

# Urban environmental exposures during the first 2000 days of life as a foundation for health across the life-course: a scoping review

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## Key points

- This review of research on life-course health outcomes from urban environmental exposures in early life found a relatively narrow scope of health outcomes, with most studies focusing on newborn health outcomes and respiratory diseases in infants and children

## Abstract

**Objectives:** By 2030, 60% of the global population is expected to live in urban areas. Exposure to urban environments during the first 2000 days of life can have positive or negative health outcomes across the life course. Understanding the types of urban exposures that influence health outcomes is needed to guide research priorities for public health and urban planning. This review aims to summarise the published research examining the health outcomes of all urban environmental exposures during the first 2000 days of life, identify the quantity and characteristics of research in this area, methods used, and knowledge gaps.

**Methods:** We conducted a scoping review using the JBI methodology for scoping reviews. Eight databases were searched for peer-reviewed primary studies. Inclusion criteria were studies that measured maternal, infant and child exposure to everyday urban environment features and conditions in cities/metropolitan areas during the first 2000 days of life and reported offspring health outcomes across the life course, including embryo, fetal/newborn, infant, child, adolescent, and adult outcomes. We used Covidence software for data screening and extraction. Study characteristics and findings were summarised using tables and narrative synthesis.

## Key points (continued)

- Most studies were cohort retrospective studies, with very few longitudinal studies that measured offspring health outcomes across various stages of the life course, including during adolescence, and no studies reporting adult health outcomes from exposures during the first 2000 days of life
- There is a lack of research in the global south; this geographic region should be a priority area for future research

**Results:** We reviewed 235 articles, which included studies conducted across 41 countries, the majority in the US ( $n = 63$ ). A broad range of environmental exposures were studied, spanning seven categories: air pollution; energy-based pollution; atmosphere, chemical and metal exposure; neighbourhood-built and natural environment features; neighbourhood community conditions; and residential living conditions. Air pollution was the most studied exposure type ( $n = 153$  studies). Health outcomes were reported for all life stages except adults, with fetal/newborn outcomes the most studied life stage ( $n = 137$ ).

**Conclusions:** We found that most research investigating urban environmental exposures in the first 2000 days and health outcomes across the life course focused on air pollution exposures and fetal/newborn health outcomes, using correlational retrospective cohort designs. Few studies included multiple environmental exposures. There is a clear need for more longitudinal research to determine the health impacts of multiple urban environmental exposures across the life course. This will assist in developing urban design and planning strategies and population health to mitigate health risks across the life course.

## Introduction

By 2030, 60% of the global population is expected to live in cities.<sup>1</sup> The design and planning of urban environments are crucial to health promotion and disease prevention, as they influence various upstream determinants of health, including social, environmental, and commercial determinants. Features and conditions of urban environments, such as the quantity and quality of green space<sup>2</sup>, access to health services<sup>3</sup>, and environmental pollution<sup>4</sup>, have multiple health impacts across the life course. Notably, urban design also has an important role in promoting health and reducing health risks from climate change.<sup>5</sup>

The first 2000 days of life (conception to 5 years) is recognised as a critical period of development that can influence physical, cognitive, social and emotional health outcomes across the life course.<sup>6-9</sup> Ensuring optimal health during this period is an international<sup>10</sup> and local priority<sup>11</sup> for health promotion and disease prevention. For example, the UNICEF *Child-Friendly Cities* initiative advocates for the right of every child and young person to live in a city free from various forms of pollutants and for this to be considered in child-responsive urban design.<sup>12</sup> The United Nations *New Urban Agenda* also recognises that a positive urban environment is a mechanism for cultivating wellbeing; routine exposure to positive urban environments fosters optimal development among children.<sup>13</sup>

