A Systematic Review and Meta-Analysis on Heat Thresholds for Maternal Health and Birth Outcomes

Descriptive Statistics ***2***

Supplementary Table 1. All included studies in this review (n=103) are classified into year of publication. **2**

Supplementary Table 2. All included studies in this review (n=103) are classified into continents in which data was collected. **2**

Supplementary Table 3. All included studies in this review (n=103) are classified into countries in which data was collected. **2**

Supplementary Table 4. All included studies in this review (n=103) are classified into health outcomes assessed. **4**

Supplementary Table 5. All included studies in this review (n=103) are classified into heat indicators used. **4**

Supplementary Table 6. All included studies in this review (n=103) are classified into sample sizes. **5**

Supplementary Table 7. All included studies in this review (n=103) are classified into study design following the categories used by the OHAT risk of bias assessment tool. **5**

Consortium: HIGH Horizon Study Group ***6***

Supplementary Note 1: PRISMA 2020 abstract checklist ***7***

Supplementary Note 2: PRISMA 2020 checklist ***8***

Descriptive Statistics

Supplementary Table 1. All included studies in this review (n=103) are classified into year of publication.

Years	Number of studies	Percentage
2025 - 2026	11	10.68
2020 - 2024	51	49.51
2015 - 2020	28	27.18
2010 - 2015	9	8.73
2005 - 2010	2	1.94
2000 - 2005	1	0.97
Pre 2000	1	0.97
TOTAL	103	100

Supplementary Table 2. All included studies in this review (n=103) are classified into continents in which data was collected.

Continents	Number of studies	Percentage
Africa	4	3.88
Asia	42	40.78
Europe	18	17.48
North America	29	28.16
Oceania	8	7.77
South America	1	0.97
Multiple continents	1	0.97
TOTAL	103	100

Supplementary Table 3. All included studies in this review (n=103) are classified into countries in which data was collected.

Countries	Number of studies	Percentage
USA	24	23.30
China	24	23.30
Australia	8	7.77
Canada	5	4.85
Spain	5	4.85
Iran	4	3.88
Italy	4	3.88
France	3	2.91
Israel	3	2.91
Nepal	3	2.91
Belgium	2	1.94
Benin	2	1.94
India	2	1.94

Japan	2	1.94
Malawi	2	1.94
Nigeria	2	1.94
Pakistan	2	1.94
Uganda	2	1.94
South Africa	2	1.94
Sweden	2	1.94
Zimbabwe	2	1.94
Cyprus	1	0.97
The Gambia	1	0.97
Peru	1	0.97
Angola	1	0.97
Turkey	1	0.97
Korea	1	0.97
Romania	1	0.97
The Netherlands	1	0.97
Northern Ireland	1	0.97
Burkina Faso	1	0.97
Burundi	1	0.97
Ethiopia	1	0.97
Greece	1	0.97
Guinea	1	0.97
Haiti	1	0.97
Kenya	1	0.97
Lesotho	1	0.97
Liberia	1	0.97
Madagascar	1	0.97
Mali	1	0.97
Philippines	1	0.97
Rwanda	1	0.97
Senegal	1	0.97
Sierra Leona	1	0.97
Taiwan	1	0.97
Tajikistan	1	0.97
Timor-Leste	1	0.97
Zambia	1	0.97
TOTAL	133	100

"Multiple" indicates that study has collected data from several continents (McElroy et al., 2022)
Only 4 studies were conducted in low-income countries (defined by World Bank Atlas Method of the fiscal year 2024-2025), all of which were conducted in 2022 or thereafter.

- The Gambia; **Bonell** et al., 2023
- Burundi, Ethiopia, Malawi, Uganda; **McElroy** et al., 2022
- Benin; **Tanou** et al. 2022
- Malawi, Mali, Nigeria, Zimbabwe, Madagascar, Senegal, Kenya, Uganda, Lesotho, Burkina Faso, Guinea, Rwanda, Zambia, Sierra Leone, Liberia; **Davenport** et al., 2020

Supplementary Table 4. All included studies in this review (n=103) are classified into health outcomes assessed.

