Extreme heat events and overheating in the home – what is a safe indoor temperature limit

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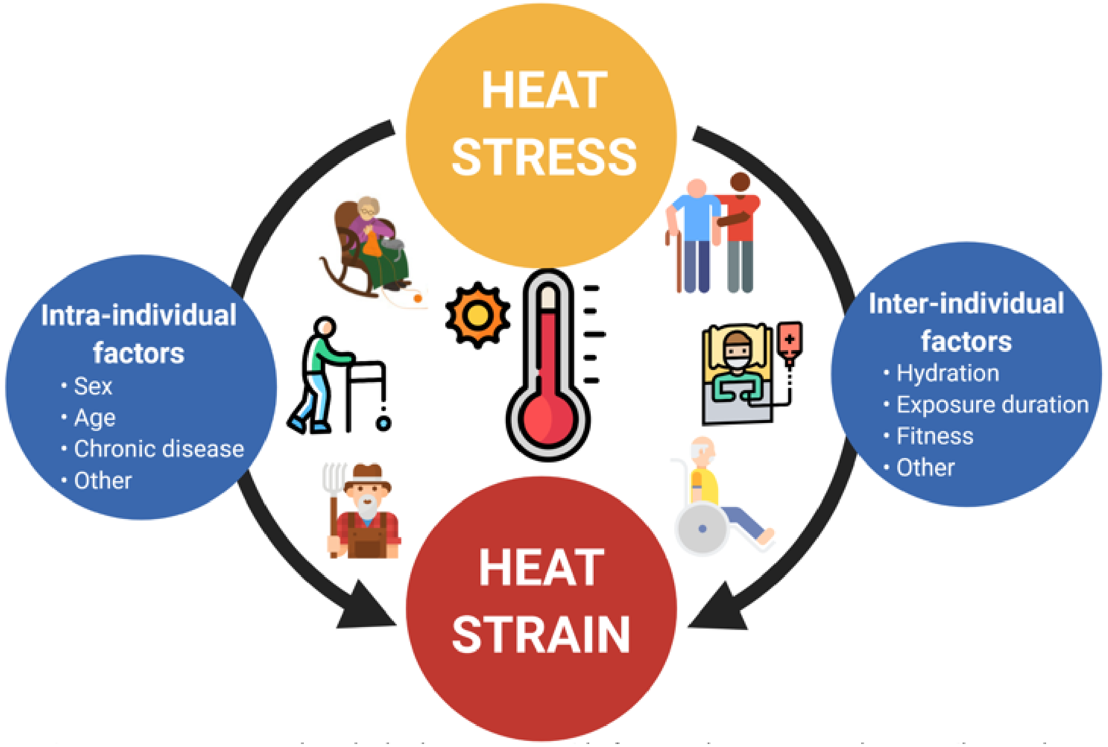
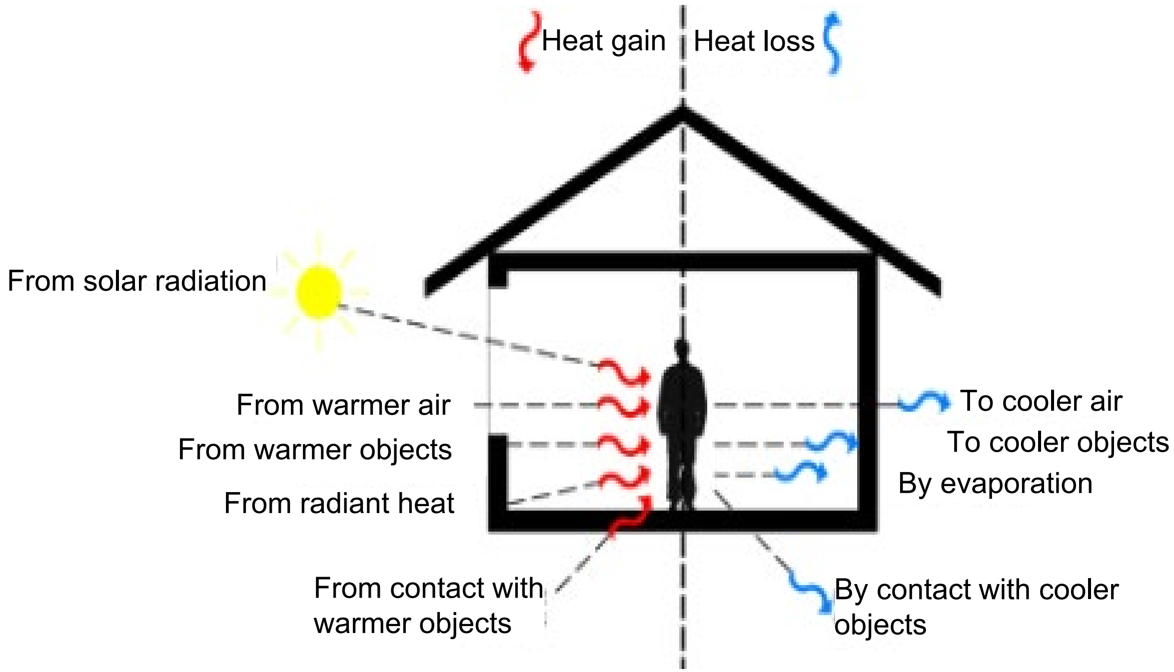
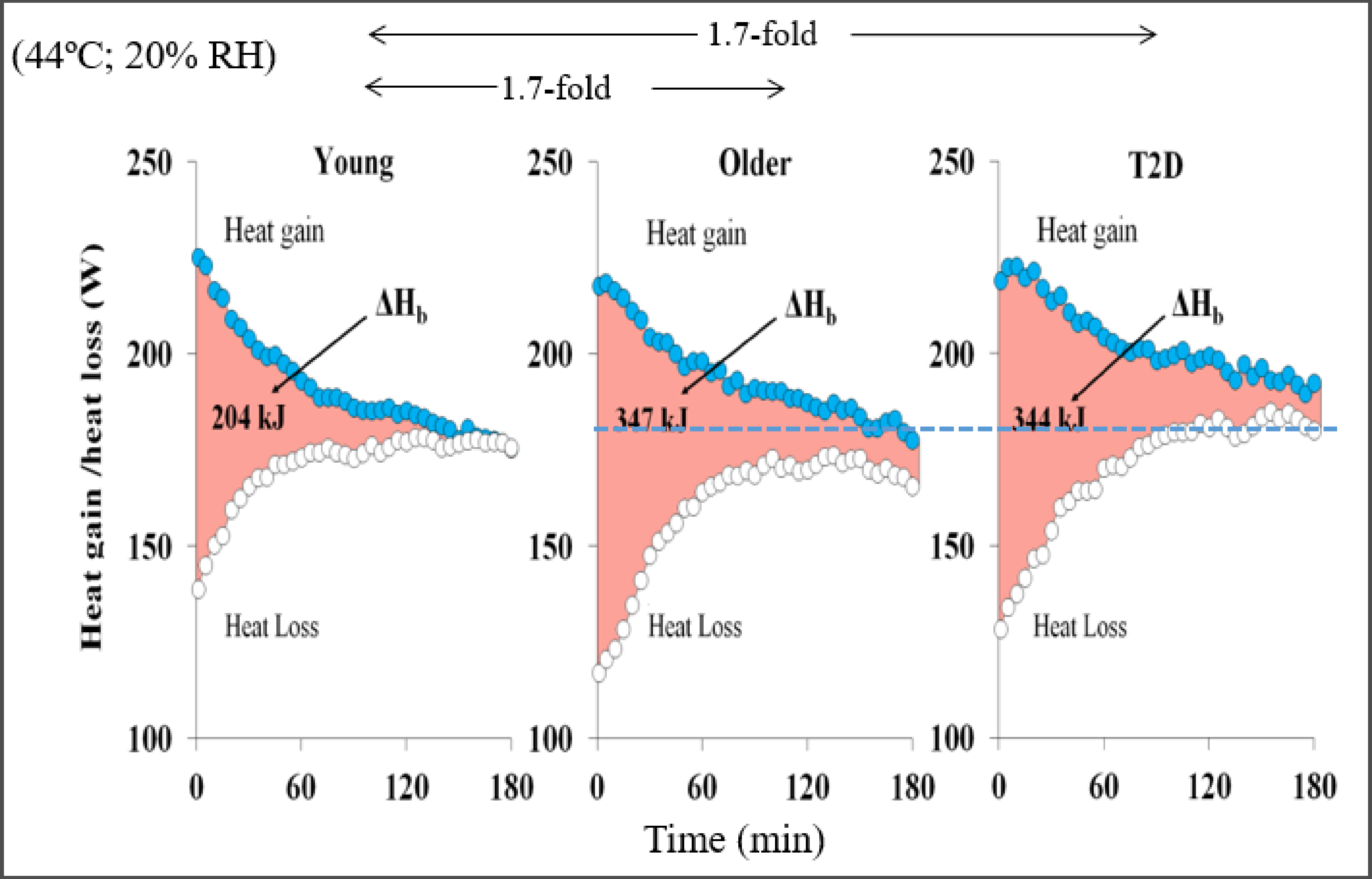
The human heat stress response - Heat strain is the overall physiological response resulting from exposure to a heat stress. Factors that contribute to heat stress are high air temperatures, radiant heat sources, high humidity, and physical activity. Elevated levels of heat strain can lead to heat-related injuries or death and occur when the body cannot get rid of excess heat.

