

Impacts of Air Pollution and Heat Exposure on Reproductive, Maternal, Neonatal, Child, and Adolescent Health Outcomes in Nepal: A Scoping Review

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ABSTRACT

Introduction: Air pollution and heat exposure are major threats to reproductive, maternal, neonatal, child, and adolescent health; however, evidence from Nepal remains fragmented. Therefore, the objective of this review is to synthesize available evidence on the impact of air pollution and heat exposure on health outcomes in Nepal.

Methods: A scoping review was conducted following Arksey and O'Malley's framework and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses-extension scoping reviews. PubMed, Embase, Scopus, Web of Science, Google Scholar, and grey literature were searched from inception to September 2025.

Results: Of 1,920 records, 27 studies were included (15 air pollution, 10 heat exposure, and 2 both). Household air pollution was associated with respiratory infections, pneumonia, and mortality, while ambient air pollution with respiratory infections and reduced fecundity. Higher temperatures were associated with diarrheal disease and adverse pregnancy outcomes, and lower temperatures with rotavirus infection and neonatal hypothermia, but nutritional outcomes were limited.

Conclusions: Air pollution and temperature exposure are important determinants of reproductive, maternal, neonatal, child, and adolescent health outcomes in Nepal. Integrating climate risks into these health programs and strengthening climate-sensitive disease surveillance are essential for evidence-based policy and practice.

Keywords: Air pollution; Child health; Climate change; Maternal health.

INTRODUCTION

Air pollution and heat exposure are increasingly important public health concerns in low and middle-income countries.^{1,2} Women of reproductive age, pregnant women, neonates, children, and adolescents are particularly vulnerable because of biological susceptibility, developmental, environmental, and healthcare-related factors.^{3,4}

Globally, studies have linked air pollution and non-optimal temperatures with preterm birth, low birth weight, neonatal complications, respiratory and diarrhoeal disease, and impaired reproductive health.⁵⁻⁷ In Nepal, evidence linking climate and

air-quality exposures to reproductive, maternal, neonatal, child, and adolescent health (RMNCAH) outcomes has yet to be explored.

The Department of Environment (DoE), Department of Hydrology and Meteorology, and the Ministry of Health and Food Safety routinely collect environmental and health data. However, these datasets remain insufficiently linked, limiting analysis of climate-sensitive RMNCAH outcomes. A Nepal-focused evidence synthesis is needed to inform climate-responsive policies and interventions. Therefore, this study is



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aimed to synthesise evidence on the impacts of air pollution and heat exposure on RMNCAH outcomes in Nepal.

METHODS

A scoping review approach was selected as the most appropriate method to address the research question: ‘What is the evidence on air pollution and/or heat exposure in relation to RMNCAH outcomes in Nepal?’. The protocol of this scoping review was registered in the Open Science Framework.⁸ This review followed the Arksey and O'Malley methodological framework, identifying the research questions, finding relevant studies, selecting studies, charting the data and collating, summarizing, and reporting the results.⁹ We reported the results of the review guided by Preferred Reporting Items for Systematic Reviews

and Meta-Analyses extension for scoping reviews guidelines (PRISMA-ScR).¹⁰

A comprehensive systematic search was conducted in PubMed, Embase, Scopus, Web of Science, Google Scholar, Google and ResearchGate from database inception to September 2025. The search strategy was developed using controlled vocabulary (e.g. MeSH terms) and keywords based on the Population-Concept-Context (PCC) framework. The population included reproductive-age individuals, maternal, neonatal, child, and adolescent; the concept was air pollution and heat exposure; and the context was Nepal. Search terms for each concept, including controlled vocabulary and keywords, were combined using ‘OR’, and the main concepts were combined using ‘AND’. The PubMed search terms and search strategy are in Table

Table 1. PubMed search terms and search strategy.

