



Heat-Related Health Risks for People Experiencing Homelessness: A Rapid Review

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Abstract Extreme heat poses a significant public health threat for people experiencing homelessness (PEH), who face heightened risks due to prolonged outdoor exposure and limited access to resources. This rapid review synthesizes research from the past five years on the health impacts of extreme heat for PEH in high-income countries. A total of 11 studies were identified through a systematic search of multiple databases, focusing on publications from 2019 to 2024. The review highlights key vulnerability factors, including demographic characteristics, pre-existing health conditions, and geographic disparities, that increase heat-related health risks for PEH. Physical health impacts, such as heat-related morbidity and

mortality, are common, alongside mental health and substance use disorders exacerbated by heat exposure. The review also highlights a significant increase in emergency department visits among PEH during heat events, emphasizing the additional burden on health-care systems. Barriers, including limited physical and social access to cooling centers, water insecurity, and stigma, further compound these challenges. Addressing the unique vulnerabilities of PEH is crucial to reducing their risks during extreme heat events. Improving housing access and stability is essential as a long-term strategy to decrease homelessness and reduce heat stress in this vulnerable population. The review also underscores the need for inclusive

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interventions such as accessible cooling centers with targeted programming, regular access to water, and tailored healthcare services to meet the needs of PEH. Future research should focus on long-term studies to assess potential cumulative heat exposure effects and evaluate the effectiveness of interventions aimed at mitigating extreme heat impacts on PEH, while applying an intersectionality lens to explore how factors like race, gender, and age shape vulnerabilities and potential intervention strategies.

Keywords Extreme heat · Homelessness · Health impacts · Climate change · Vulnerability · Public health · Heat-related illness

Introduction

The global threat to public health posed by climate change, including the increasing frequency and severity of extreme weather events, is well-established [1]. Among these, extreme heat events (EHEs) are particularly concerning, as they result in more fatalities than any other extreme weather event [2]. Although lacking a universal definition due to geographical variations in intensity, extent, and duration, EHEs are commonly described as prolonged periods of high temperatures that lead to adverse health outcomes [3, 4]. When exposed to high heat conditions, heat is stored within the body causing core body-temperature to rise. This activates sweating and skin blood flow to facilitate heat dissipation and prevent further rises in core temperature [5]. However, severe heat stress that overwhelms the body's capacity to dissipate heat, or even moderate heat stress sustained over prolonged periods, can cause physiological dysfunction and lead to numerous adverse health impacts such as heat stroke, cardiovascular events, and kidney injury [5, 6]. Vulnerable populations, such as people experiencing homelessness (PEH), face particularly heightened risks during EHEs, resulting in excess morbidity and mortality [6–11]. This review defines vulnerability as the physical, social, economic, and environmental factors that increase susceptibility to harm from hazards [12]. It reflects both individual risk factors, such as health conditions, and broader contextual factors, such as socioeconomic inequities, which together heighten exposure to risks and influence the capacity to cope with and recover from their impacts [12–14].

This multidimensional concept highlights susceptibility, risk, and adaptive capacity as core elements.

Homelessness, a pervasive global social issue, encompasses a spectrum of living situations, including rough sleeping, residing in emergency shelters, and living in precarious, unstable, or substandard housing [15]. Each situation presents unique challenges related to climate change and extreme weather. Within the 36 countries that are part of the Organisation for Economic Co-operation and Development, approximately 2.1 million individuals experience homelessness annually [16]. The housing crisis, characterized by limited affordable housing and economic disparities, has contributed to this increase in homelessness [16–18]. For example, in New York City, a 10% increase in the Zillow Rent Index was associated with a predicted rise in homelessness of 5,413 people, with a 95% probability range of 2,896 to 10,523 people, based on 2016 levels of homelessness [19]. Rising migration, driven by conflict, natural disasters, and loss of economic opportunity, has further strained housing availability and affordability, increasing the potential for homelessness [20, 21]. Without access to stable and adequate shelter, as well as other needed supports (e.g., healthcare, employment, income), PEH are at heightened risk from climate hazards like EHEs.

While the relationship between climate change and homelessness has been previously explored, the literature remains limited. A prior scoping review, focusing on studies published up to 2019, primarily examined broad climate impacts on homelessness in high-income countries [15]. It highlighted the unique vulnerabilities of PEH, including chronic illness, resource scarcity and exposure to extreme weather, and underscored the systemic inequities and inadequate infrastructure that exacerbate these risks. However, the review addressed a wide range of climate change hazards, offering limited specificity regarding EHEs.

This rapid review focuses on the health and wellbeing impacts of EHEs on PEH, distinguishing itself by narrowing the scope to this prominent environmental risk. EHEs represent a critical area for research, especially as the evidence base on this topic has expanded in recent years in high-income countries. By addressing these knowledge gaps, this review aims to provide actionable insights for policymakers, healthcare professionals, and practitioners working to address

the urgent challenges posed by climate change and homelessness. The review poses the following question: What are the research findings within the last five years (January 2019 to May 2024) regarding the health and wellbeing implications of extreme heat for people experiencing homelessness in high-income countries?

Methods

Study Design

We employed a rapid review design, which streamlines elements of the systematic review method to quickly synthesize evidence [22–24]. Given the urgency of the situation and the anticipated rise in the frequency and intensity of EHEs [6, 9, 10], this method was deemed most appropriate for providing timely evidence for decision-making [23]. The goal is to inform health policy and systems recommendations in a timely manner [22].

This rapid review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to systematically select and summarize relevant studies [25], as specific PRISMA guidelines for rapid reviews were still in development at the time of this review [26, 27]. The process involved the following key steps: (1) protocol development: defining objectives, methods, and criteria (2) literature search and screening: systematically searching databases and screening studies (3) data extraction and critical appraisal: extracting relevant information and assessing study quality (4) knowledge synthesis and reporting: analyzing, interpreting, and reporting findings. Following the development of the protocol, it was registered with Open Science Framework (OSF) (<https://doi.org/10.17605/OSF.IO/7PVMK>).

Search Strategy and Selection Criteria

A systematic search was conducted on March 26th, 2024, across three multidisciplinary databases: (1) PubMed, (2) Web of Science, and (3) Scopus. These databases were chosen for their broad coverage across various disciplines to capture a diverse range of studies. A search strategy was developed with key terms related to “heat,” “health,”

and “homelessness,” as outlined in Box 1, and applied to the title, abstract, and keyword fields. The study adopts broad definitions of homelessness to encompass a range of living situations. Between March 26th, 2024, and May 24th, 2024, an additional search on Google Scholar and an ascendancy approach involving citation tracking were used to find other relevant studies.

Box 1 Full Search Strategy for Databases

(“Heat*” OR “Increasing Temperature*” OR “Temperature Increase*” OR “Temperature Extremes” OR “Extreme Temperature”) AND (“Health” OR “Risk*” OR “Illness*” OR “Death*” OR “Disease*” OR “Hazard*” OR “Vulnerabilit*” OR “Impact*” OR “Expos*” OR “Affect*” OR “Effect*” OR “Mental” OR “Psychiat*” OR “Psycho*” OR “Mortality” OR “Morbidity”) AND (Homeless* OR “Hous*” OR “Shelter*” OR “Unshelter*”)

Filters: Title, abstract, and keyword fields, Date 2019–2024, English Language, Document type: Article

Studies that analyzed the physical and mental health effects of extreme heat on PEH and/or living in precarious housing and were conducted in one or more high-income countries with similar healthcare systems as determined by the 2021 Commonwealth Fund report [28] were included. The countries covered were Australia, Canada, France, Germany, the Netherlands, New Zealand, Norway, Sweden, Switzerland, the United Kingdom, and the United States [28]. These nations share similar healthcare system characteristics, making them suitable for comparative analysis in studying the health effects of extreme heat on vulnerable populations. Filters were applied to limit publication dates to January 1st, 2019–May 24th, 2024, language to English, and document type to “article” where possible. Studies not involving PEH and/or living in precarious housing, not directly addressing the health effects of extreme heat, published before January 1st, 2019, solely discussing general climate change health impacts, were conducted in countries outside the 11 aforementioned nations, or were sourced from grey literature, as well as reviews and commentaries, were excluded. Detailed criteria are presented in Table 1.

Screening and Data Extraction

Covidence software was used to streamline the screening process, ensuring the consistent application

of the inclusion and exclusion criteria. The citations identified through the search strategy were imported into Covidence, where duplicates were identified and removed. The screening process was conducted in two stages. In the first stage, two reviewers (J.N. and M.F.) independently screened the title and abstract of each article using predefined criteria (see Appendix Table 1) to identify studies on homelessness and extreme heat. In the second stage, the same two reviewers independently conducted a full-text review, applying the criteria more strictly to ensure only studies meeting all requirements were included. Any discrepancies between the reviewers were discussed and resolved through consensus. Data from the final selected articles were extracted by one author (J.N.) into a structured table in Microsoft Excel, including details such as author, year, country, aim, study design, population, key findings, limitations, and recommendations (see Appendix Table 2).

