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Rapid review: health and maximum indoor temperature thresholds in high income countries

Emily Loud^{1,*}, Sharif Ismail¹, Beti Evans¹, Carl Petrokofsky¹, Mo Davies¹, Dan Blake¹, Sari Kovats² and Paul Coleman¹

¹ UK Health Security Agency (UKHSA), United Kingdom

² London School of Hygiene and Tropical Medicine (LSHTM), United Kingdom

* Author to whom any correspondence should be addressed.

E-mail: emilyslound@gmail.com, Sharif.Ismail@ukhsa.gov.uk, Beti.Evans@ukhsa.gov.uk, carl.petrokofsky@ukhsa.gov.uk, mo.davies@ukhsa.gov.uk, dan.blake@ukhsa.gov.uk, Sari.Kovats@lshtm.ac.uk and paul.coleman@ukhsa.gov.uk

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Abstract

There are currently no formal guidelines on maximum indoor temperature thresholds in household, community or workplace settings in the UK, despite the built environment being a major determinant of heat-related mortality and morbidity. This rapid review considered at what temperature threshold(s) hot indoor environments begin to harm human health in high income countries, with a view to informing potential future recommendations and UK policy on this topic. We looked for articles measuring human health and high indoor temperatures in high income countries. Searches of Medline, Embase, Web of Science and Scopus identified 5,642 articles published between 2017–2024, of which 12 articles were included. Countries, populations, settings, and methods of exposure measurement differed within the final set of studies. Health outcomes were varied and included measures such as risk or odds of death, indicators of morbidity, ambulance calls, and self-reported heat related illness, among others. Thresholds at which adverse health outcomes were observed spanned a wide range of temperatures, from 17 °C to 31 °C. While there was a correlation between high indoor temperatures and health outcomes, the body of evidence was not coherent or consistent. There remains a dearth of evidence on safe maximum temperatures in indoor settings. Future research should study directly measured or well-modelled indoor temperature with acute health outcomes for groups at highest risk of heat related morbidity and mortality, to inform adaptation policy in the context of a rapidly warming climate. Until there is extensive scientific data to support a maximum indoor temperature threshold, 26 °C may be the most suitable threshold for a maximum indoor temperature threshold for at-risk groups in keeping with the existing guidance.

Introduction

As the global temperatures increase due to climate change, our understanding of the significant impacts of heat on human health has been growing [1]. The health effects of heat are felt differently by different population groups, with older people most at risk of harm [2, 3], as well as those with a range of pre-existing conditions such as dementia, depression and diabetes [4]. However, much research has focused on the health effects of ambient (external) heat exposure. The literature on relationships between indoor heat exposure and health is fragmented. The majority of published evidence on heat on population health is based on ecological exposures of outdoor temperatures [5]. However, we know that there are likely to be substantial variations in indoor exposure to heat according to building types, available cooling systems and activity levels and types (for example, by occupation) [6].

Table 1. Summary of temperature guidance for indoor environments in the UK and international contexts.

Source/organisation	Temperature guidance	Context/notes
UK Health Security Agency (UKHSA) [10]	Rooms should be kept below 26 °C	Recommends additional cooling measures if temperature exceeds this threshold
National Health Service (NHS) [11]	Overheating reported above 26 °C	Indicates concern for health and wellbeing at temperatures above this level
Home Office [12]	Accommodation should be kept below 28 °C	Applies to immigration removal centres and similar facilities
World Health Organization (WHO) [13]	Previously: <32 °C (day), <24 °C (night); now removed	2018 factsheet guidance no longer active
UK Workplace Guidance [14]	No legal maximum; general advice on managing high temperatures	Notes that risk varies by work setting; indoor heat may result from work activities

In addition, the mortality risks of hot weather at the population level, appear to be first detected at around 20–25 °C in the UK, which is lower than the temperature at which weather health alerts are issued in England (temperatures above 25 °C) [7]. In addition to established high-risk groups, the working-age population is increasingly a cause for concern in the context of rising ambient temperatures, particularly due to an ageing workforce and the prevalence of comorbid conditions within this demographic [8]. Government guidance allows people and institutions to protect any vulnerable groups they support, and to adapt to climate change more effectively. Therefore, having evidence-based maximum indoor temperature threshold recommendations (both for the general population, and for vulnerable groups) would be an important tool to protect health in the UK and globally, especially as global temperatures rise, exceeding 40 °C in England in 2022.