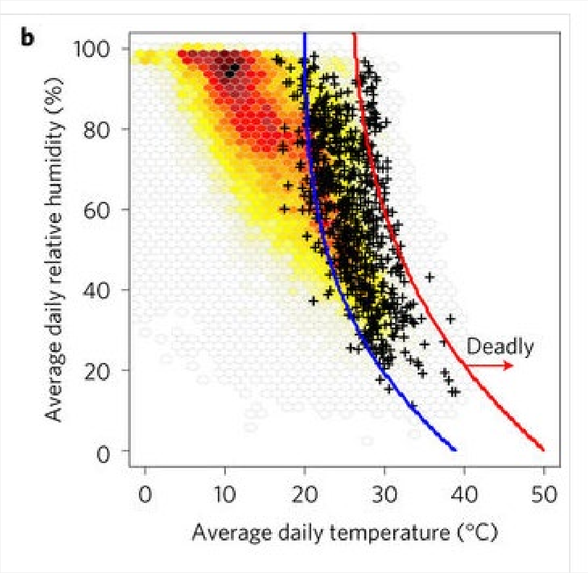


Individual factors will modulate a person's capacity to dissipate heat and therefore level of heat strain experienced during exposure to heat.

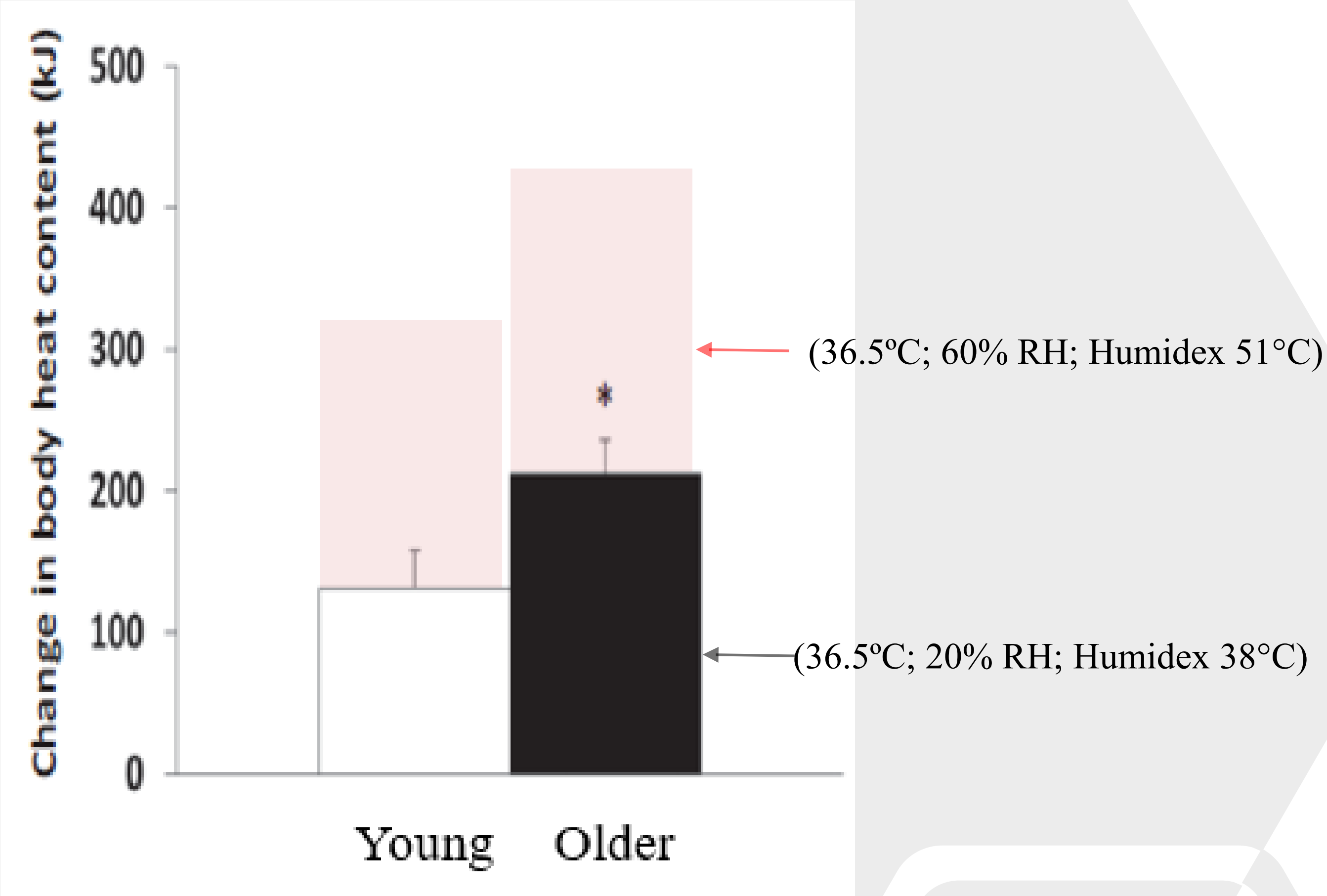


Whole-body heat exchange in vulnerable adults exposed to extreme heat

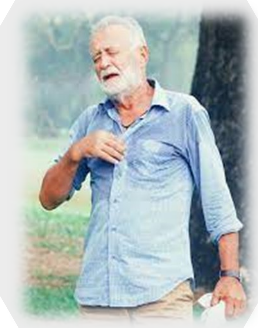

(44°C; 20% RH)
1.7-fold
1.7-fold
Young
Older
T2D
Heat gain
Heat Loss
ΔH$_b$
204 kJ
347 kJ
344 kJ
Heat gain /heat loss (W)
250
200
150
100
0
60
120
180
Time (min)



Nature Climate Change. 2017, 7:501-506.



Appl Physiol Nutr Metab. 2014, 39(3):292-8.



Estimating the level of heat exposure?