Quality Assessment

To assess the quality of the studies, critical appraisal tools from the Joanna Briggs Institute (JBI), tailored to specific study designs and article types, were utilized to ensure consistency [29–33]. Critical appraisal checklists were selected based on the appropriateness of the study design descriptions in relation to JBI study type definitions. Uncertainty or disagreements on which instrument to use were addressed through consensus between three authors (J.N., N.K., and S.A.K.). Each tool included checklists containing a list of criteria that could be marked as “yes,” “no,” “unclear,” or “not applicable.” The quality assessment was conducted independently by one author (J.N.), with all articles reviewed by a second author (N.K.) for accuracy. The method employed is based on approaches used by previous researchers [34–36]. Each study was evaluated on multiple criteria, with each criterion receiving a score of 1 if met (indicating yes) and 0 if not met (indicating no) or if there was insufficient information (indicating unclear). The “not applicable” option did not receive a score and was excluded from the computation of the total score. The scores were summed and converted to a percentage ranging from 0 to 100 to enable comparison, given the varying number of criteria per tool. Appendix Table 3 displays the assessment results.

Data Synthesis

A narrative synthesis approach was used to synthesize the findings of included studies. The process commenced with a thorough review of the included studies, followed by thematic analysis to identify recurring patterns and key themes across the studies by one author (J.N.). This approach not only facilitated the organization of initial results but also allowed for the exploration of relationships and variations among the findings [37]. By organizing initial results, identifying patterns, and comparing findings across studies, the synthesis addressed the impact of extreme heat on the health and wellbeing of PEH, providing a comprehensive update of the research findings from the past five years.

Results

Study Characteristics

A total of 11 studies were included in this review (see Fig. 1 for the PRISMA flow chart), published between 2019 and 2024. Six studies were authored in the United States [38–43], followed by three in Australia [44–46], one in Canada [47], and one in the United Kingdom [48]. The study designs varied, including three cross-sectional studies [40, 41, 46], two mixed-methods studies [39, 45], two retrospective cohort studies [42, 43], one time-series regression study [48], one case-series [44], one case-crossover study [38], and one quasi-experimental study [47]. Seven studies focused primarily on PEH [38, 39, 41, 44–46, 48], while four included them as a secondary population (e.g., studies on veterans and pregnant mothers where homelessness was also examined) [40, 42, 43, 47]. Eight studies addressed PEH generally [38–40, 44–48], two specifically examined women [41, 42], and one focused on veterans [43]. Ten studies investigated extreme heat as the main exposure [38–44, 46–48], while one included it as part of broader extreme weather events [45]. The critical appraisal revealed that six studies were of high quality [38, 40, 42, 43, 47, 48] and five of moderate quality [37, 41, 44–46].

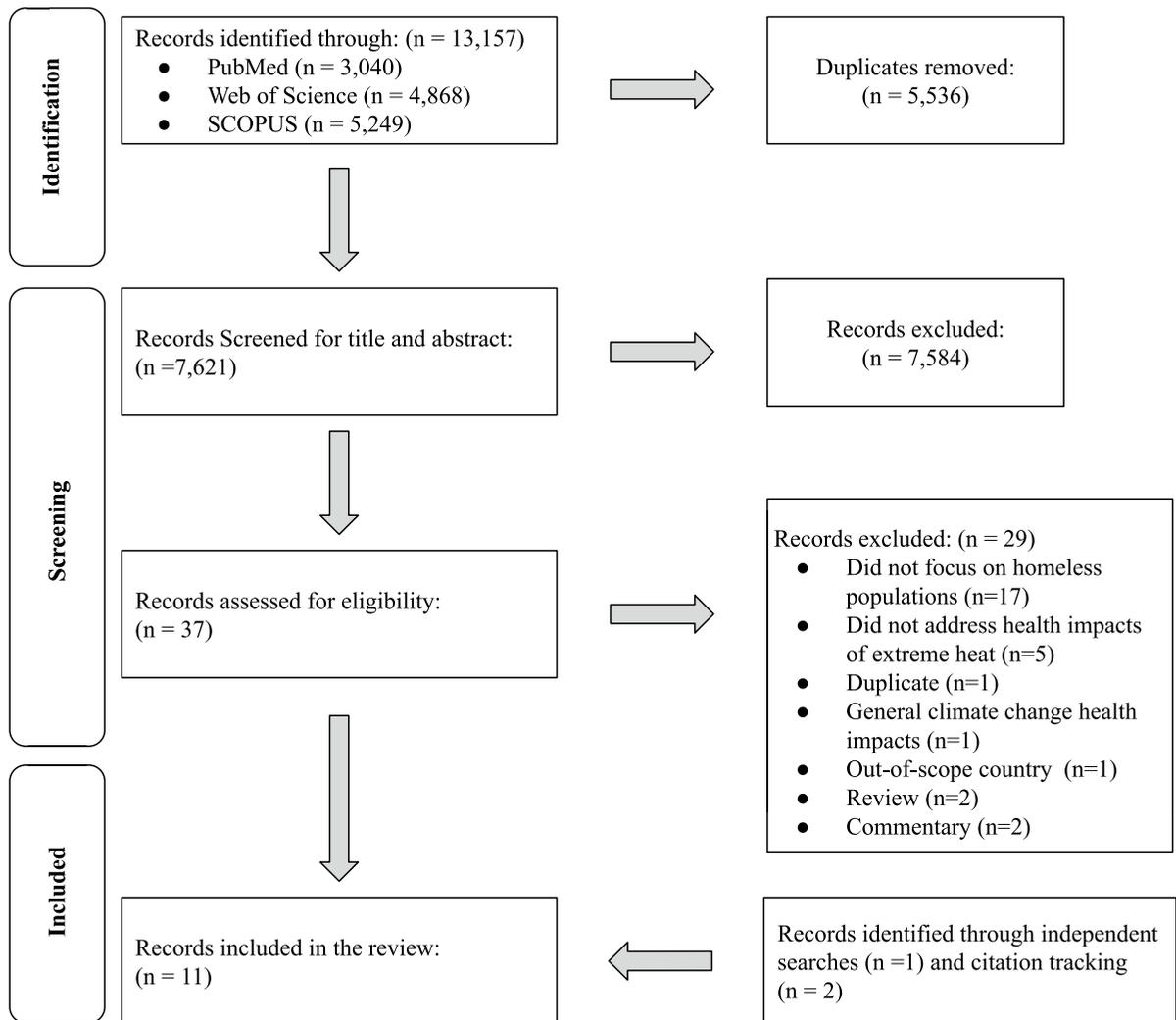


Fig. 1 PRISMA Flow Chart Diagram

Synthesis of Findings

During narrative synthesis, five key themes emerged: (1) Vulnerability Factors; (2) Physical Health Impacts; (3) Mental Health and Substance Use Disorders; (4) Heatwave-Related Emergency Department Visits; and (5) Barriers to Accessing Resources and Services.

Vulnerability Factors

The impacts of extreme heat on PEH are intensified by a range of vulnerability factors, as evidenced in five studies [38, 39, 44–46]. Demographic factors, such

as age, appear to play a crucial role in heat-related health issues. For instance, Schwarz et al. [38] found that younger individuals (aged 18–44 years) and older individuals (aged ≥ 65 years) experiencing homelessness in San Diego, California were more affected by heatwaves than the middle-aged group (aged 45–65 years), highlighting the disproportionate impact of extreme heat on these age groups. This differs from what is usually observed, where children and older adults are typically identified as the most vulnerable to heatwaves, compared to adults under 45 [38]. The same authors also observed that patients experiencing homelessness who required a psychiatric consultation were particularly vulnerable during heatwaves [38].

Moreover, prolonged exposure to outdoor conditions can increase the risk of heat-related illnesses. PEH often spend extensive time outdoors due to a lack of shelter, which was identified as a key predictor of heat-related illnesses in studies conducted in two different countries [39, 46]. Geographic location and neighborhood characteristics may also place PEH at risk of adverse heat-related health outcomes. For example, Gabbe et al. [39] highlighted “urban thermal inequity” in their study, noting that PEH in central California, USA disproportionately reside in hotter neighborhoods affected by the urban heat island effect. These neighborhoods, often with limited tree canopy coverage and more heat-retaining concrete and asphalt surfaces, can be hotter than others, making it difficult for residents to find relief from the heat. Pre-existing physical and mental health conditions, such as cardiovascular and respiratory diseases, which are often prevalent among PEH, may also contribute to increased vulnerability to heat-related illnesses and a higher risk of adverse outcomes [39].