In the United Kingdom, as in many other countries, there is currently no specified legal maximum temperature for workers [9]. However, there is a variety of existing guidance for different indoor settings (see table 1). Guidance from UK Health Security Agency (UKHSA) suggests that additional cooling measures should be introduced to keep rooms below 26 °C [10]. The National Health Service (NHS) defines overheating as when room temperature is above 26 °C [11]. The Home Office recommends that accommodation in immigration removal centres and similar settings should be kept below 28 °C [12]. By contrast, the World Health Organization previously set a higher threshold in its 2018 factsheet, stating that ‘ideally, the room temperature should be kept below 32 °C during the day and 24 °C during the night’ [13]; however, this has since been removed [14]. Current workplace guidance in the UK provides general advice on managing high temperatures, noting variations in risk by work setting and the fact that indoor temperatures may be a product of work activities as much as of external conditions [9].

Some high-income countries have introduced maximum indoor temperature thresholds in legislation, or non-legally binding guidance [15–18]. For countries using air ambient temperature thresholds, the range is 22 °C to 30 °C. However, these relate to workplaces, labour or occupational safety, as opposed to settings with specifically vulnerable groups.

A previous review published in 2020 [19], examined twenty two articles looking at indoor heat and health outcomes, only five of which reported threshold effects (26–32 °C). This review therefore found insufficient evidence to underpin definitive recommendations regarding maximum temperature thresholds in indoor settings [19]. The current review aimed to update the evidence base to explore the health effects of indoor temperature and consider the applicability of international evidence from high income settings to the UK context.

With the possibility of a future recommendation in mind, the objective of this review was: at what temperature threshold(s) do warm indoor environments begin to harm human health in different population groups in high income settings such as the UK?

Methods

We undertook a rapid review using streamlined systematic methods [20], according to the PRISMA checklist for rapid reviews [21]. After establishing a protocol for our research question, a rapid review process was used to identify evidence relevant to our research question. This was done by repurposing results of a more general search of Medline, Embase, Web of Science and Scopus, details of which are in the supplementary material (search 1). Using the search function in EPPI Reviewer, a simple terms search related to indoor temperature terms was undertaken to retrieve relevant evidence for indoor maximum temperatures from within this first search (see supplementary material—search 2).

Table 2. Inclusion and exclusion criteria.

Criteria	Included	Excluded
Population	humans only, high income countries only (World Bank definition)	Animals Medium or low income countries (World Bank definition)
Settings	Any indoor environments	Outdoor environments
Intervention	indoor temperature directly measured or statistically modelled	Studies using weather station data or other outdoor temperature measures only
Outcomes	Health outcomes, including signs or symptoms of disease, mental wellbeing, mortality, morbidity, clinical indicators (e.g. increased blood pressure), officially diagnosed or self-reported.	Thermal comfort, anything else that is not or does not relate to a sign or symptom of disease
Language	English	Languages other than English
Date of publication	1 January 2017 onwards	Before 1 January 2017
Study design	• Experimental studies • Observational studies • Modelling studies • Systematic reviews • Guidelines • Mixed methods evaluation	• Opinion pieces • Letters • Case studies/ case reports • Qualitative only studies
Publication type	• Peer-reviewed	• Conference abstracts • Grey literature • Preprints

Our inclusion and exclusion criteria are detailed in full in table 2. Dates included peer reviewed literature published between 1st January 2017 and 28th February 2024. This cut-off was applied to capture evidence published since the previously published study [19].

Study types included were varied (table 2) but were restricted to peer-reviewed publications to scope the initial evidence base for possible policy recommendations. Studies were included if they quantified the association between a health outcome and indoor temperature exposure (either measured directly or estimated using statistical modelling, such as by stating an assumed relationship between outdoor and indoor temperature using weather and building data).

