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A scoping review on heat indices used to measure the effects of heat on maternal and perinatal health

Chloe Brimicombe [1], Francesca Conway,[2] Anayda Portela [3], Darshnika Lakhoo,[4] Nathalie Roos [5], Chuansi Gao,[6] Ijeoma Solarin,[4] Debra Jackson [7,8]

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For numbered affiliations see end of article.

Correspondence to
Dr Chloe Brimicombe;
chloe.brimicombe@uni-graz.at

ABSTRACT

A previous systematic review has shown associations between exposure to high temperatures and negative birth outcomes. To date, a scoping review for heat indices and their use to measure effects of heat on maternal and perinatal health has not been considered.

Objectives To provide a scoping review on heat stress and indices for those interested in the epidemiology and working in extreme heat and maternal perinatal health.

Methods This study is a scoping review based on a previous review guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping reviews. It identifies the main ways heat stress through different heat indices impacts maternal and perinatal health in available literature. For documents that met the inclusion criteria, we extracted 23 publications.

Results We find four heat indices: heat index, apparent temperature, wet bulb globe temperature and universal thermal climate index. Exposure to elevated levels of heat stress can be associated with preterm birth. In addition, the more intense and prolonged duration of exposure to heat stress, the greater the risk of stillbirth. Negative birth outcomes can occur from change in hormonal levels (ie, cortisol), dehydration and blood flow diversion away from the placenta and fetus when suffering from heat stress. All studies demonstrate that certain socioeconomic factors influence the effect of heat on maternal and perinatal health outcomes.

Conclusion We make three suggestions based on the results: (1) heat indices should be standardised across studies and explained. (2) An increased number of perinatal and maternal health outcomes explored. Finally, (3) enhanced collaboration across climate and health to improve understanding.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Previous systematic reviews have shown associations between exposure to high temperatures and adverse birth outcomes.

WHAT THIS STUDY ADDS

⇒ It is the first scoping review to focus on heat indices, with 25 studies found. We find a range of methods used across four types of heat index and a broad lack of understanding on heat indices. In addition, few regions and health outcomes are investigated. There is consensus that socioeconomic factors are important to consider alongside heat exposure.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ We make three suggestions that we hope will shape research and clinical practice: (1) standardisation of heat indices, (2) explore an increased range of perinatal and maternal health outcomes, and (3) greater collaboration across the climate and health communities.

INTRODUCTION

Extreme heat poses a risk to the health of perinates and maternal women.[1] Extreme heat is increasing in frequency, duration and intensity, because of human-induced climate change.[2 3] It has been found that nowhere is safe from the occurrence of heatwaves.[4] This poses a health risk to a growing proportion of the population because extreme heat has many impacts on health outcomes and has been associated with increased hospital admissions and mortality rates.[5 6] A recent study reported that 65 000 people died across Europe in heatwaves during Summer 2022.[7] In addition, it has been found that babies born in 2020 will be exposed to 30 heatwaves over their lifetime with a 1.5°C warming, over six times more than someone born in 1960.[8] Extreme heat also has indirect impacts on health, for example, posing challenges to infrastructure resilience and food systems.[8 9]

Humans are homotherms and must maintain an internal temperature of around 37°C despite the surrounding environmental conditions.[7 9] Groups vulnerable to the health effects of extreme heat and heatwaves are those with a limited capacity to thermoregulate.[10] Newborns, children, pregnant women, elderly and those with a range of existing medical conditions for example, diabetes, cardiovascular diseases and respiratory conditions, such as asthma, are in this category.[7,10] Those who work outdoors and with heavy physical labour are more vulnerable because of their prolonged exposure to extreme heat.[7,10]

Pregnant women and neonates are two important groups that are at risk to extreme heat. Pregnant women are particularly vulnerable due to reductions in their ability to thermoregulate and are known to experience adverse health outcomes because of extreme heat exposure.[1] Neonates also experience adverse health outcomes, which in some cases is thought to affect development throughout childhood.[11] Through the Sustainable Development Goals (SDG) and other global programmes, targets have been set for countries to attain, which could be jeopardised by exposure to extreme heat.[12]