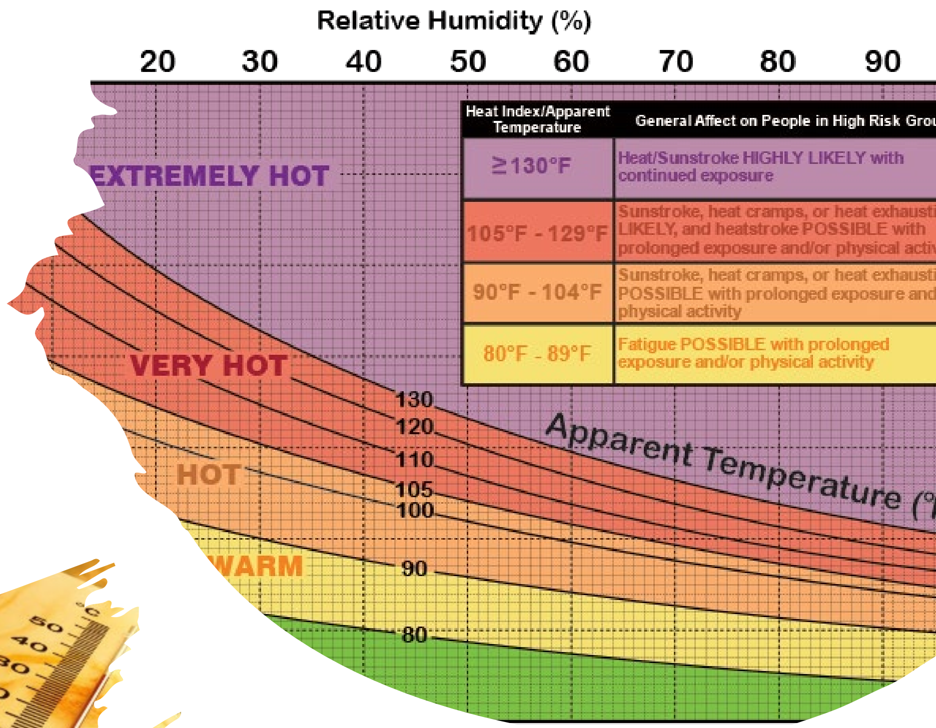
Complex methods developed to estimate heat exposure however no consensus on what measure of temperature is the best predictor of mortality.

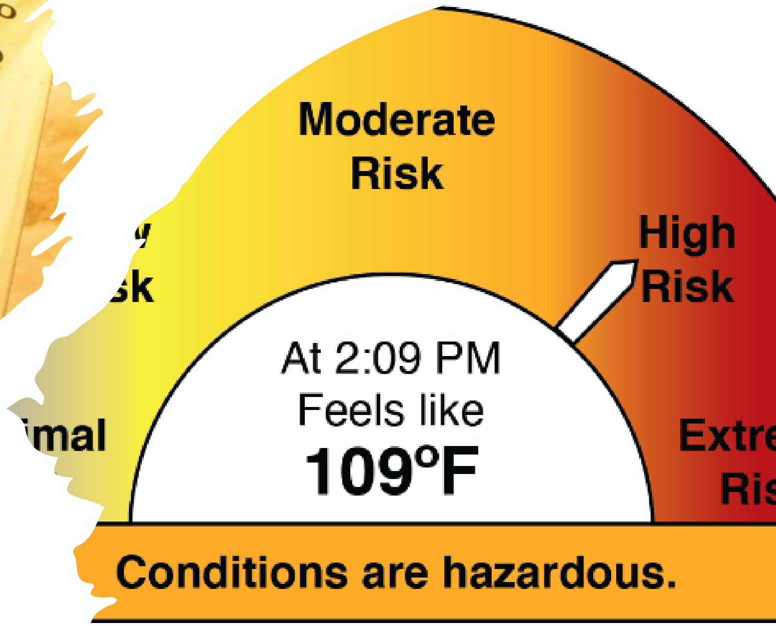
Maximum, minimum or mean temperature with and without humidity have typically been used as a simple and effective method to estimate the exposure. However, no temperature measure was consistently the best at predicting mortality in all age groups, seasons or region.

Environ Res. 2010;110(6):604

True exposure variability of the individual is underestimated when a central site monitor for the measurement of temperature is used to estimate personal exposure (e.g., airport temperature)

Crit Rev Toxicol. 2011;41:651





An over- or under-estimation of indoor temperature can lead to a ***misclassification of exposure that can have catastrophic consequences in vulnerable people***.

Table 10: Heat-related deaths by Max Outdoor Temperature on Day of Injury or Day Prior

Temperature (ºC)	Count	Percent
<30	63	10.2%
30-34	177	28.6%
35-39	207	33.4%
40+	172	17.8%
Total	619	

Report to the Chief Coroner of British Columbia, June 7 2022.

Of the 619 deaths attributed to the heat wave, **almost every death** — 98 per cent — occurred indoors. Further, fifty-six per cent of those who died lived alone.

CONSTRUCTION TYPE

brick vs vinyl siding,
single vs multi-level,
bungalow or semi-detached,
building size, other

TEMPERATURE CONTROL

availability of air conditioner,
mechanical ventilation (fan system),
open window, other

WINDOWS

number & size of windows,
fixed or operable windows,
number of panes, orientation
to sun, other

LOCATION

adjacent open space, distance
to surrounding homes, surrounded
by trees, next to road with high traffic, other

OCCUPANTS

number, type and location
of activities (e.g. live or sleep
on upper vs lower floors), others

Temperature (Austin), 2018; 6(11):11-36

Indoor temperatures during the summer in older homes

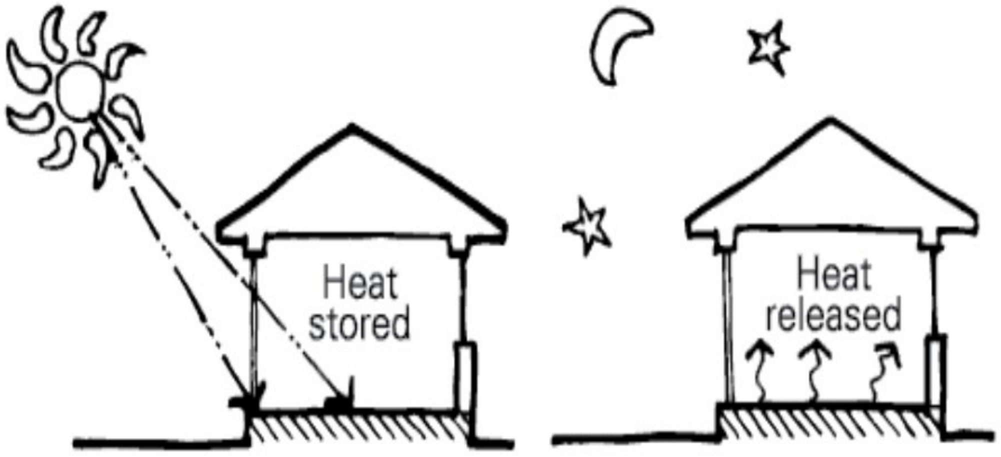
Housing characteristics and average and maximum indoor temperatures (°C) for locations monitored during the indoor heat study in Detroit, Michigan in Summer 2009. June 25, 2009 and August 8, 2009 were two of the hottest days during the summer.