Health outcomes were considered eligible if they were based on routinely collected administrative or clinical data (such as mortality records, ambulance call-out data, hospital admissions, or general practice visit data), structured population surveys (e.g., national health or housing surveys), or self-reported health outcomes collected via researcher-administered questionnaires. Studies that focused solely on thermal comfort, perceived temperature, or satisfaction with indoor environments—without linking to any health indicators—were excluded.

In summary, our criteria were as follows:

All retrieved papers were uploaded to Rayyan software for screening [22]. Screening on title and abstract was undertaken in duplicate by two reviewers for 5% of the eligible studies, with the remainder completed by one reviewer. Disagreements were resolved by discussion with a third reviewer. Screening on full text was undertaken by one reviewer and checked by a second. Bibliographies for included studies were checked in a single round of hand searching to identify additional, primary studies that might be relevant. Deduplication was also done manually at title and abstract screening stages.

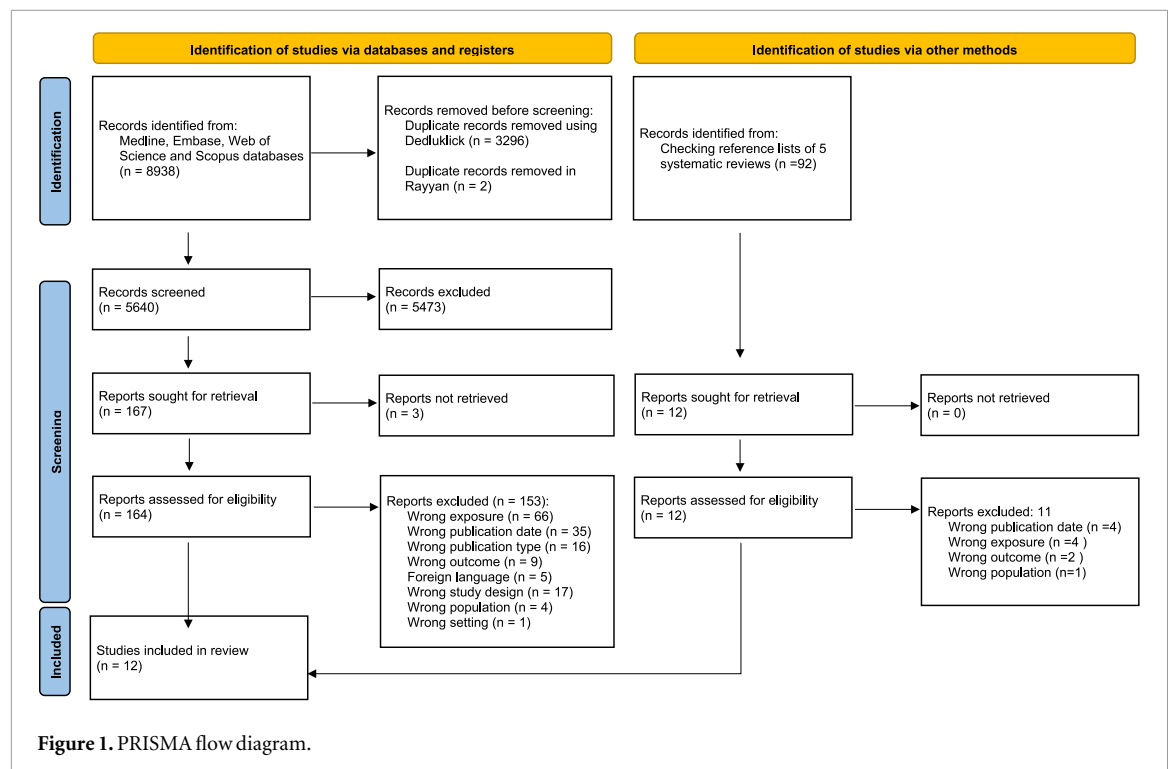
Data extraction was performed by two reviewed using a pre-developed framework. Due to resource restrictions, no critical appraisal for risk of bias was undertaken for this rapid review. The extracted data was reported in a table and findings were synthesised narratively. This included information on country, setting, study design, objective, outcomes measures, participants, study period, results and any relevant contextual data (table 3).

Results

After deduplication, 5,642 results were available, which were screened on title and abstract, 167 were screened on full text and 11 articles were included. An additional study was identified by checking the reference lists of reviews, resulting in a total of 12 included studies (figure 1).

