

Protocol

Impact of urban heat islands on human health in India – a systematic review protocol

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ABSTRACT

Background: Worldwide, urbanization is occurring at an accelerated rate, especially in India. The development of urban areas contributes to urban heat island (UHI) phenomenon. Though the health effects of UHIs have been studied in various urban areas across the world, there is a need to develop evidence in India. This is essential for implementing effective and country-specific interventions aimed at mitigating the UHI effect while expanding urban areas in the country. The objective of this review is to describe the human health impacts of urban heat islands in India. The review will consider studies that focus on urban populations irrespective of age and sex, which report on health effects due to urban heat islands, or changes in ambient temperatures due to urbanization.

Methods: This review will search for both published and unpublished studies. The information sources to be searched will include Medline (PubMed), Embase, Epistemonikos, Virtual Health Library, PsychINFO (EBSCO), Mednar, Dissertation Abstracts International, Proquest dissertations and theses, World Health Organization (WHO) website and Google Scholar. Studies published from database inception till current date, as well as those published in English, will be included. Two independent reviewers will conduct a critical appraisal of eligible studies, assess the methodological quality, and extract the data.

Conclusions: This review will add to the body of evidence on urban heat island effects on human health and help to inform urban policy and planning.

Trial registration number: PROSPERO - CRD42024588528

Keywords: Climate change, Heat stress, Low and middle-income countries, Urban health, Urbanization

INTRODUCTION

Urbanization is a worldwide phenomenon that is drastically reshaping landscapes, economies and communities. It is projected that over two-thirds of the world's population will reside in urban areas by 2050.^{1,2} India is expected to undergo the most rapid demographic shift towards urbanization. However, the unplanned

expansion of urban settlements has led to an increase in urban slums. This inevitably gives rise to the phenomenon of urban heat islands, which pose significant health risks to the residents.^{3,4}

Understanding urban heat islands

The phenomenon of urban heat island (UHI) occurs when a city experiences a warmer climate than the surrounding

rural areas.¹ Research shows that the differences in temperatures between urban and surrounding peri-urban/rural areas, in various global cities range from 1°C to 9°C.⁵ These temperature variations occur due to several urban characteristics like building parameters, urban canopy, albedo, reduced green spaces; land surface characteristics; environmental factors like wind speed patterns, solar radiation; and heat generated from anthropogenic activities.⁵ Air pollution additionally exacerbates this condition leading to heat trapping in the urban areas.^{2,6,7}

UHI can be classified into two types: Surface heat island (SUHI) and atmospheric heat island (AHI). SHI is studied using satellite images and geographic information systems (GIS), whereas AHI uses observational data from weather stations and mobile surveys. SHI occurs constantly, while AHI is more pronounced at night. AHI is further divided into Canopy layer heat island (CLHI), which is below roof level, and boundary layer heat island (BLHI) above the CLHI.^{5,8-11} Most of the research focuses on SHIs, by analysing land and surface temperatures, as it is more feasible to conduct studies on them.⁵

Health impacts of urban heat islands

Apart from adversely affecting water and air quality, increasing energy consumption, and impacting the environment, UHIs are thought to have detrimental impacts on the residents' health. Ranging from heat discomfort to exacerbating certain diseases and increasing mortality rates, it has the potential to affect vulnerable populations and developing countries to a greater extent. Decreasing work efficiency, productivity, liveability and quality of life are other impacts.^{12,13}

India's urbanization and preparedness

Urban areas in India are growing rapidly, along with a significant rise in urban slums, which significantly contribute to UHI effect. Climate change is an additional contributing factor indicating urbanization alone has increased the warming of Indian cities by 60%.¹ Case studies from Mumbai, Kolkata and Ahmedabad report that informal housing areas have a more pronounced effect on heat island intensity.¹⁴⁻¹⁶ While urbanization is a part of progress and development, it should be sustainable and environmentally friendly. As a signatory to the 2030 agenda for sustainable development goals (SDGs), India must address the issues of UHIs to meet the goals (SDGs): 3-good health and well-being, 11-sustainable cities and communities and 13-climate action.¹⁷ Achieving good health and well-being requires planned interventions to mitigate UHI effects, which requires robust evidence on the different health impacts of UHIs in Indian cities.

