A systematic review of heat exposure on fetal heart rate: more evidence is urgently needed

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Objective

Ambient heat exposure is associated with an increased risk of adverse pregnancy and birth outcomes, including pre-eclampsia, stillbirth, and preterm birth.[1] However, the physiological mechanisms underlying these heat-associated effects are poorly understood. Fetal heart rate (FHR) is a noninvasive marker of fetal wellbeing, reflecting fetal autonomic nervous system homeostasis. Distinct FHR characteristics, such as an increased baseline and reduced variability, are associated with fetal hypoxaemia and fetal distress, thus providing insight into fetal wellbeing.[2] It is plausible that heat exposure alters uteroplacental blood flow, resulting in fetal circulatory and FHR changes, which, in susceptible fetuses, could lead to stillbirth or trigger preterm birth.

We conducted this systematic review to establish whether maternal heat exposure influences fetal physiology through mechanisms detectable via FHR.

Study Design

A systematic review according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines was conducted using Medical Subject Headings terms for 'fetal heart rate', 'cardiotocography', 'temperature', and 'heat' across MEDLINE, Embase, Global Health, CINAHL, and Cochrane Register. The research protocol was registered with PROSPERO (CRD420251034926) prior to extraction. Eligible studies measured antepartum FHR in response to observational or experimental ambient heat exposure in healthy pregnant women. To ensure FHR results were attributable to heat, studies of intrapartum FHR and women with existing comorbidities or pyrexia were excluded.

Heat exposure was defined as any continuous measure of temperature and humidity, or heat stress index. FHR characteristics were categorized and extracted according to standard FHR parameters (baseline, variability, accelerations, and decelerations).[3] Other maternal and fetal physiological parameters were extracted according to availability. Study screening and data extraction were conducted independently by 3 reviewers (J.M.A., I.M.B., and G.R.), and conflicts were resolved by a third reviewer (T.I.). Included studies were assessed using the Risk of Bias in Non-Randomised Studies-of Exposures tool. Results were narratively synthesized according to SWiM guidelines.[4]

Results

Our literature search identified 115 studies. After removing duplicates, 75 unique studies were screened, and 12 studies were selected for full-text review. Four studies were included in the final systematic review. The selection process is presented in Figure and the Supplementary Materials.

Included studies ranged from 1961 to 2024 and were published across 3 countries: Finland, The Gambia, and China. FHR assessment methods were heterogeneous, including auscultation, ultrasound doppler, and cardiotocography. Heat exposure and study design varied; Pystynen and Vähä-Eskeli et al conducted experimental studies using sauna exposure, while Bonell et al and Wang et al conducted prospective cohort studies examining environmental heat.[5−8] Bonell et al defined heat stress during field visits in The Gambia using Wet Bulb Globe Temperature (WBGT) and Universal Thermal Climate Index (UTCI)_, whereas Wang et al derived local heat exposure from a Chinese national dataset, defining heat exposure as an average daily mean temperature above the 90th percentile.[7,8] Exposure and outcome details and baseline FHR results are presented in Table.

Pystynen (n=10) described qualitative changes in baseline FHR, noting a "disturbance" in 4 participants during sauna use.[5] Vähä-Eskeli et al's study (n=23) reported a rise in baseline FHR from 146±10 beats per minute (bpm) pre-exposure to 157±15 bpm post-exposure (P<.05).[6] Bonell et al's study (n=92) observed a mean increase in baseline FHR from

