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




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Impact of climate change on child outcomes: an evidence gap map review

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ABSTRACT

Background Climate change and extreme weather events significantly threaten neonatal and child health. This review aims to provide a comprehensive overview of the current evidence on the impact of climate change on child health, using the evidence gap map (EGM) to address knowledge gaps and establish a foundation for evidence-based interventions and future research.

Method From inception, academic databases (such as MEDLINE, EMBASE, Global Health, CINAHL and Scopus) and grey literature were systematically searched. We included climate change-related studies involving children aged 0–5 worldwide. Covidence facilitated a rigorous screening process, and we conducted a critical appraisal. Two independent reviewers handled screening and data extraction. Eligible studies underwent coding and extraction using Evidence for Policy and Practice Information (EPPI) reviewer software. The EGM was constructed using EPPI Mapper, and comprehensive findings were presented through live links and figures.

Result We identified 196 studies, comprising 59.2% children and 40.8% neonates, with diverse research approaches, including 94% quantitative studies. There has been a notable increase in research publications over the past 5 years. Evidence is heavily concentrated in Asia (93 studies) and Africa (47 studies). The most frequently studied exposures are those related to extreme climate events, followed by drought and floods. However, there are gaps in the study of extreme cold and storms. The significant outcomes comprised preterm birth (55 studies), low birth weight (27 studies), malnutrition (59 studies) and diarrhoeal diseases (28 studies). Evidence on mental health problems and congenital disabilities receives relatively less attention.

Conclusion This EGM is crucial for researchers, policymakers and practitioners. It highlights knowledge gaps and guides future research to address the evolving threats of climate change to global child health.

Trial registration number INPLASY202370086

INTRODUCTION

Neonates are newborns under 28 days old, while children are under 5 years old, excluding the neonatal period.^{1–3} Since 1990, there has been a significant reduction in childhood mortality and morbidity worldwide. Under-5 deaths dropped from

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Climate change poses significant health risks to neonates and children, including preterm birth, low birth weight, malnutrition and respiratory and mental health issues. Prior research has established these connections but has not fully explored the scope or specific impacts.

WHAT THIS STUDY ADDS

⇒ This study maps out the effects of climate change on neonatal and child health, identifying key disparities and research gaps. It introduces an interactive online map to aid policymakers, funders and researchers in identifying investment areas and avoiding research duplication.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings highlight critical gaps and inform policy development by providing a comprehensive overview of climate change impacts. The interactive map and detailed analysis offer practical tools for guiding research priorities and optimising resource allocation.

12.8 million to 5 million in 2021, with the global mortality rate decreasing from 93 to 38 deaths per 1000 live births. Neonatal deaths also reduced from 5.2 million to 2.3 million during this period.² However, progress has stalled since 2010, with 54 countries projected to miss the Sustainable Development Goal target for under-5 mortality and 63 countries falling short on neonatal mortality.³ Regional disparities persist, with over 80% of under-5 deaths concentrated in sub-Saharan Africa and southern Asia. Climate change and extreme weather events exacerbate these challenges globally, especially in regions like sub-Saharan Africa and southern Asia, where vulnerability is high.^{1–3} It poses significant threats to neonatal and child health, affecting critical determinants such as food security, water quality, air quality



and access to healthcare. This population group is particularly vulnerable due to their developing physical, physiological and cognitive immaturity.^{4–7}

Despite their minimal contribution to greenhouse gas emissions, newborns and children bear 88% of the disease burden linked to climate change, particularly impacting disadvantaged populations.⁸ The UNICEF's 2021 Children's Climate Risk Index highlights the vulnerability of 1 billion children to climate change, with 739 million facing drought and 436 million living in areas highly susceptible to drought and floods.⁹ These climate-related stressors lead to adverse health outcomes, including preterm birth, low birth weight, malnutrition, respiratory diseases, infectious diseases and high mortality rates. Mental health impacts, such as anxiety and depression, are additional concerns for children experiencing natural disasters or extreme weather events.^{10–12} Given their susceptibility to climate-induced risks, knowledge gaps have been identified in understanding the impact of climate change on child and neonatal health. Sound policymaking to protect them from the impacts of climate change must be evidence-based, necessitating further research to quantify the risks posed to their health.^{9 13 14} Moreover, the potential adverse effects of climate change on birth outcomes, including increased infant mortality and birth complications, highlight the urgency of this issue.^{15–18} Given the rising frequency of this complex event globally,^{16–18} our study aims to systematically investigate available evidence and develop an evidence gap map (EGM) to understand the impact of climate change on neonatal and child health, addressing critical knowledge gaps in this area.