Well-designed urban environments facilitate health-promoting opportunities by influencing lifestyle behaviours and reducing adverse environmental exposures. For example, parental lifestyle or ill health before birth has been shown to predict adverse physical health effects in the offspring much later in life, such as a higher risk of immune dysfunction or cardiovascular disease.<sup>7</sup> Likewise, sedentary lifestyles and inactivity

in childhood are associated with an increased risk of morbidity in adulthood.<sup>14</sup> The features and conditions of urban environments have been observed to influence parental and child lifestyle characteristics.<sup>15</sup>

Research has predominantly focused on the lifestyle and social factors that determine life-course health, with less focus on understanding how environmental determinants in early life, particularly those related to urban design, predict life-course health outcomes.<sup>16</sup> Addressing urban environmental impacts on health involves understanding complex systems; consequently, it is critical that priority areas for designing and conducting research are identified. For example, increasing urbanisation can adversely affect walkability and lifestyle factors and is correlated with higher obesity and asthma rates in both children and adults.<sup>17,18</sup> Conversely, urban areas containing green spaces see improved mental health outcomes for children residing near these spaces.<sup>19</sup> There is conflicting evidence about urban environments' role in influencing health, which may be partly explained by the approach to measuring environmental conditions.<sup>20</sup> Consequently, there is a need to understand how exposure to urban environments during the first 2000 days of life as a foundation for health has been researched.

This scoping review aims to assess the extent of the literature on health outcomes across the life course from exposure to everyday urban environments during the first 2000 days of life. We chose a scoping review to identify the quantity and characteristics of research in the topic area and any knowledge gaps.<sup>21</sup> We also expected a large amount of heterogeneous research that would limit study comparisons. The practical purpose of the review is to prioritise applied research that will inform public health policy, assist health services planning, and healthy urban planning and design.

This scoping review asks: what are the extent and characteristics of existing evidence about the foundations for health provided by exposure to everyday urban environments during the first 2000 days of life?

## Methods

This scoping review followed the JBI methodology for scoping reviews.<sup>21</sup> We conducted preliminary searches of Scopus, the Cochrane Database of Systematic Reviews, Web of Science and JBI Evidence Synthesis. We found no systematic reviews or scoping reviews that address this topic area. However, review articles on the health impacts of specific urban environmental exposures, such as air pollution in similar cohorts (i.e., pregnant women and children), were found.<sup>22-24</sup> This review differs from these studies as it seeks to summarise the published research examining the health impacts of all urban environmental exposures during the first 2000 days of life.

### Inclusion criteria

Our review included studies that measured maternal, infant and child exposure to everyday urban environments during the first 2000 days of life (conception to 5 years) and health and wellbeing outcomes for the offspring across the life course. Therefore, the review included studies investigating embryo, fetal/newborn, infant (0 to 1 year), child (1 to 10 years), adolescent (10 to 19 years), and adult (life course) health outcomes. Included articles needed to assess exposure to everyday urban environments at the metropolitan city scale, with no limits on the spatial scales within a given city (e.g., personal/private space, institutional space, outdoor space, virtual space, and metro/city domains such as neighbourhood, urban, suburban, peri-urban). Everyday environments were defined as those in which individuals live, work, and interact, including built environment or natural environment features or conditions identified as correlates of the population's health outcomes. Potential correlates included but were not limited to spaces (indoor or outdoor), built environment design features (e.g., housing and other building design), climate, pollution, biodiversity, access to services (e.g., health and education), access to food, access to play spaces, and connectivity. Articles had to be original peer-reviewed primary research published in the 10 years from 2011 to 2021, and written in English.

### Search strategy

Literature searches were conducted from August to October 2021 across various interdisciplinary databases to identify published studies that describe urban environmental exposures during the first 2000 days of life and their influence on health and wellbeing across the life course. Keyword, MeSH terms and Subject Headings

were used in the following databases: Web of Science, MEDLINE (OVID), EMBASE (OVID), Maternity and Infant Care (OVID), CINAHL (EBSCO), PsycINFO (EBSCO), ProQuest, and Scopus. Limits included: title and abstract, studies in humans, articles published in the last 10 years, and articles written in English. The search strategy was adapted for each included database (see Supplementary Table 1, available from: [figshare.com/s/87a554b74b0c6e2dda8c?file=43314876](https://figshare.com/s/87a554b74b0c6e2dda8c?file=43314876)).