PCC element	Search term
Population	("Fertility"[Mesh] OR "Infertility"[Mesh] OR fecund*[tiab] OR "Reproductive Health"[Mesh] OR "Pregnancy"[Mesh] OR pregnan*[tiab] OR miscarriage[tiab] OR "Abortion, Spontaneous"[Mesh] OR "Pregnancy Outcome"[Mesh] OR maternal[tiab] OR antenatal[tiab] OR prenatal[tiab] OR gestati*[tiab] OR childbirth[tiab] OR "Parturition"[Mesh] OR birth[tiab] OR intrapartum[tiab] OR obstetric*[tiab] OR labo?r[tiab] OR postpartum[tiab] OR perinatal[tiab] OR puerper*[tiab] OR maternity[tiab] OR foet*[tiab] OR fetal[tiab] OR fetus[tiab] OR "Maternal Health"[Mesh] OR morbidity[tiab] OR mortality[tiab] OR placental abruption[tiab] OR "Pre-Eclampsia"[Mesh] OR "Eclampsia"[Mesh] OR birth outcomes[tiab] OR "Birth Weight"[Mesh] OR "Fetal Death"[Mesh] OR "Stillbirth"[Mesh] OR preterm[tiab] OR "Premature Birth"[Mesh] OR prematur*[tiab] OR newborn[tiab] OR "Infant, Newborn"[Mesh] OR neonat*[tiab] OR low birthweight[tiab] OR low birth weight[tiab] OR postterm[tiab] OR "Child"[Mesh] OR child*[tiab] OR "Infant"[Mesh] OR under five[tiab] OR under-five[tiab] OR under 5[tiab] OR pediatric*[tiab] OR paediatric*[tiab] OR "Growth"[Mesh] OR respiratory[tiab] OR congenital[tiab] OR "Child, Preschool"[Mesh] OR toddler[tiab] OR school-age children[tiab] OR school age children[tiab] OR schoolchildren[tiab] OR "Adolescent"[Mesh] OR adolescen*[tiab] OR teen*[tiab] OR under-18[tiab] OR "Young Adult"[Mesh] OR young[tiab])
Concept	("Air Pollution"[Mesh] OR "Air Pollutants"[Mesh] OR "Particulate Matter"[Mesh] OR air pollut*[tiab] OR air quality[tiab] OR particulate matter*[tiab] OR PM _{2.5} [tiab] OR PM10[tiab] OR black carbon[tiab] OR BC[tiab] OR "Nitrogen Dioxide"[Mesh] OR NO ₂ [tiab] OR "Ozone"[Mesh] OR O ₃ [tiab] OR "Sulfur Dioxide"[Mesh] OR SO ₂ [tiab] OR "Nitrogen Oxides"[Mesh] OR NO _x [tiab] OR "Carbon Monoxide"[Mesh] OR CO[tiab] OR "Air Pollution, Indoor"[Mesh] OR indoor air pollution[tiab] OR household air pollution[tiab] OR cooking fuel*[tiab] OR biomass[tiab] OR solid fuel*[tiab] OR household smoke[tiab] OR household cooking fuel*[tiab] OR cooking smoke[tiab] OR "Hot Temperature"[Mesh] OR "Extreme Heat"[Mesh] OR "Temperature"[Mesh] OR "Extreme Weather"[Mesh] OR "Droughts"[Mesh] OR heat[tiab] OR temperature[tiab] OR heat wave*[tiab] OR weather[tiab] OR drought*[tiab] OR "Climate Change"[Mesh] OR Land Surface Temperature[tiab] OR heat stress[tiab])
Context	("Nepal"[Mesh] OR Nepal*[tiab])

Forward citation searching, reference list screening, grey literature searches, and expert consultation supplemented the database search. All original studies of any epidemiological design conducted in Nepal (or reporting Nepal-specific data) published in English, involving women of reproductive age, pregnant women, neonates, children, or adolescents, and examining air pollution (including solid biomass use as a proxy for household air pollution) and/or heat exposure in relation to at least one RMNCAH outcome were included. Studies without Nepal-specific findings, focused on non-RMNCAH populations or outcomes, review/opinion articles, or studies without accessible full text or published in languages other than English

were excluded.

All identified records were imported into EndNote, and duplicates were removed. Two reviewers independently screened titles and abstracts, followed by full-text review against the eligibility criteria. Any disagreements between reviewers were resolved through consensus and, if necessary, in consultation with a third reviewer.

