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FOCUS ON

Elevated Indoor Temperatures and Health

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Key Findings

- Prolonged exposure to elevated indoor temperatures above 25–32°C (depending on the study) is associated with physiological outcomes or symptoms (e.g., cardiovascular strain, respiratory distress, worsening mental health symptoms), reduced physical and cognitive performance, and adverse health outcomes (higher morbidity and mortality risk), particularly among vulnerable groups
- Extremes of age (particularly older age), chronic medical conditions, mental health disorders, social isolation, and living in poverty or inadequate housing can result in increased risk of adverse health outcomes during heat events
- Heat-related health risks are modified by individual behaviors (e.g., cooling measures) and environmental factors (e.g., poorly ventilated or insulated buildings, upper floor apartments, dense urban areas, urban heat islands)
- While there is insufficient evidence of a definitive threshold for maximum indoor temperature to prevent adverse health effects, some jurisdictions have advised or set a policy of 26°C
- A combination of individual behaviors (e.g., hydration, reduced activity), building modifications (e.g., insulation, shading) and community or policy actions (e.g., urban greening, building codes, social supports) can mitigate the risk of exposure to excessive indoor heat

Background

Exposure to excessively elevated temperatures during summer has been associated with excess morbidity and mortality.[1] Seasonal warm temperatures and extreme heat events are expected to increase in intensity due to climate change, which has resulted in calls to better understand the effects of temperature on health.[1]

Canadians spend the vast majority (approximately 90%) of their time indoors.[2] As the majority of heat-related deaths occur indoors, an optimal indoor air temperature range may prevent the negative health effects of excessive heat exposure.[3–5] Both environmental and behavioural factors influence the level of heat experienced by an otherwise healthy individual indoors; these include air and radiant temperature, humidity and air speed, clothing and activity, duration of exposure, as well as available adaptive (cooling) options.[6] Building and individual characteristics (e.g., age, medical comorbidities, tolerance) are also important, adding to the complexity of the relationship between indoor heat and health.

Population level increases in morbidity and mortality are associated with elevated outdoor temperatures using meteorological data (e.g., ambient temperature and heat waves).[7,8] Because indoor temperature data are less available, an association with elevated indoor temperatures has not been demonstrated.[9–11] However, there is evidence that indoor temperatures exceed outdoor temperatures, particularly in spaces where building-associated risk factors (discussed below) may be present.[12]

Heat-related morbidity and mortality is difficult to quantify as excessive ambient heat can cause heat stroke and dehydration, accidental and non-accidental injuries, as well as less clearly heat-related cardiovascular events and exacerbation of underlying chronic illnesses.[13–15] Though heat exposure may cause or exacerbate these outcomes, at an individual level they may not be recognized or reported as heat-related;[16] furthermore, even if the individual outcomes are attributed, we lack high quality heat exposure data to derive quantitative associations with such a broad array of outcomes.

There are additional challenges to study indoor temperature and health. They include limited study populations compared to large epidemiologic cohorts common in studies of ambient temperatures and health, number of studies and availability of temperature data from individual homes. Additionally, the potential for confounding bias may be greater when studying the effects of indoor temperature on health, as indoor exposures are more likely to be influenced by individual behaviors and socioeconomic status, unlike area-level ambient temperature. Where studies exist on indoor temperature and health, there is heterogeneity, and pooling them for analysis has not been possible due to varying temperatures examined, methods of exposure assessment, exposure contexts (e.g., experimental vs. observational), and populations studied (e.g., urban vs. rural residence).[4,17]

Therefore, two main challenges in this area of research are present. The first is how to translate evidence on outdoor heat and health to inform understanding on the effects of indoor heat on health. The second is that evidence on indoor heat relates to behavioural or physiological effects of heat to relatively small groups of individuals (e.g., experimental volunteer studies). Thus, when it comes to optimum or maximum indoor temperature to protect and promote health, it is a challenge to develop a guidance value that applies across the population while also considering feasibility and local determinants of the outdoor to indoor temperature relationship.

Within Ontario's public health community, related questions have included the scientific evidence for indoor temperatures that may be protective of health, including maximum indoor temperatures (and subsequent cooling requirements), and the effects of daytime and nighttime temperatures.