A preliminary search of Prospero, Medline, Epistemonikos, the Cochrane Database of Systematic Reviews and the JBI Evidence Synthesis was conducted. Several systematic reviews have examined the relationship

between heat waves, mortality and urban heat islands.^{18,19} One systematic review by Ramly et al provides evidence of the impact of urban heat islands on human health.²⁰ However, none of the studies included in this review were focused on Indian urban areas. There are individual studies done in different Indian urban regions in recent years. Though India is one of the most vulnerable countries in the world to the effects of urbanization and climate change, there is a paucity of data on the human health impact of UHIs. Therefore, we propose to conduct a systematic review specifically focussing on Indian urban areas to gather relevant data tailored to their unique context, as the human health impact may differ by region and country and so do the evidence-based interventions.

METHODS

The proposed systematic review will be conducted following the JBI methodology for systematic reviews of aetiology and risk.²² The review has been registered on PROSPERO - CRD42024588528.²³

Inclusion criteria

Participants

This review will include studies on populations living in cities or urban areas in India, irrespective of age and sex. The definition of urban unit will be followed as per the Circular No. 2 of the Census of India, 2021.

All administrative units that have been defined by statute as urban like Municipal Corporation, Municipality, cantonment Board, Notified Town Area Committee, Town Panchayat, and Nagar Palika are known as Statutory Town. Further, Statutory Towns with a population of 1,00,000 and above are categorized as cities.

All other places which satisfies the following criteria: a minimum population of 5,000 persons, 75 per cent and above of the male main working population being engaged in non-agricultural pursuits, and a density of population of at least 400 persons per sq. km. (1,000 per sq. mile).²¹

Studies exclusively based on occupational groups in cities and their health outcomes will be excluded, unless the exposure studied specifically is urban heat island and its direct impact on these groups.

Exposure of interest

This review will consider studies that measure urban heat islands in India. As a limited number of studies are anticipated, we will maintain a broad scope, to include studies that indirectly measure urban heat islands, such as measurement of ambient temperature in urban areas and its impact on human health. Studies on urban cold islands, if any, will be excluded.

Outcomes

This review will consider studies reporting on various outcomes, but not limited to: all-cause mortality, all-cause morbidity, heat-related illnesses (heat stress, heat stroke, heat exhaustion, heat cramps), specific diseases like cardiovascular diseases, respiratory diseases, renal diseases, mental disorders, electrolyte disturbances, hospital admissions, ambulance calls, hospital/emergency department visits. Indirect and subjective indicators like thermal comfort will also be included.

Types of studies

This review will include observational studies including prospective and retrospective cohort studies, case-control studies, cross-sectional studies and time series studies. Observational methods would include remote sensing, data from meteorological weather stations or field measurements. The review will also include both experimental and quasi-experimental study designs including randomized controlled trials, non-randomized controlled trials, before and after studies and time-series studies that report on the risk associated with an intervention. However, it must be noted that randomized controlled trials may not always be feasible in environmental studies. Numerical and computational studies and modelling studies, if present, will also be included.

Search strategy

The search strategy will aim to locate both published and unpublished studies. A three-step search strategy will be utilized in this review. First, an initial limited search of Medline (PubMed) and Embase was undertaken to identify articles on the topic. The text words contained in the titles and abstracts of relevant articles, and the index terms used to describe the articles were used to develop a full search strategy for Medline (PubMed) and Embase (Figure 1). The search strategy, including all identified keywords and index terms, will be adapted for each included database and/or information source. The reference list of all included articles will be screened for additional studies. References list of studies included in systematic reviews on similar topics will also be searched. Studies published in any language other than English will be excluded and databases from inception till current date will be included. The databases to be searched will include Medline (PubMed), Embase, Epistemonikos, and Virtual Health Library. Unpublished studies or grey literature will be searched in the databases of Mednar, Dissertation Abstracts International, World Health Organization (WHO) website and Google Scholar. Study authors will be contacted in case of any clarification or missing data.