A growing body of literature demonstrates that temperature alone is not an accurate indication of the impact of the thermal environment on the body's thermoregulatory response for heat stress.[13,14] For example, a previously published heat primer for public health describes heat stress as the buildup of body heat resulting from exertion and/or the external environment, with the external environment, including air temperature and other factors, such as wind speed, humidity and incidence of radiation.[15] In addition, physical activity and clothing also influence human body heat balance and heat strain. There is also a primer discussing the importance of humidity, a factor in heat stress[16] and human thermoregulation and heat stress is reviewed by another.[17]

Over time, heat stress and thermal comfort indicators have been developed with the aim of better capturing the risk levels associated with the thermoregulatory response of the body to different aspects of the thermal environment.[18,19] Multiple reviews and studies consider the effectiveness and ease of use of these metrics.[19,20] Consistently studies find that heat and thermal comfort indices that consider temperature, humidity, solar radiation and wind speed are a better indication of the risk than simpler metrics.[21] However, the literature states that no perfect indicator is present.[18,19]

There is no consensus on how to include extreme heat in studies, making it a challenge to build up a reliable evidence base for how extreme heat affects health across the globe. For maternal and perinatal health, most studies only use mean and/or maximum air temperature when considering the impact of heat.[1,22–30] Reviews showed that the health outcomes associated with exposure to extreme heat were preterm birth, low birth weight, congenital anomalies and stillbirth.[1,22–27] Very few studies considered by these reviews use comparable methodologies and none of these reviews focused solely on heat stress exposure, often combining the metrics with air temperature.[1]

Therefore, given targets to improve quality of care and protect the lives of mothers and neonates and because heat indices better capture body responses and risk levels associated with the thermal environment, it is important to outline the evidence to date for heat stress and maternal and neonatal health. The purpose of this scoping review is to answer three questions: (1) what is the biometeorological background of heat indices? (2) How does heat stress influence maternal and perinatal health outcomes? And (3) how do heat indices fit within the maternal heat balance?

METHODS

We conducted a scoping review to summarise heat indices used and outcomes reported in available studies of the impact of extreme heat on maternal perinatal health. We were guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping reviews.[31] We used the original search terms from Chersich *et al*[1] and carried out an updated search on SCOPUS and PubMed. The full update methodology was registered on OSF Registries and is available at https://osf.io/nm4q3 and the checklist is in the online supplemental material.

Search

This review forms a part of a larger systematic mapping and subsequent systematic review by Chersich *et al*, that surveyed published literature on high temperature impacts on health and adaptation interventions.[1,32] The initial mapping review was carried out in September 2018, which searched Medline (PubMed), Science Citation Index Expanded, Social Sciences Citation Index, and Arts and Humanities Citation Index. The review was updated in September 2019 and November 2022 in Medline (PubMed) and November 2022 in Scopus using a simplified search to identify studies published since the date of the initial search; the search keywords can be seen in the online supplemental material. A word search filter identifies papers with heat stress indices from method sections of manuscripts (ie, search 'apparent temperature').

Inclusion criteria

We included human studies that assessed heat stress, defined using heat stress indices, on all maternal and perinatal health outcomes. We included only peer-reviewed studies that are in the English language (for the updated review), and grey literature was not considered. In addition, no date restrictions were applied. All study designs were eligible except systematic reviews, qualitative studies and studies that modelled the potential or hypothetical associations between heat exposure and the health outcomes.

Screening and selection

We imported all references retrieved into Microsoft Excel; two researchers (CB and DL) screened the titles and abstracts of all records and assessed the methods of all remaining articles 25 documents were read and extracted in full. At both stages, reasons for exclusion were recorded (ie, no access to the article or a systematic review).