Objectives

With a changing climate and the reality that people in Canada spend the majority of their time indoors, evidence on indoor heat and health, and ways to reduce its impact are timely issues. The objective of this Focus On is to describe the relationship between elevated indoor temperatures and potential adverse health effects. This Focus On answers the following questions:

- Is there an ambient temperature threshold for a significant increased risk for adverse heat-related health effects?
- What factors influence temperature in indoor environments?
- What strategies can reduce the risk for adverse indoor heat-related health effects?

Methods

A literature search was conducted on July 6, 2024, to retrieve peer-reviewed articles and reviews from MEDLINE and Scopus databases. Public Health Ontario (PHO) Library Services updated the search on November 11 and 28, 2024, and again on February 24, 2026, to ensure all recent publications were fully captured. The search was restricted to English language papers published after 1999. The search strategy included a combination of terms related to setting (housing, indoor, living space), exposure (e.g., indoor heat, elevated temperatures, room temperatures), and health outcomes (morbidity and mortality). Guidance was drawn from the World Health Organization (WHO) Practical Guide to Rapid Reviews and the National Collaborating Centre for Methods and Tools Rapid Review Guidebook, using an umbrella review approach.[18–20]

Results (N=205) were appraised by two reviewers, and filtered to include reviews, systematic reviews, meta-analyses, and books. Google Scholar was also used (up to the date of publication) to identify grey literature such as policy briefings and government reports. All articles were screened by title and abstract for inclusion prior to data extraction. The references of identified articles were manually examined to identify other relevant sources. Articles published after the latest systematic reviews were included for screening. A copy of the PHO Library search results is available upon request.

Results

Health Effects of Elevated Indoor Temperature

The adverse population outcomes attributed to indoor heat are primarily based on epidemiologic studies of heat and heat events and associated adverse health effects (e.g., emergency department visits). Few studies offer clues on the potency (e.g., dose-response) of indoor heat exposure. One study looking at the relationship between indoor heat exposure and self-reported symptoms in elderly individuals observed significantly increased symptoms (e.g., thirst, sweating, sleep disturbance) per degree increase indoors (up to 33%) versus outdoors (up to 13%), suggesting increases in indoor temperatures may be a stronger predictor of adverse health effects than outdoor temperatures.[21]

Physiologic responses to indoor heat exposure can be helpful to look more specifically at health effects on an individual level. One review identified 17 observational/experimental studies of physiologic changes associated with increased indoor temperatures, several of which are discussed below.[4] Locations included homes, schools, health care settings, and workplaces.[4] Of them, five studies attempted to identify a temperature threshold for adverse health effects ranging from 26^{o}C–32^{o}C, but findings were not statistically significant.[4]

A recent scoping review of observational studies identified 29 studies relevant to the topic, and the authors identified the two most common adverse health effect categories as cardiovascular and respiratory overall, with thermal discomfort also noted.[22] This latter, more subjective aspect of heat and health effects, is mentioned in many of the below discussed articles, but should be distinguished from measurable adverse health effects. It is defined as "the state of mind that expresses satisfaction with thermal environment and depends on the personal and ambient parameters."[23] This is subjective and individualized, hence individuals experiencing discomfort from heat exposure should be distinguished from an adverse health effect at the population level.

Cardiorespiratory Effects

Increasing temperature and worsening cardiorespiratory symptoms is mediated by a complex interaction between temperature, humidity, and indoor air quality.[24,25] In a healthy individual, the cardiovascular system responds to heat with a variety of mechanisms peripherally (e.g., blood vessel dilation in extremities) and centrally (e.g., increased heart rate and strength of cardiac contraction).[26] Older individuals may be at risk for adverse heat-related cardiovascular effects due to a relative blunting of these mechanisms, particularly during physical activity or with prolonged heat exposure.[26] The below studies provide a few specific examples, but generally find that exposure to excess indoor heat increases the risk for various cardiorespiratory symptoms/outcomes.