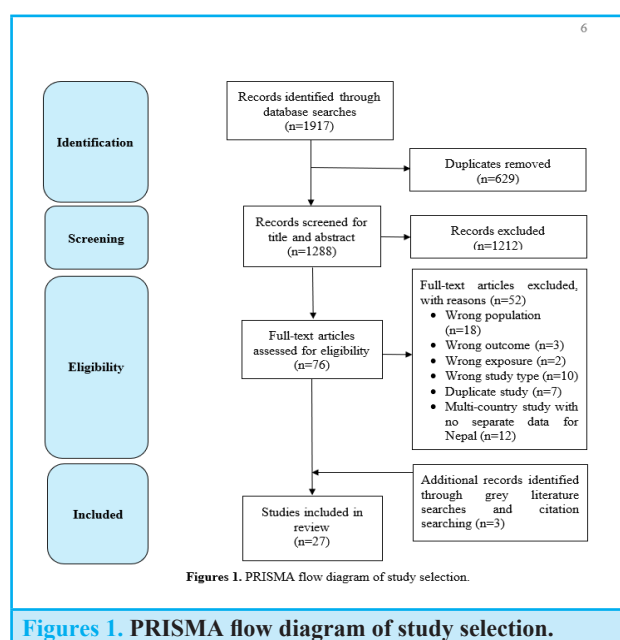
Two reviewers independently extracted data using a structured Microsoft Excel form. Extracted data included author, year, location, study design, setting, population, sample size, exposure type (air pollution, heat exposure or both, heat metrics),

exposure assessment method, RMNCAH outcome examined, and key findings (effect size, associations, confidence intervals). Any disagreements between reviewers on data extraction and charting were resolved via consensus and, if necessary, in consultation with a third reviewer.

Findings were descriptively and narratively synthesized by exposure type and RMNCAH outcomes. Meta-analysis and formal quality appraisal were not conducted due to study heterogeneity and the scoping review design.

RESULTS

A total of 1,920 studies were identified, including 1,917 studies from database searches and three studies from grey literature searches and citation searching. Following removal of duplicates, 1,288 studies were screened by title and abstract. Following title and abstract scanning, 76 full text articles were assessed for eligibility. After full-text screening, 52 studies were excluded, and 27 studies were included in the review. Of these, three studies were identified through grey literature searches and citation searching (Fig. 1).



Characteristics of included studies are presented in [Supplementary Table 1](#). The included studies, published between 2008 and 2025, were mostly cross-sectional (n=11, 41%), followed by cohort studies (n=5, 19%), and a randomised controlled trial (n=1, 4%). The sample sizes of included studies ranged from 141 to 219,773 participants. Twenty-five studies examined either air pollution or temperature exposure, while two assessed both. Most studies focused on child health (n=18, 66.7%), followed by pregnant women (n=6, 22.2%), women of reproductive age (n=2), one study on neonates. However, no studies specifically examining adolescent health outcomes were identified, highlighting an important evidence gap in the Nepalese literature on the health impacts of air pollution and heat exposure. Respiratory infections (n=9) were the most

examined health outcomes, followed by adverse birth outcomes (n=6), nutritional status (n=5) and diarrheal diseases (n=4). The studies also examined outcomes such as obesity, hypertension, anaemia, depression, anxiety, fertility/fecundity, hypothermia, and mortality.

Six studies explored the relationship between household air pollution and respiratory infection, including pneumonia in children under five.¹¹⁻¹⁶ Five studies consistently found that solid fuel use was associated with higher odds of acute respiratory infection.^{11-14,16} Evidence from national demographic and health surveys data demonstrated that children living in households using polluting fuel had nearly double the risk of suffering acute respiratory tract infection, including pneumonia (RR=1.98; 95% CI: 1.01-3.92) compared to those living in households using cleaner fuel.^{11,14} However, a cluster-randomised trial found that reduction in indoor PM_{2.5} through improved stoves did not significantly decrease risk of acute lower respiratory infection in children.¹⁵

Two studies explored household air pollution and nutritional status in children and showed inconsistent results.^{17,18} A nationwide population-based study (n=9914) revealed that indoor air pollution was associated with a higher risk of stunting and underweight, but not wasting.¹⁷ However, a community-based prospective cohort study (n=572) in Bhaktapur reported no statistically significant effect of biomass fuel use on the nutritional status of children.¹⁹