Study selection

Following the search, all identified citations will be collated and uploaded into Rayyan software and duplicates removed.²⁴ Following a pilot test, titles and abstracts will then be screened by two independent reviewers for assessment against the inclusion criteria for the review. Potentially relevant studies will be retrieved in full and their citation details imported into the JBI System for the Unified Management, Assessment and Review of Information (JBI SUMARI) (JBI, Adelaide, Australia).²⁵ The full text of selected citations will be assessed in detail against the inclusion criteria by two independent reviewers. Reasons for exclusion of papers in full text that do not meet the inclusion criteria will be recorded and reported in the systematic review. Any disagreements that arise between the reviewers at each stage of the selection process will be resolved through discussion with a third reviewer. The results of the search and the study inclusion process will be reported in full in the final systematic review and presented in a preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram.²⁶

Assessment of methodological quality

Eligible studies will be critically appraised by two independent reviewers at the study level for methodological quality in the review using JBI standardized critical appraisal instruments for experimental, quasi-experimental and observational studies.^{22,27-29} Authors of papers will be contacted to request missing or additional data for clarification, where required. Any disagreements that arise will be resolved through discussion, or with a third reviewer. The results of critical appraisal will be reported in narrative form and a table. All studies, regardless of the results of their methodological quality, will undergo data extraction and synthesis (where possible).

Data extraction

Data will be extracted from studies included in the review by two independent reviewers using the standardized JBI data extraction tool. The data extracted will include specific details about the exposure of interest including different exposure categories if applicable, populations, study methods and outcomes or dependent variables of significance to the review question and specific objectives. Any disagreements that arise between the reviewers will be resolved through discussion or with a third reviewer. Authors of papers will be contacted to request missing or additional data, where required.

Table 1: Search strategy (PubMed). Search conducted on December 30, 2024.