Table 3. Rapid review findings by temperature threshold.

Study lead author and date	Indoor temperature threshold (modelled/measured)	Country	Population	Setting	Design	Health outcomes associated (modelled/measured)
Quinn (2017)	Not clearly reported	USA	Households	Domestic	Cohort study	Odds of self-reported heat related illness increased with measured indoor temperature, but not significantly
Tartarini (2017)	22.6 °C	Australia	Nursing home residents with dementia	Social care	Cohort study	Cohen-Mansfield Agitation Inventory scores were found to significantly ($p < 0.01$) increase when average indoor air temperature deviated from 22.6 °C
Gouder (2018)	22 °C	Malta	Primary school age children attending state schools	Education	Case control study	Indoor classroom temperatures above the third tertile were associated with an increased risk of doctor-diagnosed allergic rhinitis ($p=0.002$, OR 4.83, 95% CI 1.98–7.56). The third tertile was ~18 °C–22 °C
Haverinen-Shaunhessy (2018)	Not clearly reported	Finland and Lithuania	Adults living in apartment buildings	Domestic	Cross-sectional survey	None significantly associated with warmer temperatures
Zhao (2019)	21 °C	England	Adults aged 16 years+	Domestic	Cross-sectional survey	A one SD increase in indoor temperature was associated with a 1.10 mmHg decrease in systolic blood pressure (95% CI: 1.64 to 0.56) and a 1.02 mmHg decrease in diastolic blood pressure (95% CI: 1.43 to 0.62). Larger effects in groups with no to low physical activity.
Kim (2020)	22.9 °C	South Korea	Adults aged 65+ living in rural areas	Domestic	Cross-sectional survey	Every 1 °C increase in indoor temperature was associated with a significant decrease in diastolic blood pressure of 0.44 mmHg (95% CI: 0.04–0.84 mmHg), association with systolic was not significant.
Murage (2020)	>31.1 °C (modelled)	UK	All those in Greater London who died between 2007–2016	Domestic	Modelling study	Odds ratio of mortality was highest in highest modelled indoor temperature (OR 1.043, 31.1 °C–33.63 °C) but the differences were not statistically significant
O’Lenick(2020)	23 °C (modelled)	USA	Adults aged 65+	Domestic	Modelling study	Odds ratio of death from circulatory diseases 1.16 per every 5 degrees above 23 °C (95% CI 1.03–1.3)
Ibbetson (2021)	17 °C (modelled)	UK	Care home residents in England and Wales aged 65+	Social care	Modelling study	Relative risk of mortality in care home residents was 1.05 (modelled) for every 1 degree increase in indoor temperature.
Hansen (2022)	28 °C	Australia	Individuals over 65 years old	Domestic	Mixed methods	Self-reported wellbeing decreased over this threshold
Plott (2022)	23.9 °C	USA	Primary school children	Education	Cohort study	RR 1.53, 95% CI 1.06–2.20 for visits to a health centre for asthma for 5 °C above 23.9 °C (10°F temp increase above baseline of 75°F)
Uejio (2022)	21.1 °C	USA	Adults living in the City of Atlanta	Domestic	Case control study	Association between temperature and emergency calls became steeper for diabetics at 21.1 °C, and at 24.6 °C for those with respiratory conditions. OR: 1.12 (95% CI: 1.08–1.16) for diabetes-related 9-1-1 calls versus control from 30 to 31 °C. OR: 1.18 (95% CI: 1.09–1.28) respiratory-related 9-1-1 call versus control from 34 to 35 °C.



Characteristics of included studies

The final total included three modelling studies, and nine observational studies (three cohort, three cross-sectional, two case control and one mixed methods), spanning locations including the USA [23–26], UK [27–29], South Korea, Australia [30, 31], Finland and Lithuania [32], and Malta [33]. Populations included individuals aged over 65 years old living at home (three studies, [28, 30, 34]), over 65s living in care home settings (two studies, [27, 31]), household representatives living in multifamily buildings (two studies, [25, 32]), whole populations of a city (two studies, [26, 28]), individuals over the age of 16 (one study [29]), school aged children (two studies, [24, 33]).