The EGM approach analyses existing literature, identifies research gaps and proposes evidence-based interventions, serving as a valuable tool for crafting policies and interventions in the face of escalating global climate change.¹⁹ These tools enable rapid evidence-informed decision-making by multisectoral stakeholders, including families, health professionals, decision-makers and policymakers. Through in-depth analysis, the EGM addresses research disparities, the rising frequency of extreme climate events, and the unique vulnerabilities of neonates and children on it.^{2 17 20} By leveraging this evidence and responding to calls for action, stakeholders can develop effective strategies to safeguard the health of newborns and children amidst climate change challenges. This initiative aligns with urgent calls for action from leading organisations like the WHO, the UNICEF and the United Nations Population Fund, urging collective efforts to protect children from the adverse effects of climate change.⁸

METHODS

This research employs a systematic methodology, prioritising the construction of an EGM to rigorous standards set by the Campbell Collaboration.¹⁹ The EGM visually depicts evidence of child health and climate impact using

a matrix format. The row represents climate-related events, while the columns outline its impact on neonatal and child health. The methodological process involves crafting a framework based on a literature review and stakeholder input, collaboratively establishing inclusion criteria, executing a thorough database search, rigorously assessing study quality and creating the evidence map with Evidence for Policy and Practice Information (EPPI Mapper). This research is registered with the International Platform of Registered Systematic Review and Meta-analysis Protocols.

Developing scope

We initiated the EGM production by establishing the scope and developing a framework and matrix representing evidence, exposure and outcomes. This crucial first step involved consulting with various stakeholders, including academic experts, policymakers, practitioners and funders.²⁰ We crafted an initial framework based on a comprehensive policy and academic literature review. Subsequently, we shared this framework with team members and key stakeholders, seeking their feedback and making necessary adaptations.¹⁹ This EGM, a systematic evidence synthesis product, showcases the evidence relevant to the impact of climate change on child health. Its purpose is to identify gaps that require filling with new evidence.¹⁹

Eligibility

The research team collaboratively established stringent eligibility criteria (table 1) to ensure the relevance and reliability of studies included in the development of EGM.²¹ This review focuses on children aged 0–5 globally, seeking published and unpublished primary and review studies, research papers and reports investigating the link between climate change and newborn and child health. Selected studies should involve children aged 0–5 years, exploring various child health outcomes. Due to resource and time limitations, the review exclusively includes English-based studies. However, there are no publication date type or status restrictions, ensuring a comprehensive review of available literature over time.

Table 1 Summary of eligibility using P.C.C. format

P.C.C. framework	Justification
P—population	Children: 0–5 years (Neonates and under-5 child)
C—concept	<ul style="list-style-type: none"> ▶ Climate change, climate threat, global warming, droughts, floods, extreme weather events ▶ Impact on newborn/child: preterm births, low birth weight, malnutrition, respiratory disease, infectious diseases, mental health, etc...
C—context	Global

