World Health Organization

WHO HOUSING AND HEALTH GUIDELINES

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High indoor temperatures

5 High indoor temperatures

High temperatures and temperature variations harm health. Human response to heat is dependent on the body's ability to cool itself *(249)*. An important cooling mechanism is perspiration and its evaporation from the skin and, therefore, because high air humidity can reduce and eventually prevent net evaporation, the health effects of high temperatures depend also on relative humidity (or more precisely the dew point temperature of air). High outdoor temperature is associated with thermal discomfort *(250)* and adverse health outcomes, including higher rates of all-cause and cardiovascular mortality and emergency hospitalizations, across a range of study designs and across geographical regions *(251–255)*. Children, the elderly, and those with psychiatric, cardiovascular and pulmonary illnesses have a weaker physiological response to heat, and are more vulnerable to the negative impact of high temperature on health *(249, 256–258)*.

Public health interest in the effects of heat on health has grown recently in part because of climate change and the increasing frequency and duration of heat waves across all continents *(6)*. For example, the May 2010 heat wave in Ahmedabad, India, was associated with significant excess all-cause mortality: 4462 all-cause deaths occurred, meaning an estimated 43.1% increase when compared with the reference period with 3118 deaths *(259)*. It is further estimated that an excess of 70 000 people in 16 countries across Europe died in August 2003 due to a major heat wave *(260)*. Across Africa, the frequency (spatial coverage) of extreme heat waves has increased to 24.5 observations per year (60.1% of land area) between 2006 and 2015, as compared with 12.3 per year (37.3% of land area) in the period from 1981 to 2005 *(261)*. People who live in temperate climates are more likely to be affected by high temperatures; the temperature threshold where heat-related deaths begin to increase during a heat wave is lower in cities with cooler climates *(262, 263)*. Exposure to heat waves earlier in the season has a greater impact on mortality, because the population has not had a chance to adapt to higher temperatures *(264)*.

The importance of acclimatization (i.e. physiological adaptation to excessive heat exposure) is stressed in the WHO-World Meteorological Organization (WMO) guideline for heat wave warning systems, but complete acclimatization to an unfamiliar thermal environment may take several years. Long-term adaptation results in a lower rise in core body temperature and a lower increase in heart rate at a given heat load *(265)*. In addition, while people may adapt to usual temperatures, they may not be able to adapt to variable temperatures. Unstable temperatures harm the cardiovascular and immune system, and are associated with an increase of mortality *(266)*.

Studies have shown an association between high indoor temperatures and adverse health effects *(267)*. Outside of regions where air conditioning is common, high indoor temperatures are associated with high outdoor temperatures. In a case cross-over study carried out in three Latin America cities, same and previous day apparent temperatures were strongly associated with mortality risk, with susceptibility increasing with age *(268)*. Therefore, studies of morbidity and mortality rates during periods of high outdoor temperatures can also be used to provide indirect evidence of the harmful health effects of high indoor temperatures in such regions. For example, during the 2003 heat wave in France, the number of deaths at home was considerably higher compared with years without extreme heat events *(269)*. In Japan, a study showed that heatstroke most often occurs at home during summer; elderly people developed heatstroke in their homes with greater frequency compared with patients in other age groups *(270, 271)*. In summary, given that people spend most of their time indoors *(2)* and that, in the absence of air conditioning, they will be exposed to an increased risk of high indoor temperatures during periods of high outdoor temperature, protection against outdoor heat is a key characteristic of healthy housing.

Air conditioning, insulation, certain building materials, wall thickness, shading from direct sunlight, natural ventilation (especially during night time), and increased air motion (fans) to cool indoor temperatures can help protect people against heat and heat-related illness. However, large numbers of people in developing countries, as well as low-income groups in developed countries, do not have access to such housing facilities. As a consequence, low socioeconomic groups are at higher risk of heat-related mortality *(249, 264)*. Research carried out in São Paulo, Brazil, for example, showed that those with less education were more susceptible to heat-related mortality *(268)*. Air conditioning can also reinforce health inequalities by exacerbating urban noise and heat, which negatively affect the health of others, particularly those who cannot afford air conditioners. Air conditioning contributes to climate change, with knock-on effects on health, due to heavy energy consumption and use of powerful greenhouse gases as coolants.

In order to establish clear guidance on minimizing the health risk associated with high indoor temperatures, a systematic review of the evidence was commissioned.

Question for the systematic review
Do residents living in housing where indoor temperatures are above 24 °C have worse health outcomes than those living in housing with indoor temperatures below 24 °C? The categorical cut-off point at 24 °C was chosen based on the conclusions of a previous WHO working group on indoor environment finding that "there is no demonstrable risk to human health of healthy sedentary people living in air temperature of between 18 and 24 °C" *(213)*.