Five of Tham et al.'s cited studies focused on respiratory symptoms, all of which observed increased reports of respiratory symptoms (e.g., shortness of breath) with increasing indoor temperatures, though only one study specified a threshold for effect (>26ºC).[4]

One case-control study in New York compared 338 respiratory cases, 291 cardiovascular cases, and 471 controls derived from a group of patients attended by paramedics, who carried temperature and humidity sensors and collected these data along with clinical data from their patients.[27] They noted a possible indoor temperature threshold of 26ºC for respiratory distress-related calls.[27]

Six studies found that higher indoor temperatures were associated with statistically significant decreased systolic and diastolic blood pressure.[4] A large scale study from the WHO was also cited with similar findings, though the authors surmised that the clinical significance of this is unclear, as decreases of only 1–2 mmHg were noted, and no specific threshold for effect was specified.[4]

In one study, older healthy volunteers (N=16, mean age 72 years) in Ontario were subjected to a series of four 8-hour indoor simulations, where temperature ranged from 22ºC to 36ºC, at relative humidity (RH) of 45%.[28] They reported no significant change in core temperature or cardiovascular strain at the 26ºC simulation.[28] They observed a statistically significant rise in core temperature with 31ºC temperature and above, and these temperatures were also associated with elevated cardiovascular parameters (heart rate, reduced blood pressure) per degree Celsius increase.[28]

Another group of volunteers with congestive heart failure (N=55) in Montreal were periodically observed over a 2 year period, along with measurements of indoor temperature, humidity, $PM_{2.5}$, and carbon monoxide.[24] They observed a reduction in oxygen saturation and decreased diastolic blood pressure with temperatures above 2.9ºC from baseline (mean 23.49ºC, RH=38.98).[24] This same group reported worsening shortness of breath and increased episodes of hypoxia with increasing indoor temperature.[24]

Mental Health Effects

Two studies showed that mental health symptoms worsened with increasing indoor temperature.[4] One observational study of hospitalized patients with schizophrenia (N=22–34, changed weekly due to admissions/discharges) measured nightly ambient temperature and humidity over a 32-week period, and observed worsening symptoms scores (using a validated symptom score) with relative increases in temperature up to 25^{o}C (RH=40–55%) when compared to a control group of non-schizophrenia patients on the same ward (but with psychotic symptoms), possibly suggesting that the observed effect was not attributable to thermal discomfort.[29]

One study observing nursing home residents with dementia (N=21) over a 10-month period noted a significant correlation between worsening symptoms (using standardized testing) and temperatures above 26^{o}C.[30]

Other Effects

In relatively healthy older adults, exposure to higher indoor temperatures (27^{o}C) during heat waves was linked to reduced physical functioning, including slower gait speed, poorer chair-rise performance, and reduced balance.[31]

Multiple studies found increasing indoor temperatures led to rises in core body temperature, along with greater self-reported discomfort, fatigue, and impaired sleep.[4] Very high indoor temperatures (30–35^{o}C) were associated with metabolic effects in people with diabetes, including increased insulin absorption and faster declines in blood glucose levels.[4,32,33]

Additional research identified broader physiological responses to heat exposure, such as increased cardiovascular strain, heightened heart rate variability, and increased markers of cellular stress.[4,28,34] Overall, the available evidence is varied, but suggests that, consistent with research on outdoor elevated temperature health effects, a range of higher indoor temperatures can lead to measurable physiological impacts, which may increase the risk for heat-related symptoms, and in certain individuals (e.g., older adults, individuals with certain medical conditions) the risk for adverse health effects and subsequent morbidity, and mortality.

Children

An Environmental Protection Agency (EPA) review on climate change and children's health noted many of the same heat-related physiologic changes observed in adults noted above (e.g., worsening medical and mental health conditions).[35] Though the focus of the review was not specifically on indoor heat exposure, they cited observational population-level studies suggesting an association with excess heat exposure in classrooms and reduced capacity for learning/concentration leading to learning loss in affected populations.[35,36]

A study in schoolchildren aged 10–12 years observed significant improvement in arithmetical and language based tests when testing was done at 20^{o}C compared to 25^{o}C.[37] Though more research is needed specifically on indoor heat exposure and health effects in children, studies suggest a relationship between indoor heat exposure and learning outcomes/performance in this particular group.[36–39]

Factors Influencing Indoor Temperatures and Related Health Effects

Many factors can modify the individual risk of adverse health effects due to elevated temperatures. These include individual characteristics (e.g., acclimatization, age, medical comorbidities) that affect health outcomes; as well as building characteristics (e.g., materials, ventilation), neighborhood characteristics (e.g., proximity of trees, urban heat islands), and contextual factors (e.g., socioeconomic status, housing availability) that act by affecting indoor temperatures or exposure to indoor heat. Each is discussed below.