Home	Start date[a]	Type[b]	Floor area sq. ft.[c]	Date built	# of floors	Exterior construction	Central AC	Room 1[d]	Room 2[d]	Prevailing surroundings[e]	6/25/2009 (max, mean)	8/9/2009 (max, mean)
1	1-Jun	Single family	950	1951	2	Brick	Yes	lr[f]	br	Residential	27.5, 26.2	25.5, 24.6
2	1-Jun	Single family	1488	1914	2	Brick	No	dr	br	Residential	31.3, 30.5	25.5, 24.6
3	1-Jun	Single family	2600	1929	3	Brick	Yes	dn	br	Residential	28.3, 27.6	24.7, 23.9
4	1-Jun	High rise	800	1987	14	Brick	Yes	br	lr[f]	Urban	30.3, 29.5	27.7, 26.9
5	1-Jun	High rise	800	1987	14	Brick	Yes	lr[f]	br	Urban	28.7, 28.0	27.9, 26.8
6	1-Jun	High rise	800	1987	14	Brick	Yes	lr[f]	br[f]	Urban	26.9, 24.8	26.1, 24.4
7	1-Jun	Single family	1348	1940	1	Brick	No	br	lr	Residential	31.5, 30.3	26.5, 25.7
8	1-Jun	Single family	692	1944	2	Asphalt	Yes	dn	dr	Residential	34.8, 33.2	29.9, 29.1
9	2-Jun	Two family flat	2400	1925	2	Brick	No	dr	br	Residential	28.9, 28.5	26.1, 25.3
10	2-Jun	Single family	798	1913	2	Asphalt	No	lr	br	Residential	30.5, 29.1	24.7, 23.8
11	4-Jun	Single family	1255	1931	2	Brick	No	dr	lr	Yard/Park	32.7, 30.7	27.1, 25.8
12	4-Jun	Single family	1819	1927	3	Brick	Yes	dn	br	Residential	31.1, 29.9	24.5, 23.7
13	4-Jun	Single family	1457	1923	3	Brick	No	dn	.	Residential	33.5, 32.3	29.1, 26.7
14	5-Jun	Single family	2692	1931	3	Brick	Yes	dn[f]	br	Residential	30.7, 29.8	24.9, 24.2
15	5-Jun	Two family flat	2226	1922	2	Brick	No	dr	br	Concrete	30.7, 30.0	25.7, 25.2
16	8-Jun	Two family flat	2650	1925	2	Brick	No	dr	lr	Concrete	29.1, 28.3	24.5, 23.3
17	11-Jun	High rise	800	1982	13	Brick	Yes	lr[f]	br[f]	Concrete	27.9, 25.5	25.5, 23.6
18	11-Jun	High rise	800	1980	13	Brick	Yes	lr[f]	br[f]	Concrete	31.5, 29.1	29.1, 28.5
19	11-Jun	High rise	737	1980	18	Brick	Yes	br	lr[f]	Yard/Park	29.7, 27.1	27.3, 27.13
20	16-Jun	Single family	829	1949	2	Brick	No	br	dn	Yard/Park	29.3, 28.7	25.3, 24.4
21	16-Jun	Single family	2371	1919	2	Brick	No	lr	br	Residential	30.9, 29.1	27.3, 26.1
22	16-Jun	Single family	1267	1938	2	Brick	No	br	dn	Yard/Park	30.1, 28.5	25.3, 24.4
23	22-Jun	Single family	535	1919	2	Wood siding	No	lr	dn	Yard/Park	30.7, 29.5	25.1, 24.3
24	24-Jun	Single family	1046	1980	1	Brick	Yes	dn	br	Yard/Park	32.7, 31.1	27.9, 26.0
25	24-Jun	High rise	737	1980	18	Brick	No	lr	br	Concrete	30.7, 29.4	25.7, 25.1
26	24-Jun	Single family	970	1962	1	Brick	Yes	den	br[f]	Residential	28.9, 26.1	27.5, 26.2
27	10-Jul	Single family	6746	1912	2	Brick	Yes	dr[f]	dn[f]	Yard/Park	–	26.7, 26.6
28	14-Jul	High rise	737	1980	18	Brick	Yes	lr[f]	br	Urban	–	27.1, 26.4
29	14-Jul	High rise	800	1987	13	Brick	Yes	lr[f]	br	Urban	–	27.1, 26.4
30	1-Aug	Single family	908	1953	1	Vinyl paneling	No	lr	br	Yard/Park	–	24.9, 23.7

Temperatures in homes (n=55 over 79 days) occupied by elderly individuals (> 65 years) were assessed in metropolitan Detroit, Michigan.

Mean outdoor temperature at the Detroit Metropolitan Airport was 21.0°C (7.2 to 34.3°C).

Across all homes, the highest daily temperature recorded ranged from 16.7 to 34.8°C with individual rooms for some dwellings reaching a maximum value of 35°C.



Environ Res. 2012; 112:20-27

Indoor temperature is dependent on the timing and duration of the heat event.

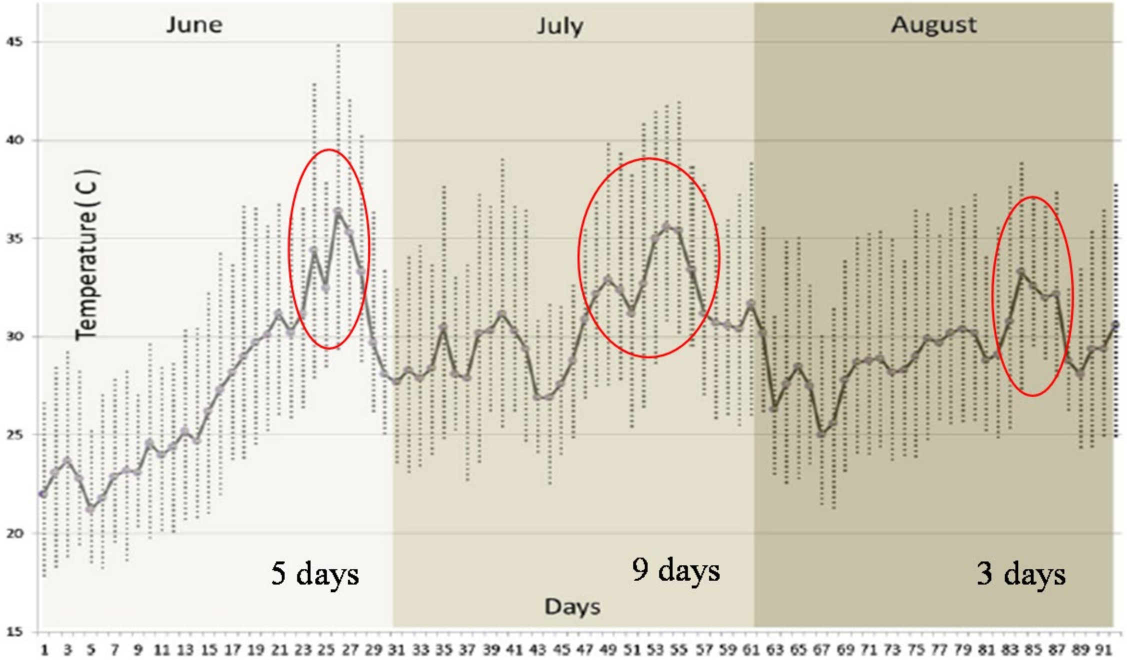


Fig. 1. Daily average, maximum and minimum ambient temperatures for June, July and August of 2007 in Athens.

Table 1
Average, maximum and minimum indoor and outdoor temperatures during the heat waves of June, July and August 2007.

	Indoor			Outdoor		
	June	July	August	June	July	August
Average *T*	31.5	31.7	31.3	34.3	33.3	32.3
Average Max *T*	34.1	35.2	34.7	41.5	39.9	37.8
Average Min *T*	29.1	29.3	29.6	27.9	25.2	24.8
Absolute Max *T*	43.8	39.5	44.0	44.8	41.9	38.8

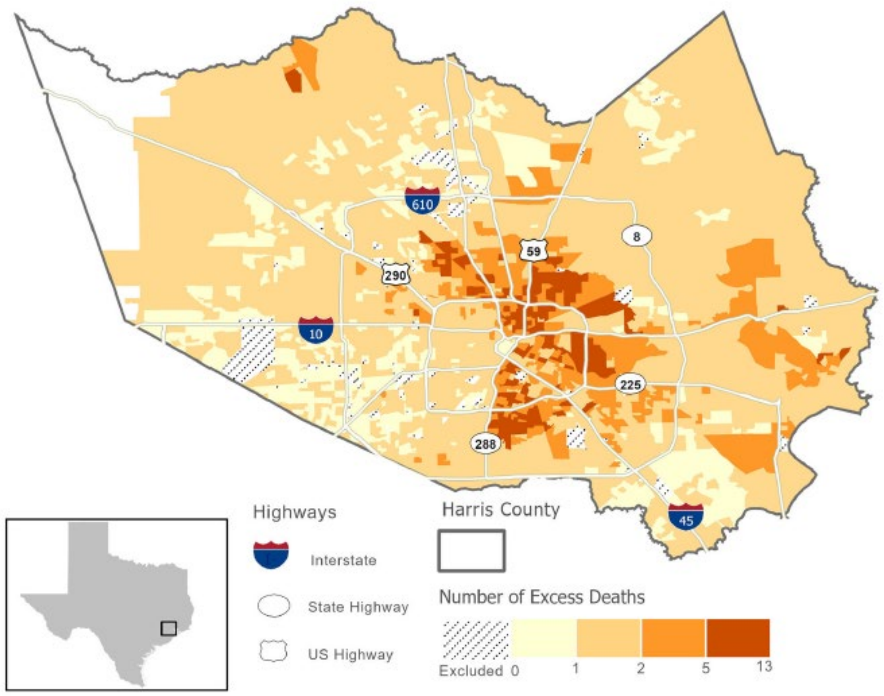
Energy Build. 2012;(49):69–77.