The systematic review focused on the following priority health outcomes:
- all-cause mortality
- heatstroke
- hyperthermia
- dehydration
- hospital admission.

The systematic review is available online at http://www.who.int/sustainable-development/publications/housing-health-guidelines/en/index.html, along with the GRADE tables used to assess the certainty of the evidence in Web Annex D. Additional analysis conducted to provide indirect evidence to support the recommendation regarding high indoor temperatures is also available online. This looked at the likely effect of high indoor temperatures on health but did not specifically address temperatures of above 24 °C.

The review identified six studies that included indoor dwelling temperature as an exposure variable. However, none of these studies provided direct evidence on the prioritized health outcomes or the minimal risk temperatures for heat-related health effects. Therefore, no firm answer can be given to the question of whether people living in housing with a temperature above 24 °C have worse health outcomes than those living in housing with an indoor temperature below that threshold.

5.1 Guideline recommendation

Recommendation	Strength of recommendation
In populations exposed to high ambient temperatures, strategies to protect populations from excess indoor heat should be developed and implemented.	Conditional

Remarks

- Identification of the minimal risk temperature for heat-related health effects will require research to determine the indoor temperature below which no adverse health effects related to heat are expected. Likewise, research is needed to identify the "maximum acceptable temperature", above which the risk to human health increases drastically. As people are acclimatized to different temperatures in different climate regions, the optimal indoor temperature range is dependent on the specific region. Examples of minimal risk temperature for heat-related health effects and maximum acceptable temperature are listed in Table 5.1, drawing on the analysis set available at http://www.who.int/sustainable-development/publications/housing-health-guidelines/en/index.html.
- There is an association between high indoor temperatures and some adverse health effects. Implementing agencies should work to reduce indoor temperatures to the minimal risk temperature, because this is likely to have beneficial effects on health. It is particularly important to keep the indoor temperature of the housing of vulnerable individuals, such as the elderly, infants, sick and the disabled, below the maximum acceptable temperature.
- The GDG assessed the certainty of the evidence to indicate the extent to which the research on each health outcome supports the recommendation. As there are so few studies of the direct effect of high indoor temperature on health, the certainty of the evidence that reducing high indoor temperatures would reduce morbidity and mortality was assessed as **low to very low**. However, there is higher certainty of evidence that there is a relationship between high indoor and high outdoor temperatures and that high outdoor temperatures are associated with morbidity and mortality.
- Therefore, having considered the certainty of this range of evidence on high temperature and health, the balance of benefits to harms of preventing exposure to high indoor temperature, the values and preferences associated

with preventing exposure to high indoor temperature, and the cost and feasibility of preventing such exposure, the GDG made a **conditional** recommendation.

Table 5.1 Examples of estimated minimal risk temperature for heat-related health effects and maximum acceptable temperature

City/country	Indoor minimal risk temperature for heat-related health effects	Indoor maximum acceptable temperature
Boston (United States of America)	21–22 °C	25 °C
New York (United States of America)	22–24 °C	27–28 °C
London/Manchester (United Kingdom)	22–23 °C	~25 °C
Harbin (China)	~24 °C	26 °C
Republic of Korea	~25–26 °C	~29–30 °C
Thailand	~30 °C	~32 °C

5.2 Summary of evidence

The systematic review on the association between high indoor temperatures and adverse health outcomes identified eight eligible studies. Further, indirect evidence to support the association between high indoor temperatures and adverse health outcomes was identified in the following manner:

- Step 1: Studies on health and outdoor temperature were reviewed to obtain estimates of the relationship between outdoor temperature and health outcomes.
- Step 2: Studies that measured both indoor and outdoor temperature were reviewed and used to model the association between indoor and outdoor temperatures. This association was used to derive indoor temperature based on the outdoor temperature.
- Step 3: An assumption was taken that the estimates derived in Step 1 would equally apply to the indoor temperatures calculated in Step 2. These were used to support the recommendations regarding high indoor temperatures.

5.2.1 Temperature and morbidity

Indoor temperature and morbidity

Eight studies investigated the effect of indoor heat on health outcomes including, sleep disorders (three studies); general health, blood pressure, respiratory and cardiovascular disease (two studies each); and body temperature, mental health, pregnancy outcomes (one study each).

One quasi-experimental study of 57 people in the United States of America found that reductions in number of days above 27 °C corresponded with improved quality of health and life, reduced emotional distress and increased hours of sleep *(272)*.

Three cohort studies explored the association between indoor heat and morbidity. While there were no associations between indoor temperatures and reports of respiratory viral infection or heat illness in a cohort of 40 households in the United States of America, the same study found a significant relationship in sleep problems and prior day's temperature in the summer season but not in winter *(273)*. Similarly, among 113 elderly people in the Netherlands, an increase of 1 °C of indoor temperature raised the risk of sleep disturbance by 24% (in the temperature range of 20.8 to 29.3 °C) *(274)*. A third cohort study, in Slovenia, reported worse cardiovascular symptoms with a higher heat burden and low indoor air quality *(275)*.

