of HHAPs describing indoor heat reduction for pregnant women. The South African HHAP proposes monitoring indoor temperatures and creating heat-resistant environments in maternal and childbirth facilities [36]. Italy's *Safe Summer: How to Beat the Heat During Pregnancy* brochure outlines household strategies for reducing indoor heat, such as darkening windows and utilising air conditioners and fans [48]. It also recommends blocking sunlight with curtains and blinds and keeping windows closed during the hottest hours of the day. The Portuguese HHAP advises pregnant women to use frozen water bottles to reduce excessive indoor heat and avoid associated health risks [45].

### 3.2.5. Governance support

This analysis found limited evidence of government involvement and stakeholder engagement, with only 31 % HHAPs mentioning lead agency and stakeholder collaboration for maternal-specific heat-health interventions. Most Indian HHAPs describe the roles and responsibilities of various stakeholders, such as Health & Family Welfare, Women & Child Development, ICDS, and Anganwadi centres [37,49–54,56,57]. These groups collaborate to disseminate IEC materials, educational campaigns, and health-social services to pregnant women during heatwaves. They also collaborate in developing maternal heat-health guidelines, train healthcare workers, and ensure resources (e.g., hospital beds and ambulances) are prioritised for high-risk pregnant individuals [37,49,50,56]. Additionally, the government and stakeholders are responsible for enforcing workplace guidelines that focus on pregnant women. For instance, the HHAP in North Macedonia indicated that the North Macedonian Government and the Ministry of Health implemented labour protection guidelines recommending flexible work hours, remote work, or reassignment to lighter duties for pregnant women during heatwaves [60].

## 4. Discussion

To our knowledge, this is the first content analysis to assess HHAPs from a maternal health perspective, examining the extent to which they recognise pregnant women as a heat-vulnerable group and the heat-health interventions to protect them during extreme heat events.

### 4.1. Key findings

Our analysis of 36 HHAPs across thirteen countries identified that 18 plans incorporated preventive or adaptive interventions to protect pregnant women from extreme heat. The most common strategies were maternal heat health education (36 %) and heat risk communication (33 %). Health-social care and governance support were each outlined in 31 % of HHAPs, while only 8 % addressed maternal-specific indoor heat reduction. No HHAPs included long-term heat-health plans, real-time surveillance, or early warning systems targeting pregnant women.

### 4.2. Gaps and recommendations

Significant gaps remain in current HHAPs from a maternal health perspective. Of the 68 reviewed plans, nearly half ( $n = 32$ ) failed to recognise pregnant women as a heat-vulnerable group. Among the 36 plans that acknowledged their vulnerability, 50 % lacked targeted interventions. This reflects that pregnant women remain under-prioritised in existing HHAPs.

### 4.3. Heat-health communication, education, and health-social services

HHAPs incorporated targeted heat risk communication, education, and health-social care support services for pregnant women to raise awareness and timely access to essential services. These interventions appear in two broad forms: individual-level strategies to promote behavioural adaptation and community-level strategies to build community support for pregnant women.

Individual-level interventions empower pregnant women with essential knowledge, early recognition of heat-health symptoms, encourage protective behaviours, and seek supportive services. European HHAPs more often detailed individual-level interventions, promoting behavioural adjustments for pregnant women through direct engagement with trusted healthcare professionals. HHAPs from Italy [44,48], Portugal [45,46], and Vienna (Austria) [47] emphasise individual discussions focusing on behavioural adjustments with GPs, gynaecologists, and midwives, who are well-prepared to deal with at-risk pregnant individuals. These discussions cover the importance of hydration, heat symptom management, and strategies to minimise heat exposure. Health professionals also serve as primary communicators to deliver warning messages and alerts for pregnant individuals [44,47,48]. Vienna's HHAP promotes the delivery of behavioural advice via calls, SMS, and App messages, while Italy's HHAP endorses disseminating heat-health education brochures to pregnant women, promoting hydration, heat prevention, and safe food-handling strategies to encourage timely behavioural changes that minimise heat-health risks [44,47,48].

Compared to Europe's detailed individual interventions, those in Australia, India, and South Africa remain underdeveloped, with brief maternal-specific advice and limited intervention details. For instance, HHAPs in Australia (Queensland and South Australia) encourage GPs to identify heat-vulnerable pregnant individuals and notify relevant staff for tailored support; however, the current plans do not specify follow-up strategies to ensure continuity of care [58,59]. Indian HHAPs recommend maternity ward education sessions targeting new mothers [50], a 24/7 child and women's "helpline" [49], and mobile heat stroke units [37] that provide maternal-specific assistance during heatwaves. However, these strategies lack details; thus, our study recommends that future HHAPs should document intervention details, service capacity, and outreach mechanisms.