Searching strategies and screening

The collaborative development of our search strategy, spearheaded by the experienced health sciences librarian (MK) in conjunction with our research team, ensured a comprehensive exploration. This involved an exhaustive database search encompassing MEDLINE, Embase, CINAHL, Web of Science, Scopus and distinct organisational websites. The strategy, meticulously crafted, employed key terms addressing child health issues (eg, child mortality, infant health, neonatal mortality, premature birth, birth weight, mental health, malnutrition) and climate change-related events (eg, carbon cycle, climate change, global warming, droughts, floods, extreme weather events). No constraints were placed on the publication year (online supplemental file 1). Following this, the identified studies' title/abstract and full text were meticulously screened using COVIDENCE,²² overseen by two independent reviewers (YAA and SUN), with discrepancies resolved by the senior reviewer (SM). To ensure inclusivity, forward and backward citation chaining was conducted.¹⁶ The principal and lead researchers conducted a rigorous double-screening of the final compilation. The selected articles were then exported to EndNote as RIS files²³ and transferred to EPPI-Reviewer V.6.15.0.2 for coding.^{19 24} Following the

removal of duplicates and relevance screening, the 196 articles underwent final coding and analysis, culminating in creating the ultimate map. The search strategy strictly adheres to Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Protocols: Extension for Scoping Reviews guidelines (figure 1).

Data extraction and critical appraisal

Data extraction and critical appraisal were executed with precision and rigour. A standardised data extraction form, facilitated by EPPI-Reviewer²⁰ and detailed in the Annex (online supplemental file 2), was used to extract pertinent information from studies meeting the inclusion criteria. Two independent coders meticulously extracted information on characteristics, outcomes and exposures or events and conducted quality assessments to minimise errors. Given the diverse exposures in many studies, each exposure's effects were coded individually and then grouped. Both primary studies (qualitative and quantitative) and synthesis reviews included in the analysis underwent thorough critical appraisal. Quality ratings were assigned using the Mixed Methods Appraisal Tool²⁵ and Assessment of Multiple Systematic Reviews 2.^{15 26} The quality appraisal reveals that 182 (173 primary and 9 review studies) demonstrated high or medium