Health Outcomes	Number of studies	Percentage
Preterm Birth	54	52.42
Low Birth Weight	20	19.42
Stillbirth	13	12.62
Congenital anomalies / heart defects	8	7.77
Preeclampsia / gestational hypertension*	7	6.80
Adverse Pregnancy Outcomes, Adverse Birth Outcomes (composite)	5	4.85
Spontaneous abortions / miscarriage	6	5.83
Premature rupture of membranes (PROM)*	3	2.91
Small for gestational age (SMA)	4	3.88
Umbilical artery resistance index (RI)*	2	1.94
Placenta volume*	1	0.97
Neural tube defects*	2	1.94
Gestational diabetes*	5	4.85
HCGAZ, head circumference-for-age Z-score	1	0.97
Severe Maternal Morbidity*	1	0.97
Placenta weight*	1	0.97
Placenta to birthweight ratio (PFR)*	1	0.97
Placental abruption*	1	0.97
Sleep*	1	0.97
TOTAL	138	100

* Maternal Health outcomes (n=25/138, 18.12%)
Note: different total number since some studies have focused on several health outcomes
Percentage is calculated out of the included studies, n=103

Supplementary Table 5. All included studies in this review (n=103) are classified into heat indicators used.

Heat Indicators	Number of studies	Percentage
Air temperature	80	77.67
AT	18	15.53
Heat Index	7	6.80
WBGT	5	4.85
UTCI	3	2.91
heat variability	7	6.80
TOTAL	117	100

NOTE: different total number since some studies have focused on several health outcomes and used several heat indicators. Percentage calculated of total included studies n=103.

Supplementary Table 6. All included studies in this review (n=103) are classified into sample sizes.

Countries	Number of studies	Percentage
<1000	5	4.85
1000-100000	50	48.54
100000-1000000	37	35.92
>1000000	11	10.68
TOTAL	103	100

Supplementary Table 7. All included studies in this review (n=103) are classified into study design following the categories used by the OHAT risk of bias assessment tool.

Study design	Number of studies	Percentage
Cohort	62	60.19
Case Control	23	22.33
Cross Sectional	17	16.50
Human Controlled Trial	1	0.97
TOTAL	103	100

Consortium: HIGH Horizon Study Group

Stanley Luchters[1,2,3], Matthew Chersich[4], Gloria Maimela[4], Celeste Madondo[4], Shobna Sawry[4], Mags Beksinska[4], Lebohang Radebe[4], Darshnika Lakhoo[4], Ijeoma Solarin[4], Craig Parker[4], Pascalia Munyewende[4], Jean Le Roux[4], Rose Lamola[4], Sibusiso Mkwananzi[4], Nicholas Brink[4], Chuansi Gao[5], Jakob Eggeling[5], Günter Alce[5], Clara Heil[5,] Olof Stephansson[6], Claudia Hanson[6], Nathalie Roos[6], Jeroen de Bont[6], Veronika Tirado[6], Mian Bao[6], Massimo Stafoggia[6,7], Federica Nobile[6,7], Anayda Portela[8] Jørn Toftum[9], Ilona Otto[10], Chloe Brimicombe[10], Katharine Wieser[10], Tobias Monthaler[10], Zeenat Sulaiman[11], Sohail Baloch[11], Aquinius Mung'atia[11], Fortunate Machingura[12], Jetina Tsvaki[12], Thabani Moronzie[12], Concilia Mutasa[12], Brian Mqondisi Sibanda[12], Tariro Chinozvina[12], Elizabeth Dangaiso[12], Jaspar Maguma[12], Bongani Mutimutema[12], Progress Chiworeka[12], Leslie Nyoni[12], Llyod Pisa[12], Jeffrey Dirawo[12], Tapiwa Nyakabau[12], Perkins Watambwa[12], Debra Jackson[13], Veronique Filippi[13], Giulia Greco[13], Nasser Fardousi[13], Olimpia Lamberti[13], Isabelle Lange[13], Giorgia Gon[13], Jo Borghi[13], Paul Lokubal[13], Cherie Part[13], Christos Hadjichristodoulou[14], Barbara Mouchtouri[14], Maria Kyritsi[14], Michalis Koureas[14], Fani Kalala[14], Chara Bogogiannidou[14], Ioanna Voulgaridi[14], Ioannis Messinis[14], Christina Messini[14], Xara Skentou[14], Matthaios Speletas[14], Andreas Flouris[14], Vana Papaevagelou[14], George Daskalakis[14], Androniki Naska[14], Vassiliki Benetou[14], Anastasia (Tania) Konstantinidou[14], Boris Kingma[15], Koen van der Sanden[15], Birgit Kerstens[16]