**Community-level interventions** enhance local engagement and support networks, and timely access to resources. Indian HHAPs focus more on community-level interventions to support pregnant women during heatwaves. Such strategies include the dissemination of heat-health information through IEC materials at Anganwadi centres, engagement with ICDS, ASHA, and ANM workers to deliver guidance on maternal dehydration, and targeted education to raise awareness of "what to do" and "what not to do" during heatwaves [37,49–56]. However, we could not find details of the content included in the IEC materials targeting pregnant women, as this was not included in the associated HHAPs. Other interventions include use of designated community health days, such as Nutrition Day and Routine Immunisation Day, to reach pregnant women and young girls, educating them on heat stroke management and dehydration prevention [37,49,50]. The provision of safe drinking water and pre-stocked oral rehydration solutions at Anganwadi centres further supports continuity of care for the maternal population [49,50]. In Europe, Vienna's (Austria) neighbourhood assistance program reflects similar strategies by providing information on domestic help services, meal delivery, and fostering mutual contact with pregnant individuals who need additional support [47].

Despite these promising interventions, we found that approximately 60 % of HHAPs lack targeted education, and 70 % miss heat-risk communication and support services, highlighting a critical gap in current HHAPs from a maternal health perspective. HHAPs consistently referred to heat-health information dissemination and health and social workers focusing on the maternal population; however, they lack clarity on content and execution. To enhance the effectiveness of the interventions, future HHAPs should outline specific actions at individual and community levels, define the roles of frontline workers, and establish a system to evaluate the effectiveness of maternal-specific interventions.

### 4.4. Indoor heat reduction interventions

Indoor heat reduction interventions were articulated for households and facilities. Household-level maternal-specific indoor heat reduction measures include shading windows with curtains or blinds and improving ventilation through natural ventilation, fans, and air conditioners to enhance thermal comfort for pregnant women [36,48]. Facility-level strategies include monitoring indoor temperatures, designing heat-resilient maternal and childbirth facilities, and relocating maternity wards to cooler areas to promote a safe and comfortable environment for mothers and babies [36]. Evidence from Ahmedabad, India, found that a 1 °C increase in daily maximum temperature during heatwaves was associated with a 43 % increase in neonatal admissions; cooler, lower-floor maternity wards offered a protective effect [62]. Therefore, low-resource settings with limited cooling facilities could benefit from ward relocation to minimise heat-related adverse pregnancy outcomes. Structural adaptations, such as cool roofs and wall insulators, are also recommended to reduce indoor heat exposure [36,51]. Ahmedabad has successfully implemented cool roof strategies as part of a HHAP, showing promising results in reducing indoor temperatures that could benefit the maternal population. However, maternal-focused indoor heat reduction strategies were limited; over 90 % of HHAPs failed to include targeted indoor heat reduction strategies. Future HHAPs should prioritise indoor heat reduction interventions, especially for pregnant women living in poorly ventilated, high thermal risk housing conditions.

### 4.5. Governance support

Governance support was consistently featured in Indian HHAPs, led by state-level lead agencies, with the involvement of women and child development agencies, health, and family welfare, ICDS, and Anganwadi centres [37,49–54]. Additionally, North Macedonia's HHAP details collaborative efforts between the government and the Ministry of Health to support pregnant workers during

heatwaves through flexible work policies and targeted interventions such as flexible hours, remote work, or reassignment to lighter duties in heat-affected areas [60]. Several other HHAPs acknowledge the need for specific considerations for pregnant workers [37,49,50,52,54], but lack clear strategies. Collaboration efforts between government and stakeholders are essential for capacity building, workforce training, and strategic funding to mitigate the impacts of extreme heat [32,63]. However, our study found that 70 % HHAPs lack details of roles, responsibilities, and collaboration between the lead agency and stakeholders, a critical gap in current HHAPs. Therefore, we recommend incorporating details of roles and responsibilities of lead agencies and stakeholders specific to maternal health, and explicit governance support strategies within HHAPs to strengthen maternal-focused heat-health interventions.