Both population-level epidemiologic studies, as well as the above cited experimental/observational studies of individuals, offer clues about personal characteristics which may increase the risk of heat-related morbidity or mortality. The most common causes of death during heat events include cardiovascular events, renal failure, cognitive impairment, and respiratory compromise.[40,41] The most consistent risk factor cited is increasing age, particularly those over 65 years.[41] Other relevant demographic factors include younger children (<5 years), female sex, obesity, and pregnancy, though the risk for these is less than in those >65.[41–46] Medical factors include use of certain medications (e.g., diuretics), certain medical conditions (e.g., cardiovascular disease or CVD, respiratory disease, type II diabetes, hypertension), and mental health/cognitive disorders (e.g., substance use disorders, schizophrenia, cognitive impairment).[41] Many of these can occur in combination, which may additionally increase risk.[4,25] Acclimatization, or an individual's physiologic adaptation to heat exposure, is also relevant for heat waves that occur earlier in the warmer seasons, where individuals will not have acclimatized and may be more vulnerable to heat effects.[47]

Several social/contextual characteristics that increase risk of heat vulnerability have also been identified and include geographic location (e.g., proximity to urban heat islands), low socioeconomic status (e.g., lack of access to housing and/or adequate/quality housing, air conditioning), social isolation, and lack of knowledge around managing heat exposure (e.g., appropriate clothing, reducing physical activity).[18,48]

Building-related factors have been identified that may increase the risk for adverse heat-related health effects by increasing exposure, including lack of windows or window coverings, or windows that do not open; being situated on higher floors (in high-rise apartments); or being situated in a house constructed of wood or vinyl (versus brick).[18,41] Unshaded clear glass facades that make up the entire wall (e.g., popular in high rise buildings) are also associated with significant increase in indoor air temperature.[49]

Certain urban thermal characteristics also potentially increase the risk for elevated indoor temperatures, such as increased building density, lack of green space, increased paved surfaces, which contribute to the urban heat island effect (UHI) up to 10°C increase compared to proximal rural areas.[41] This effect is exaggerated at night, when stored heat accumulated in paved surfaces is released.[41]

Altogether, these individual, building, neighbourhood and other contextual influences on the health effects of indoor heat exposure demonstrate the complexity of the relationships but also suggests ways to mitigate the health risk.

Reducing Risk

Optimal Range or Threshold for Indoor Temperature

Few high-quality studies have examined optimal indoor temperature and health. A 2018 systematic review conducted by the WHO to examine all-cause mortality or hospital admission from exposure to indoor temperatures above 24ºC found no eligible studies that assessed this association.[17] Based on available evidence, the WHO stated that indoor temperatures between 18–24ºC pose minimal risk of adverse health effects.[50,51] Health Canada also published a guidance on upper indoor temperature limits for older adults (≥60 years) which recommended an upper indoor temperature limit of 26°C to protect older adults from heat related morbidity and mortality in residential settings, based on limited available physiologic (34) and epidemiologic studies.[52] However, a clear "one-size-fits-all" threshold for a measurable increased risk for all individuals is not currently possible.[22,51,53]

While the science on optimal indoor temperature is evolving, multiple sources cite 26ºC as a reasonable guideline recommendation (assuming typical relative humidity of roughly 40–60%).[17,54–61] This is consistent with several jurisdictional standards for indoor maximum acceptable temperature, including Toronto (AC systems are to achieve temp ≤26ºC),[62] Mississauga ("adequate and suitable cooling" defined as ≤26ºC),[63] and the province of British Columbia ("indoor design temperature requirement" for cooling systems to achieve ≤26ºC).[64] The basis for recommending an indoor threshold of 26ºC comes from research of healthy individuals in office environments, based on thermal comfort levels, in addition to studies on the effects of indoor and outdoor temperature on health.[4,50,51,65,66]

Are there measures to reduce the health risk of elevated indoor temperatures?