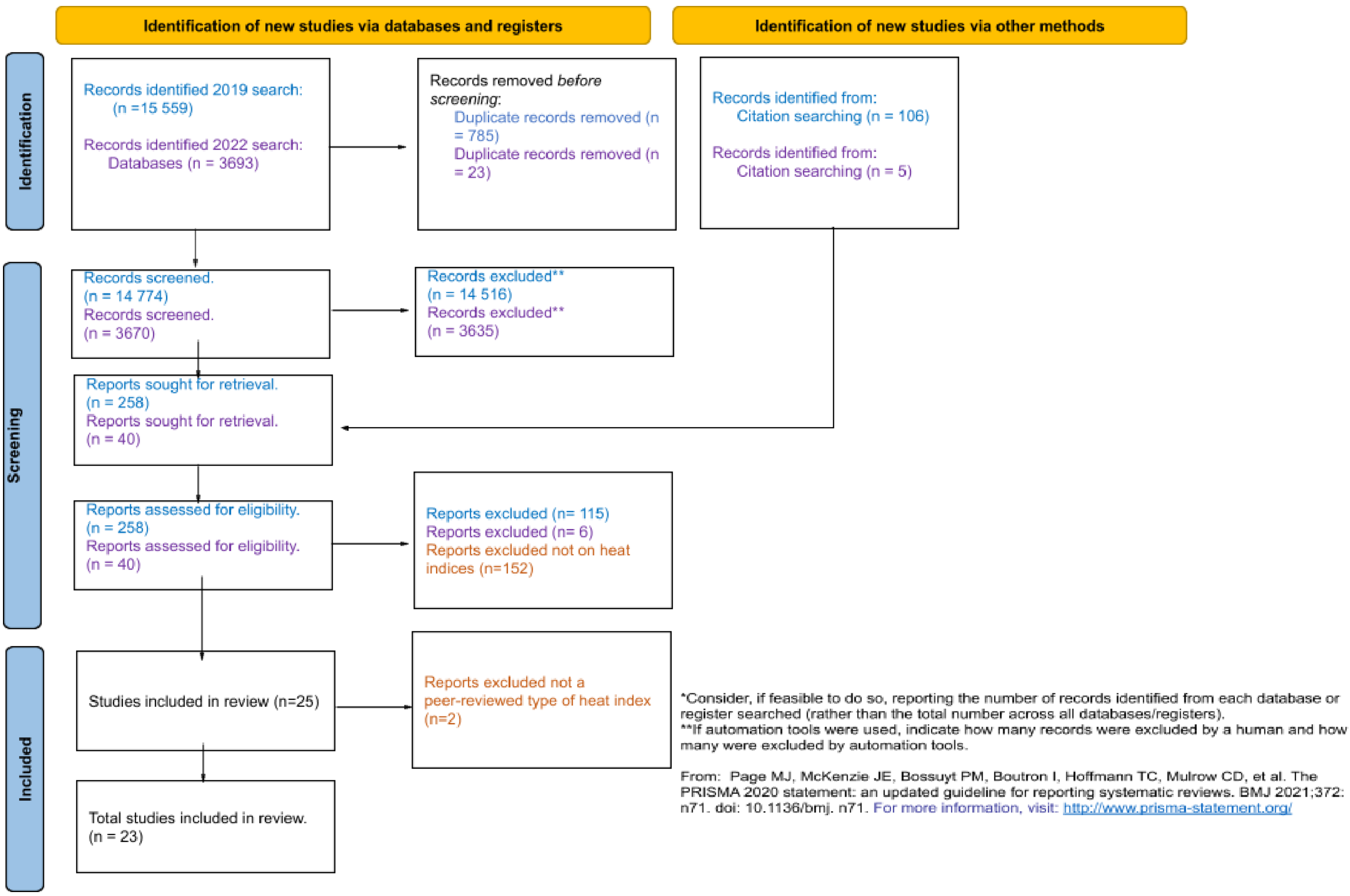

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart of scoping review selection and extraction.

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart documents screening and selection decisions (figure 1).

Data extractions

A separate Microsoft Excel spreadsheet was used to extract key information relevant to the study objectives for all included publications. We extract characteristics including author, year of publication, study design, country, maternal and perinatal outcomes, and heat index used. One author (CB) extracted information, and this was then considered by all authors.

Synthesis of results

Results are presented in a tabular form and described in a qualitative manner to provide as much information as possible.