Despite the role indoor exposure plays in heat-related mortality, few epidemiological studies have examined the health effects of exposure to indoor heat.

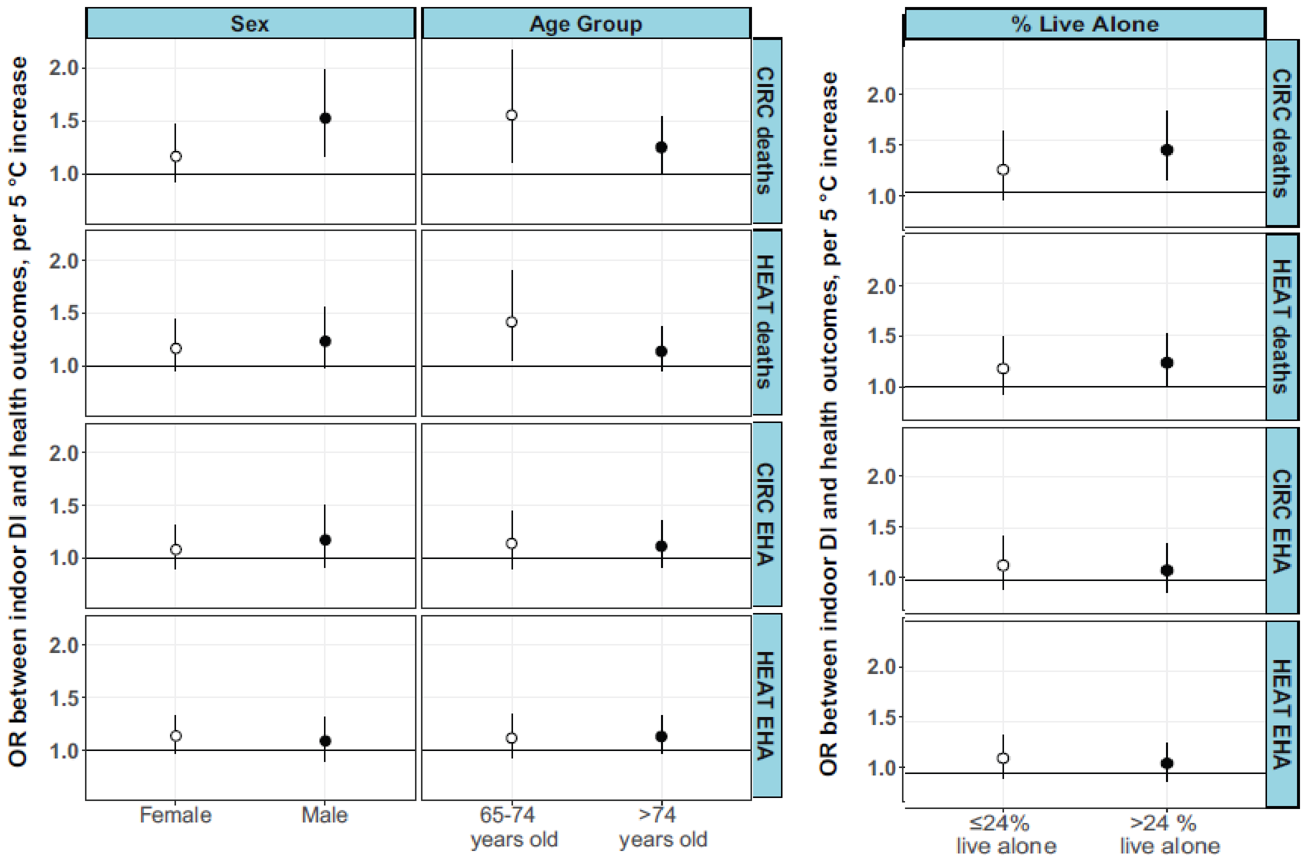
As a result, knowledge gaps regarding indoor heat–health thresholds, vulnerability, and adaptive capacity persist.

Analysis of Indoor Heat Exposure on Mortality and Hospitalizations among the Elde

Discomfort index (DI) is the average of dry-bulb and wet-bulb temperature ; DI = 0.5 × (Tdb +Twb)



Environ Health Pers 2020;128(12):127007



CIRC: circulatory diagnoses; DI: discomfort index; EHA: emergency hospital admissions; HEAT: heat-related diagnoses; OR: odds ratio.

What is a safe indoor temperature limit to safeguard the health and well-being of vulnerable individuals during an extreme heat event?

Indoor temperature threshold of 26°C - What is the evidence?

CANADA
Lytton, BC
49.6°C
29 June 2021

Toronto Public Health: maximum indoor temperatures for multi-unit residential building of 26°C.

- [1]Daily mortality increased by up to ~3% with a 5°C increase in daily mean temperature across cities in Ontario.
- Median ambient temperature for the warm-temperature months in Toronto is ~21°C → maintaining indoor temperature limit of 26°C would reduce risk of heat-related mortality.
- National Health Services in the UK recommends indoor temperatures should not exceed 26°C. Specifically recommended for rooms or areas (cool zones) where people in long-term care, nursing and residential facilities can relocate during heat waves.
- New York City's Office of Emergency Management recommends that at-risk individuals visit a cooling center or use air conditioning set at 78°F (~25.5°C). Recommendation is in part defined by the need to lessen the strain on the energy grid while providing an environment that is protective to health.

[1]*CMAJ Open.* 2016;4(1):E48-58

Characterize the human heat stress response to different indoor temperatures.

22°C, to simulate an air-conditioned environment (**COOL**; humidex: 23°C);

26°C, corresponding to recommended upper limits for indoor environments as set by Toronto Public Health (**TEMP**; 29°C);

31°C, similar to average daytime summer temperatures in Ontario and Quebec and slightly below World Health Organization recommended day-time indoor temperature limit during heat events (**WARM**, humidex: 37°C); and

36°C, based on maximal indoor temperatures measured during extreme heat events in a temperate continental climate (**HOT**, humidex: 45°C).