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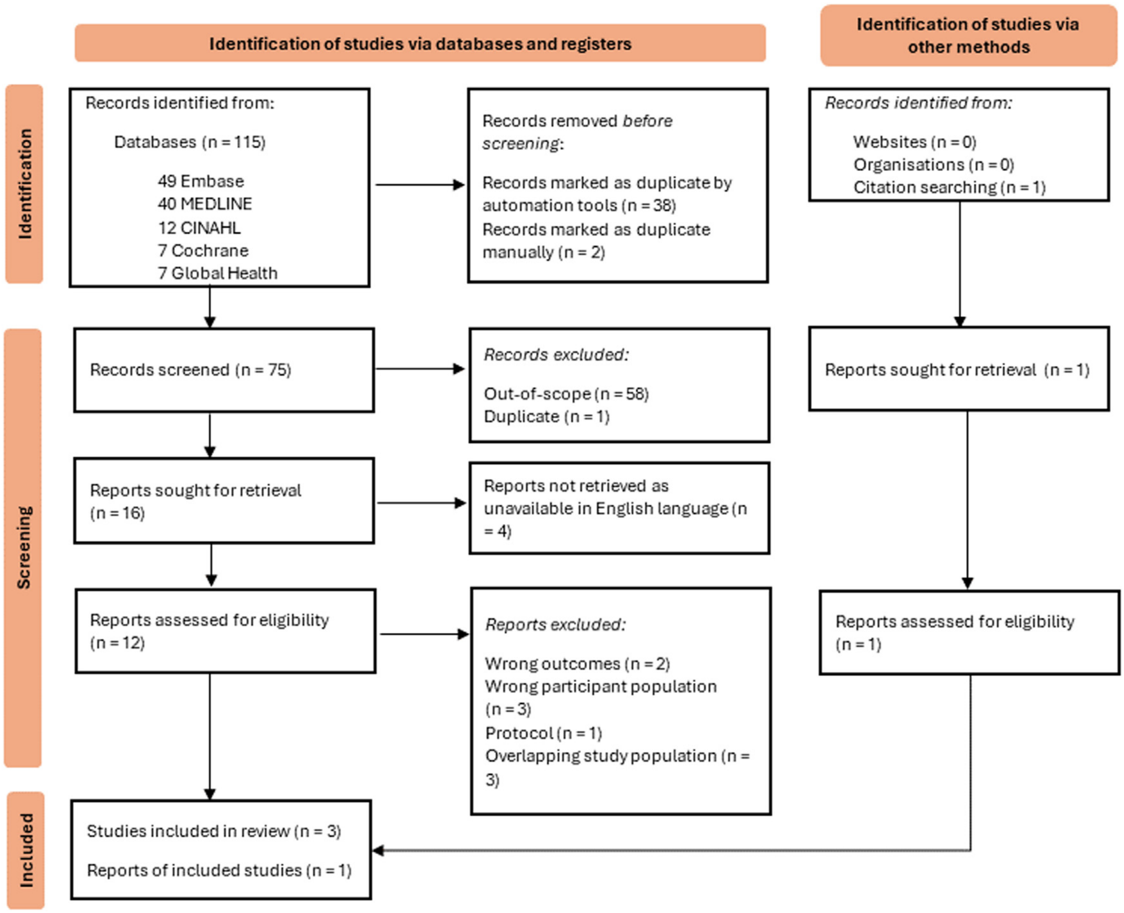
FIGURE
PRISMA flow diagram detailing the identification, screening and inclusion of studies



PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

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TABLE
Summary of results of included studies

Characteristic	Pystynen[5]	Vähä-Eskeli et al.[6]	Bonell et al.[7]	Wang et al.[8]
Study design	Non-randomised controlled trial	Non-randomised controlled trial	Prospective cohort	Prospective cohort
Study population	Healthy pregnant women	Healthy pregnant women accustomed to sauna bathing	Healthy pregnant women working as subsistence farmers	Healthy pregnant women from selected monitoring district sites
Sample size (n)	10	23	92	162,407 (main analyses); 163,014 (4-wk pre-delivery analysis)
Heat exposure	Sauna heat. Average dry bulb temperature: 64.4°C (50°C–77°C) Average wet bulb temperature: 45.6°C (40°C–55.5°C)	Sauna heat. Temperature: 70°C Humidity: 15% relative humidity	Ambient heat measured by WBGT and UTCI	Daily average mean temperature $\geq$90th percentile of participant's residential address