One case series involving 20 low-income elderly people in the Republic of Korea and one cohort study including 132 women in India, found a non-significant positive relationship between indoor temperature and systolic blood pressure but a significant positive association with diastolic blood pressure *(276, 277)*.

A case-control study reported that humidity exposure and indoor heat above 26 °C non-significantly increased the proportion of emergency calls in New York that were due to cardiovascular cases and respiratory distress calls *(278)*.

Finally, a cross-sectional study among 1136 women in Ghana found a non-significant increase in adverse pregnancy outcomes, such as stillbirth or miscarriage, with each additional 1 °C increase in atmospheric heat exposure *(476)*.

In view of the mixed findings and the relatively small amount of evidence, the certainty of the direct evidence that reducing high indoor temperatures would reduce morbidity or mortality was assessed as **low.**

Outdoor temperature and morbidity

In order to help with the discussions in the GDG, analyses were also done of the effects of outdoor temperature, for which studies on the association between high temperature and morbidity show a non-linear temperature-effect relationship. For example, associations between daily average temperatures and the relative risk estimates for hospital admissions for kidney disease are U-shaped (admissions occur in both the lower and higher temperature ranges) or J-shaped (admissions occur in the higher temperature ranges). Temperatures at around 25 °C present the lowest risk for hospital admission for kidney disease, and high temperatures increase the risk of admission more than low temperatures *(254)*. Although heat waves are significantly associated with elevated risk of cardiovascular hospitalizations *(279)*, recent meta-analysis indicated no apparent association between increased ambient temperature and cardiovascular morbidity *(255, 280)*.

The certainty of this evidence linking high outdoor temperature with increased morbidity was assessed as **low to moderate** and, although indirect, it was used in conjunction with the evidence on the relationship between outdoor and indoor temperature to provide support for the recommendation on indoor temperatures.

5.2.2 High temperature and mortality

High indoor temperature and mortality

No eligible studies assessed the effect of high indoor temperature on mortality.

High outdoor temperature and mortality

Reviews and meta-analyses provide strong evidence of the association between high outdoor temperature and mortality *(251, 252, 264, 279, 281)*. There is a non-linear temperature-mortality effect relationship, with U- or J-shaped curves for temperature-mortality relationships for all-cause mortality categories *(282)*; J-shaped curves for cardiovascular disease mortality *(283)*; J-shaped curves for non-accidental, cardiorespiratory and cardiovascular mortality as cumulative effects of diurnal temperature range; and U-shaped for respiratory mortality, with strong monotonic increases at a diurnal temperature range of approximately 16 °C *(284)*.

The exposure-response curve helps to identify a minimal risk temperature above which mortality increases as temperature increases *(249)*. The minimal risk temperature extends up to 31 °C for different cities in low- and middle-income countries *(262)*. It averages 29.4 °C in Mediterranean cities, and 23.3 °C in northern continental cities *(285)*. The optimal outdoor temperature for health varies considerably across populations, depending on climate and socioeconomic profile *(263, 281)*. The mortality risk due to high and low temperatures varies from roughly the 60th percentile of the location-specific temperature range in tropical areas to the 80–90th percentile in temperate regions, which is equivalent to 19 °C in Stockholm, Sweden, and 30 °C in Bangkok, Thailand *(281)*.

The certainty of the evidence relating high outdoor temperature to mortality was assessed as **high**, and, although indirect, it was used in conjunction with the evidence on the relationship between outdoor and indoor temperature to provide support for the recommendation regarding indoor temperatures.

5.2.3 Relationship between indoor and outdoor temperature

Thirty-two studies were identified which reported the relationship between indoor and outdoor temperature. These showed a positive correlation in the higher temperature range (>20 °C). The slope of a linear regression between outdoor and indoor temperatures in the warm/hot temperature range (>20 °C) varied depending on several factors including air conditioning, ventilation, insulation, building direction, socioeconomic status and the behaviour of the occupants.

Most of the studies were conducted in temperate climate zones. The studies show that the slope of the correlation curves between indoor and outdoor temperatures in this climate zone was usually not steep, which may be due to the influence of air conditioning in some dwellings *(286)* and the practice of keeping the windows closed rather than opening them for ventilation *(287)*. Specific cities have unique correlation curves *(288, 289)*. Some studies are better able to predict indoor temperatures from outdoor temperatures by incorporating other environmental factors into a multivariate regression. These factors include urban heat islands affecting the immediate environment *(290)*, solar radiation *(291, 292)* or dwelling characteristics *(293)*. The relationship between indoor and outdoor temperatures depends on the socioeconomic status of the participants with indoor temperatures of the dwellings of low-income residents more closely associated with outdoor temperatures because they are not influenced by the use of air conditioners *(276, 294)*. Indoor and outdoor temperatures are also more closely correlated where the occupants opened their window for ventilation *(295)*.