Air conditioning is by far the most effective evidence-based means to reduce heat related morbidity and mortality.[41] During the extreme heat event in BC in 2021, 93% of those who died did not have air conditioning.[5,67] However, a consistent message in the literature is that overreliance on air conditioning alone is not a viable solution for cooling, as this would increase greenhouse gas emissions, lead to perpetuating climate change and strain power grids beyond their capacity especially during a heat event; it is important to acknowledge that newer high efficiency technologies (e.g., heat pumps) may offset some of these impacts.[68–70] Use where energy supply is inconsistent further argues against an overreliance on this technology.[71] Consideration for energy efficient options such as ventilation and efficient building materials could also be incorporated into planning and design before construction.[4,25,54] Additionally, air conditioning is also unlikely to be accessible financially to all.[70]

Building surroundings, specifically landscaping, are potentially important upstream factors in mitigating the risk for indoor heat exposure. One modelling study estimated that an increase of tree density by 30% in an urban area could reduce indoor temperatures by a mean of 0.4ºC, and reducing heat-related annual mortality by 1.84%.[72] A systematic review of studies looking at urban green (urban land with plants/trees of any kind) and cardiovascular/cerebrovascular disease incorporated 36 studies in their findings that exposure to urban green reduced the risk of both cardiovascular and cerebrovascular-related mortality.[73] A review on mitigating strategies noted that both green and blue (water) spaces can potentially reduce heat related morbidity and mortality for local inhabitants.[71]

As discussed above, certain building factors have been associated with increased indoor temperatures. Managing or mitigating these building characteristics could reduce indoor temperatures, in turn reducing the risk for adverse health effects. In some cases retrofits to improve thermal control could be considered, such as improved insulation and gap sealing (e.g., updated insulation and windows), improved attic ventilation in homes, roof modification (e.g., reflective surfaces, green roofs), and external shading (e.g., planting trees).[41] New buildings could be constructed to be more heat resistant, and might include considerations such as building orientation, building materials, and landscaping.[41] Urban planning could include strategic incorporation of green or blue space, avoidance of factors that may create UHIs, and use of surface materials that decrease absorption of solar radiation (e.g., increasing surface albedo).[41]

Factors relating to individual behaviours include a variety of techniques with evidence for potentially reducing adverse heat related health effects.[41,71,74] Aside from individual acclimatization, these include misting fans, ice/cooling towels, limb immersion, self-dousing, reducing activity, and cold fluid consumption.[41,71] However, these are dependent on ability and willingness of an individual to pursue them. Though the evidence for the use of fans to reduce adverse heat-related health effects has not been consistent, there is evidence for their use for cooling under certain conditions.[75–77] Use of fans seems to be only effective up to 33–35^{o}C, above which evaporative cooling is unlikely to meaningfully cool an individual.[75]

Public health and community level initiatives to increase resilience to indoor heat should also consider socioeconomic status as a risk factor; for instance, focusing on individuals and groups of lower socioeconomic status could help develop a more targeted intervention approach to reduce the disproportionate burden of heat-related illness in this group.[12]

Discussion

While the adverse impacts of outdoor heat exposure are well-documented, less is known about the indoor temperature optimums or maximums applicable for population health. There is growing recognition that indoor heat exposure represents a significant public health concern, particularly as climate change increases the frequency and intensity of extreme heat events.[27,47]

Available studies suggest that high indoor temperatures may lead to physiological outcomes including elevated heart rate, exacerbation of chronic health conditions, worsening of mental health and reduced cognitive or physical performance.[24,31,75] Studies report adverse effects beginning around 25–32^{o}C, though there is currently limited evidence for a definitive threshold for health risks and thresholds for health impacts are not consistent across the literature; they may also vary depending on individual characteristics such as comfort/tolerance, age, sex, pre-existing health status, and geographic or seasonal acclimatization.[4,41] Early-season heat waves in particular may pose elevated risk due to limited physiological adaptation and insufficient behavioural or environmental preparation.[41,47,71]