Medications were discussed in two studies, highlighting how drugs such as antipsychotics, antidepressants, beta blockers, and antihistamines, which are commonly used to manage physical and mental health conditions, may impair thermoregulation and increase vulnerability to heat stress [44, 45]. For example, in a case series conducted in Sydney, Australia, English et al. [44] reported that the first case of classic heatstroke involved a patient taking antipsychotic, anticholinergic, and calcium channel blocker medications, whereas the second case of heat exhaustion involved a patient on an antidepressant medication. These medications may have contributed to the heat-related illnesses by reducing autonomic heat loss responses, such as skin blood flow and sweating, which are essential for dry and evaporative heat loss. The study noted that more empirical evidence is needed to understand the impacts of these medications on thermoregulation, specifically in realistic doses and environmental conditions [44]. Lastly, PEH often face challenges in behaviourally adapting to and coping with hot weather or EHEs [44]. Behavioural thermoregulation strategies, such as seeking shade or hydration, can be limited by environmental conditions and personal circumstances for PEH [44].

Physical Health Impacts

The impact of extreme heat on the physical health of PEH was a prominent theme across eight studies [39–46]. Heat-related morbidity was highlighted in six studies [39, 41–44, 46]. For example, in Australia, Every et al. [46] found that 81% of participants reported dehydration despite consuming a liter or more of water in the previous 24 hours, and 79% experienced at least one of the seven heat-stress symptoms, such as thirst and dizziness, which, if unaddressed, may lead to severe heat-related illnesses like heat stroke. Gabbe et al. [39] emphasized similar findings, with participants in Santa Clara, California, describing health issues exacerbated by heat, including dehydration, migraines, sunburn, and dizziness, some of which required emergency medical care. Extreme heat was also shown to worsen pre-existing health conditions such as cardiovascular disease, diabetes, and cancer, complicating illness management [39]. Heat-related mortality was another key observation, as Iverson et al. [40] documented 213 (23.2%) heat-associated deaths among PEH in Maricopa County, Arizona, between 2006–2016, with 200 (94.8%) resulting from heat-related injuries sustained outdoors.

Physical health impacts were also highlighted within specific subgroups [41–43]. For example, Carlson et al. [42] observed a significant impact of homelessness during pregnancy on the association between heat exposure and measures of gestational growth. Mothers experiencing homelessness in Boston, Massachusetts, saw a tenfold increase in the odds of delivering a small-for-gestational-age baby and a 420-g reduction in term birth weight for each 1 °C (1.8 °F) rise in the standard deviation of the weekly heat index during the entire second trimester [42]. In contrast, mothers who were not homeless had a 24% lower likelihood of having a small-for-gestational-age baby and a smaller reduction in birth weight of 9.5 g when exposed to similar conditions. Mukarram et al. [41] studied underserved women experiencing homelessness in the American Southwest, finding that one-third had suffered from heat-related illnesses at some point, yet many did not seek medical care. Osborne et al. [43] focused on veterans experiencing homelessness across the United States, noting an initial increase in heat-related illnesses until 2014, followed by a decline until 2019, potentially linked to the

introduction and mobilization of health and wellness initiatives, such as mobile clinics, patient-aligned care teams, and training for peer providers among others.

Mental Health and Substance Use Disorders

Mental health and substance use disorders related to extreme heat among PEH were reported in three studies [39, 44, 45]. Extreme heat has been associated with exacerbations of mental health and substance use disorders, which may lead to increased stress and anxiety [39]. Gabbe et al. [39] found that PEH in San José, California, self-reported that extreme heat exacerbated their mental health and substance use disorders. Participants described increased anxiety and feeling overwhelmed as they navigated complex health and homelessness challenges in unfamiliar environments. The authors also noted that the constant heat intensified stress, leading to increased interpersonal tensions and a greater risk of violence. Hotter months intensified the hazards of substance use, exacerbating hardships for PEH, including coping with opioid withdrawal in intense heat [39].

Heatwave-Related Emergency Department Visits

The impact of extreme heat on emergency department (ED) visits among PEH was addressed in four studies [38, 44, 47, 48]. Three of the studies quantified the impact of heat on emergency department visits among PEH [38, 47, 48]. For example, Schwarz et al. [38] reported that between 2012 and 2019, patients identified as homeless accounted for 24,688 ED visits out of 242,262 total visits at two hospitals in San Diego County, during the heat-prone months of May to September. The study also highlighted that, during a two-day heatwave with maximum temperatures at the 99th percentile, the odds of an ED visit among PEH increased 1.29 times (95% CI: 1.02, 1.64).

Similarly, Hajat et al. [48] found a significant increase in hospitalization risks associated with higher temperatures in London, United Kingdom. For example, at 25 °C (77 °F), the relative risk was 1.36 (95% CI: 1.22, 1.58) for “no fixed abode” admissions, compared to the minimum morbidity temperature of 6 °C (41 °F), and 1.35 (95% CI: 1.04, 1.76) for admissions involving a homelessness diagnosis, compared to the minimum morbidity temperature of 9 °C (48.2 °F). Clemens et al. [47] highlighted that

individuals at-risk of homelessness faced a tenfold higher risk of ED encounters for heat-related illnesses compared to other subpopulations in Ontario, Canada. The authors found that individuals with a recent history of homelessness had higher rates of ED visits for heat-related illnesses, averaging 337 visits relative to 47.5 visits per 100,000 for the general population.

The substantial healthcare costs and extended hospital stays associated with heat-related illnesses among homeless populations was also reported. English et al. [44] documented two cases of heat-related illnesses among PEH during an early heatwave in November 2020 in Sydney, Australia. The first case involved classic heatstroke, resulting in a 26-day hospitalization and \$66,537 AUD in hospital expenses. The second case involved heat exhaustion, leading to a 5-day hospitalization costing \$3,647 AUD. These cases underscore the substantial financial burden that heat-related illnesses may impose on healthcare systems.

Barriers to Accessing Resources and Services

People experiencing homelessness encounter numerous barriers to accessing resources and services, which were highlighted in two studies [39, 45]. These barriers may significantly impact their ability to find relief and maintain their health during EHEs. Firstly, access to cooling centres and other public facilities are often limited for PEH [39]. Cooling centres, typically located in community centres or public libraries, provide essential amenities like air conditioning, water, and rest areas. However, as noted by Gabbe et al. [39], these centres are often not well advertised, inconveniently located, and operate with restrictive rules that exclude unhoused individuals. For example, restrictions on substance use, pets, and personal belongings, as well as requirements for identification or sign-in, may deter PEH from using these facilities [39].

Water insecurity is another critical issue [39, 45]. Public water sources are often in disrepair or inaccessible, and individuals can face hygiene and safety concerns when using public taps and water fountains [39, 45]. In some areas, businesses often deny access to water, and bottled water is both expensive and hard to obtain [39]. Stigma, social exclusion, and discrimination faced by PEH can be additional barriers to accessing resources and services [39]. Lastly,

mobility and stability are ongoing challenges [39]. Gabbe et al. [39] describe the conflict between the need for shade and the desire for stability among unhoused individuals, highlighting how stable locations often lack reliable access to shade and water, increasing health risks. Participants frequently relocate to find shaded areas, underscoring the scarcity of these vital resources.

Discussion

This rapid review synthesized research from the past five years on the health and wellbeing impacts of extreme heat on PEH in high-income countries. Recent research has delved deeper into the specific risks faced by homeless populations, particularly high-risk groups like pregnant women, and emphasized the vulnerability of individuals with mental health challenges and substance use disorders, demonstrating how extreme heat exacerbates these conditions. Studies have examined structural and systemic factors contributing to the heightened risks for PEH. Systemic deprivation, including limited access to adequate shelter, healthcare, and social services, significantly increases the adverse health effects of extreme heat. Stigma and discrimination further compound this deprivation, leading to reduced access to cooling centers, public water sources, and emergency medical care during heatwaves.