A study using national demographic and health survey data found that the use of polluting cooking fuels doubled the risk of under-five mortality, with a stronger association observed for neonatal mortality (OR=2.67; 95% CI: 1.47-4.82).²⁰ Similarly, a nationwide population-based study in women of reproductive age indicates that use of solid cooking fuels was significantly associated with a higher risk of anaemia (OR=1.58; 95% CI: 1.29-1.92) but a lower risk of obesity (OR=0.73; 95% CI: 0.59-0.91).²¹

Two studies examined the impact of household air pollution on pregnancy outcomes and reported contrasting findings.^{22,23} KC et al. reported that use of polluting fuels during pregnancy was associated with a higher risk of congenital birth defect (OR=1.49; 95% CI: 1.16-1.91) compared to mothers using cleaner fuels, whereas a randomised controlled trial reported no significant effect of reducing household PM_{2.5} and carbon monoxide exposure on low birthweight, small for gestational age, or preterm birth.^{22,23}

Three studies examined the association between ambient air pollution (PM_{2.5}) and respiratory infection.^{19,24,25} Two studies found that exposure to ambient air pollution was significantly associated with increased risk of acute respiratory infection.^{19,24} However, Tiwari et al. did not observe a significant association between mean PM_{2.5} exposure and acute respiratory infection, but the same study indicated that mean PM_{2.5} exposure was positively associated with risk of diarrhoea in children (OR=1.02, 95% CI 1.003 - 1.03).²⁵ Diarrhoea risk was greater

among urban children (OR=1.03, 95% CI 1.001 – 1.07) and in the wetter season (OR=1.05, 95% CI 1.02 – 1.07).²⁵

Each study explored the association between ambient air pollution and either fecundity or pregnancy outcomes. Higher exposure to ambient particulate matter (PM₁, PM_{2.5}) was associated with reduced fecundity, as reflected by an increased fertility time ratio, whereas no significant association was observed between PM_{2.5} exposure and adverse pregnancy outcomes (stillbirth, preterm birth, and low birth weight).^{26,27}

Four studies assessed ambient temperature and pregnancy outcomes, three reported higher temperatures were associated with adverse pregnancy outcomes.²⁷⁻³⁰ One hospital-based study found that exposure to temperatures $\geq 32^\circ\text{C}$ in the two weeks before delivery increased the risk of preterm birth in Biratnagar, but not in Pokhara or Bhairahawa.²⁹ Similarly, another study in seven heat-prone districts of Nepal reported exposure to higher-ambient temperatures (28°C), compared with lower temperatures (24.1°C), increased the cumulative risk of preterm birth by 1.29-fold within 28 days.³⁰ Likewise, Tiwari et al. found that exposure to higher temperatures was associated with a greater risk of low birth weight during wetter seasons.²⁷ However, Ali et al. found no association between ambient temperature and extremely low birthweight.²⁸

A large community-based cohort from Sarlahi ($n=23,240$) found that each 5°C decrease in ambient temperature was associated with a 41.3% (95% CI: 40.0%–42.7%) increase in the risk of moderate or severe neonatal hypothermia.³¹ Additionally, compared with the highest temperature quintile ($25.6\text{--}29.3^\circ\text{C}$), neonates in the lowest quintile ($3.8\text{--}11.7^\circ\text{C}$) had a 4.03-fold higher risk of hypothermia.³¹

Three studies examined the association between increased ambient temperature and the risk of diarrhoeal diseases, of which two reported a significant association.^{32,33} Bhandari et al. reported an 8.1% increase in diarrhoeal risk among children under five per 1°C rise in maximum temperature in Kathmandu (RR=1.081; 95% CI: 1.02–1.14), while Dhimal et al. found 1°C increases in mean, maximum, and minimum temperatures were associated with 4.4%, 3.87%, and 3.79% higher risks, respectively.³²⁻³³ However, Tiwari et al. found no significant association between temperature metrics (2-week mean, mean maximum, and mean minimum) and diarrhoeal risk in children under five.²⁵ In contrast, Bhandari et al. found an inverse association between temperatures and rotavirus infection among children under five years of age where lower quantile (10th percentile) average weekly mean (RR=1.52; 95% CI: 1.08–2.15), minimum (RR=1.42; 95% CI: 1.04–1.95), and maximum (RR=1.93; 95% CI: 1.40–2.65) temperatures were associated with an increased risk of rotavirus infection.³⁴