RESULTS

We identified 25 studies that met the inclusion criteria (see figure 1). Table 1 summarises the different heat indices used in each study; five indices were used, with differences in methodologies present. Studies mostly make use of a heat stress index in a continuous manner. However, a few studies constructed categories based on fixed width or percentiles. Most studies calculate heat indices from local observations or meteorological data, but the more complex thermal comfort indices are more likely to be calculated from a type of numerically modelled dataset. Studies were conducted in a small proportion of countries: USA, South Korea, Europe, The Gambia and Ghana.

Twelve studies found an association between exposure to heat stress and a higher risk of preterm birth,[33–44] confirmed across studies from various geographical regions, including the USA, Italy and Spain. In addition, exposure to heat stress can trigger preterm birth in those acclimatised to heat (those who have had long-term exposure to their surrounding climate).[33–44] For example, one study conducted in California found that where apparent temperature had a weekly average cumulative increase of 5.6°C in total, there was a rise in risk of preterm births.[34] In addition, one study from Detroit found that exposure to extreme heat resulted in a higher risk in younger and older mothers, those with lack of access to prenatal care, and those who smoked during pregnancy.[39]

Three studies reported on the impact of extreme heat on stillbirths; the results are mixed. Cumulative exposure to heat stress as indicated by universal thermal climate index (UTCI) is found to raise the risk of stillbirth in Australia[45] the higher the intensity and the longer the duration of the exposure, the higher the risk and there

Table 1 Showing the results of the literature reviewed and what heat indices are used, and maternal and perinatal health outcomes explored

Heat stress index	Lead authors	Title	Health outcome	Use of heat index
	Avalos	The impact of high apparent temperature on spontaneous preterm delivery: a case-crossover study	Preterm birth	No methodology for apparent temperature is listed, it can be assumed to be the same as studies by Basu *et al*. Continuous use of the index, considering 7-day lags. Calculated using meteorological data.
	Basu	The impact of maternal factors on the association between temperature and preterm delivery	Preterm birth	Apparent temperature calculated not considering wind. Only the warm season is considered. Continuous use of index. Calculated using meteorological data from nearest weather station to zip code of mother.
	Basu	High ambient temperature and the risk of preterm delivery	Preterm birth	As above
	Basu	Temperature and term low birth weight in California	Low birth weight	As above
	Gronlund	Time-series analysis of total and direct associations between high temperatures and preterm births in Detroit, Michigan	Preterm birth	As above, except all seasons are considered.
	Schifano	Effect of ambient temperature and air pollutants on the risk of preterm birth, Rome 2001–2010	Preterm birth	As above
	Schifano	Heat and air pollution exposure as triggers of delivery: A survival analysis of population-based pregnancy cohorts in Rome and Barcelona	Preterm birth	As above
Apparent temperature[62] The equation to calculate apparent temperature is: 2.653 + (0.944 * t2m) + 0.0153 * d2m² *where t2m is air temperature (°C) and d2m is dew point temperature (°C)*	Vicedo-Cabrera	Exposure to elevated temperatures and risk of preterm birth in Valencia, Spain	Preterm birth	Apparent temperature calculated not considering wind. Only the warm season is considered. Percentile, categorical use of index. Calculated using meteorological data from nearest weather station to zip code of mother. Index only calculated for 4 hours during every 24-hour period.