(continued)

TABLE
Summary of results of included studies *(continued)*

Characteristic	Pystynen[5]	Vähä-Eskeli et al.[6]	Bonell et al.[7]	Wang et al.[8]
Exposure timing	During sauna session - average duration 17.4 min (10–25 min)	During sauna session - duration 20 min	Exposure during field visits - unspecified duration	Trimester 1, Trimester 2, Trimester 3, Whole pregnancy and 4-wk pre-delivery
FHR measure & method	Auscultation	CTG	FHR derived from umbilical artery doppler	FHR derived from ultrasound; site of measurement not described
FHR pre-exposure	Not reported numerically	146±10 bpm	125±7.9 bpm	N/A – effect estimates reported
FHR post-exposure/ effect estimates				
Exposure in Trimester 1	—			FHR T2: 0.14 bpm (CI: 0.05–0.24) FHR T3: 0.04 bpm (CI:−0.04 to 0.12)
Exposure in Trimester 2	—			FHR T2: 0.16bpm (CI: 0.06–0.26) FHR T3: 0.06bpm (CI: −0.03 to 0.15)
Exposure in Trimester 3	—			FHR T3: 0.24 bpm (CI: 0.16–0.32)
Whole pregnancy exposure	—			FHR T3: 0.14 bpm (CI: 0.06–0.22)
Exposure 4-week predelivery	—			FHR 4-wk pre-delivery: 0.12 bpm (CI: 0.02–0.23)
FHR post-exposure	Not reported numerically; 'disturbance' reported in 4 participants	157±15 bpm (P<.05)	147±11.9 bpm (P<.01)	N/A – effect estimates reported

Wang et al (2024) report effect estimates as deviations from the FHR within the trimester of exposure.

—, not applicable or not reported; *bpm*, beats per minute; *CTG*, cardiotocography; *FHR*, fetal heart rate; *T2*, second trimester; *T3*, third trimester, *CI*, confidence interval

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125±7.9 bpm to 147±11.9 bpm during the working period (P<.01).[7] Wang et al's study (n=162,407) found that heat exposure during the whole pregnancy was associated with a 0.14 bpm increase in third-trimester baseline FHR (95% confidence interval, 0.06–0.22).[8] When examined by trimester, heat exposure was associated with an increased FHR ranging from 0.14 to 0.24 bpm, with the largest effects noted following third-trimester exposure.

Descriptions of other FHR parameters were sparse. Vähä-Eskeli et al described a transient reduction of accelerations and increased fetal movements during exposure, but no significant changes in FHR variability or uterine activity.[6] All 4 studies demonstrated a high risk of bias due to limitations in exposure and outcome measurement, selection bias, and insufficient control for confounding.

Conclusion

This systematic review suggests that maternal heat exposure is associated with measurable changes in baseline FHR. Data on other FHR components were limited and derived from 1 study. Due to the heterogeneity, low quality, and sparsity of relevant literature, the magnitude and clinical significance of the FHR response to heat stress and its association with clinical outcomes remain unclear.

High-quality longitudinal research involving real-world heat exposure and reliable FHR assessments across diverse populations is required to evaluate the fetal physiological effects of heat stress and to inform and guide clinical practice and climate health policy. The Heat in Pregnancy project addresses this key evidence gap through monitoring of maternal and fetal parameters alongside individualized environmental exposure assessment.[9]

Declaration of AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work the authors used ChatGPT (Open AI) in order to refine the wording of selected sentences. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication. ■

CRediT authorship contribution statement

Julie Mariam Abraham: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Conceptualization. **Imane Ben M'Barek:** Writing – review & editing, Writing – original draft, Validation, Investigation. **Gal Rubin:** Validation, Investigation. **Tanya Isaac:** Validation. **Gabriel Davis Jones:** Supervision. **Aris T. Papageorghiou:** Supervision. **Jane E. Hirst:** Writing – review & editing, Supervision. ■

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.ajogmf.2026.102045.

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