Three studies examined temperature and child nutritional status.³⁵⁻³⁷ These studies reported that each 1°C increase in ambient temperature was associated with an increased risk of stunting (11% among children under two years) and wasting, while no association was found with underweight or mortality.^{35,36}

However, findings also indicated regional variation, with improved weight-for-height Z-scores in the Terai but not in hills or mountains.³⁷

DISCUSSION

Overall, this review highlights climate-related environmental exposures as important determinants of RMNCAH outcomes in Nepal, with the strongest and most consistent evidence observed for household air pollution and ambient temperature. Household air pollution from the use of solid fuel was strongly linked to acute respiratory infections, mortality, and maternal anaemia, while evidence for nutritional and pregnancy outcomes was mixed. Ambient air pollution demonstrated less consistent associations, with some studies indicating increased risks of respiratory infections, diarrhoeal diseases, and reduced fecundity. Higher and lower ambient temperatures were consistently associated with diarrhoeal diseases, adverse pregnancy outcomes, and neonatal hypothermia.

Household air pollution remains a major concern in Nepal because many rural and socioeconomically disadvantaged households continue to rely on solid fuels for cooking and heating.³⁸ This review showed that household air pollution from solid-fuel use was consistently associated with acute respiratory infections, including pneumonia, among children under five.^{11-14,16} National Demographic and Health Survey data also linked household air pollution with neonatal mortality²⁰, consistent with evidence from other low- and middle-income countries.³⁹⁻⁴¹ Although a randomised controlled trial in Sarlahi found that reducing indoor PM_{2.5} was not significantly associated with acute lower respiratory infections, it was associated with persistent cough and wheeze in children.¹⁵ Together with evidence that current interventions remain suboptimal in low- and middle-income countries.⁴² These findings highlight the need for robust, community-based intervention trials with long-term follow-up. Household air pollution also impacts women of reproductive age.⁵ National representative data from Nepalese women of reproductive age show that use of non-clean fuels was significantly associated with a higher risk of anaemia among women of reproductive age group.²¹ Studies in similar settings have shown that household air pollution is associated with an increased risk of anaemia among women of reproductive age in pregnant and non-pregnant and the risk is directly proportional to the household's air quality index.⁴³⁻⁴⁵

We identified mixed results regarding association between household air pollution and both nutritional outcomes in children and pregnancy outcomes. However, evidence from low- and middle-income countries suggested that household air pollution is strongly associated with adverse nutritional and pregnancy outcomes.^{39-41,46} Therefore, more well-designed studies are needed to better understand the impact of household air pollution on children's nutritional status and pregnancy outcomes in Nepal.

A few studies in Nepal have reported that children's proximity to sources of ambient air pollution is associated with an

increased risk of acute respiratory infections and related hospital admissions in Nepal.^{19,24} A study in Bhaktapur found that each 10 µg/m³ increase in ambient PM_{2.5} concentration correlates with a higher risk of hospital admission for acute respiratory infection in children (RR=1.16; 95% CI: 1.02–1.31).¹⁹ These findings are consistent with global evidence showing that ambient air pollution is strongly associated with both acute and chronic respiratory diseases and increased hospital admissions.^{47,48} In addition, exposure to ambient air pollution (PM_{2.5} and NO_x) has been linked to an increased risk of diarrhoea, particularly among urban Nepalese children during wetter seasons.²⁵ Evidence from global burden of disease studies shows that air pollution is associated with an increased burden of diarrhoeal diseases in children in low- and lower-middle-income countries, with greater effects among males and a contribution to child mortality.⁴⁹ Moreover, ambient air pollution is associated with a broad range of adverse child health outcomes internationally, including lower lung function, reduced cognitive abilities, obesity, and cancer.^{48,50}

Ambient air pollution is also a major risk factor for adverse reproductive health outcomes.⁵ Increased exposure to ambient PM₁ and PM_{2.5} has been associated with reduced fecundity among Nepalese women of reproductive age, with each 10 µg/m³ increase linked to a higher adjusted fertility time ratio of 1.06 (95% CI: 1.02–1.09) and 1.03 (95% CI: 1.00–1.06), respectively.²⁶ A similar finding has been reported in China, where a 10 µg/m³ increase in PM_{2.5} was associated with an 11% reduction in fecundity and a 20% increased likelihood of infertility.^{51,52} These findings highlight the necessity of enhancing the integration of air quality monitoring with health surveillance systems. Connecting air quality data with District Health Information Software 2 (DHIS2) and Integrated Health Information Management System (IHIMS) indicators could facilitate quicker identification of risk periods and hotspot locations, aiding in informed planning and decision-making.