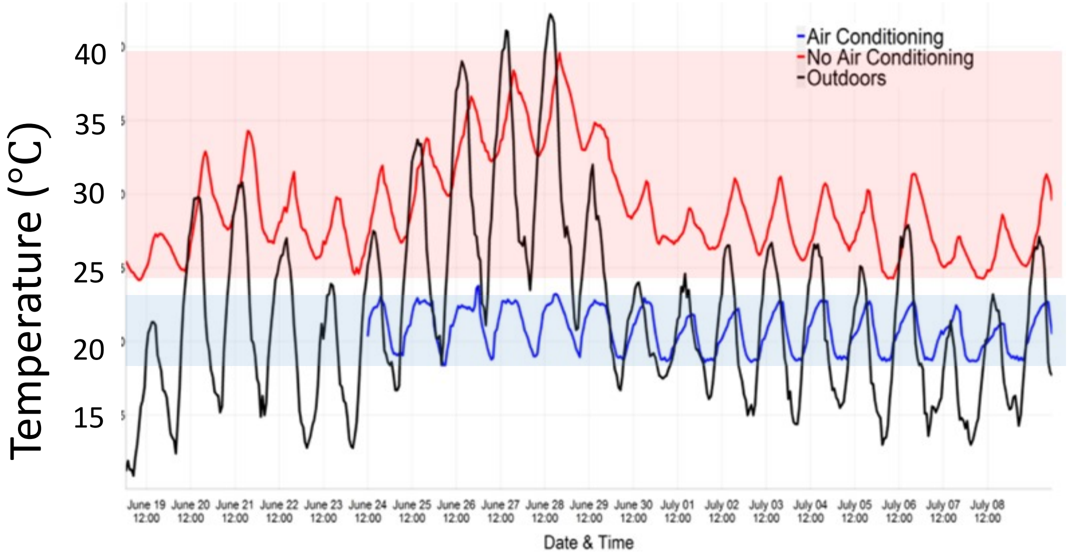


Figure. Hourly temperature measurements during the 2021 heat dome in greater Vancouver. Outdoor measurements (black line) were taken from the weather station at Abbotsford International Airport. Indoor measurements (blue and red lines) were accessed through the ecobee Donate Your data program.

Environmental Epidemiology, 2022, 6:e189; Report to the Chief Coroner of British Columbia, June 7 2022.

Question: Will an elevation in body temperature and resting cardiovascular responses only occur above an indoor temperature thresholds of 26°C?

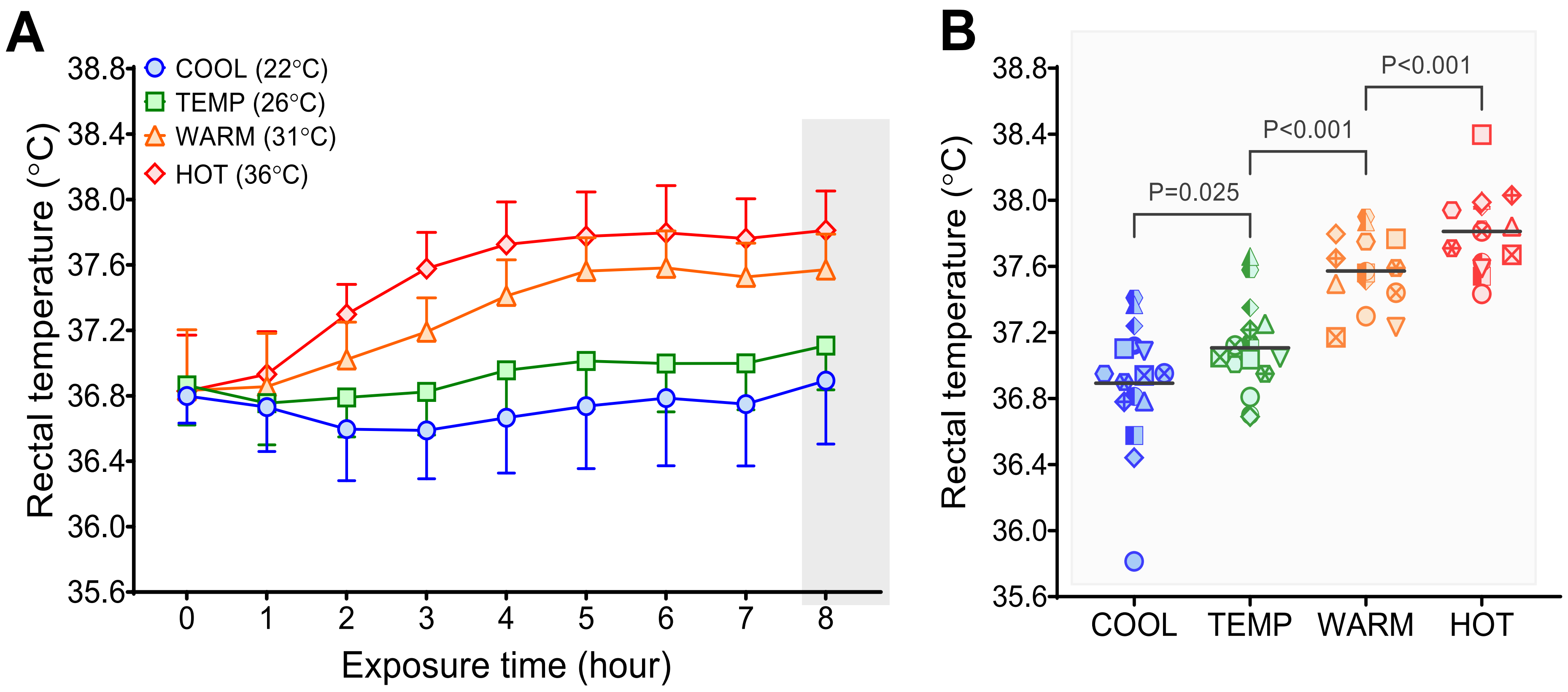


Figure 1. Time-dependent responses of rectal (panel A) in the older adults (n=16) over the 8-hour exposure in COOL (22°C), TEMP (26°C), WARM (31°C) and HOT (36°C) conditions (relative humidity of 45% in each; humidex equivalent, cool: 23°C, temp: 29°C, warm: 37°C and hot: 45°C). Individual data at the end of each exposure are presented in panel B. Data reported as mean ± SD and individual points. P-values indicate the output of post-hoc comparisons between model estimated marginal means (adjusted for baseline values) of adjacent conditions (following detection of a significant effect of condition).