There is currently no universally accepted standard for a maximum indoor temperature.[4,17,54] Most existing studies are observational, with limited longitudinal follow-up or use of direct indoor temperature measurements.[4,75] In addition, there is no consensus on the most appropriate exposure metric whether maximum, mean, or diurnal temperature variation for predicting health outcomes.[17,41] Co-exposures such as indoor humidity, indoor air quality (e.g., elevated $PM_{2.5}$ levels) may modify heat-related risks, but have not been systematically evaluated across studies.[24,25]

Vulnerability to indoor heat is shaped not only by individual factors (e.g., physiological, behavioural) but by a complex interplay between social and environmental factors.[4,41] Older adults, individuals with chronic illnesses or mental health conditions, perhaps due in part to reduced heat perception and subsequent response, and those with limited physiologic adaptive capacity, are particularly at elevated risk; the literature also highlights inequities based on race, disability, and gender identity, although these dimensions remain underexplored in most existing studies.[32,56] In cooler-climate regions such as Canada, both physiological and infrastructural preparedness for extreme heat may be lower.[41,47,71] Many high-risk individuals also reside in poorly insulated housing (particularly where there is concomitant poor building design) or lack access to air conditioning, conditions frequently linked to socioeconomic disadvantages.[78] This is sometimes referred to as "cooling poverty," which illustrates how energy insecurity can amplify heat-related risk.[71,79] Although children were less commonly studied, emerging evidence suggests that indoor heat may impair learning, sleep quality, and behavioural regulation, underscoring an important gap in the evidence base.[27,71]

Public health guidance increasingly emphasizes the need for preparedness measures that address indoor environments.[3,47] However, significant jurisdictional and regulatory challenges remain, particularly in private residences, where most heat-related deaths occur and where public health interventions have limited authority.[3,5] This was demonstrated during the 2021 heat dome in British Columbia, when 98% of heat-related deaths occurred indoors, primarily among older adults without access to cooling.[5] Although some jurisdictions have begun to respond, for example, through local indoor temperature bylaws or building code updates, such measures are typically restricted to rental units or new construction.[80,81] Protections in owner-occupied homes remains a challenge given difficulties in establishing and enforcing bylaws or standards, and additionally, rental properties may not optimize cooling for inhabitants if the owners are not legally obligated to cool buildings.[82]

Addressing indoor heat risks requires both upstream and immediate strategies. Structural interventions such as reflective building materials, urban greening, and building code reform offer long-term protection but require sustained policy coordination.[49,72] Short term actions at the building and individual level include improved insulation, shading, and access to cooling devices and encouraging hydration.[41,71] Air conditioning has been shown to reduce health risks, and during extreme heat events it is an important measure.[41] However it is also important to acknowledge that its widespread use (e.g., for comfort) raises concern about affordability, energy demand and emissions.[70] Fans may be effective below 33–35°C, but their effectiveness is lost above these temperatures.[75,83] Community-based interventions, including the activation of social networks during heat events, remain critical to identifying and protecting vulnerable individuals.[84] Technological advances, such as wearable sensors and smart home monitoring, could improve exposure tracking and enable more responsive public health interventions.[85]

This Focus On summarized existing evidence and provided an overview of indoor heat related health risks and vulnerability factors, while highlighting evolving public health guidance and mitigation strategies. Many of the included studies used cross-sectional or other observational designs as a proxy rather than direct measurement of indoor heat exposure, and exposure characteristics were variably/inconsistently reported. Most of the studies were from high income countries. Certain groups including younger children (<5 years), pregnant women, people with disabilities were generally under-represented in the studies reviewed.

Conclusion

Heat waves and day-to-day heat have been associated with increased morbidity and mortality, and with climate change they are expected to increase. More research is needed to better understand indoor temperatures at which exposure results in adverse health effects. While indoor temperatures above around 25–32^{o}C are frequently associated with a range of adverse effects, there is currently limited evidence for a definitive threshold for health risks. Given that most heat related death occur indoors and in private housing, multifaceted interventions including improved building design, targeted outreach and coordinated policy actions are needed to reduce risk. Future research could also strengthen knowledge on the prevalence of indoor heat exposure, evaluate feasible and sustainable mitigation strategies, and explore means to address inequity in indoor heat exposure and access to cooling.

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