Continued

Table 1 Continued

Heat stress index	Lead authors	Title	Health outcome	Use of heat index
Apparent temperature[63] The equation to calculate apparent temperature is: AT=t2 m + 0.33 * rh – 0.7 * va – 4 *where t2m is air temperature (°C), rh is relative humidity (%) and va is wind speed (m/s).*	Cushing	Extreme heat and its association with social disparities in the risk of spontaneous preterm birth	Preterm birth	Steadman method of apparent temperature is used. Maximum apparent temperature considered in increments of 5°C. The index is calculated using weather station meteorological data for the warm season.
	Mohammidi	Environmental extreme temperature and daily preterm birth in Sabzevar, Iran: A time-series analysis	Preterm birth	Steadman method of apparent temperature is used. Index is calculated from meteorological data and is used continuously.
	Soim	A population-based case–control study of the association between weather-related extreme heat events and orofacial clefts	Congenital defects (orofacial clefts)	Steadman method of apparent temperature is used. Maximum apparent temperature considered in percentile categories. The index is calculated using weather station meteorological data.
	Kent	Heat waves and health outcomes in Alabama (USA): The importance of heat wave definition.	Preterm and stillbirth (non-accidental death)	Steadman method of apparent temperature is used. Maximum apparent temperature considered in percentile categories. The index is calculated using weather station meteorological data.
Heat index[64] The equation to calculate heat index is: HI=–42.379 + 2.04901523*T+10.14333127*RH – .22475541*T*RH – .00683783*T*T – .05481717*RH*RH + 0.00122874*T*T*RH + 0.00085282*T*RH*RH – .00000199*T*T*RH*RH A number of adjustments are applied to increase the suitability of the index across climate regions: where ADJ=0 unless (1) R<13% and T is between 80 and 112°F, then ADJ=–((13–R)/4)SQRT((17–ABS×(T–95.))/17); or (2) if R>85% and T is between 80 and 87°F, then ADJ = ((R–85)/10)((87–T)/5) *T is air temperature(°F) and R is relative humidity (%).*	Cil	Potential climate change health risks from increases in heat waves: Abnormal birth outcomes and adverse maternal health conditions.	Maternal and intrapartum health	Heat index calculated as outlined from the National Weather Service of the USA. Heat index is used for defined heatwave periods.
	Porter	The relation of gestation length to short-term heat stress	Preterm birth	Heat index calculated as outlined from the National Weather Service of the USA. Heat index is used for defined categories for the warm season.
	Son	Is ambient temperature associated with risk of infant mortality? A multi-city study in Korea	Postperinatal infant mortality	Heat index calculated as outlined from the National Weather Service of the USA. Meteorological data are used to calculate the index. Study only uses index for sensitivity analysis.
	Son	Impacts of high temperature on adverse birth outcomes in Seoul, Korea: Disparities by individual- and community-level characteristics	Preterm and/or low birth weight	Heat index calculated as outlined from the National Weather Service of the USA. Meteorological data are used to calculate the index. Continuous use of the heat index.
	Ward	The impact of heat exposure on reduced gestational age in pregnant women in North Carolina, 2011–2015	Preterm birth	Heat index calculated as outlined from the National Weather Service of the USA. Modelled PRISM reanalysis data used to calculate the index for the warm season. Continuous use of the heat index.
	Wells	Birth weight and environmental heat load: A between-population analysis	Low birth weight	Heat index calculated as outlined from the National Weather Service of the USA. Meteorological data used to calculate the index for the warm season. Categorical use of the heat index.

Continued

Table 1 Continued

Heat stress index	Lead authors	Title	Health outcome	Use of heat index
Universal thermal climate index[65] The universal thermal climate index (UTCI) is a bioclimatological model of an average human body's response to different thermal conditions where the subject is not acclimatised to the climate and is outdoors, doing minimal work, that is, walking at about 3.5 km/hour.[65 66]. It was developed as part of the COST European Cooperation in Scientific and Technical Research action 370 in the early 2000s. Most research uses a 6-order polynomial that is an approximation of a more complicated body model.[65] The input variables are air temperature (K), dew point temperature (K), mean radiant temperature (K) and wind speed (m/s).	Bonell	A feasibility study of the use of UmbiFlow™ to assess the impact of heat stress on fetoplacental blood flow in field studies	Placental function	No method listed for the universal thermal climate index. Observed data are used from field study.
	Nyadanu	Maternal acute thermophysiological stress and stillbirth in Western Australia, 2000–2015: A space-time-stratified case-crossover analysis	Stillbirth	Universal thermal climate index is from the ERA5 reanalysis product. Continuous use of the index.
	Liu	Same environment, stratified impacts? Air pollution, extreme temperatures, and birth weight in South China	Low birth weight	Universal thermal climate index is from the ERA5 reanalysis product. Continuous use of the index.
Wet bulb globe temperature[67] Wet bulb globe temperature is calculated using observations from a wet bulb thermometer—a thermometer wrapped in a damp muslin cloth, a globe thermometer to measure incidence of radiation and a dry air thermometer. Or approximated using empirical models of these values.[68 69] The equation for an outdoor WBGT with solar radiation is: WBGT=0.7 * Tw+0.2 * Tg+0.1 * Ta The equation for an indoor WBGT is: WBGT=0.7 * Tw+0.3 * Tg where Tw is wet bulb temperature (°C), Tg is globe temperature (°C) and Ta is air temperature (°C).	Asamoah	Is ambient heat exposure levels associated with miscarriage or stillbirths in hot regions? A cross-sectional study using survey data from the Ghana Maternal Health Survey 2007	Stillbirth	Indoor WBGT that does not consider radiation is calculated using meteorological data, the Lijegren method is used. The annual average of the data is used, in comparison to health survey data.
	Bonell	A feasibility study of the use of UmbiFlow™ to assess the impact of heat stress on fetoplacental blood flow in field studies	Placental function	No method listed for the wet bulb globe temperature. Observed data are used from field study.
	Rahman	Environmental heat stress among young working women: A pilot study	Deformities and miscarriage	Indoor WBGT that does not consider radiation is calculated using a type of reanalysis data with observed data. Continuous use of the index.
Heat humidity index	Walfisch	Early-term deliveries as an independent risk factor for long-term respiratory morbidity of the offspring		
Heat humidity index	Lajinian	An association between the heat-humidity index and preterm labor and delivery: a preliminary analysis		