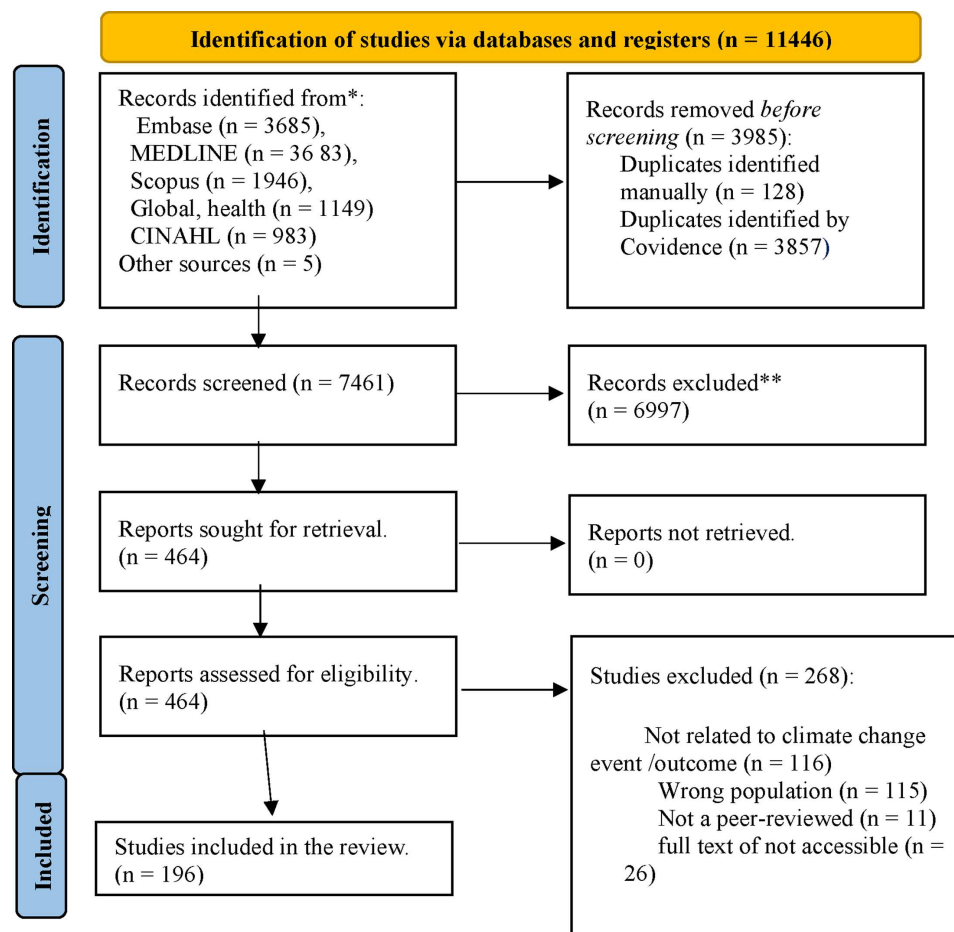


Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram for mapping the impact of climate change on child health.

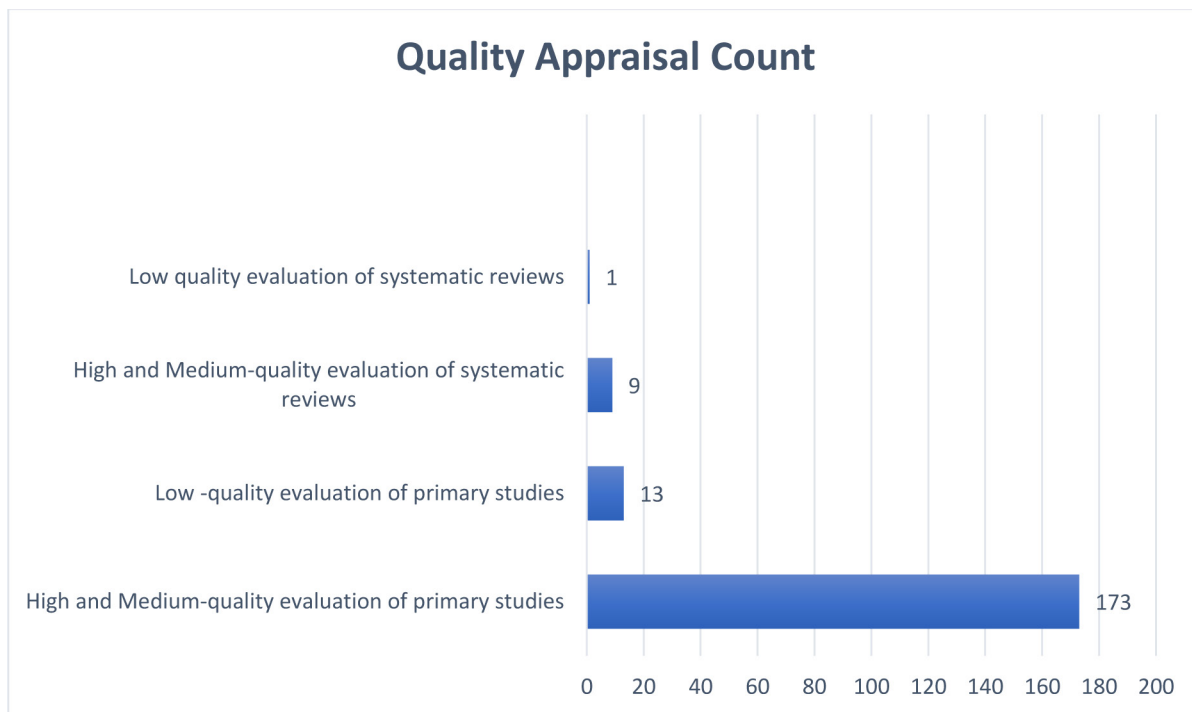


Figure 2 Overall quality of the included studies.

quality, reflecting commendable methodological rigour. However, 14 studies fall into the low-quality category (figure 2), indicating a meticulous and nuanced evaluation of the overall study landscape. The detailed quality scoring is also provided in online supplemental file 3. In this study, we ensured no double counting by evaluating each primary study only once. If primary research was included in a review, it was counted once within that specific review.