Public Health Implications

This review underscores the urgent need for action-oriented strategies and large-scale prevention initiatives to address the health risks of extreme heat for PEH, with a focus on health equity and systemic solutions. A comprehensive, systems-level approach needs to be prioritized, with policies focusing on enhancing housing access and stability as a long-term strategy to reduce the vulnerability of homeless populations [39, 49]. Policies should aim to increase the availability of affordable housing that is equipped to regulate a comfortable and low-risk indoor environment, provide supportive housing options, and implement homelessness prevention programs. This is vital as the lack of affordable housing is a root cause of homelessness [50, 51]. Addressing substandard housing and ensuring accessible, climate-resilient

options is crucial. Policies should include maximum indoor temperature regulations to protect those in poorly-adapted housing [11, 52]. Substandard housing, typically part of older building stock, often lacks insulation, ventilation, and cooling, making it dangerous during temperature extremes [53, 54]. Mandating improvements in building standards for existing buildings to meet energy efficiency and climate resilience standards are necessary, including retrofitting for extreme weather with reflective roofing and better insulation [11]. Government programs should fund and incentivize landlords for these improvements, alongside regular inspections to ensure compliance and safety. Urban planning must prioritize constructing energy-efficient, climate-resilient housing accessible to low-income and homeless populations. Systems-level approaches to protecting PEH from extreme heat must extend beyond housing alone. These approaches require tackling broader systemic barriers such as limited access to healthcare and the lack of community-based support structures. By integrating efforts across multiple sectors, including public health, urban planning, and social services, policies can more effectively reduce the risks PEH face during EHEs while promoting equity and resilience.

Building on these systemic changes, targeted interventions are essential to address the immediate risks faced by PEH during extreme heat. First, ensuring accessibility to resources and services is critical. Accessibility should encompass not only physical factors, such as the strategic location of cooling centers, but also psychological and social factors, such as fostering an environment where individuals feel welcome, respected, and supported. Moving to a cooler environment for two hours during a hot day has been shown to effectively limit heat and cardiovascular strain in laboratory settings [55], underscoring the importance of establishing widely available and accessible cooling centers [39, 56–58]. These centers should have inclusive policies that address the needs of PEH, such as allowing pets, offering storage for personal belongings, and extending operating hours. To address stigma and improve approachability, staff should receive training to understand the unique challenges faced by PEH and create an atmosphere of dignity and respect [58]. Offering services like food, clothing, and referrals can increase the appeal of cooling centers, providing essential support while offering heat relief [56]. Regular access to drinking

water is also crucial. This can be achieved by increasing public water fountains, distributing bottled water through outreach programs, and ensuring cooling centers provide sufficient hydration resources [46, 49, 59]. Providing self-care resources like water bottles, cooling towels, electric fans, misting fans, hats, sunscreen, and additional water for dousing can also help PEH to better protect themselves from extreme heat [39, 44].

Tailoring health services to the unique needs of PEH is essential, as inclusive and responsive care can significantly improve health outcomes during EHEs [60]. These services should encompass both physical and mental healthcare, focusing on recognizing and treating heat-related illnesses. Training healthcare providers to understand the specific vulnerabilities of PEH can enhance the effectiveness of care [61]. Policies should aim to eliminate barriers such as lack of identification, transportation challenges, and stigma that prevent access to healthcare services. For example, mobile health clinics and outreach programs can deliver services directly to PEH, improving access to timely care [62, 63]. Mobile clinics can serve targeted communities over extended periods, which is especially important for patients with pre-existing health conditions exacerbated by heat and for ensuring continuity of care, as many PEH lack access to primary care [62–64].

Enhancing social services by equipping providers to support PEH during EHEs and integrating health and social services to provide holistic care is paramount [47, 65, 66]. Community engagement with PEH is also important for developing heat-preparedness plans that inform PEH about upcoming heatwaves, nearby cooling centers, and available supplies [45, 67]. Tailoring interventions, ideally through codesign, to the specific circumstances and needs of PEH fosters trust, enhances outreach efforts, and ensures the effectiveness of these initiatives [68]. Securing consistent funding is essential to support these efforts, enabling the staffing, training, and resources required to address the heat-related health needs of PEH.

Aligning these efforts with the United Nations' Sustainable Development Goals (SDGs), particularly Goal 3 (Good Health and Well-being) and Goal 11 (Sustainable Cities and Communities), is crucial [69]. Ensuring good health and wellbeing (Goal 3) involves providing accessible health services that address the

specific needs of PEH during EHEs, such as mobile clinics and outreach programs to deliver timely care and mitigate barriers like transportation challenges and stigma. Creating sustainable cities and communities (Goal 11) involves making urban areas inclusive, safe, and resilient. Specific actions for PEH under this goal could include equitable access to water, cool spaces, and resources for making built environments more climate resilient. This alignment ensures that strategies not only address the immediate health risks associated with extreme heat but also contribute to broader objectives of health equity and sustainable development.

Research Gaps

Although the reviewed studies covered a wide range of health and wellbeing impacts, significant research gaps remain. One key area is the lack of studies examining the health impacts of extreme heat on PEH through an intersectional lens. This approach considers how multiple identities, such as gender, race, and age, intersect to create unique vulnerabilities for PEH [70–72]. For instance, over a third (39.1%) of PEH in the United States are female [71]. Factors such as poverty, reproductive coercion, and economic inequality intersect with gender, placing women at unique risks for housing insecurity, particularly due to interpersonal violence, unintended pregnancies, and single parenthood [71, 73]. Black, African American, or African individuals represent 37% of the homeless population in the US, while they make up only 13% of the general population [74]. Addressing this research gap is crucial for developing comprehensive interventions that consider the compounded risks faced by PEH [70–72]. An intersectional framework can help identify and address the unique needs of different subgroups, leading to more effective and equitable support systems to mitigate the health impacts of extreme heat on these vulnerable populations.

Longitudinal studies on the health impacts of extreme heat on PEH are largely absent. These studies are essential for understanding how repeated exposure to heat affects both physical and mental health over time [75]. While current studies are mostly cross-sectional, offering short-term insights, longitudinal studies can reveal how continuous exposure worsens existing conditions, contributes to new health issues, and impacts mortality rates among

PEH. Such research could track the progression of heat-related illnesses, like chronic dehydration and heat stroke, and identify critical periods when PEH are most vulnerable, helping to inform targeted interventions. It would also allow for the evaluation of these interventions over time, providing evidence for effective public health strategies [75].

Existing research lacks high-quality studies examining the level of heat stress, including actual heat exposure parameters such as air temperature, humidity, and air velocity, and their physiological impacts on PEH. For example, research could explore whether PEH, due to their prolonged outdoor exposure, exhibit greater acclimatization to heat compared to individuals in climate-controlled environments. Future studies employing rigorous methodologies, such as controlled experiments and longitudinal designs, are essential to examine these dynamics, providing a stronger evidence base for targeted interventions.

There is limited understanding of how heat response plans at municipal, provincial/state, and national levels address the specific needs of homeless populations. Current plans may not adequately protect these individuals during EHEs. Research could examine how these plans incorporate outreach strategies for PEH, assess and support emergency personnel training, and evaluate the integration of health services into emergency response plans. Understanding these aspects can inform more effective and inclusive response planning. Intervention research evaluating the effectiveness of programs aimed at mitigating the health impacts of extreme heat for PEH is also underexplored. While Australian studies have recommended interventions like outreach programs [44–46], their long-term effectiveness and adaptability remain underexplored. Testing and refining these strategies is essential for developing best practices.

Finally, projections of risk based on worsening environmental conditions and increasing homelessness rates are lacking. With climate change expected to increase the frequency and severity of EHEs [10, 76], it is vital to understand how these changes will affect PEH. Future research should develop models to project risks and identify the most vulnerable populations, while also considering how shifts in homelessness rates could influence vulnerability. This information can help guide proactive measures and policies to protect at-risk groups from escalating climate-related threats.

Strengths and Limitations

A strength of this review lies in the systematic approach to study selection, appraisal, and quality assessment, which upheld rigorous methodological standards, despite following a rapid review design. The tailored search strategy across multiple databases helped capture a diverse range of evidence on extreme heat and homelessness within the scope of a rapid review. The focused scope allowed for a detailed examination of the health impacts of extreme heat on PEH. The review also focused exclusively on primary peer-reviewed studies, excluding grey literature, reviews, and commentaries. This approach ensures the inclusion of high-quality, reliable evidence, aligning with best practices for rigorous reviews. Nonetheless, the review has limitations. The search strategy did not include terms such as "heatwaves" or "climate," which might have resulted in the exclusion of key studies. Moreover, the geographic focus on high-income countries limits the generalizability of the findings to regions with different socioeconomic or healthcare systems. While two independent reviewers conducted the initial screening, only one reviewer performed data extraction, which could introduce bias or error. Involving multiple reviewers in these processes would have further strengthened the reliability of the findings, but this was not feasible due to the rapid nature of the review. Despite these limitations and the significant research gaps outlined above, particularly the lack of high-quality research studies, this review offers some preliminary insights into the health and wellbeing impacts of extreme heat for PEH.