Exposures

Nine studies reported findings based on direct temperature measurement indoors [24–26, 29–34]. In all cases this was done using a thermometer at different intervals (hourly, daily just before a health measurement was taken) and for different durations. Three studies modelled indoor temperature and took very different approaches [23, 27, 28]. Of these, one study assumed that the relationship between mortality and temperature was the same indoors as outdoors [27], another based their model on a previous sample of 24 homes [23], and the third was based on a combination of external energy model and national database of energy efficiency information [28].

Outcomes

Health outcomes were measured in a variety of ways, ranging from self-reported symptoms to clinical and emergency records, and varied in severity. Three studies assessed self-reported health outcomes, three used mortality (all of which reported modelled temperature), and others used ambulance calls, visits to a primary care physician, blood pressure, diagnosis of allergic rhinitis and a dementia specific agitation index.

For self-reported outcomes, wellbeing declined significantly at internal temperatures over 28 °C in one study [30], reported heat illness increased in another (threshold not specified) [25], and one reported no link between self-reported health outcomes (upper respiratory tract infections) and internal temperature [32].

The studies that looked at the effects of indoor temperature on blood pressure, a one degree increase in indoor temperature was associated with a significant decrease in diastolic blood pressure in over 65s [34]. Another study of over 16s also found a negative association between high indoor temperature and blood pressure [29].

One case control study using accident and emergency calls as their outcome, found that diabetes related calls increased above 21.1 °C and had a non-linear significant increase from 30 °C–31 °C (OR: 1.12, 95% CI: 1.08–1.16), while for respiratory conditions, calls increased above 24.6 °C, and saw a non-linear significant increase between 34 °C–35 °C (OR: 1.18, 95% CI: 1.09–1.28) [26].

For the three modelling studies that reported mortality as a health outcome, one found that circulatory deaths increased in individuals over 65 years old for every five degrees above 23 °C indoor modelled maximum temperature (OR 1.16, 95% CI 1.03–1.3) [23], another based their work around the assumption that the relative risk of death for care home residents was 1.05 for every degree above 17 °C [27], and the last study found that mortality was highest in highest modelled indoor temperature (OR 1.043, 95% CI 31.1 °C–33.63 °C) but the differences were not statistically significant [28].

Studies by setting

The most common indoor setting described (eight studies) was household or domestic, and results were varied. Three of these focussed on self-reported symptoms [25, 30, 32], which are considered less useful for the purposes of this review because they are subject to recall bias, may lack clinical confirmation, and are more prone to misclassification compared to objective health measures. In contrast, objective outcomes such as mortality, hospital admissions, or physiological indicators like blood pressure offer greater reliability and comparability across studies. Two of the remaining five looked at blood pressure, and both found that this significantly decreased in relation to measured indoor temperatures [29, 34], which could contribute to episodes of dizziness or falls in some individuals. The other three studies had mixed conclusions. One based in London, which modelled mortality against modelled living room temperature found a non-significant association between increased temperature about 28.56 °C and death [28]. Another study modelled indoor temperature against hospitalisation and death in the USA, and found statistically significant positive associations between high indoor temperature exposure and health outcomes e.g. circulatory deaths OR 1.16 (95% CI 1.03–1.3) per 5 °C increase above 23 °C. The final study of this set was a case control design, looking at measured indoor temperature and emergency calls from people with pre-existing diabetes or respiratory conditions, compared to those without [26]. They saw ‘notable’ increases from temperatures in the mid-twenties, but only report finding a significantly increased odds of calling 911 above thirty degrees for both conditions.

There were two studies from this review that covered educational settings; one was from Malta [33], the other from the USA [24]. The Maltese study directly measured indoor temperature and looked for connections with doctor-diagnosed allergic rhinitis, although the study is not clear as to whether this was discerned via a clinical assessment or a parental questionnaire. The study population was 191 children and they found a significantly increased likelihood of being diagnosed with allergic rhinitis in classrooms in the 18 °C–22 °C temperature range, compared to lower temperatures. The American study focussed on asthma, and found there was a statistically significant association between asthma visits to a health centre outside school for temperatures above 23.9 °C (75 °F).