Patient and public involvement

Patients or the public WERE NOT involved in the design, conduct, reporting or dissemination plans of our research. Since this EGM focuses on research studies rather than individual human subjects, patients and the public were not directly involved in its design, conduct, reporting or dissemination plans. However, we consulted with academic experts, policymakers, practitioners and funders to ensure the study's robustness and relevance.

RESULTS

Characteristics and distributions of studies

This study assessed 196 findings to elucidate the nuanced landscape of climate change research, mainly focusing on its implications for neonatal and child health. Most studies focused on children's outcomes, accounting for 59.2%, and on neonates, representing 40.8% of the focus. The research fabric exhibited a diversity of approaches, encompassing 50.5% institution-based studies, and a substantial majority (94%) were quantitative studies. From the quantitative studies, 49.7% and 44.9% adopted analytical (eg, cohort) and descriptive

research design (eg, cross-sectional), respectively. Noteworthy, eight studies used systematic reviews or meta-analyses to synthesise existing evidence. However, qualitative research should have been given more attention.

Geographically, Asia emerged as the focal point with a representation of 93 studies, followed by Africa (47), North America (28), Europe (18), South America (16) and Australia (14). However, more evidence is needed from the Caribbean (11) and Central America (5)—the publication trends of the included studies indicate a dynamic pattern with significant implications. Over the past 5 years, there has been a notable surge in climate change research, ranging from 11 studies in 2013 to a peak of 36 studies in 2022. This surge is driven by the escalating frequency and severity of extreme climate events, emphasising the urgent need to comprehend and address the repercussions of climate change on neonatal and child health outcomes. This highlights a palpable and pressing demand for comprehensive research in this domain.

Climate change-related exposures/events

A detailed examination of climate change exposure events revealed a significant variation in research focus. Extreme heat was the most studied (102 studies), followed by drought (50 studies) and floods (49 studies). On the contrary, there was a notable scarcity of research on events such as extreme cold (12 studies), storms (17 studies) and earthquakes (26 studies), highlighting the need for further investigation into their health consequences (see the live link or a QR code below).