Conclusion

This rapid review presents research findings from January 2019 to May 2024, highlighting the significant health and wellbeing implications of extreme heat for PEH in high-income countries, including key vulnerability factors, heightened physical and mental health issues, increased emergency department visits, and barriers to accessing essential resources and services. Addressing these issues requires immediate, action-oriented and prevention-based strategies, such as establishing accessible cooling centres, ensuring regular access to drinking water, and providing tailored healthcare services. Comprehensive policies that

improve housing stability and quality, ensure a safe indoor climate, enhance social services, and promote equitable access to healthcare are essential. Aligning these efforts with the Sustainable Development Goals, along with testing and scaling interventions, will foster more inclusive, safe, and resilient urban environments. This process will ultimately support the health and wellbeing of homeless populations in the face of escalating climate change impacts, while significantly reducing hospital expenditure. Future research should focus on understanding how intersecting identities,

such as gender, race, and age, create unique vulnerabilities to heat among PEH to inform targeted interventions. Longitudinal studies are needed to explore the long-term effects of repeated heat exposure on physical and mental health, as well as the effectiveness of interventions aimed at reducing this exposure to protect PEH. Studies should also assess the extent of heat exposure experienced by PEH during individual extreme heat events. Research should further focus on developing models to project risks based on worsening environmental and homelessness conditions.

Appendix

Table 1 Inclusion and Exclusion Criteria

	Include	Exclude
Population	- Studies involving people experiencing homelessness and/or living in precarious housing, either as the primary population or as a secondary group within a broader study focus	- Studies not involving people experiencing homelessness and/or living in precarious housing
Focus	- Studies focusing on the health effects/risks of extreme heat, including physical and mental health impacts	- Studies not directly addressing the health effects/risks of extreme heat - Studies solely discussing general climate change health impacts without specific emphasis on extreme heat
Country	- Studies conducted in high-income countries with comparable healthcare systems, as identified in the 2021 Commonwealth Fund report [28] This includes Australia, Canada, France, Germany, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, and United States	- Studies conducted in countries not mentioned in the 2021 Commonwealth Fund report
Article Type	- Primary research articles	- Reviews, commentaries, and grey literature sources (e.g., pre-prints, dissertations, conference abstracts, and government/industry reports)
Publication Date	- Studies published from January 1st, 2019, to May 24th, 2024 (inclusive)	- Studies published before 2019
Language	- Studies published in English	- Studies not published in English

Table 2 Extracted Study Characteristics

Author & Year	Country / Setting	Study Aim(s)	Study Design & Methods	Population & Sample size	Key Findings	Limitations	Recommendations
Carlson et al., 2023	Boston, MA, United States	This study aimed to identify key periods during pregnancy when exposure to heat may affect birthweight and increase the likelihood of small-for-gestational-age infants. It delved into how heat exposure influences birthweight and small-for-gestational-age odds among infants born to mothers who experienced homelessness during pregnancy.	This study used a retrospective cohort approach, analyzing information from mother-child pairs ($n = 4442$) within the Children's HealthWatch (CHW) cohort situated in Boston. Birthweight data were gathered from surveys and electronic health records, while daily temperature and heat index values were sourced from spatial climate datasets. Study also employed distributed lag-nonlinear models to investigate how weekly heat metrics impacted gestational growth measures (such as birth weight, small-for-gestational-age status, and birth weight z-scores). Analyses were stratified by child gender and whether the mother experienced homelessness during pregnancy.	Mother-child pairs enrolled in the Boston-based CHW site from 2005 to 2015. Families were recruited into CHW while seeking care for a child under 48 months old at the Boston Medical Center pediatric emergency department. To be eligible, families had to be residents of Massachusetts, have a caregiver proficient in English or Spanish, and consent to participate in interviews.	The study found a significant influence of homelessness during pregnancy on how heat exposure relates to measures of gestational growth. Among mothers who were homeless, a rise of 1 °C (1.8 °F) in weekly standard deviation (SD) Heat Index (HI) during the entire second trimester was linked to a tenfold increase in the odds of having a small-for-gestational-age baby and a 420 g reduction in term birth weight compared to those experiencing the average SD HI during that period. In contrast, for those not experiencing homelessness, the odds of having a small-for-gestational-age baby were 0.76 times lower, with a birthweight decrease of 9.5 g during the second trimester. This discrepancy likely stems from variations in access to cooling measures like fans or air conditioning. Moreover, mothers experiencing homelessness showed notably decreased birth weight z-scores during the second trimester when exposed to increased SD HI and during the second and third trimesters with higher mean HI levels. These findings imply that heat exposures during these trimesters lead to significant reductions in birth weight, even after considering gestational age and gender.	Incomplete data on individual factors like nutrition access, prenatal care, maternal BMI, and environmental exposures may lead to unaccounted confounding. Although neighborhood-level socioeconomic factors were considered, incorporating individual-level data could have improved covariate classification. Lacking data on time spent outdoors and heat mitigation strategies might bias results toward the null. Lastly, potential misclassification of birthweight due to inconsistent health-care provider recording is anticipated.	Efforts to alleviate Heat Index exposures during the second and third trimesters, particularly for homeless mothers, are recommended. The study indicates that the variability in heat exposure, notably HI, is a more influential factor in predicting term birthweight and the risk of infants being born small-for-gestational-age than average heat levels alone, and this trend varies by sex. Future research examining the effects of heat on birth outcomes should integrate this more biologically significant heat metric.

Table 2 (continued)

Author & Year	Country / Setting	Study Aim(s)	Study Design & Methods	Population & Sample size	Key Findings	Limitations	Recommendations
Clemens et al., 2022	Ontario, Canada	This study investigated if there were changes in emergency department (ED) visits for heat-related illnesses after the introduction of the harmonized Heat Warning and Information System (HWIS). It explored whether these effects varied across different heat warning regions and among various vulnerable subgroups.	The study employed a quasi-experimental design using population-based interrupted time series analysis spanning from April 30 to September 30, 2012–2018, utilizing administrative health records and outdoor temperature data. Autoregressive integrated moving average models were utilized to investigate if there were changes in emergency department rates after the introduction of the unified HWIS, while adjusting for maximum daily temperature. The study explored whether these effects varied among heat-vulnerable groups (≥ 65 years or < 18 years, individuals with comorbidities, those recently experiencing homelessness), and across different heat warning regions.	The primary population was the over-all population of Ontario, Canada. Subgroups comprised children (< 18 years old), older adults (≥ 65 years old), adults with four major medical conditions (diabetes, heart failure, chronic obstructive pulmonary disease, and asthma), and individuals aged 14 and above who were homeless.	Individuals aged 65 years and older, those with medical comorbidities, and individuals with a recent homelessness history exhibited higher ED visit rates compared to the general population. Specifically, the mean rate among individuals with a recent homelessness history was 337.0 per 100,000. The study revealed that those at risk of homelessness faced a tenfold higher risk of ED encounters compared to other subpopulations. Among at-risk subpopulations, ED encounter rates increased over time, showed a positive correlation with temperature, and peaked in June and July. However, there was no statistically significant change in ED encounter rates following the implementation of the harmonized HWIS.	The study's validity is questioned due to time-varying confounding factors like changes in homeless coding and temperature, despite adjustments made. The choice of intervention date may not align with earlier adoptions in some communities. Sole focus on ED visits for heat-related illness may overlook milder cases. Other heat-related outcomes like cardiovascular events weren't explored. Weather station data might not fully capture intra-urban climate variations. The study lacked statistical power to assess HWIS effectiveness across cities or specific components' impact.	Considering the heightened vulnerability of at-risk groups to heat-related issues, it is suggested that policymakers and Public Health Units prioritize outreach and support for these populations, particularly those with medical comorbidities and those experiencing homelessness, who exhibit a significantly increased risk of emergency department encounters. Opportunities exist for targeted education and tailored warnings for these groups, drawing from successful programming examples in various cities. Future evaluations of Heat Warning Programs should consider capturing additional heat-health indicators, such as ambulance calls for heat-related illness, to enhance understanding of Heat Warning Program effectiveness and outcomes within specific communities.