#### 4.6. Early warning system

All HHAPs outlined response measures for heatwave severity levels (low, medium, high) or specific threshold temperatures; however, these measures focus on the public, and they lack targeted guidance for pregnant women. Pregnancy is vulnerable to heat, with studies showing that even a 1 °C increase in ambient temperature increases health risks for both mother and foetus [64,65]. A recent meta-analysis revealed a 4 % increase in PTB risk per 1 °C rise in ambient temperature and a 26 % increase during heatwaves [65]. Heat exposure also elevates the risk of stillbirth, congenital anomalies, and gestational diabetes, with severity associated with intensity and duration [65]. Therefore, pregnant women require early recognition of heat risk and prompt actions to keep them and their foetuses safe. However, a one-size-fits-all threshold at a broad regional scale may overlook critical periods with a higher risk of adverse birth and pregnancy outcomes because temperature metrics vary significantly by region [3]. Therefore, temperature thresholds for initiating action should be defined at the local level, as local data can better account for microclimate variations [3,64,66]. Personalised notification systems based on localised temperature thresholds could enhance timely awareness and response capacity for the maternal population.

#### 4.7. Real-time surveillance and long-term planning

Developing personalised alerts and timely actions for pregnant individuals requires real-time surveillance, which is currently lacking in reviewed HHAPs. Some Indian HHAPs mention a monitoring system for children, women, and breastfeeding mothers [49,57]. However, specifics for pregnant women are missing. Italy's HHAP includes health surveillance, but it is not detailed for pregnant women [44]. There is also a lack of long-term plans and heat-health policies for this group, another critical gap identified from this review. Effective surveillance and long-term plans depend on local epidemiological and temperature data at the individual level. Individual heat exposure varies due to indoor and outdoor temperatures, housing conditions, behaviours, socioeconomic conditions, and cultural norms [27,67]. Therefore, scientific research, including randomised control studies and observational analysis across diverse geographic and socioeconomic settings are required to validate and refine long term interventions, as well as track and respond to pregnant women during heatwaves.

#### 4.8. Strengths and limitations

The study has several strengths. We reviewed HHAPs from a maternal health perspective and identified interventions aimed at mitigating heat-related health issues for pregnant women. These interventions focus on targeted communication, education, health-social support, and governance support for pregnant women. Our analysis included HHAPs from five continents and diverse climates, ensuring global representation and applicability of the findings across different regions. The study also included an updated review through to mid-2025, allowing us to incorporate the most recent versions of HHAPs and capture relevant, up-to-date information focusing on pregnant women.

Several limitations should be acknowledged. First, the study only included publicly available standalone HHAPs due to time constraints; plans embedded within broader climate adaptation and disaster management frameworks may have been missed. However, widely recognised HHAPs were captured, and key maternal-focused interventions were included. Second, the study focused solely on interventions targeting pregnant women and did not address newborns, as HHAPs rarely defined them (those aged within 28 days), and often refer more generally to children or infants without specific interventions. Future HHAPs should address heat-health interventions for newborns as they are highly susceptible to heat. Third, due to absence of both national and subnational HHAPs from the same countries, this study limits our ability to conduct direct comparisons between different governance tiers. Although the study provides a descriptive overview of interventions at both levels (Supplementary file 1:Fig. S1), we were unable to investigate the degree of consistency or coordination between maternal-specific initiatives at these two levels. Future studies should focus on examining how national and subnational HHAPs interact and align, especially in countries with multilevel governance, to improve understanding of heat-health interventions for pregnant populations across different governmental levels.

## 5. Conclusion

Our analysis indicates that most current HHAPs overlook the risks associated with extreme heat for the maternal population. Although many plans incorporate the core elements identified by WHO guidance, heat-health interventions for pregnant women were limited, as were targeted heat risk communication, education, health-social services. The lack of a maternal-specific early warning system, long-term policies, and real-time surveillance emphasises the need for solid governance support and stakeholder engagement to enhance plans from a maternal health perspective. We recommend future HHAPs include more maternal-specific heat-health

interventions to minimise heat-related adverse birth and pregnancy outcomes.

### CRediT authorship contribution statement

**Yohani Dalugoda:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Dwan Vilcins:** Writing – review & editing, Supervision. **Darsy Darssan:** Writing – review & editing, Supervision. **Amie Steel:** Writing – review & editing, Validation, Methodology. **Dung Phung:** Writing – review & editing, Supervision, Methodology, Conceptualization.

### Ethics approval

Not required. No human subjects or individual data were used in this study.

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### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijdr.2025.105831>.

### Data availability

No data was used for the research described in the article.

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