is a higher risk associated with male fetuses. In addition, a study in Ghana did not find a significant trend between average wet bulb globe temperature (WBGT) values and odds of stillbirth or miscarriage.[46] The study suggests that every 1°C increase in heat stress exposure as indicated by WBGT resulted in an insignificant 15% increase in the odds of having a stillbirth or miscarriage in Ghana.[46]

There are also mixed results on the impact of extreme heat on birth weight, with four included studies researching this outcome. On average, a rise of exposure to heat stress in the UTCI to values higher than 34.23°C for an average of 4.3 days, reduced birth weight by 12–31 g in Southern China.[47] In addition, long-term exposure to high levels of heat stress indicated by apparent temperature in the third trimester is positively associated with low birth weight in term births for California.[48] In contrast, for a study conducted in South Korea, considering exposure to heat stress using HI found no association with low birth weight.[49]

One study identified the impact of heat stress as indicated by heat indices on congenital anomalies. Soim *et al*[50] in the USA examined orofacial clefts and did not find a significant relationship when considering apparent temperature.[50] In addition, only one study found an association between heat index measurements of heatwaves in the USA and birth outcomes and maternal health conditions.[51] Exposure to a heatwave during the third trimester could cause a 3.5% increase in the fraction of births with at least one abnormal condition: fetal distress, the need for ventilation and meconium aspiration.[51] In addition, the study suggests that incidence of eclampsia is the highest among women who have experienced the second trimester of pregnancy during summer months.[51] Across studies, there is not enough evidence for which part of pregnancy should be considered as the window of susceptibility and a lack of consistency in methodology.

There are various factors that increase the vulnerability of a pregnant mother and neonates to extreme heat, and many studies included factors to account for types of vulnerability. These include young or older maternal age,[39 49] poverty, including energy poverty (access to electricity),[44] lower socioeconomic status or lower social capital,[49] low body mass index and ethnicity/race.[48] In addition, those with pre-existing chronic medical conditions such as hypertension or diabetes mellitus were at higher risk; however, this effect was reduced when mothers received appropriate healthcare interventions.[35 36] In addition, periods of extreme heat can be consequential with high levels of air pollution causing a compound hazard.[33 38 47] However, in one study, pregnant women that experienced increased exposure to extreme heat and compounding high levels of air pollution were more likely to carry out protective behaviours, which is encouraging.[47]

DISCUSSION

What is the biometeorological background of heat indices?