### Study/source of evidence selection

EM conducted searches and downloaded citations and abstracts from each database into EndNote X9<sup>25</sup> citation management software, which was used to remove duplicates before importing into Covidence review software. EM screened article titles and abstracts for eligibility. Full-text articles were then screened independently by EM, and another review team member for inclusion, and reasons for article exclusion were recorded. Disagreements were discussed by the two reviewers until a consensus was reached. The search and study selection results are reported in Figure 1 as Preferred Reporting Items for Systematic Reviews and Meta-analyses extensions for the scoping review (PRISMA-ScR) flow diagram.

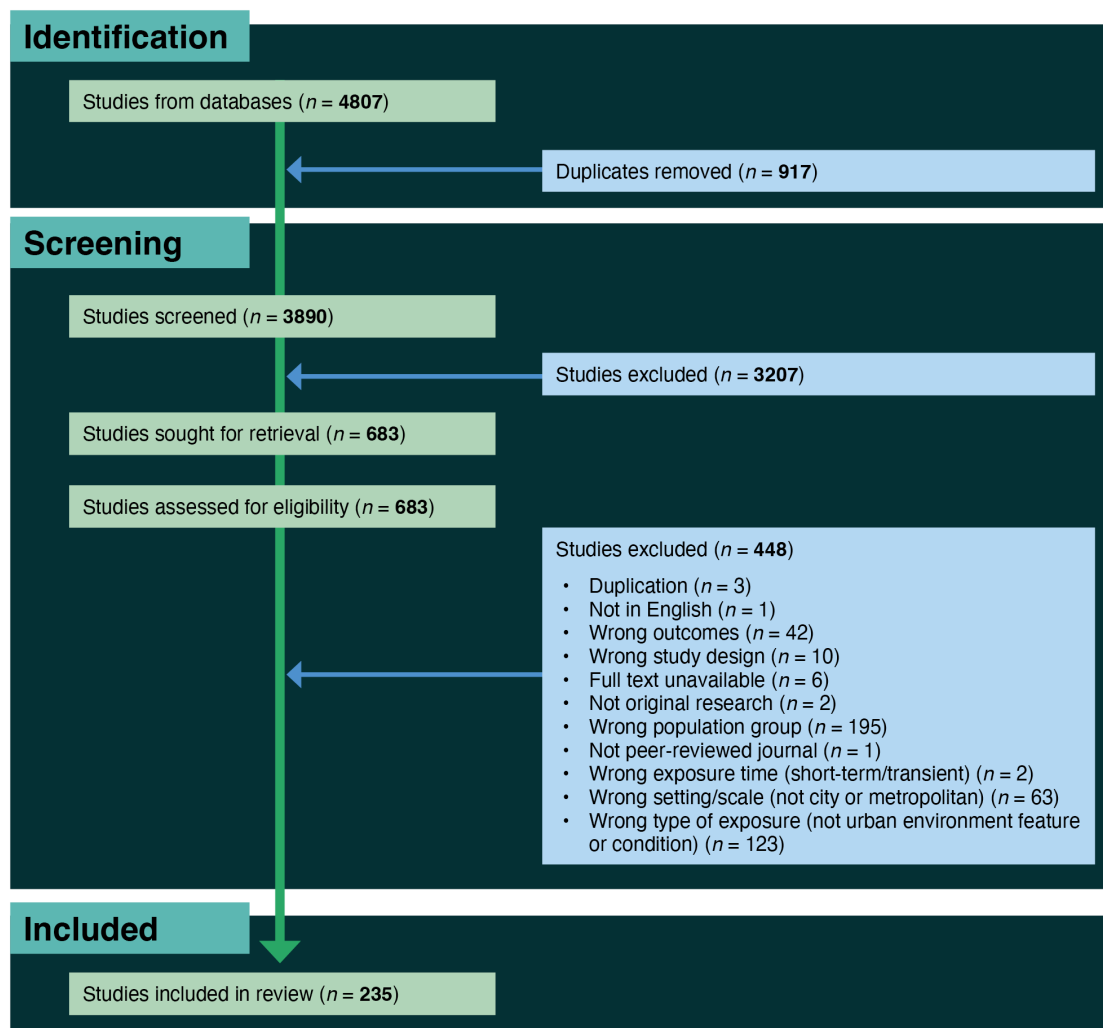
### Data extraction and synthesis

Covidence review software was used for data extraction. Data from eligible studies were extracted independently by at least one review team member and reviewed for accuracy by a second independent reviewer. Disagreements were discussed until a consensus was reached. Data extracted included details about study citation, population (*N*), country/city, urban environmental exposure type (quantitative measures or qualitative descriptions of built and natural urban environmental features or conditions), exposure duration, study design, health outcomes measured, and key findings relevant to the review questions. Descriptive and narrative synthesis were used to organise the data. The exposure categories were determined by identifying common factors in the independent variables measured.