A significant association between rising temperature and diarrhoeal diseases in children was observed in this study.^{32,33} Evidence shows that each 1°C increase in temperature is associated with 4.4% to 8.1% diarrhoeal incidence among Nepalese children.^{32,33} This could be due to rapid pathogen replication and survival of pathogens causing diarrhoea over a longer period, compromised water safety and behaviour-mediated exposures (e.g., water scarcity and storage), which mainly occur in the warmer season.^{3,53,54} In contrast, rotavirus infection tends to peak at lower weekly temperatures, consistent with known cooler-season transmission dynamics of rotavirus infection.³⁴ Taken together, these findings suggest that both elevated and reduced temperatures can facilitate disease transmission in children, consistent with evidence from South Asian countries.⁴¹

Studies included in this review indicate that exposure to elevated temperature is associated with adverse pregnancy outcomes, including preterm birth and low birthweight.^{27,29,30} These findings are consistent with evidence from previous reviews.^{7,55} Socioeconomic disparities were evident, with stronger associations observed among socially disadvantaged women.³⁰ This indicates

that women from socially disadvantaged populations in Nepal are in pre-existing chronic physical and psychological stress, and an elevated ambient temperature triggers the release of cortisol to enter the placental circulation, leading to the initiation of labour.⁵⁶ Moreover, most of the women from socially disadvantaged communities often have limited decision-making power, and lack access to adaptive resources, thus increasing their vulnerability to temperature-related risks.³⁰

Lower ambient temperatures were associated with a higher risk of moderate or severe neonatal hypothermia, highlighting newborns' vulnerability to cold exposure.³¹ This finding is consistent with evidence from South Asia and sub-Saharan Africa, where thermal care practices are often suboptimal.^{54,57} Evidence linking temperature to child nutritional status remained limited and inconsistent. This reflects the context-specific effects of temperature on child nutritional outcomes, mediated by variations in food security, disease burden, and environmental conditions.^{58,59}

A major gap is the lack of studies on Nepalese adolescents, despite their unique vulnerabilities to air pollution and heat exposure. These exposures are linked to a wide range of adverse outcomes, from respiratory disorders to neurodevelopmental impairment; air pollution remains a widespread threat, particularly for vulnerable populations.^{60,61} Hence, future research should examine adolescent girls and boys as a distinct population.

Limitations: This review included only English-language literature, which may have excluded relevant local reports or Nepali-language evidence. However, academic and institutional reports are rarely written in Nepali language. Formal quality appraisal was not undertaken, consistent with the scoping review design. Many studies relied on proxy exposure measures, especially fuel type, rather than direct assessment of indoor air pollution. Meta-analysis was not possible because of heterogeneity in designs, exposures, outcomes, and effect measures. Publication bias and incomplete identification of grey literature remain possible.

CONCLUSION

This scoping review highlights that air pollution and temperature significantly affect RMNCAH outcomes in Nepal. Evidence is strongest for both household and ambient air pollution and child respiratory illness, temperature-related diarrheal disease, and adverse pregnancy outcomes. However, important evidence gaps persist, particularly for adolescents, women of reproductive age, neonates beyond hypothermia, mental health, and high-resolution exposure assessment. These findings underscore the need to mainstream climate risk within RMNCAH programming, strengthen climate-sensitive surveillance and systems and promote research linking environmental exposure data with routine health information systems to enable timelier and evidence-informed decision-making.

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manuscript drafting, review, and editing; **Bernhard Fassl:** Study conception and design, data extraction and interpretation, manuscript drafting and critical revision; **Meghnath Dhimal:** Study conception and design, data extraction and interpretation, manuscript drafting and critical revision.

Conflict of Interest: The authors declare no conflict of interest.

Data availability: The data are available from the corresponding author upon reasonable request.

Ethical Considerations: This review used published studies and grey literature only. No primary data were collected from human participants. Ethical approval was therefore not applicable.

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