Our results confirm a lack of a consistent definition of heat in the literature and numerous challenges. Four heat stress indices with prior peer-reviewed literature methodologies are in studies. However, calculations were different and a lack of understanding of heat stress indices is present in this literature. For example, apparent temperature is calculated in two different ways, one considers the effect of wind speed while the other only considers temperature and dew point temperature used in the calculation of relative humidity.[34 42] In two studies using the WBGT method, radiation and wind speed are not considered by studies known as indoor WBGT.[46 52] In two studies, the complete methodology for the heat stress indices was not listed making it more difficult to compare the results with the wider body of literature.[36 52]

Previous reviews on extreme heat and maternal and perinatal health are numerous and methodologies are often compared as like for like. But, in the case of heat stress indices, humidity is considered differently across methods.[14] In addition, we also know that using categories and percentiles in comparison to continuous use of the metrics leads to different outcomes within results.[30] Most studies use a form of meteorological or observation data. Evidence shows differences between heat indices values between meteorological and reanalysis datasets that use a form of numerical modelling, but that reanalysis datasets are an acceptable methodological choice in the absence of observation data.[53]

A consistent methodological approach is needed across studies and in most cases a more detailed description of the heat stress index used should be discussed. Within reviews differences in metrics should be included, especially within meta-analysis. More widely, greater collaboration, between health and climate experts, is needed to enhance understanding of climate change and health across disciplines. We see this as an important part of monitoring the effects of climate on health and helping countries to achieve SDG and national targets.

How does heat stress influence maternal and perinatal health outcomes?

There is consensus that there is insufficient research on the maternal heat balance and what pathways may lead to negative birth outcomes due to exposure to extreme heat.[34–36] Unpacking these pathways is challenging as preterm birth, stillbirth and congenital malformations all have multifactorial aetiologies.[34 47] Heat stress studies to date agree with temperature only studies.[1 22–30] More research around a heat stress index is needed to accurately capture the whole maternal and perinatal heat balance and adverse health outcome pathways. In addition, a focus on methods that allow for windows of susceptibility across pregnancy should be prioritised.

For preterm birth studies, in animals or humans, it has been proposed that heat stress can lead to hyperthermia and oxidative stress which affects the physiology surrounding the fetus and feto-placental exchange.[45 54] Many studies cite the possibility of an impairment of thermoregulation of the mother placing stress on fetal development.[33 37 47] In the study by Bonell *et al*,[52] it was found that exposure to above heat stress thresholds in WBGT and UTCI ultimately leads to insufficient fetoplacental circulation. In animal models, heat triggers an increase in the release of prostaglandin F and oxytocin, both known to be linked to labour induction in humans.[33 34] Many studies have found a rise in heat shock proteins as a result of exposure to extreme heat, a mechanism that may lead to increased inflammation and may influence the production of prostaglandin E2 potentially triggering labour.[33 36 55] Another key factor discussed in maternal health studies that use heat indices is dehydration, which reduces the fluids of the mother, and therefore the blood volume in the fetus, which can lead to growth restriction and lower birth weight.[33 38 49]

For a low birth weight outcome, it is thought that during extreme heat conditions, maternal blood flow is diverted from the fetoplacental district to the skin surface, potentially depriving the fetus of adequate nutrition.[48] In addition, several stress responses including inflammation and elevated cholesterol levels are suggested to perhaps have an influence on birth weight.[48] It is suggested by Liu *et al*[47] that dehydration and psychosocial stressors could be the main factors contributing to a low birth weight. In addition, it is important to note that those who are pregnant and have pre-existing medical conditions such as diabetes or hypertension have an additional limit to their thermoregulation capacity.[35]

How do heat indices fit within the maternal heat balance?

There is an opportunity for maternal and perinatal research to lead the wider health research agenda by consistency in methodology using heat stress indices. Heat stress indices are a more accurate representation of the heat balance of the human body.[15] Heat indices are created from empirical models and selected meteorological variables. These are air temperature,[12] incident radiation on the body,[56 57] wind speed and indications of atmospheric moisture known as humidity.[58 59] Each of these variables interacts with the body's heat transfer allowing for or hindering the loss of heat. The motivation behind the creation of each index is different from each other. In addition, there is evidence that there has been reluctancy to incorporate heat indices fully within epidemiology because of a lack of understanding of the role humidity plays in the body heat balance.[13]

However, there is a push to come to consensus on which one thermal comfort index is more beneficial than the hundreds of others in different health conditions and with different confounding factors.[19 20 60 61] One recent study that makes progress in this assesses major heat stress indices, and demonstrates that for 17 clinical criteria (ie, mean body temperature and dehydration) the heat stress index that performs best is WBGT (both indoor and outdoor).[21] Following this in the rankings was the UTCI. Both indices already appear in maternal and perinatal health studies.