## Results

A total of 4807 papers were identified from the initial database search, of which 917 were duplicates (Figure 1). This left 3890 articles for title and abstract screening, where 3207 were excluded. A remaining 683 were eligible for full-text consideration. After screening the full texts, a total of 235 papers were included in the review. See Supplementary Table 2 for summarised extracted data and additional details on each study (available from: [figshare.com/s/87a554b74b0c6e2dda8c?file=43314876](https://figshare.com/s/87a554b74b0c6e2dda8c?file=43314876)).

**Figure 1.** PRISMA flowchart of included studies

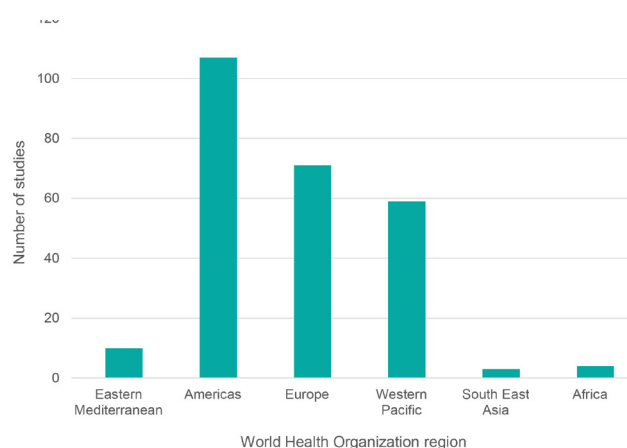


Most studies were conducted in the Americas ( $n = 107$ ), Europe ( $n = 71$ ), and the Western Pacific ( $n = 59$ ), while a smaller selection concentrated on the Eastern Mediterranean ( $n = 10$ ), South-East Asia ( $n = 3$ ), and Africa ( $n = 4$ ), according to the WHO's definition of world regions (Figure 2a). Within the regions, studies were conducted in 41 different countries. Most of the included papers focused solely on one country and the urban metropolitan cities within ( $n = 225$ ), while a few had samples drawn from locations across multiple countries ( $n = 10$ ). Most studies were conducted in the US ( $n = 63$ ) and China ( $n = 40$ ).

The characteristics of the included studies are shown in Figures 2a-2c.