Table 2 (continued)

Author & Year	Country / Setting	Study Aim(s)	Study Design & Methods	Population & Sample size	Key Findings	Limitations	Recommendations
English et al., 2022	Sydney, Australia	This study aimed to highlight the urgency of further research to protect homeless individuals from heat-related illnesses and fatalities by reporting two cases requiring emergency care.	Employed a retrospective case series investigating heat illness cases seen at a hospital's emergency department during the November 2020 heatwave in Sydney, Australia.	People experiencing homelessness (primary, secondary or tertiary) and admitted to the emergency department for heat illness. $n=2$	The study presents two cases of heat-related illnesses among homeless individuals during an early heatwave in November 2020 in Sydney, Australia. The first case involved classic heatstroke, resulting in a 26-day hospitalization and \$66,537 AUD in hospital expenses. This individual may face heightened risks of long-term health complications common in heat stroke survivors, potentially increasing their mortality risk compared to other homeless individuals. The second case involved heat exhaustion, leading to a 5-day hospitalization costing \$3647 AUD. These cases underscore the significant health threat posed by heatwaves to homeless populations and emphasize the need for further research to protect this vulnerable group.	The findings, based on two cases, are not generalizable, highlighting the need for a more representative sample and further research on heat-related illness in this vulnerable population. The lack of specific costing for establishing cooling hubs limits the ability to assess their potential and cost-effectiveness.	To protect homeless individuals during heatwaves, prompt implementation of evidence-based cooling strategies, like community outreach and cooling hubs, is essential. Plans should address individual and community-level risk factors but will require collaboration and cost-benefit analysis. Further research should focus on understanding environmental exposure and evaluating the effectiveness of cooling hubs.

Table 2 (continued)

Author & Year	Country / Setting	Study Aim(s)	Study Design & Methods	Population & Sample size	Key Findings	Limitations	Recommendations
Every et al., 2019	Australia	This study aimed to measure and illustrate the experiences of extreme weather among the homeless community through the collection of survey data and conducting interviews.	The study utilized a mixed-method methodology, incorporating both quantitative and qualitative data obtained from two sources including (1) a survey disseminated online and in print to all housing and homeless services throughout Australia and (2) interviews conducted with service providers, service recipients, and emergency responders in five areas affected by recent incidents such as bushfires, severe cold, floods, heatwaves, and/or storms.	Emergency and housing service providers, as well as individuals facing homelessness or residing in precarious housing situations. <u>Survey</u> $n=161$ <u>Interviews</u> $n=45$ (15 People experiencing homelessness, 20 employed by homeless service providers, and 10 from emergency services.)	The study revealed significant effects on shelter, particularly concerning how extreme weather disrupts the daily lives of individuals who habitually use outdoor sleeping areas in parks, shop fronts, or along riverbanks. Severe cold, heat, or excess water can impact these areas, altering people's routines. For example, young individuals seek refuge in shopping centers during hot weather to avoid discomfort. Interviews underscored the physical repercussions; notably how extreme heat can influence individuals' responses to medication. For instance, two homeless service providers noted that certain medications lose effectiveness in high temperatures, affecting those on heat-sensitive prescriptions like tricyclic antidepressants, antihistamines, and beta blockers for heart conditions. Substance abusers and individuals taking medications that interfere with sweating or thirst regulation face heightened risks during extreme heat. The research also emphasized the vulnerability of individuals on diuretics or fluid restrictions, requiring careful monitoring to prevent dehydration and electrolyte imbalances during extreme heat. Furthermore, living on the streets during hot and humid	The study's data's scope is limited due to incomplete survey responses and the inability to capture the experiences of individuals with the most complex needs in most interviews. While 161 survey responses were received, only 58 were completed in full, with the hard-copy version yielding better completion rates. Interviews primarily involved individuals with some stability, omitting those who are most isolated and vulnerable. Future research should strive to include these marginalized voices by exploring alternative methods, such as engaging peer researchers.	To address shelter loss impacts, it's crucial to include homeless shelters in pre- and post-disaster assessments. Involving representatives from local homeless services in the assessment process can ensure equitable distribution of assistance. Expanding preparedness efforts to consider early weather impacts is essential. Trauma-informed approaches should be integrated into emergency planning and response, prioritizing trust-building, peer support, and empowerment for homeless populations. These approaches acknowledge past trauma and aim to create safe, culturally sensitive spaces. Trauma-specific training and resources for emergency personnel can enhance understanding and identification of trauma effects. Collaborating with homeless communities to develop

Table 2 (continued)

Author & Year	Country / Setting	Study Aim(s)	Study Design & Methods	Population & Sample size	Key Findings	Limitations	Recommendations
Every et al., 2021	Adelaide, Australia	The objective of this study was to collect insights from a sample of homeless individuals living on the streets of Adelaide regarding their encounters with heat stress and dehydration during extremely hot days.	Study employed a single-sample, cross-sectional, descriptive field survey utilizing structured interviews. It was done on days forecasted to have a maximum temperature exceeding 35 °C in early January 2019.	Participants were individuals who were homeless and sleeping rough within the Adelaide Central Business District. $n=48$	<p>conditions poses challenges, as individuals struggle to access hygiene facilities and maintain personal cleanliness due to financial constraints. Accessing free resources becomes imperative during these periods, which can extend up to three months, but such resources are often scarce.</p> <p>During the 6-day interview period, the average temperature was 39 °C, significantly surpassing Adelaide's typical daytime summer temperature of 29 °C. Most participants were dressed in light clothing, spent over 2 hours outdoors, often in partial or no shade, and engaged in moderate to heavy activities. Although over half reported drinking at least a liter of water within the preceding 24 hours, 81% appeared to be significantly dehydrated based on their recollectured urine colour compared to reference chart colours. Additionally, 79% experienced at least one heat-stress symptom, with thirst being the most common, followed by dizziness or lightheadedness. These findings indicate that participants faced conditions conducive to heat stress due to high temperatures and prolonged outdoor exposure.</p>	<p>The sample size was smaller than ideal, likely representing only 17% to 34% of the city's homeless population, and was based on convenience rather than systematic selection. Therefore, the findings should be considered indicative only. It's important to note that homelessness takes various forms, and these findings and these findings specifically pertain to individuals sleeping rough. Different cities have distinct summer weather patterns, infrastructure, and welfare services, making it unclear how these findings might translate more broadly.</p>	<p>preparedness materials tailored to their circumstances is vital. Such approaches are particularly crucial for addressing heightened risks of aggression and violence during and after extreme weather events.</p> <p>Public health information should be updated to better assist homeless individuals, considering their limited access to cooling amenities. Key recommendations include seeking shade, wearing light clothing, avoiding strenuous activity, and staying hydrated. Outreach efforts by homeless service providers are vital in providing support during extreme weather conditions, requiring adequate funding. Also, local governments should review public access to water sources and cool environments as essential public health measures, especially due to predicted temperature rises due to climate change.</p>

Table 2 (continued)

Author & Year	Country / Setting	Study Aim(s)	Study Design & Methods	Population & Sample size	Key Findings	Limitations	Recommendations
Gabbe et al., 2023	San José, California, United States	This study aimed to: a) Describe neighborhoods where unhoused people reside. b) Identify clusters of areas with high unhoused populations, high temperatures, and limited shade. c) Understand how unhoused individuals navigate extreme heat, focusing on challenges and coping strategies.	Study employed a mixed-methods approach. It compared tracts with high unhoused population densities to others and identified spatial clusters and hotspots. Then, qualitative interviews were conducted to understand unhoused individuals' experiences and coping strategies related to heat, focusing on these spatial clusters and hotspots.	Individuals who were either currently or previously experiencing homelessness in downtown San José and the Columbus Park encampment. $n=82$	The study found that unhoused individuals face a multitude of challenges exacerbated by extreme heat. Physically, the lack of access to cooling resources such as air conditioning, fans, and shade means that encampments and vehicles quickly become unbearably hot, leading to a host of health problems. Overheating, dehydration, migraines, dizziness, fainting, and sunburn are commonly reported, sometimes necessitating hospitalization. The situation is compounded for those with pre-existing health conditions like cardiovascular disease, diabetes, or high blood pressure, as the heat exacerbates their symptoms and makes managing their illnesses even more difficult. Mentally, the relentless heat takes a toll, worsening existing mental health conditions and increasing stress levels. Substance use becomes riskier during hotter months, with the stigma and intoxication associated with it preventing individuals from seeking out necessary services. The heat also heightens interpersonal tensions, leading to potential conflicts and violence within encampments. Access to water and shade is limited, with stability often prioritized over seeking cooling resources. Participants face challenges	The January point-in-time count may not accurately reflect the locations of unsheltered individuals during summer months. Moreover, additional measures are needed to capture "hidden" homelessness, such as those temporarily staying with family or friends. While tract-level reporting provides some insight, finer resolution data is necessary to understand the built environment and environmental conditions where unhoused individuals reside, including temperature variations and tree shade coverage. There's a lack of ongoing data collection on homeless encampments and their residents. Land surface temperature may not accurately represent air temperature or individual thermal comfort, and additional temperature measures are needed for future research. Lastly,	The findings underscore the importance of housing as a primary solution to mitigate the vulnerability of unhoused individuals, including heat exposure. Establishing equitable policies for permanent supportive and affordable housing is essential, as the lack of affordable housing is a root cause of homelessness. In the interim, policymakers can support temporary shelter options like managed encampments, tent cities, and "tiny house villages" to provide sun protection and basic shelter. With the increase in vehicular homelessness, planning for "safe parking" programs in designated lots is recommended, offering amenities like water, restrooms, and shade, while ensuring protection from harassment. The establishment of cooling centers near unhoused populations, designed to accommodate their