Search terms	Results retrieved
"Urban population"[Text Word] OR "City dwellers"[Text Word] OR "Metropolitan communities"[Text Word] OR "major Indian cit*" [Text Word] OR "urban slum"[Text Word] OR "Metropolitan cities"[Text Word] OR Delhi[Text Word] OR Mumbai[Text Word] OR Varanasi[Text Word] OR Ahmedabad[Text Word] OR Surat[Text Word] OR Mumbai[Text Word] OR Hyderabad[Text Word] OR Chennai[Text Word] OR Kolkata[Text Word] OR Calcutta[Text Word] OR Pune[Text Word] OR Bangalore[Text Word] OR Jaipur[Text Word] OR Lucknow[Text Word] OR Kanpur[Text Word] OR Visakhapatnam[Text Word] OR Indore[Text Word] OR Thrissur[Text Word] OR Coimbatore[Text Word] OR Ludhiana[Text Word] OR Agra[Text Word] OR Vadodara[Text Word] OR Nashik[Text Word] OR Gwalior[Text Word] OR Ludhiana[Text Word] OR Jamshedpur[Text Word] OR Rourkela[Text Word] OR Bokaro[Text Word] OR Bhilai[Text Word] OR Ghaziabad[Text Word] OR Faridabad[Text Word] OR "Navi Mumbai"[Text Word] OR Gurgaon[Text Word] OR Noida[Text Word] OR Ghaziabad[Text Word] OR Navi[Text Word] OR Mumbai[Text Word] OR Indore[Text Word] OR Kochi[Text Word] OR Trivandrum[Text Word] OR Thiruvananthapuram[Text Word] OR Dehradun[Text Word] OR Shimla[Text Word] OR Chandigarh[Text Word] OR Panaji[Text Word] OR Dispur[Text Word] OR Agartala[Text Word] OR Faridabad[Text Word] OR Bhopal[Text Word] OR Jabalpur[Text Word] OR Raipur[Text Word] OR Gwalior[Text Word] OR Guwahati[Text Word] OR Shillong[Text Word] OR Imphal[Text Word] OR Aizawl[Text Word] OR Kohima[Text Word] OR Bhubaneswar[Text Word] OR Cuttack[Text Word] OR Patna[Text Word] OR Ranchi[Text Word] OR Jamshedpur[Text Word] OR Durgapur[Text Word] OR Siliguri[Text Word]	1,02,740
"Urban population"[Title/Abstract] OR "City dwellers"[Title/Abstract] OR "Metropolitan communities"[Title/Abstract] OR "major Indian cit*" [Title/Abstract] OR "urban slum"[Title/Abstract] OR "Metropolitan cities"[Title/Abstract] OR Delhi[Title/Abstract] OR Mumbai[Title/Abstract] OR Varanasi[Title/Abstract] OR Ahmedabad[Title/Abstract] OR Surat[Title/Abstract] OR Mumbai[Title/Abstract] OR Hyderabad[Title/Abstract] OR Chennai[Title/Abstract] OR Kolkata[Title/Abstract] OR Calcutta[Title/Abstract] OR Pune[Title/Abstract] OR Bangalore[Title/Abstract] OR Jaipur[Title/Abstract] OR Lucknow[Title/Abstract] OR Kanpur[Title/Abstract] OR Visakhapatnam[Title/Abstract] OR Indore[Title/Abstract] OR Thrissur[Title/Abstract] OR Coimbatore[Title/Abstract] OR Ludhiana[Title/Abstract] OR Agra[Title/Abstract] OR Vadodara[Title/Abstract] OR Nashik[Title/Abstract] OR