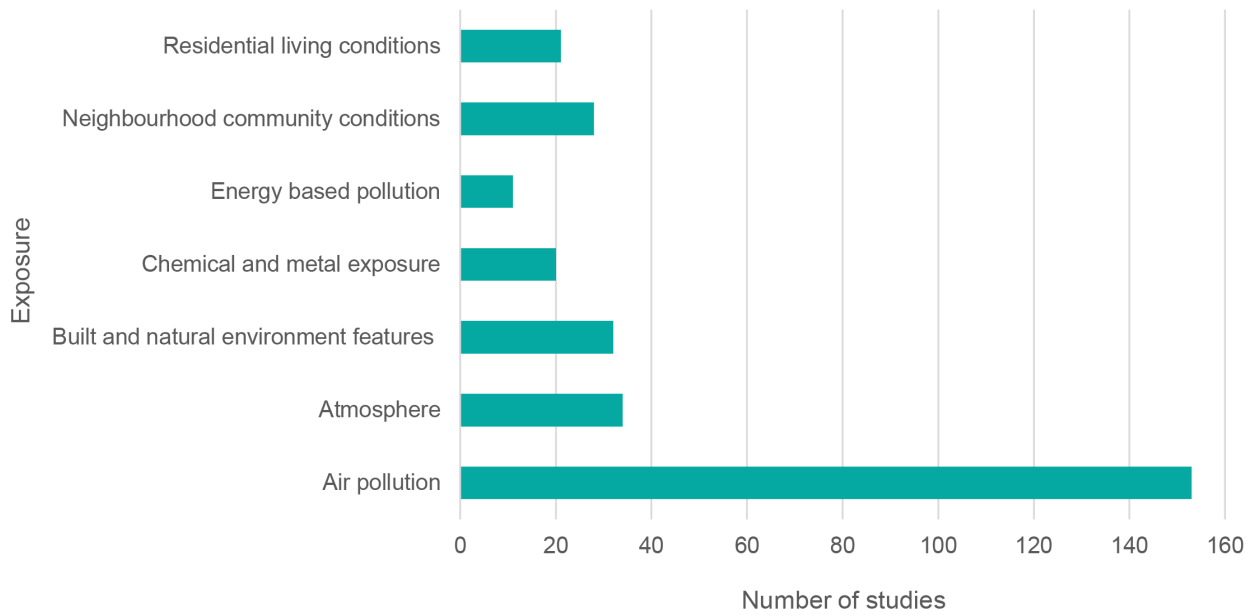
Most study designs were quantitative and observational. Cross-sectional studies ( $n = 169$ ) were the most common, which included cohort retrospective ( $n = 83$ ), cohort prospective ( $n = 49$ ), and comparative studies ( $n = 9$ ). Fewer studies implemented case-control ( $n = 26$ ), time series ( $n = 19$ ), longitudinal ( $n = 17$ ), and case-crossover ( $n = 2$ ) designs. Only one of the included papers was qualitative.