Table 2 (continued)

Author & Year	Country / Setting	Study Aim(s)	Study Design & Methods	Population & Sample size	Key Findings	Limitations	Recommendations
Hajat et al., 2023	London, United Kingdom	This study aimed to describe how ambient temperatures affect emergency hospital admissions among homeless individuals in Greater London.	The study utilized daily time-series regression analysis, employing distributed lag nonlinear models, to examine 148,177 emergency inpatient admissions for individuals with "no fixed abode" and 20,804 admissions for individuals diagnosed as homeless in London, United Kingdom, spanning from 2011 to 2019.	People experiencing homelessness in Greater London and admitted to hospital. $n = 148,177$ (patients with "no fixed abode" and 20,804 (patients identified as homeless)	From 2011 to 2019, there were at least 148,177 emergency inpatient admissions in London categorized as "no fixed abode" and 20,804 where homelessness was either the primary or secondary diagnosis. High temperatures were significantly associated with an increased risk of hospitalization. At 25 °C compared to the minimum morbidity temperature (MMT), relative risks were 1.359 (95% confidence interval [CI]= 1.216, 1.580) for "no fixed abode" admissions and 1.351 (95% CI= 1.039, 1.757) for admissions with a homelessness diagnosis. Between 14.5% and 18.9% of admissions were attributable to temperatures above the MMT. These risks exceed those reported for the general population of England, indicating heightened vulnerabilities for homeless individuals. There was no significantly raised risk associated with low temperatures.	more individual-level data is required to examine the relationship between heat exposure, sensitivity, adaptive capacity, and health outcomes among the homeless population. Admissions from homeless individuals may be underreported as homelessness is only recorded if deemed clinically relevant, potentially leading to power limitations. To address this, the study considered "no fixed abode" as an alternative indicator, though it may include individuals concealing their address. Exclusion of days with 0 to 5 admissions may also introduce bias, but sensitivity analysis showed minimal impact.	The findings suggest a need to prioritize addressing homeless vulnerabilities during hot weather over cold weather. Current emergency protocols like the Severe Weather Emergency Protocol (SWEP) in England, which traditionally focus on cold weather, now incorporate heatwave guidance. However, the study indicates that the current activation threshold of 25 °C for SWEP may already pose health risks, with a 35% increased risk of hospitalization. Given that adverse health impacts occur even at moderate temperatures, there's a call to revise existing activation thresholds to reach homeless individuals before

Table 2 (continued)

Author & Year	Country / Setting	Study Aim(s)	Study Design & Methods	Population & Sample size	Key Findings	Limitations	Recommendations
Iverson et al., 2020	MariCopa County, Arizona, US	In 2005, the MariCopa County Department of Public Health initiated a surveillance system to monitor heat-related deaths, collecting data on the circumstances surrounding the deaths of residents and visitors. This study focused on analyzing data from this surveillance system spanning the years 2006 to 2016, aiming to examine the attributes and conditions associated with heat-related fatalities.	Heat-associated deaths were categorized using International Classification of Diseases, Tenth Revision codes (X30, T67.X, and P81.0) and specific phrases related to heat exposure on death certificates. Data on decedents' demographics, residency duration in Arizona, location of death (indoors vs outdoors), air conditioning presence, and homelessness were summarized, with associations examined using Pearson χ^2 tests and logistic regression.	Residents and non-residents of MariCopa County who experienced heat-associated deaths during the specified time frame.	Between 2006 and 2016, 23.2% of deaths were among people experiencing homelessness, with 94.8% of these deaths resulting from outdoor injuries. The proportion of heat-related deaths among the homeless declined from 37.6% in 2006 to 6.5% in 2008, then rose to 36.2% in 2016. Roughly one-third of outdoor deaths during this period were among the homeless. Unsheltered homelessness is an important risk factor for heat-associated injuries leading to death, because most heat-associated deaths among people experiencing homelessness occur outdoors.	Data spanned an 11-year period, potentially leading to inconsistencies in how heat-associated deaths were classified due to changing coding practices, although no formal coding policy changes were noted. Secondly, classification of heat-associated deaths relied on available information, potentially leading to misclassification, especially regarding factors like substance and alcohol use. Thirdly, data from this study may not align with national or broader surveillance systems, limiting comparability. Lastly, findings are specific to MariCopa County and may not apply elsewhere.	The findings highlight the need for more resources, particularly to expand the heat-relief network and cooling center hours, and to prevent heat-related deaths in uncooled residences, including those with air conditioning. Increasing awareness and funding for energy-assistance programs in Arizona could help prevent mortality among older, income-limited residents. Surveillance data could aid in assessing the impact of long-term strategies to mitigate the urban heat-island effect, such as shade and urban greening projects. Continuous evaluation of interventions can refine the surveillance system and identify best practices for preventing heat-related deaths.

Table 2 (continued)

Author & Year	Country / Setting	Study Aim(s)	Study Design & Methods	Population & Sample size	Key Findings	Limitations	Recommendations
Mukarram et al., 2021	Phoenix, Arizona, United States	This study aimed to gain insights into the self-reported menopausal symptoms experienced by underserved and homeless women residing in areas with extreme heat across different seasons.	A descriptive cross-sectional study, incorporating the Greene Climatic Scale (GCS), climate-related questions, and demographic data, was conducted via a self-administered written questionnaire spanning the summer months from June to August 2017 and the winter months from December to February 2018.	Homeless and underserved women aged 40–65, either attending a clinic or accompanying patients to the clinic. $n = 104$	The study surveyed predominantly Hispanic women, many of whom were homeless or uninsured, residing in an area with extreme heat. Among participants, 22% were homeless or living in a shelter. While 20% of all participants reported significant bother from hot flushes, the overall symptom severity, as measured by the GCS, indicated a medium level of symptom bother, with psychological, somatic, depression, and anxiety clusters scoring highest. One-third of women reported falling ill due to heat, yet most did not seek treatment for heat-related symptoms. Interestingly, more women believed that the summer season influenced their menopausal symptoms compared to winter, though they did not perceive outdoor temperature to impact their symptoms significantly. Homeless women reported more symptoms on the GCS compared to non-homeless counterparts.	A limitation of the study is its small sample size, which hampers the generalizability of findings. Differences between summer and winter populations may be randomly attributed to this small sample size. The absence of physiological measurements and reliance on observational, self-reported data introduce potential recall bias. Health information solely relies on self-reports, lacking independent confirmation. Moreover, confounding variables are restricted to questionnaire content.	Future research should focus on increasing the sample size with participants from various geographic locations. Conducting a longitudinal study, tracking participants during summer and winter, could provide valuable insights.

Table 2 (continued)

Author & Year	Country / Setting	Study Aim(s)	Study Design & Methods	Population & Sample size	Key Findings	Limitations	Recommendations
Osborne et al., 2023	United States	This Veteran Health Administration population-level assessment aimed to: 1) quantify the incidence of heat-related illnesses (HRI) over time; 2) examine temporal and geographic trends of HRI; 3) evaluate HRI impacts on various patient groups; and 4) inform efforts to improve care and identify communities that would benefit from strategic heat mitigation interventions.	This study conducted a retrospective analysis of Veterans Affairs national electronic health records from January 1, 2002, to December 31, 2019, examining heat-related illness diagnoses in relation to patient demographics, comorbidities, and geographic location. Descriptive statistics, linear regression, and additive seasonal decomposition were used to assess risk factors and trends.	Veterans enrolled in the Veterans Health Administration.	The correlation between HRI and homelessness rose steadily from 2002, peaking in 2014, before declining from 2015 to 2019. This indicates that HRI rates among homeless Veterans increased initially but then decreased in the latter half of the assessment period. While these trends are statistically and clinically significant, the data does not pinpoint a specific cause. The study speculates that the observed decrease may be linked to the initiation and expansion of health and wellness programs for homeless Veterans during a time of rising environmental temperatures.	Due to inconsistent data from non-veteran affairs care, this study only includes Veterans Affairs data, which improves reliability but likely undercounts total HRIs and understates the trend of increasing HRIs. The study's generalizability is limited since it focuses on Veterans, who are typically older, predominantly male, have more comorbidities, and face greater socioeconomic challenges compared to the general US population. However, these differences may lessen as the US population ages and comorbidities rise nationally.	Future research should consider additional variables like specific medications (beta-blockers, diuretics, calcium-channel blockers) that may increase HRI risk by affecting thermoregulation and hydration. Factors such as excessive alcohol and drug use, mental health conditions, renal disease, obesity, and gout should also be assessed as potential HRI risk factors. Investigating the impact of early-life high temperature exposure, such as during military service, could help identify individuals at higher risk for HRI. Understanding the effects of heat islands, county-level social determinants of health, and local temperature changes is crucial. These factors could contribute to predictive models and detailed heat maps, aiding clinicians and decision-makers in identifying and assisting those at greatest risk.