1 Department of Public Health and Primary Care, Ghent University, Ghent, Belgium
2 Centre for Sexual Health and HIV/AIDS Research, Harare, Zimbabwe
3 Liverpool School of Tropical medicine (LSTM), UK
4 Wits Planetary Health, Faculty of Health Sciences, University of Witwatersrand, Johannesburg, South Africa
5 Faculty of Engineering, Department of Design Sciences, Lund University, Lund, Sweden
6 Karolinska Institutet, Stockholm, Sweden
7 Department of Epidemiology, ASL Roma, Roma, Italy
8 World Health Organization, Geneva, Switzerland
9 Technical University of Denmark, Lyngby, Denmark
10 Wegener Center for Climate and Global Change, University of Graz, Graz, Austria
11 Aga Khan Health Services Kenya, Nairobi, Kenya
12 Centre for Sexual Health and HIV/AIDS Research, Harare, Zimbabwe
13 London School of Hygiene and Tropical Medicine, London, United Kingdom
14 Laboratory of Hygiene and Epidemiology, Medical Faculty, University of Thessaly, Larissa, Greece
15 TNO, Soesterberg, the Netherlands
16 Ghent University, Ghent, Belgium

Supplementary Note 1: PRISMA 2020 abstract checklist

Section and Topic	Item #	Checklist item	Reported (Yes/No)
TITLE			
Title	1	Identify the report as a systematic review.	Yes
BACKGROUND			
Objectives	2	Provide an explicit statement of the main objective(s) or question(s) the review addresses.	Yes
METHODS			
Eligibility criteria	3	Specify the inclusion and exclusion criteria for the review.	Yes
Information sources	4	Specify the information sources (e.g. databases, registers) used to identify studies and the date when each was last searched.	Yes
Risk of bias	5	Specify the methods used to assess risk of bias in the included studies.	Yes
Synthesis of results	6	Specify the methods used to present and synthesise results.	Yes
RESULTS			
Included studies	7	Give the total number of included studies and participants and summarise relevant characteristics of studies.	Yes
Synthesis of results	8	Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e. which group is favoured).	Yes
DISCUSSION			
Limitations of evidence	9	Provide a brief summary of the limitations of the evidence included in the review (e.g. study risk of bias, inconsistency and imprecision).	Yes
Interpretation	10	Provide a general interpretation of the results and important implications.	Yes
OTHER			
Funding	11	Specify the primary source of funding for the review.	Yes
Registration	12	Provide the register name and registration number.	Yes

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic

Supplementary Note 2: PRISMA 2020 checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	p. 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	p. 1 (also additional file)
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	p. 3
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	p. 3
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	p. 13
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	p. 14
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	p. 14-15, Appendix 1
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	p. 15
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	p. 15
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	p. 15-16
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	p. 15-16
Study risk of	11	Specify the methods used to assess risk of bias in the included studies,	p. 16

Section and Topic	Item #	Checklist item	Location where item is reported
bias assessment		including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	p. 16
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	p. 16
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	p. 15
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	p. 17
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	p. 17
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	p. 16
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	p.16
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	p. 15
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	p. 16
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	p. 4
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	p. 5
Study characteristics	17	Cite each included study and present its characteristics.	Supplementary Data 1
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Supplementary Data 3
Results of	19	For all outcomes, present, for each study: (a) summary statistics for each group	Supplementary Data 1

Section and Topic	Item #	Checklist item	Location where item is reported
individual studies		(where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	p. 4-8
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	p. 5
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	p. 6-8
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	p. 5-6
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	p. 8-9
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	p. 6-8
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	p. 9-10
	23b	Discuss any limitations of the evidence included in the review.	p. 12
	23c	Discuss any limitations of the review processes used.	p. 11-12
	23d	Discuss implications of the results for practice, policy, and future research.	p. 10-11
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	p. 1, p. 14
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	p. 14
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	p. 14
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	p. 25
Competing interests	26	Declare any competing interests of review authors.	p. 25
Availability of data, code and other	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Supplementary Data 1 & 2 for data extracted from all studies Figshare:

Section and Topic	Item #	Checklist item	Location where item is reported
materials			https://doi.org/10.6084/m9.figshare.32802512 for data used from included meta-analysis studies