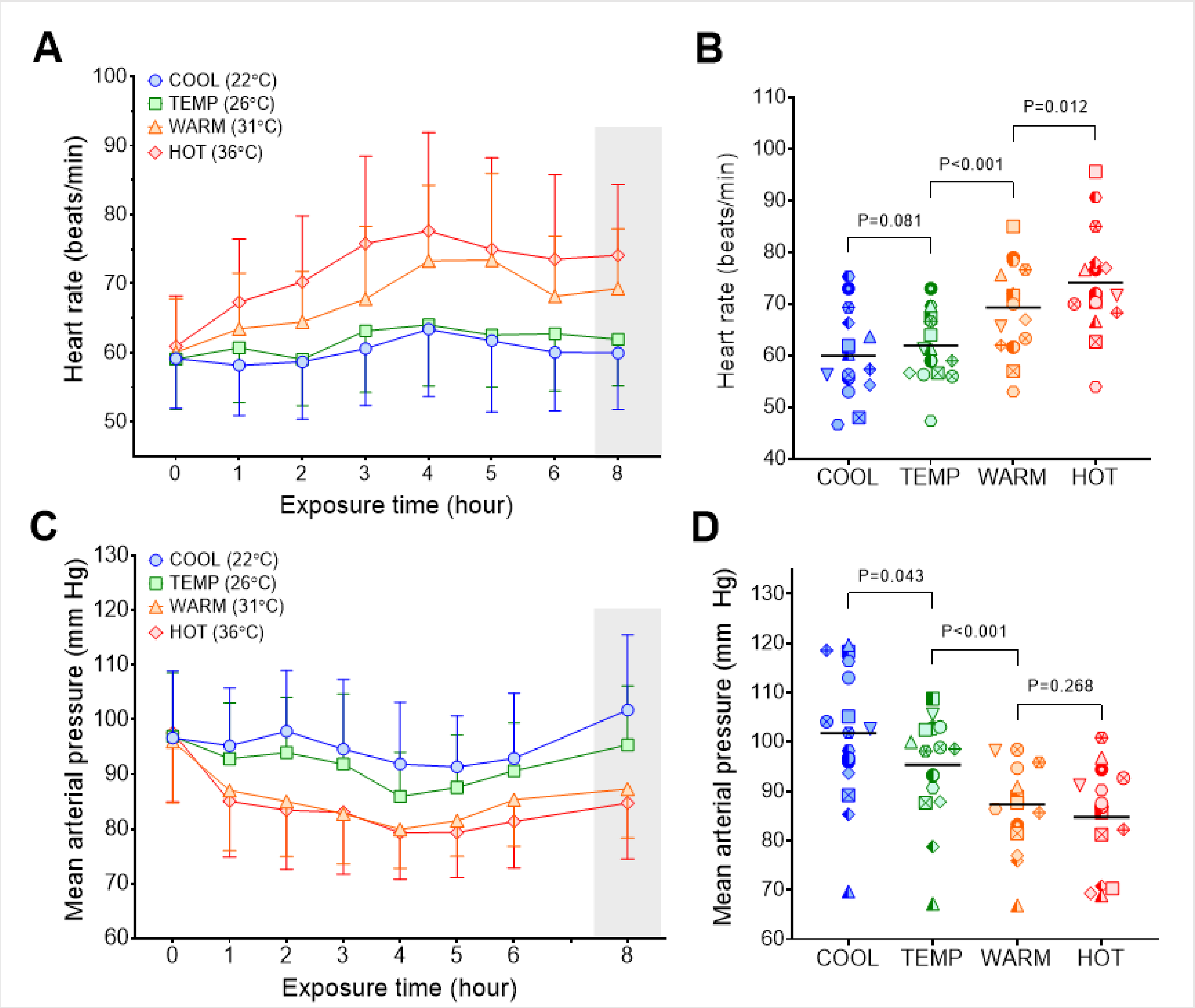


Figure. Heart rate (panel A) and mean arterial pressure (panel C) in the older adults (n=16) over the 8-hour exposure for each condition. Individual data at the end of each exposure are presented in panels B, and D. P-values indicate output of post-hoc comparisons between model estimated marginal means (adjusted for baseline values) of adjacent conditions (following detection of a significant condition effect).

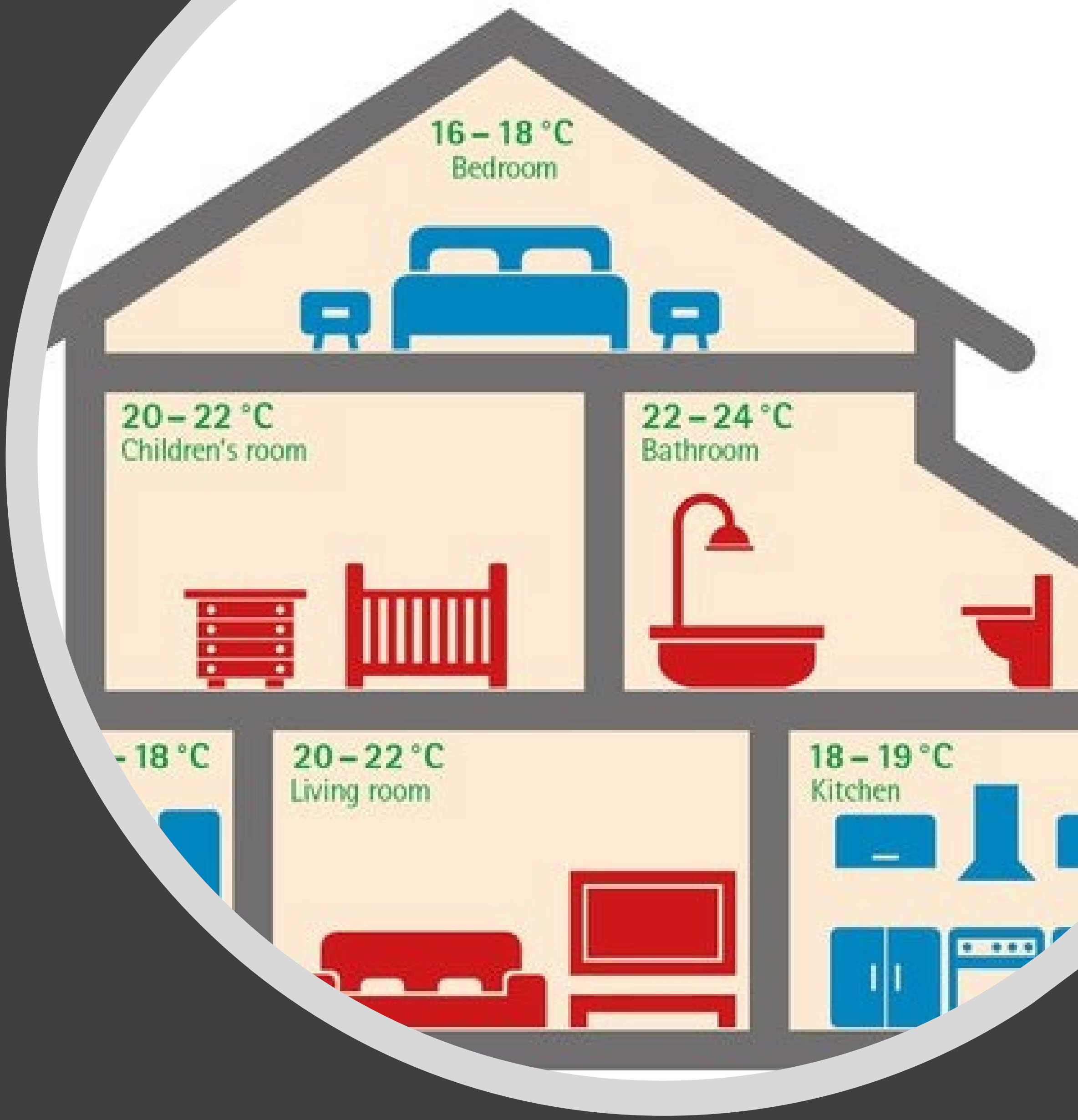
The marked reductions in cardiovascular function that occur in older adults during a prolonged heat exposure must be considered when assessing impact of heat on health and well-being.

Key take-home message:

A single-day exposure to temperatures ≤26°C will likely not create an undue physiological strain in older adults.

Sustained exposure to temperatures greater than 26°C but less than 31°C may pose a risk to health in some adults, whereas sustained exposure to temperatures ≥31°C should be avoided for heat-susceptible populations whenever possible.

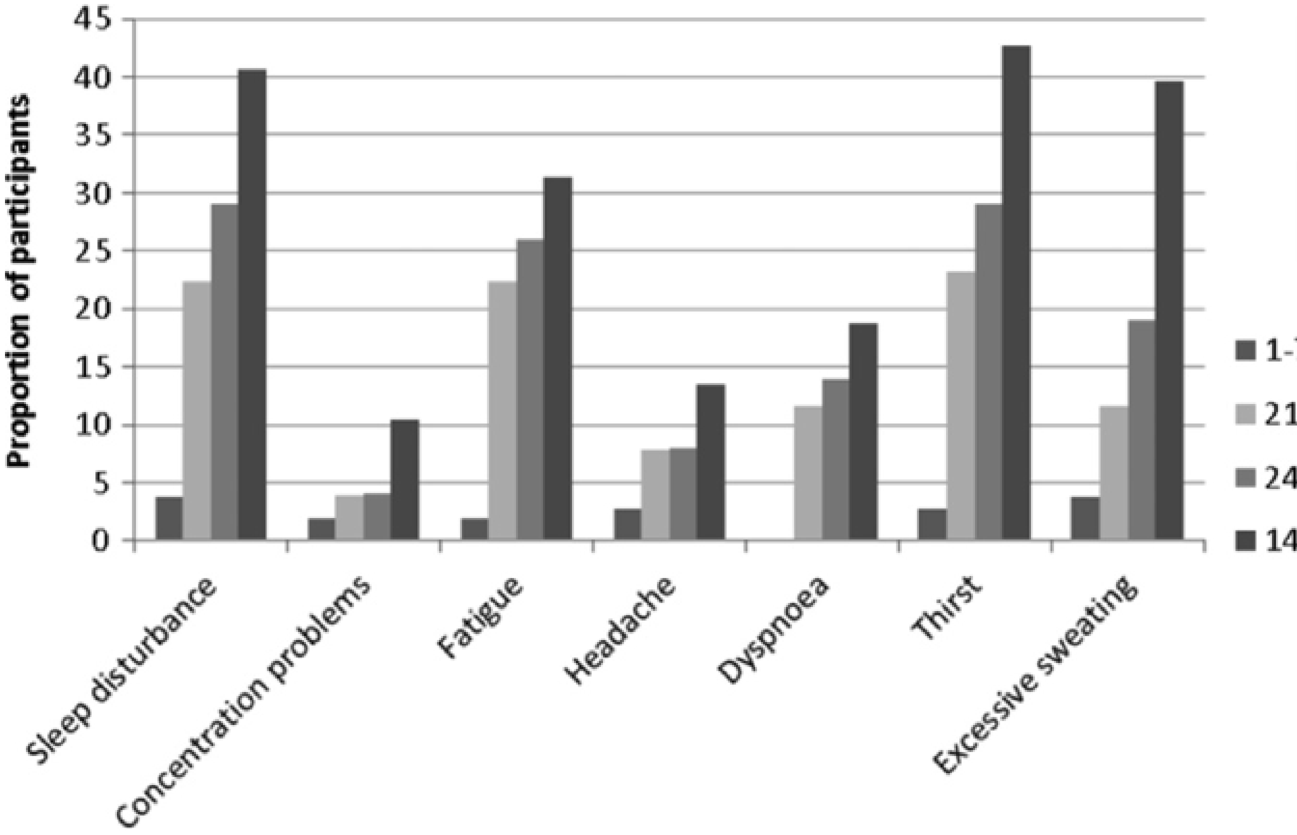
To inform the creation of more encompassing guidelines, it is important that future work explore the consequences of these findings on health and well-being over successive days especially in individuals with poor health.