Table 2 (continued)

Author & Year	Country / Setting	Study Aim(s)	Study Design & Methods	Population & Sample size	Key Findings	Limitations	Recommendations
Schwarz et al., 2021	San Diego, California, United States	This study aimed to assess how heatwaves impact ED visits among people experiencing homelessness and investigate factors contributing to their vulnerability.	Utilized detailed data on sociodemographic factors from San Diego's ED visits (2012–2019), applying a time-stratified case-crossover design to study heatwave effects on individuals facing homelessness. Compared findings with a matched non-homeless population using coarsened exact matching.	Patients identified as facing homelessness in two hospitals from May to September, spanning 2012 to 2019, $n = 24,688$	The study found a consistent positive association between heatwaves and ED visits among homeless individuals across all heatwave definitions. The most significant effect was observed with 2-day heatwaves defined at the 99th percentile of maximum temperature, increasing the odds of an ED visit by 1.29 (95% CI = 1.02, 1.64). Longer and more extreme heatwaves, particularly on the second day of 2-day heatwaves, showed higher odds of ED visits. The youngest (aged 18–44 years) and oldest (aged ≥ 65 years) homeless populations exhibited a stronger effect compared to the middle-aged group (aged 45–65 years). Additionally, those requiring psychiatric consultations showed a consistently stronger effect than those who did not. Overall, homeless individuals were more vulnerable to heatwaves compared to non-homeless individuals.	The study didn't account for humidity in the analysis. The focus was on ED visits in one hospital system, potentially impacting other systems and health measures. While not applicable to all homeless individuals in San Diego, the findings highlight their vulnerability and pave the way for future research. Homeless status determination upon ED arrival may exclude those with inadequate housing. The annual point-in-time counts of homelessness in San Diego, conducted in January, may not fully represent summer months, although the city's moderate climate mitigates this discrepancy.	Future research on homelessness and heat-related health impacts should explore variations across different cities and contexts to understand susceptibility better. Investigating different definitions of homelessness or housing exclusion is essential. While the study couldn't examine racial disparities due to sample size limitations, future work should explore potential differences. Given the overrepresentation of minority populations among the homeless, understanding differential vulnerability is crucial. As heat waves become more frequent and intense, understanding and addressing the needs of homeless individuals is imperative for effective mitigation strategies.

Table 3 Critical Appraisal for Studies Included in the Rapid Review

Article	JBI Checklist*	Item											Score (%)	
		1	2	3	4	5	6	7	8	9	10	11		
Carlson et al., 2023**	Analytical Cross-sectional	Y	Y	Y	Y	Y	Y	Y	Y	Y				8/8 = 100%
Clemens et al., 2022	Quasi-experimental studies	Y	N	Y	N	Y	NA	Y	Y	Y				6/8 = 75%
English et al., 2022	Case-series	Y	Y	Y	U	U	Y	Y	Y	N	NA			6/9 = 66.7%
Every et al., 2019	Analytical Cross-sectional	Y	Y	Y	U	N	N	Y	Y					12/18 = 66.7%
	Qualitative research	N	Y	Y	Y	Y	N	N	Y	Y	Y			
Every et al., 2021	Analytical Cross-sectional	Y	Y	Y	U	N	N	U	Y					4/8 = 50%
Gabbe et al., 2023	Analytical Cross-sectional	Y	Y	Y	Y	N	N	U	Y					11/18 = 61.1%
	Qualitative research	N	Y	Y	Y	Y	N	N	Y	U	Y			
Hajat et al., 2023	Analytical Cross-sectional	Y	Y	Y	Y	N	N	Y	Y					6/8 = 75%
Iverson et al., 2020	Analytical Cross-sectional	Y	Y	U	Y	Y	Y	Y	Y					7/8 = 87.5%
Mukarram et al., 2021	Analytical Cross-sectional	Y	Y	N	Y	U	N	Y	Y					5/8 = 62.5%
Osborne et al., 2023**	Prevalence Studies	Y	Y	Y	Y	Y	Y	Y	Y	NA				8/8 = 100%
Schwarz et al., 2021	Case-control	Y	Y	Y	Y	Y	Y	Y	Y	U	Y			9/10 = 90%

Y = Yes (1). N = No (0). U = Unclear (0). NA = Not Applicable

Analytic Cross-Sectional items (31): [1] Were the criteria for inclusion in the sample clearly defined? [2] Were the study subjects and the setting described in detail? [3] Was the exposure measured in a valid and reliable way? [4] Were objective, standard criteria used for measurement of the condition? [5] Were confounding factors identified? [6] Were strategies to deal with confounding factors stated? [7] Were the outcomes measured in a valid and reliable way? [8] Was appropriate statistical analysis used?

Quasi-Experiment items (33): [1] Is it clear in the study what is the 'cause' and what is the 'effect' (i.e. there is no confusion about which variable comes first)? [2] Were participants included in any comparisons similar? [3] Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest? [4] Was there a control group? [5] Were there multiple measurements of the outcome, both pre and post the intervention/exposure? [6] Was follow-up complete and if not, were differences between groups in terms of their follow-up adequately described and analyzed? [7] Were the outcomes of participants included in any comparisons measured in the same way? [8] Were outcomes measured in a reliable way? [9] Was appropriate statistical analysis used?

Case-series items (32): [1] Were there clear criteria for inclusion in the case series? [2] Was the condition measured in a standard, reliable way for all participants included in the case series? [3] Were valid methods used for identification of the condition for all participants included in the case series? [4] Did the case series have consecutive inclusion of participants? [5] Did the case series have complete inclusion of participants? [6] Was there clear reporting of the demographics of the participants in the study? [7] Was there clear reporting of clinical information of the participants? [8] Were the outcomes or follow up results of cases clearly reported? [9] Was there clear reporting of the presenting site(s)/clinic(s) demographic information? [10] Was statistical analysis appropriate?

Qualitative Research items (29): [1] Is there congruity between the stated philosophical perspective and the research methodology? [2] Is there congruity between the research methodology and the research question or objectives? [3] Is there congruity between the research methodology and the methods used to collect data? [4] Is there congruity between the research methodology and the representation and analysis of data? [5] Is there congruity between the research methodology and the interpretation of results? [6] Is there a statement locating the researcher culturally or theoretically? [7] Is the influence of the researcher on the research, and vice-versa, addressed? [8] Are participants, and their voices, adequately represented? [9] Is the research ethical according to current criteria or, for recent studies, and is there evidence of ethical approval by an appropriate body? [10] Do the conclusions drawn in the research report flow from the analysis, or interpretation, of the data?

Prevalence Studies (30): [1] Was the sample frame appropriate to address the target population? [2] Were study participants sampled in an appropriate way? [3] Was the sample size adequate? [4] Were the study subjects and the setting described in detail? [5] Was the data analysis conducted with sufficient coverage of the identified sample? [6] Were valid methods used for the identification of the condition? [7] Was the condition measured in a standard, reliable way for all participants? [8] Was there appropriate statistical analysis? [9] Was the response rate adequate, and if not, was the low response rate managed appropriately?

Case-control items (31): [1] Were the groups comparable other than the presence of disease in cases or the absence of disease in controls? [2] Were cases and controls matched appropriately? [3] Were the same criteria used for identification of cases and controls? [4] Was exposure measured in a standard, valid and reliable way? [5] Was exposure measured in the same way for cases and controls? [6] Were confounding factors identified? [7] Were strategies to deal with confounding factors stated? [8] Were outcomes assessed in a standard, valid and reliable way for cases and controls? [9] Was the exposure period of interest long enough to be meaningful? [10] Was appropriate statistical analysis used?

* Two checklists were used for mixed-methods studies

** For retrospective cohort studies, the existing JBI cohort checklist was deemed unsuitable as it assumes the presence of two distinct groups, consistent with JBI's conceptual framework. However, both studies involved retrospective cohort designs without predefined groups. Consequently, based on consensus, the next best alternative for appraisal was utilized.

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