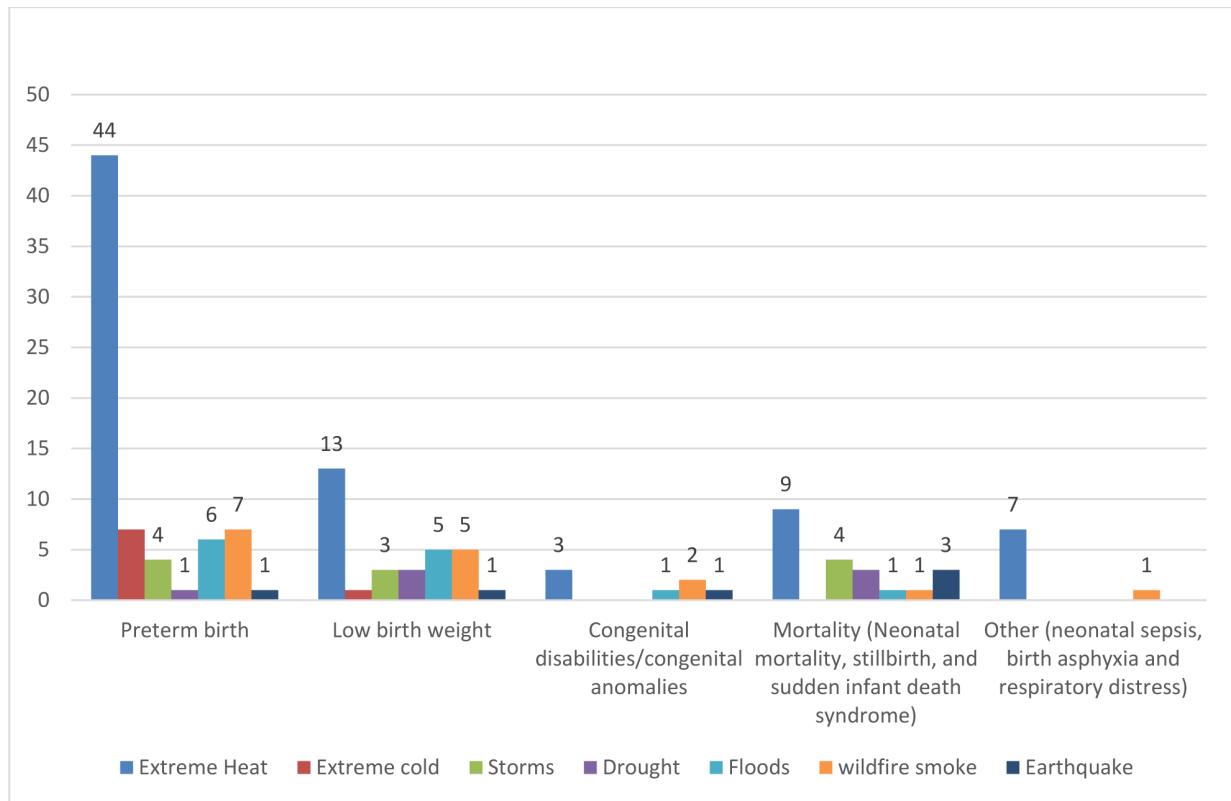


Figure 3 Distribution of studies across neonatal outcomes and exposure categories.

Climate change-related child and neonatal health outcomes

When assessing climate change-related health outcomes for neonates and children, persistent disparities highlight urgent areas requiring attention. In neonatal health, we noted a significant emphasis on preterm birth (55 studies), low birth weight (27 studies), (6 studies), 17 neonatal mortality (17 studies) and complications like sepsis (7 studies). Our analysis also systematically examines how studies are distributed across different outcomes and specific exposure categories. For instance, we found that extreme heat is associated with preterm birth (44 studies), low birth weight (13 studies), neonatal mortality (9 studies) and congenital disabilities (3 studies) (figure 3). Additionally, our research sheds light on the distribution of research efforts concerning various child health outcomes linked to climate change. Malnutrition emerges as a primary concern (59 studies), followed by respiratory diseases (29 studies), diarrhoeal diseases (28 studies), mental health problems (11 studies), child mortality (7 studies) and other conditions (2 studies). Notably, extreme heat is linked with respiratory issues (18 studies), followed by diarrhoeal diseases (17 studies) and malnutrition (16 studies). Additionally, drought is linked to malnutrition (25 studies). In comparison, floods lead to diarrhoeal diseases (22 studies) and respiratory issues (6 studies), further underscoring the diverse impacts of climate-related events on child health outcomes. However, while specific health outcomes like preterm birth and malnutrition are extensively studied, others,

such as mental health problems and congenital disabilities, receive comparatively less attention.

These comprehensive EGM results are also presented with live links (Climate change and neonatal health-EGM) or a QR code.



DISCUSSION

This study presents a detailed examination of climate change research, focusing on its implications for neonatal and child health. Notable disparities and critical research gaps are identified, emphasising the urgent need for strategic interventions.²⁷ The study underscores a deliberate effort to understand the vulnerabilities of children (59.2%) and neonates (40.8%), highlighting a significant emphasis on these populations. However, the predominant reliance on quantitative methodologies

(94%) raises concerns about potentially overlooking qualitative dimensions crucial for understanding the complex climate-child health relationship. Despite the richness of primary research findings, the limited reliance on systematic reviews and national/international reports highlights a distinct research gap, necessitating immediate attention. This underscores the need for a more balanced approach to evidence generation and synthesis in neonatal and child health research, with methodological rigour pivotal in evaluating research reliability.^{28 29}