**Figure 2a.** Number of studies conducted per region<sup>a</sup>

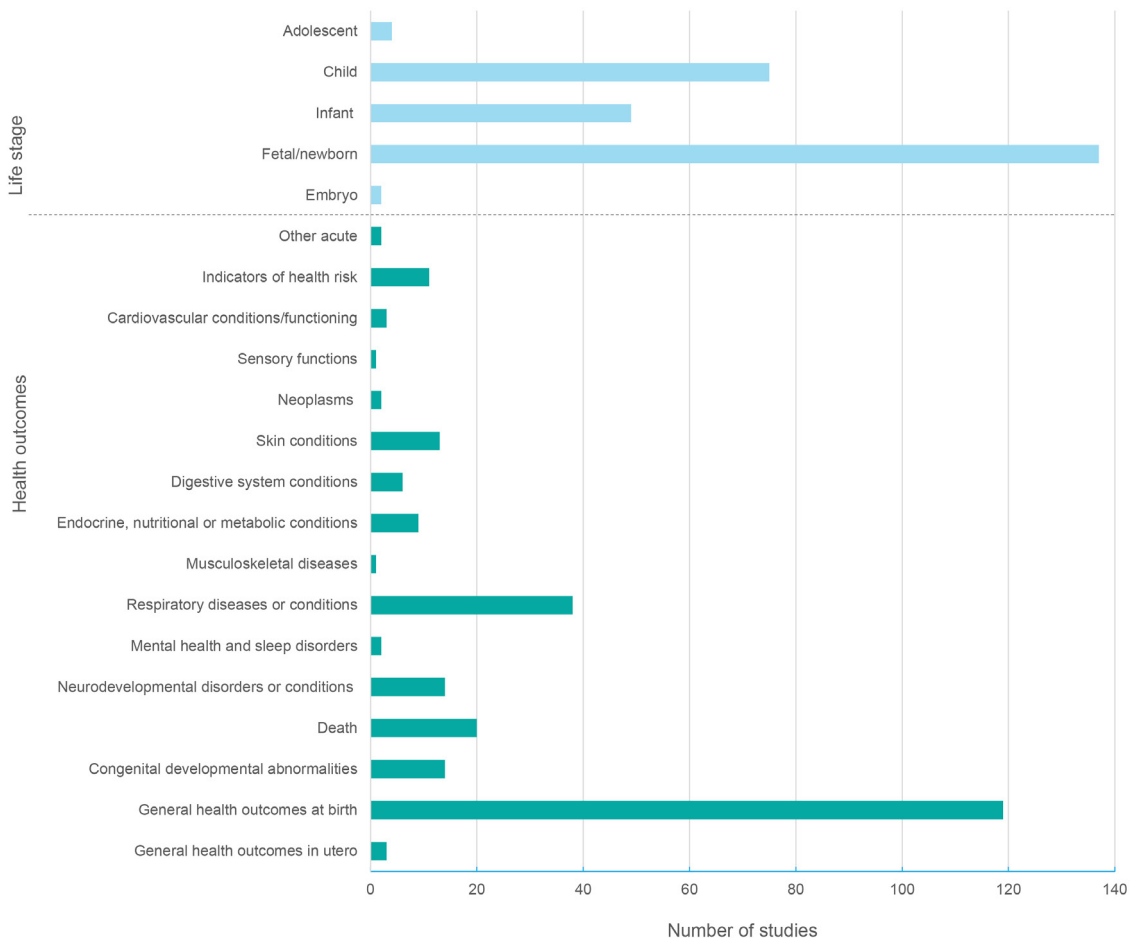


<sup>a</sup> 10 studies included more than one country.

**Figure 2b.** Types of environmental exposures in included studies



**Figure 2c.** Types of health outcome and life stages in included studies<sup>a</sup>



<sup>a</sup> Several studies included more than one exposure type and/or life stage.

Most of the included studies had populations that included pregnant women and offspring pairs ( $n = 181$ ), consisting of the mother paired with either fetal/newborn ( $n = 137$ ), infant ( $n = 10$ ), or child ( $n = 34$ ). A smaller selection had solely infants (ages 0 to 1 years) ( $n = 9$ ), children (up to 10 years) ( $n = 39$ ) or adolescents ( $n = 11$ ) as the sample population group. No studies included health outcomes for adults.

The included studies considered the effect of a range of urban environmental exposures on health across the life course (Figure 2b). The most investigated exposure was air pollution ( $n = 153$ ), including particulate matter and gases. Atmospheric conditions ( $n = 34$ ), including temperature, humidity, and wind, received moderate attention across the included papers, as did features of the built and natural environment ( $n = 32$ ; e.g., access to green or blue space) and neighbourhood community conditions ( $n = 28$ ) such as residential segregation and characteristics of the local community population. Areas that were less investigated included residential living conditions ( $n = 21$ ), chemical and metal exposures ( $n = 20$ ), and energy-based pollution ( $n = 11$ ; e.g., noise). See Supplementary Table 3 for a detailed summary of the types of exposures included in studies (available from: [figshare.com/s/87a554b74b0c6e2dda8c?file=43314876](https://figshare.com/s/87a554b74b0c6e2dda8c?file=43314876)).