Gwalior[Title/Abstract] OR Ludhiana[Title/Abstract] OR Jamshedpur[Title/Abstract] OR Rourkela[Title/Abstract] OR Bokaro[Title/Abstract] OR Bhilai[Title/Abstract] OR Ghaziabad[Title/Abstract] OR Faridabad[Title/Abstract] OR "Navi Mumbai"[Title/Abstract] OR Gurgaon[Title/Abstract] OR Noida[Title/Abstract] OR Ghaziabad[Title/Abstract] OR Navi[Title/Abstract] OR Mumbai[Title/Abstract] OR Indore[Title/Abstract] OR Kochi[Title/Abstract] OR Trivandrum[Title/Abstract] OR Thiruvananthapuram[Title/Abstract] OR Dehradun[Title/Abstract] OR Shimla[Title/Abstract] OR Chandigarh[Title/Abstract] OR Panaji[Title/Abstract] OR Dispur[Title/Abstract] OR Agartala[Title/Abstract] OR Faridabad[Title/Abstract] OR Bhopal[Title/Abstract] OR Jabalpur[Title/Abstract] OR Raipur[Title/Abstract] OR Gwalior[Title/Abstract] OR Guwahati[Title/Abstract] OR Shillong[Title/Abstract] OR Imphal[Title/Abstract] OR Aizawl[Title/Abstract] OR Kohima[Title/Abstract] OR Bhubaneswar[Title/Abstract] OR Cuttack[Title/Abstract] OR Patna[Title/Abstract] OR Ranchi[Title/Abstract] OR Jamshedpur[Title/Abstract] OR Durgapur[Title/Abstract] OR Siliguri[Title/Abstract]	44,674
("Urban population"[Text Word] OR "City dwellers"[Text Word] OR "Metropolitan communities"[Text Word] OR "major Indian cit*" [Text Word] OR "urban slum"[Text Word] OR "Metropolitan cities"[Text Word] OR Delhi[Text Word] OR Mumbai[Text Word] OR Varanasi[Text Word] OR Ahmedabad[Text Word] OR Surat[Text Word] OR Mumbai[Text Word] OR Hyderabad[Text Word] OR Chennai[Text Word] OR Kolkata[Text Word] OR Calcutta[Text Word] OR Pune[Text Word] OR Bangalore[Text Word] OR Jaipur[Text Word] OR Lucknow[Text Word] OR Kanpur[Text Word] OR Visakhapatnam[Text Word] OR Indore[Text Word] OR Thrissur[Text Word] OR Coimbatore[Text Word] OR Ludhiana[Text Word] OR Agra[Text Word] OR Vadodara[Text Word] OR Nashik[Text Word] OR Gwalior[Text Word] OR Ludhiana[Text Word] OR Jamshedpur[Text Word] OR Rourkela[Text Word] OR Bokaro[Text Word] OR Bhilai[Text Word] OR Ghaziabad[Text Word] OR Faridabad[Text Word] OR "Navi Mumbai"[Text Word] OR Gurgaon[Text Word] OR Noida[Text Word] OR Ghaziabad[Text Word] OR Navi[Text Word] OR Mumbai[Text Word] OR Indore[Text Word] OR Kochi[Text Word] OR Trivandrum[Text Word] OR Thiruvananthapuram[Text Word] OR Dehradun[Text Word] OR Shimla[Text Word] OR Chandigarh[Text Word] OR Panaji[Text Word] OR Dispur[Text Word] OR Agartala[Text Word] OR Faridabad[Text Word] OR Bhopal[Text Word] OR Jabalpur[Text Word] OR Raipur[Text Word] OR Gwalior[Text Word]	1,02,740