Furthermore, the surge in climate change research over the past 5 years, driven by escalating extreme climate events, signals a heightened focus on neonatal and child health. The global review, supported by the Intergovernmental Panel on Climate Change report, underscores widespread concerns about climate change's impact on child and neonatal health³⁰ and highlights extensive concerns about climate change's impact on child and neonatal health. However, the geographical distribution of research efforts reveals significant disparities, with certain regions being under-represented. Despite Asia emerging as a hub of research activity, regions such as the Caribbean and Central America receive scant attention. This imbalance skews our understanding of regional vulnerabilities and undermines efforts to develop tailored interventions for populations facing unique climate-related challenges. A more equitable distribution of research resources is imperative to ensure comprehensive global coverage and address the specific needs of marginalised communities.^{5 8 17}

Another critical gap lies in the uneven focus on climate change exposure events. While studies on extreme heat predominate, other events such as extreme cold, storms and earthquakes are comparatively neglected. This skewed emphasis needs to capture the full spectrum of climate-related hazards faced by neonates and children, limiting our ability to mitigate their adverse health effects. A more holistic approach considering a broader range of climate change exposure events is essential for developing comprehensive adaptation strategies and resilience-building initiatives.^{7 8 12 31 32}

Among neonatal health outcomes related to climate change is the lack of attention to congenital disabilities despite the significant focus on preterm birth and low birth weight. This oversight hampers our insight into the full scope of neonatal health impacts.⁹ Similarly, in child health outcomes, mental health problems receive less attention compared with malnutrition, diarrhoeal and respiratory diseases. Neglecting these outcomes could leave vulnerable populations at risk. Addressing these gaps is crucial for developing effective interventions to protect vulnerable populations from the diverse health effects of climate change.¹⁴ This gap underscores the need for a more comprehensive approach to understanding and addressing all health impacts on neonates and children. While we rigorously map literature on climate change's effects on neonatal and child health worldwide

and provide an interactive online map, our study has limitations. These include strict English language criteria potentially excluding valuable non-English insights, a focus on health exposure studies possibly overlooking other climate impacts, and the inclusion of moderate to low-quality studies affecting result interpretation. Addressing these will enhance our understanding of climate change's impacts on neonatal and child health.

Implications

This EGM holds significant implications for research, practice and policy. In terms of research, there is a pressing need for a more balanced methodology, incorporating both qualitative and quantitative approaches, to comprehensively understand the intricate climate-child health relationship, including the impact on infectious diseases, respiratory problems, malnutrition, mental health and other health issues. Researchers should conduct exhaustive investigations into diverse climatic events, addressing disparities in focus and ensuring a holistic understanding of health consequences. In addition, researchers need to develop, implement and evaluate the effectiveness of adaptation strategies and resilience-building initiatives in mitigating the health impacts of climate change on children and neonates.

In practice, healthcare professionals must be clinically aware of highlighted health outcomes, emphasising early detection and intervention for children and neonates affected by climate change-related health issues. Multidisciplinary collaboration is crucial for developing holistic strategies. Moreover, healthcare providers should be trained to recognise climate-related disease and condition symptoms. Integration of climate change considerations into healthcare planning is crucial. This includes anticipating increased demand for specific healthcare services during extreme weather events and adapting healthcare infrastructure accordingly.³³ In the policy domain, urgent prioritisation of neonatal and child health research is significant, aligning funding allocations and policy initiatives with the identified disparities and critical gaps. Tailored strategies are essential, considering regional imbalances and reflecting the global call to action on climate change. This EGM is a stakeholder compass, guiding evidence synthesis to support the theme for future research and resource allocation based on the identified gaps.^{34 35} Collaborative efforts among researchers, practitioners and policymakers are significant to address imbalances, methodological gaps and regional health disparities, strengthening the global response to climate change impacts on child health.

CONCLUSION

Our study rigorously examines the intricate link between climate change and child/neonatal health, stressing global importance and region-specific remedies. The EGM exposes disparities, urging swift action and a holistic global strategy. A surge in quantitative research in the

last 5 years signals urgency in addressing climate impacts on children globally. Despite methodological rigour, imbalances in region and theme highlight the need for a comprehensive research approach to explore the complex impact of climate change on child and neonatal health outcomes. This study nuances the understanding of diverse climatic impacts on child health, pinpointing critical areas for immediate attention and strategic interventions.

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