There were two studies from this review from social care settings; one was from the UK [27] and the other was from Australia [31]. The Australian study observed 21 participants with dementia over 10 months, and found that Cohen-Mansfield Agitation Inventory (CMAI, a tool used to assess agitated behaviours across two-week periods) scores increased significantly when indoor temperature was above 22.6 °C. The study based in the UK combined various modelling assumptions to understand to what extent adaptation measures might reduce mortality from heat in care homes. Their assumption was that the relative risk of death for care home residents (England and Wales, over age 65) was 1.05 for every degree of indoor temperature rise above 17 °C. However, this was based on previous modelling data from 2007.

Notably, no relevant studies were found in prisons, healthcare settings, or workplaces. Table 3 below illustrates the range of findings in further detail, and by temperature.

Discussion

Findings from this rapid review corroborate those from the previous systematic review [19] that there is still limited evidence around indoor maximum temperature thresholds in high income countries such as the United Kingdom. This is surprising given rising global temperatures and increased heat mortality in these nations since this time [35].

The results illustrate various weaknesses with the current method of assessment, specifically challenges and variations around exposure and outcome selection, as well as how these are paired. These make the current body of evidence difficult to synthesise. With respect to exposure to indoor high temperatures, the nine studies that directly measured this used thermometers or data loggers but there was no consistency in how often these readings were recorded, or when they were recorded in relation to the specified health outcome. The three modelled studies also took very different approaches, with only one using a large dataset that accounted for building characteristics [28]. These findings underscore a need for greater consensus on optimal approaches to indoor temperature measurement and well-informed modelling, in order to expand the evidence base available

and potentially enable high quality ecological studies on indoor temperature and mortality, for example. In this context, it is perhaps not surprising that there was a wide range for the indoor baseline temperatures at which health outcomes were observed, from 17 °C to 31 °C. Additionally, studies did not share whether cooling technologies were used in relation to the reported temperature, which could be relevant for future studies considering interventions.

More importantly, however, future studies could be optimised by incorporating objective measures of health outcomes that are clinically significant and relevant to policy development—such as mortality, hospital admissions, or emergency service use. In this review, most included studies did not focus on these high-consequence outcomes, limiting their utility for informing robust recommendations on maximum indoor temperatures for health adaptation policies. For example, while two studies examined the impact of heat on blood pressure [29, 34], this outcome is highly dependent on population characteristics and may not translate directly into meaningful clinical or policy action. Similarly, self-reported symptoms or allergic rhinitis are unlikely to be the key signals of serious morbidity or healthcare use on which indoor heat thresholds may be based. Of the twelve studies, only four focussed on acute health outcomes that might be the starting point for such a recommendation, such as deaths, hospital admission or emergency services calls. Only one directly measured indoor temperatures [26]. In order to build a solid method of assessment for future recommendations or legislation, more studies that both directly measure or model indoor temperature using robust datasets (alongside other relevant factors such as humidity) and high-consequence health outcomes are required.

Furthermore, the existing evidence base was limited due to several methodological and reporting factors. Two studies did not clearly report temperature thresholds at which they looked for associated health outcomes [25, 32], and for the studies directly measuring health outcomes, sample size numbers were low. The imperative for further primary research to improve understanding of high indoor temperature risks therefore is high.

The majority of the settings were household and domestic, with only two social care and no healthcare settings. This significantly limits our ability to make temperature recommendations for health, care or other organisations looking after vulnerable people, who are at highest risk of heat related illness and death [36]. Importantly, there were also no studies focussing on workers in challenging indoor workplaces (e.g. indoor agricultural, manufacturing or warehousing work) which is an identified evidence gap for future research.. A recent report from The Physiological Society [37] recommended that: ‘employers must develop a physiologically-informed plan for workers during extreme heat events to protect health and safety, and Government should introduce statutory guidance on maximum temperatures for different levels of activity and types of Personal Protective Equipment worn.’ This will not be possible without significant further evidence from workplace settings. We also noted no data for some groups potentially at risk of extreme heat exposure for whom evidence gaps have been noted elsewhere—e.g. those in custodial settings [36]. These findings emphasise the need for both setting- and population-oriented research to better understood indoor heat exposure risks.