A variety of exposure measures were used across the included studies. Most studies used stationary data ( $n = 119$ ; e.g., air pollution monitors), followed by model data ( $n = 97$ ; e.g., land use regression), self-reported data ( $n = 53$ ), administrative units ( $n = 31$ ; e.g., MeSH blocks), biomarkers ( $n = 20$ ), satellite measures ( $n = 11$ ), sample collection from environmental media ( $n = 9$ ), observational/field data ( $n = 8$ ), personal monitors ( $n = 7$ ), and administrative records ( $n = 4$ ). Supplementary Table 4 summarises the number of studies by exposure type and exposure measures (available from: [figshare.com/s/87a554b74b0c6e2dda8c?file=43314876](https://figshare.com/s/87a554b74b0c6e2dda8c?file=43314876)).

Health outcomes were measured across various stages of the offspring's life course (Figure 2c). See the Supplementary Table 5 for details (available from: [figshare.com/s/87a554b74b0c6e2dda8c?file=43314876](https://figshare.com/s/87a554b74b0c6e2dda8c?file=43314876)). Most typically, studies examined a particular health outcome among fetal/newborns ( $n = 137$ ), while child ( $n = 75$ ) and infant ( $n = 49$ ) outcomes were also relatively common. Little research considered health outcomes at the adolescent ( $n = 4$ ) or embryo ( $n = 2$ ) stages. Most research concentrated on health outcomes for fetal/newborns, general health outcomes at birth, such as preterm birth ( $n = 76$ ), birthweight and length ( $n = 70$ ), stillbirths or infant deaths ( $n = 20$ ) and congenital developmental outcomes ( $n = 14$ ). Physical health outcomes, such as skin conditions ( $n = 13$ ), endocrine, nutritional or metabolic conditions ( $n = 9$ ), digestive system conditions ( $n = 6$ ), and cardiovascular functioning ( $n = 3$ ), were investigated less frequently, as were conditions relating to neurodevelopmental disorders ( $n = 14$ ) and mental health and sleep disorders ( $n = 2$ ). A small number of studies investigated general health

outcomes in utero ( $n = 3$ ), neoplasms ( $n = 2$ ), abortive outcomes ( $n = 1$ ), sensory functions ( $n = 1$ ), physical injuries ( $n = 1$ ), and musculoskeletal diseases ( $n = 1$ ).

## Discussion

This scoping review aimed to assess the extent of the peer-reviewed literature studying the health outcomes across the life course from exposure to everyday urban environments during the first 2000 days of life. We found that the characteristics of the included studies were heterogeneous for geographic region, study design, health outcomes and environmental exposures. We expected this finding, given the interdisciplinary focus of the review. Most of the research was conducted in the US and China, with a notable lack of study in the global south. This is particularly concerning given that countries in this region are more likely to be affected by impacts from climate change, amplifying health risks in the early years of life.<sup>26</sup> Consequently, the global south should be a priority area for future research.

Most included studies were cohort retrospective studies focused on newborn health outcomes. Very few longitudinal studies were found that measured offspring health outcomes across various life-course stages, including adolescence, with no studies reporting adult health outcomes from exposures during the first 2000 days of life. As it is well established that certain environmental exposures during the first 2000 days of life – such as air pollution – impact newborn and child health outcomes<sup>22,27</sup>, it is critical to determine how in-utero and early life exposures affect adolescent and adult health.