By using existing heat indices within studies that evaluate physiological pathways and aim to understand the wider maternal heat balance, we can improve existing metrics. This will allow for more robust monitoring of important targets that have been set out to improve quality of care and protect the lives of mothers and neonates.

Limitations and knowledge gaps

One limitation of this study is the small number of included studies and the difficulty with highlighting robust evidence of the impact of extreme heat on birth and health outcomes. Very few health outcomes are evaluated in terms of heat stress (ie, preterm, stillbirth, low birth weight). Another limitation is the decision to only search peer-reviewed English language literature; grey literature may contain important information. A further limitation is that most studies aside from Bonell *et al*[52] only theorise biological pathways and therefore we do not fully understand the impact of heat on perinatal and maternal health.

CONCLUSION

Many papers and reviews demonstrate that heat stress indices are a more accurate consideration of the human heat balance than temperature alone in the fields of public health and epidemiology. Despite this, there is no consensus among maternal and perinatal health studies on how to capture the impact of extreme heat on health outcomes. Some barriers remain around the understanding of heat, which metric is the best from both the climate and health fields and collaboration across diverse fields. However, based on the results we make the following recommendations: (1) standardised heat indices should be used across studies to fully capture the thermal environment and authors need to provide sufficient detail about the methods used. (2) Exploration is needed for an expanded range of birth and perinatal outcomes with heat indices. And (3) greater collaboration, between health and climate experts, is needed to improve understanding across the climate-health nexus. It is hoped that this paper can help to break down barriers and build consensus in the field to promote the uptake of policy and programmes that can be used to try to protect women and perinates from the impact of heat and climate change going forward.

Author affiliations

[1]Wegener Center, University of Graz, Graz, Austria
[2]Independent Obstetrician Gynaecologist Consultant, Rome, Italy
[3]Department of Maternal, Newborn, Child and Adolescent Health, World Health Organization, Geneva, Switzerland
[4]Wits RHI, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa
[5]Department of Medicine, Karolinska Institutet, Stockholm, Sweden
[6]Faculty of Engineering, Lund University, Lund, Sweden

[7]Faculty of Epidemiology and Population Health, London School of Hygiene and Tropical Medicine, London, UK
[8]Department of Public Health, University of the Western Cape, Cape Town, South Africa

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Twitter Chloe Brimicombe @ChloBrim

Collaborators HIGH Horizons Study Group, Stanley Luchters, Matthew Chersich, Gloria Maimela, Celeste Madondo, Fiona Scorgie, Craig Parker, Jakob Eggeling, Günter Alce, Ilona M. Otto, Katharina Wieser, Tobias Monthaler, Zeenat Sulaima, Aquinius Mungatia, Jetina Tsvaki, Thabani Moronzie, Nelson Muparamoto, Fortunate Machinguro, Veronique Filippi, Giulia Greco, Nasser Fardousi, Isabelle Lange, Giorgia Gon, Jo Borghi, Cherie Part, Christos Hadjichristodoulou, Barbara Mouchtouri, Elina Kostara, Maria Kyritsi, Michalis Koureas.

Contributors CB: guarantor,conceptualisation, methodology, formal analysis, investigation, resources, writing - original draft, writing - review and editing. FC: conceptualisation, methodology, resources, writing - review and editing. AP: conceptualisation, methodology, writing - review and editing. DL: resources, methodology, writing – review and editing. NR: resources, writing- review and editing. CG: writing - review and editing, resources. IS: writing - review and editing. DJ: conceptualisation, methodology, resources, writing - review and editing.

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ORCID iDs
Chloe Brimicombe http://orcid.org/0000-0001-5550-1556
Anayda Portela http://orcid.org/0000-0001-6368-1585
Nathalie Roos http://orcid.org/0000-0001-9752-2355
Debra Jackson http://orcid.org/0000-0003-3307-632X

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