Limitations to this paper should be noted. First, we report findings from a rapid review which repurposed a more general search, rather than a full systematic review. Although database coverage was broad, searches were limited to peer-reviewed publications and relevant grey literature and preprints will not have been captured. The restriction to English-only publications will have excluded a body of work from elsewhere, including Mediterranean Europe, with potentially relevant findings. Second, studies which used only outdoor weather data were excluded (which excluded most of the epidemiological evidence on heat and health), as were studies from countries not classified as high income by the World Bank. In addition, no critical appraisal was conducted.

More broadly, we acknowledge that there are several factors influencing indoor temperatures that we have not discussed while synthesising these studies, including building type and cooling mechanisms. However, not only were these not commonly reported by included studies, but they also—as the modifiers of indoor temperature—are beyond the scope for this review, which is examining the initial evidence for thresholds between health outcomes and high indoor temperatures. These factors will therefore be more relevant for future reviews considering sub-group analysis or interventions, once the thresholds for high indoor temperatures and health effects have been better established.

Finally, only studies from 2017 onwards were included as the majority of those included in a previous systematic review had dated from before this point [19] (although there are two overlapping studies from 2017 in this review and in Tham *et al* 2020, and we also included modelling studies which they did not). Therefore, the findings of this rapid review should be considered in context of their findings, looking at a global picture without date limits, that ‘the indoor temperature threshold at which adverse effects begin to occur remains unclear as studies seldom report the exposure–response relationship over a temperature continuum. Until there is extensive scientific data to support a maximum indoor temperature threshold, 26 °C may be the most suitable threshold for a maximum indoor threshold for at-risk groups in keeping with the existing guidance documents’ [19]. Although some of the studies in this review do indicate that a lower threshold than 26 °C may be appropriate, it is clear that further primary data with more robust methodologies are still required.

Conclusion

Despite renewed attention on heat and health due to globally climbing temperatures and a record number of heat deaths in England in 2022, this rapid review finds that the primary evidence for substantial health-based indoor temperature guidelines is still lacking. A need remains to clearly establish the indoor heat health risks in groups vulnerable due to age and pre-existing conditions, the lower risk individuals who may support them, and the settings in which they spend most of their time. Therefore funders, researchers and health organisations in England should consider a renewed commitment to generating primary evidence across all settings. This is important because, while indoor heat thresholds could be very helpful adaptation policy to protect health for the most vulnerable groups, they could also generate significant pressures on the energy grid if active cooling measures such as air conditioning are deployed to maintain them. Policy thresholds should therefore be rooted in the highest quality data. Until there is extensive scientific data to support a maximum indoor temperature threshold, 26 °C may be the most suitable threshold for a maximum indoor temperature threshold for at-risk groups in keeping with the existing guidance.

Generation of further evidence could take many forms, including lab-based (controlled) settings to understand effects of variations in indoor conditions (such as temperature/humidity mix), innovation in exposure measurement, and consensus on how we do this reliably (and at low cost) at the frontline in occupational settings. Data linkage to improve outcome reporting by occupational setting, professional group or vulnerability is also likely to be a useful way forwards, particularly for institutional settings such as care homes, hospitals and prisons where continuous temperature monitoring may be possible and health outcomes are likely already recorded in some form. It is particularly urgent to strengthen evidence for especially vulnerable groups such as prisoners, those in older age care homes in the UK and similar settings [36].

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Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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Justification statement

This rapid review looked at evidence for maximum indoor temperature thresholds and health outcomes in high income countries. The 12 identified articles showed a correlation between high indoor temperatures and health outcomes, but did not represent a coherent or consistent enough body of evidence to recommend a specific threshold. Clear guidelines around maximum thresholds for the indoor environment are needed, in order to adapt effectively to the climate change and protect the health of the most vulnerable populations. Therefore these findings have significant implications for efforts to adapt to climate change, as without evidence-based indoor maximum temperature thresholds, advice given to workers, the public, and professionals looking after the most vulnerable groups may be non-specific or incorrect. These results will be of broad interest to researchers working across environmental research disciplines, because our paper outlines the research gaps which still urgently require filling by primary research.

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