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Search terms	Results retrieved
OR Guwahati[Text Word] OR Shillong[Text Word] OR Imphal[Text Word] OR Aizawl[Text Word] OR Kohima[Text Word] OR Bhubaneswar[Text Word] OR Cuttack[Text Word] OR Patna[Text Word] OR Ranchi[Text Word] OR Jamshedpur[Text Word] OR Durgapur[Text Word] OR Siliguri[Text Word]) OR ("Urban population"[Title/Abstract] OR "City dwellers"[Title/Abstract] OR "Metropolitan communities"[Title/Abstract] OR "major Indian cit*"[Title/Abstract] OR "urban slum"[Title/Abstract] OR "Metropolitan cities"[Title/Abstract] OR Delhi[Title/Abstract] OR Mumbai[Title/Abstract] OR Varanasi[Title/Abstract] OR Ahmedabad[Title/Abstract] OR Surat[Title/Abstract] OR Mumbai[Title/Abstract] OR Hyderabad[Title/Abstract] OR Chennai[Title/Abstract] OR Kolkata[Title/Abstract] OR Calcutta[Title/Abstract] OR Pune[Title/Abstract] OR Bangalore[Title/Abstract] OR Jaipur[Title/Abstract] OR Lucknow[Title/Abstract] OR Kanpur[Title/Abstract] OR Visakhapatnam[Title/Abstract] OR Indore[Title/Abstract] OR Thrissur[Title/Abstract] OR Coimbatore[Title/Abstract] OR Ludhiana[Title/Abstract] OR Agra[Title/Abstract] OR Vadodara[Title/Abstract] OR Nashik[Title/Abstract] OR Gwalior[Title/Abstract] OR Ludhiana[Title/Abstract] OR Jamshedpur[Title/Abstract] OR Rourkela[Title/Abstract] OR Bokaro[Title/Abstract] OR Bhilai[Title/Abstract] OR Ghaziabad[Title/Abstract] OR Faridabad[Title/Abstract] OR "Navi Mumbai"[Title/Abstract] OR Gurgaon[Title/Abstract] OR Noida[Title/Abstract] OR Ghaziabad[Title/Abstract] OR Navi[Title/Abstract] OR Mumbai[Title/Abstract] OR Indore[Title/Abstract] OR Kochi[Title/Abstract] OR Trivandrum[Title/Abstract] OR Thiruvananthapuram[Title/Abstract] OR Dehradun[Title/Abstract] OR Shimla[Title/Abstract] OR Chandigarh[Title/Abstract] OR Panaji[Title/Abstract] OR Dispur[Title/Abstract] OR Agartala[Title/Abstract] OR Faridabad[Title/Abstract] OR Bhopal[Title/Abstract] OR Jabalpur[Title/Abstract] OR Raipur[Title/Abstract] OR Gwalior[Title/Abstract] OR Guwahati[Title/Abstract] OR Shillong[Title/Abstract] OR Imphal[Title/Abstract] OR Aizawl[Title/Abstract] OR Kohima[Title/Abstract] OR Bhubaneswar[Title/Abstract] OR Cuttack[Title/Abstract] OR Patna[Title/Abstract] OR Ranchi[Title/Abstract] OR Jamshedpur[Title/Abstract] OR Durgapur[Title/Abstract] OR Siliguri[Title/Abstract])	
((((((((((((Mortality[Text Word]) OR (Mortality[Title/Abstract])) OR (Mortality[MeSH Terms])) OR ((Morbidity[MeSH Terms]) AND (Morbidity[Title/Abstract])) OR (Morbidity[Text Word])) OR (((("heat-shock response"[MeSH Terms]) OR ("heat-shock response"[Text Word])) OR ("heat-shock response"[Title/Abstract])) OR (((("heat stress disorders"[MeSH Terms]) OR ("heat stress disorders"[Text Word])) OR ("heat stress disorders"[Title])) OR (((("heat stress disorders"[MeSH Terms]) OR ("heat stress disorders"[Text Word])) OR ("heat stress disorders"[Title])) OR ((("Heat stress"[Text Word]) OR ("Heat stress"[Title/Abstract])) OR ((("heat stroke"[MeSH Terms] OR Heatstroke[Text Word]) OR (heatstroke[Title/Abstract])) OR (((("Heat exhaustion"[Text Word]) OR ("Heat exhaustion"[Title/Abstract])) OR ("Heat exhaustion"[MeSH Terms])) OR (((("Heat-related illness"[Text Word])) OR ("Heat-related illness"[Title/Abstract])) OR (Heat-induced conditions[Text Word])) OR ("mental health"[MeSH Terms] OR mental health[Text Word])) OR ("chronic disease"[MeSH Terms] OR Chronic diseases[Text Word])) OR (((Anxiety[MeSH Terms]) OR (anxiety[Text Word])) OR (Anxiety[Title/Abstract])) OR (((depression[MeSH Terms]) OR (depression[Text Word])) OR (depression[Title/Abstract]))	33,85,689
(((((((((((("Urban heat islands"[Text Word]) OR ("Urban heat islands"[Title/Abstract])) OR ((("Urban thermal environment"[Title]) OR ("Urban thermal environment"[Title/Abstract])) OR ((("Heat islands"[Text Word]) OR ("Heat islands"[Title/Abstract])) OR (Anthropogenic heat island)) OR ((("Land surface temperature"[Text Word]) OR ("Land surface temperature"[Title/Abstract])) OR ((("Urban climate"[Text Word]) OR ("Urban climate"[Title/Abstract])) OR ((("Urban meteorology"[Text Word]) OR ("Urban meteorology"[Title/Abstract])) OR ((("Urban meteorology"[Text Word]) OR ("Urban meteorology"[Title/Abstract])) OR ((("Urban meteorology"[Text Word]) OR ("Urban meteorology"[Title/Abstract])) OR ((("Urban green spaces"[Text Word]) OR ("Urban green spaces"[Title/Abstract])) OR ((("Urban morphology"[Text Word]) OR ("Urban morphology"[Title/Abstract])) OR ((("Ambient temperature"[Text Word]) OR ("Ambient temperature"[Title/Abstract])) OR (((Urbanization[Text Word]) OR (Urbanization[Title/Abstract])) OR (Urbanisation[Text Word])) OR (Urbanisation[Title/Abstract]))	48,689
(India[Text Word]) OR (India[Title/Abstract])	1,99,869
(((((India[Text Word]) OR (India[Title/Abstract])) AND ((("Urban population"[Text Word] OR "City dwellers"[Text Word] OR "Metropolitan communities"[Text Word] OR "major Indian cit*"[Text Word] OR "urban slum"[Text Word] OR "Metropolitan cities"[Text Word] OR Delhi[Text Word] OR Mumbai[Text Word] OR Varanasi[Text Word] OR Ahmedabad[Text Word] OR Surat[Text Word] OR Mumbai[Text Word] OR Hyderabad[Text Word] OR Chennai[Text Word] OR Kolkata[Text Word] OR	88