Fewer studies have been done in subtropical regions, but these also suggest relationships between indoor and outdoor temperatures. In low-income countries, where air conditioning is seldom available, indoor temperature is directly related to outdoor temperature *(296–298)*. The relationship becomes weaker further away from the equator *(299, 300)*. There is no relationship between indoor and outdoor temperature in countries where air conditioning is widely available everywhere, such as Oman *(301)*. One study found that the indoor temperature could be higher than the outdoor temperature due to cooking activities and inadequate ventilation *(302)*.

The certainty of the evidence that indoor and outdoor temperatures are correlated was assessed as **moderate to high**, and this indirect evidence was used in conjunction with the evidence on the relationship between high outdoor temperatures and adverse health outcomes to provide support for the recommendation regarding indoor temperatures.

5.3 Considerations for implementation of the guideline recommendation

Thermal insulation, housing location, building materials and house orientation, window shades, green spaces and ventilation (including use of cooler night-time air) and air conditioning can help to mitigate high indoor temperatures *(303)*. Improved ventilation and air conditioning have helped decrease the relative risk of heat-related mortality in the United States of America, Japan and Spain over the past two decades *(304)*.

However, air conditioning is not always feasible because of implementation and running costs. Increased reliance on mechanical air conditioning has a disadvantage in that it increases costs, energy consumption and carbon emissions. Furthermore, poor maintenance of air conditioning can create health problems, due to mould, lack of condensation drainage and circulation of airborne pollutants. Therefore, passive mitigation measures or mechanical ventilation systems that are free or low-cost to run, such as those powered by solar technology, are often preferable. World Health Organization guidance on natural ventilation measures in health care settings may also be relevant to housing *(305)*.

Member States can support measures to cool housing through regulations on minimum requirements for ventilation, insulation and air conditioning measures through subsidies to support such measures, and through building codes that emphasize the importance of maximizing thermal comfort; and through planning codes that acknowledge the importance of urban design, such as urban forests, shading, wind management and green roofs, in keeping cities cool.

Public health authorities should develop and activate heat wave warning systems, as stipulated in the WHO-WMO guidance, and should prepare for extreme heat events *(265)*. In addition, public awareness campaigns can increase understanding of the harms associated with heat exposure. This includes encouraging people to engage in cooling behaviours at home, such as taking showers and remaining hydrated *(306)*, to counter the negative health effects of indoor heat.

5.4 Research recommendations

Some of the evidence summarized in this chapter is indirect, based on the association between indoor and outdoor temperatures, and the association between high outdoor temperatures and health outcomes. However, there is great variation between outdoor and indoor temperatures in terms of the types of heat exposure (direct or indirect sun), the types of activity typically carried out, and the possible interactions with other risk factors associated with housing, including humidity, housing conditions, socioeconomic conditions, the type of structure (including insulation), ventilation/air conditioning, and outside temperature. Further research should therefore focus on the direct effects of high indoor temperatures on health.

Table 5.2 Research recommendations: high indoor temperature

Current state of the evidence	Few high-quality studies have assessed the direct effects of indoor temperature on health. The current research base is limited by a lack of data on indoor household temperature and the difficulty of designing studies capable of entirely excluding the health impact of outdoor temperatures. High-quality studies that control for confounders are required. These should focus on exposure-response associations and take into account peak (occasional high temperatures), chronic (extended periods of high temperatures) and cumulative exposure.
Population of interest	The whole population; in particular people who are both more likely to spend time at home and experience adverse health effects related to heat (the elderly, children, women, obese people, and people with long-term illnesses). Studies across different groups will help establish whether the threshold level (the temperature above which temperature poses a risk to health) is different for different population groups.
Interventions of interest	Installing ventilation and other measures aimed at reducing indoor temperature in housing in hot climates; and moving people to cooler housing in hot climates.
Comparisons of interest	Groups living in hot climates in home environments at different temperatures; groups before and after interventions to reduce indoor temperatures.
Outcomes of interest	A range of health outcomes should be included, including mortality and morbidity generally, but, in particular, cardiovascular disease, blood pressure, respiratory symptoms, sleep disturbance, heatstroke, hyperthermia, dehydration.
Time stamp	Current systematic review on the direct association between high indoor temperatures and health outcomes included studies published up to April 2018. The literature review to provide evidence on the indirect relationship between high indoor temperatures and health was done by members of the GDG in April 2016.