A broad range of environmental exposures were studied in the included articles. Overall, there was a lack of consistency in the operationalisation of the exposure measures used across the studies, which made it difficult to draw comparisons. The majority focused on air pollution using either stationary monitoring data or model data. Fewer studies concentrate on the features of the natural or built environment, the socioeconomic neighbourhood environment, or residential living conditions. It was uncommon for studies to include multiple environmental exposures to reflect the number of exposures present within an urban setting. Notably, one study considered a range of exposures more holistically using a Sustainable Development Index that included indicators of neighbourhood equity, demographic profile, and environmental and economic sustainability.<sup>28</sup> Researchers could consider adopting similar methodologies to accommodate multiple interacting exposures within urban environments, consistent with a planetary health approach.<sup>29</sup>

A relatively narrow scope of health outcomes was measured in the included studies. Most focused on newborn general health outcomes (e.g., preterm birth, birthweight) and respiratory diseases or conditions. Notably, only one study reported mental wellbeing

outcomes in children. Given the increasing prevalence of mental health conditions in children and adolescents<sup>30</sup>, and that aspects of urban design – such as access to green space – promote mental wellbeing<sup>31</sup>, more research on mental health impacts from early life exposures is needed.

This review summarises published research and identifies the quantity and characteristics of this research, methods used, and knowledge gaps. This will inform research priorities to guide policy direction, such as establishing links between urban planning policy and health policy. For example, in New South Wales (NSW), Australia, NSW Health has established *The First 2000 Days Framework*<sup>11</sup> as a strategic policy to address the importance of early life exposures on health and wellbeing and guide actions that can be taken within the NSW Health system to ensure that all children have the best possible start in life. However, the framework does not address the role that everyday urban environments provide as a foundation for health during the first 2000 days of life.

Good urban design can directly address primordial health prevention and promote health across the life course, and it is critical that interventions that address a broad range of environmental exposures are evaluated for their health and wellbeing impacts over time. This requires collaboration across various disciplines to determine which environmental health indicators can be used to help inform urban design, health services planning and clinical care. Multidisciplinary collaborations among built environment and public health practitioners, clinicians and others are needed to deliver preventive health strategies that address the types of exposures and health outcomes highlighted by this review, and contribute to urban environments that support health. This review contributes to the knowledge base to guide future research into urban environments to support health during the first 2000 days of life.

The limited number of studies in the global south may relate to a lack of financial resources and research infrastructure in low- and middle-income countries, institutional barriers, and disabling policies and procedures.<sup>32</sup> High-income countries with greater access to these resources could co-create research priorities and assist with securing project funding to better understand the impacts of urban environments in low-income countries.

## Limitations

This scoping review excluded studies focused on prenatal maternal health, which can also influence offspring health outcomes. To manage the large amount of research in this area and remain within scope, the search was limited to papers published within a specific date range, which may have excluded additional studies on this topic. The selection criteria for this study were focused on addressing the research aims; consequently,

we did not evaluate the quality of the included articles. We did not report the scale of the exposure measures, which limited our understanding of the methodological quality of the included studies.

## Conclusion

This scoping review has identified gaps and future research priorities to address urban environmental exposures during the first 2000 days of life and life-course health outcomes. The research in this area is heterogeneous regarding populations studied, methods used and health outcomes studied. Few studies include multiple environmental exposures. There is a clear need for more longitudinal research to determine what health impacts multiple urban environmental exposures during the early years of life have across the life course. This will inform the development of urban design and planning strategies and population health that can mitigate health risks across the life course. There are many opportunities for further research in this area through data linkage, geographic information system technologies, and new cohorts, such as the longitudinal GenV Study in Victoria, Australia.<sup>33</sup> The rise of new (or repurposed) data and methods is re-shaping our understanding of the health impacts of environmental exposures. In future, we will be able to ask more precise questions.

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## Peer review and provenance

Externally peer reviewed, commissioned.

## Competing interests

Authors CC and AH served on the executive committee of the funding organisation.

## Author contributions

EM contributed to the study design, overseeing the data extraction and analysis, drafting, and editing of the manuscript. JP, CC, DV, JF and AH contributed to the study design, data extraction, and critical revision of the manuscript. RL and CP contributed to data extraction, analysis, drafting and revision of the manuscript. CR contributed to the data extraction and drafting of the manuscript, and VE contributed to the study design and critical revision of the manuscript.

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