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Search terms	Results retrieved
Calcutta[Text Word] OR Pune[Text Word] OR Bangalore[Text Word] OR Jaipur[Text Word] OR Lucknow[Text Word] OR Kanpur[Text Word] OR Visakhapatnam[Text Word] OR Indore[Text Word] OR Thrissur[Text Word] OR Coimbatore[Text Word] OR Ludhiana[Text Word] OR Agra[Text Word] OR Vadodara[Text Word] OR Nashik[Text Word] OR Gwalior[Text Word] OR Ludhiana[Text Word] OR Jamshedpur[Text Word] OR Rourkela[Text Word] OR Bokaro[Text Word] OR Bhilai[Text Word] OR Ghaziabad[Text Word] OR Faridabad[Text Word] OR "Navi Mumbai"[Text Word] OR Gurgaon[Text Word] OR Noida[Text Word] OR Ghaziabad[Text Word] OR Navi[Text Word] OR Mumbai[Text Word] OR Indore[Text Word] OR Kochi[Text Word] OR Trivandrum[Text Word] OR Thiruvananthapuram[Text Word] OR Dehradun[Text Word] OR Shimla[Text Word] OR Chandigarh[Text Word] OR Panaji[Text Word] OR Dispur[Text Word] OR Agartala[Text Word] OR Faridabad[Text Word] OR Bhopal[Text Word] OR Jabalpur[Text Word] OR Raipur[Text Word] OR Gwalior[Text Word] OR Guwahati[Text Word] OR 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Ludhiana[Title/Abstract] OR Agra[Title/Abstract] OR Vadodara[Title/Abstract] OR Nashik[Title/Abstract] OR Gwalior[Title/Abstract] OR Ludhiana[Title/Abstract] OR Jamshedpur[Title/Abstract] OR Rourkela[Title/Abstract] OR Bokaro[Title/Abstract] OR Bhilai[Title/Abstract] OR Ghaziabad[Title/Abstract] OR Faridabad[Title/Abstract] OR "Navi Mumbai"[Title/Abstract] OR Gurgaon[Title/Abstract] OR Noida[Title/Abstract] OR Ghaziabad[Title/Abstract] OR Navi[Title/Abstract] OR Mumbai[Title/Abstract] OR Indore[Title/Abstract] OR Kochi[Title/Abstract] OR Trivandrum[Title/Abstract] OR Thiruvananthapuram[Title/Abstract] OR Dehradun[Title/Abstract] OR Shimla[Title/Abstract] OR Chandigarh[Title/Abstract] OR Panaji[Title/Abstract] OR Dispur[Title/Abstract] OR Agartala[Title/Abstract] OR Faridabad[Title/Abstract] OR Bhopal[Title/Abstract] OR Jabalpur[Title/Abstract] OR Raipur[Title/Abstract] OR Gwalior[Title/Abstract] OR Guwahati[Title/Abstract] OR Shillong[Title/Abstract] OR Imphal[Title/Abstract] OR Aizawl[Title/Abstract] OR Kohima[Title/Abstract] OR Bhubaneswar[Title/Abstract] OR Cuttack[Title/Abstract] OR Patna[Title/Abstract] OR Ranchi[Title/Abstract] OR Jamshedpur[Title/Abstract] OR Durgapur[Title/Abstract] OR Siliguri[Title/Abstract])) AND (((((((((((("Urban heat islands"[Text Word] OR ("Urban heat islands"[Title/Abstract])) OR ("Urban thermal environment"[Title]) OR ("Urban thermal environment"[Title/Abstract])) OR ("Heat islands"[Text Word] OR ("Heat islands"[Title/Abstract])) OR (Anthropogenic heat island)) OR ("Land surface temperature"[Text Word] OR ("Land surface temperature"[Title/Abstract])) OR ("Urban climate"[Text Word] OR ("Urban climate"[Title/Abstract])) OR ("Urban meteorology"[Text Word] OR ("Urban meteorology"[Title/Abstract])) OR ("Urban meteorology"[Text Word] OR ("Urban meteorology"[Title/Abstract])) OR ("Urban meteorology"[Text Word] OR ("Urban meteorology"[Title/Abstract])) OR ("Urban green spaces"[Text Word] OR ("Urban green spaces"[Title/Abstract])) OR ("Urban morphology"[Text Word] OR ("Urban morphology"[Title/Abstract])) OR ("Ambient temperature"[Text Word] OR ("Ambient temperature"[Title/Abstract])) OR (((Urbanization[Text Word] OR (Urbanization[Title/Abstract]) OR (Urbanisation[Text Word]) OR (Urbanisation[Title/Abstract])))) AND (((((((((((Mortality[Text Word] OR (Mortality[Title/Abstract]) OR (Mortality[MeSH Terms]) OR ((Morbidity[MeSH Terms] AND (Morbidity[Title/Abstract]) OR (Morbidity[Text Word])) OR (((("heat-shock response"[MeSH Terms]) OR ("heat-shock response"[Text Word])) OR ("heat-shock response"[Title/Abstract])) OR (((("heat stress disorders"[MeSH Terms]) OR ("heat stress disorders"[Text Word])) OR ("heat stress disorders"[Title])) OR (((("heat stress disorders"[MeSH Terms]) OR ("heat stress disorders"[Text Word])) OR ("heat stress disorders"[Title])) OR ("Heat stress"[Text Word] OR ("Heat stress"[Title/Abstract])) OR ("heat stroke"[MeSH Terms] OR Heatstroke[Text Word] OR (heatstroke[Title/Abstract])) OR (((("Heat exhaustion"[Text Word] OR ("Heat exhaustion"[Title/Abstract]) OR ("Heat exhaustion"[MeSH Terms])) OR (((("Heat-related illness"[Text Word]) OR ("Heat-related illness"[Title/Abstract])) OR	

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Search terms	Results retrieved
(Heat-induced conditions[Text Word])) OR ("mental health"[MeSH Terms] OR mental health[Text Word])) OR ("chronic disease"[MeSH Terms] OR Chronic diseases[Text Word])) OR (((Anxiety[MeSH Terms]) OR (anxiety[Text Word])) OR (Anxiety[Title/Abstract])) OR (((depression[MeSH Terms]) OR (depression[Text Word])) OR (depression[Title/Abstract]))	

Table 2: Draft data extraction instrument.

Author/year of publication	Study method	Spatial resolution
Year of study	Sample size	Season
Setting, city, state	Sampling method	Details of assessment of UHI indicator
Location (latitude/longitude)	Statistical analysis	Outcome variable
Age	Data type (primary/secondary)	How outcome variable was collected
Gender	Data source	Outcome variable expressed as
Study title	Tools of measurement	Details of relationship between exposure and outcome
Study design	Exposure Indicators	Tables and details

Data synthesis

Studies will, where possible be pooled in a statistical meta-analysis using JBI SUMARI or details of other software to be used. Effect sizes expressed as odds ratios or relative risk or other measures of association and their 95% confidence intervals will be calculated for analysis. Where effect estimates and standard errors are not available, they will be calculated from crude data and 95% confidence intervals (95% CIs). When correlation coefficients are used as the effect-size measure, effect sizes will be converted into a standard normal metric (using Fisher's *r*-to-*Z* transformation) and then a weighted average of these transformed scores will be calculated. In a random effects model, untransformed effect-size estimates will be used in calculating the weighted mean correlation coefficient. The choice of model (random or fixed effects) and method for meta-analysis will be based on the guidance by Moola et al. Subgroup analyses will be conducted where there is sufficient data to investigate. Sensitivity analyses will be conducted to test decisions made regarding. Heterogeneity will be assessed statistically using the standard chi-squared and I-squared tests.

A funnel plot will be generated using RevMan software to assess publication bias if there are 10 or more studies included in a meta-analysis. Statistical tests for funnel plot asymmetry (Egger test, Begg test, and Harbord test) will be performed where appropriate.

Where meta-analysis is not possible, the findings will be presented in narrative form including tables and figures to aid in data presentation, where appropriate.

Assessing certainty in the findings

The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach for grading the certainty of evidence will be followed³⁰ and a Summary of Findings (SoF) will be created using

GRADEpro GDT (McMaster University, ON, Canada). This will be undertaken by two independent reviewers at the outcome level. Any disagreements that arise between the reviewers will be resolved through discussion or with a third reviewer. The SoF will present the following information where appropriate: estimates of relative risk, and a ranking of the quality of the evidence based on the risk of bias, directness, heterogeneity, precision and risk of publication bias of the review results. The outcomes reported in the SoF will be: all-cause mortality, all-cause morbidity, heat-related illnesses (heat stress, heat stroke, heat exhaustion, heat cramps), specific diseases like cardiovascular diseases, respiratory diseases, renal diseases, mental disorders, electrolyte disturbances, hospital admissions, ambulance calls, hospital/emergency department visits, thermal discomfort, human health experiences and impact.

CONCLUSION

This review will help to add to the evidence of public health implications of urban heat island effect. This could inform urban planners, policymakers, public health experts and other stakeholders on the specific health impacts, and the need for planned urban expansion.

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