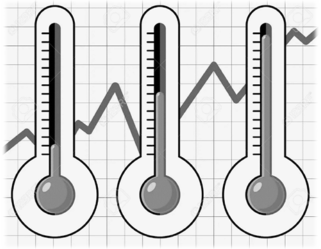


Changes in indoor temperature over the spring and summer period – impact on health and well-being

Mean (minimum–maximum) of weekly average temperatures for each study period (outdoor, living room, bedroom) and the proportion of study participants that perceived their indoor climate (living room, bedroom) as too warm.

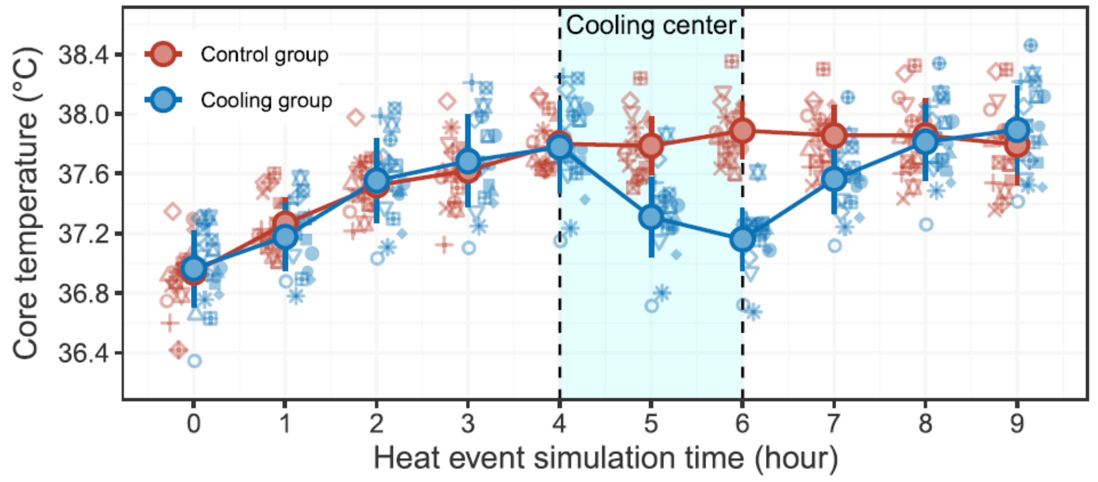
	Mean temperature[a] (Min–Max) °C			Climate perceived as too warm[b] %	
	Outdoor[c] N=77	Living room N=113	Bedroom N=113	Living room N=113	Bedroom N=113
1–7 May[d]	11.9 (10.9–12.9)	20.9 (17.5–26.6)	19.3 (15.7–25.5)	1.9	2.9
21–27 May	21.5 (20.3–22.9)	24.0 (19.9–28.8)	23.6 (19.7–27.9)	28.3	29.2
24–30 July	20.4 (19.0–22.4)	24.2 (21.0–29.1)	23.8 (20.1–28.2)	36.0	33.0
14–20 August	23.6 (22.7–24.7)	25.4 (22.3–30.2)	25.1 (20.8–29.3)	55.3	50.0

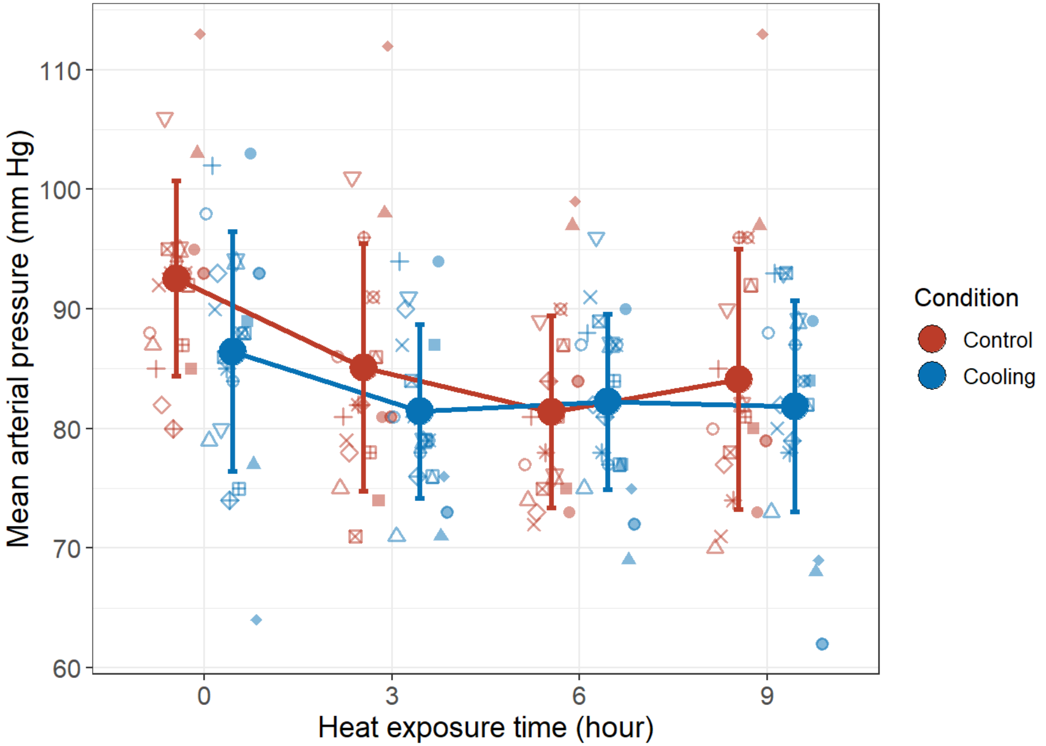




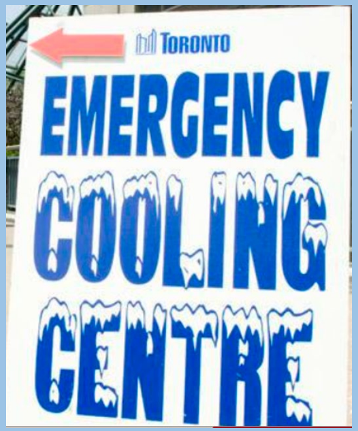
Environ Res. 2016;146:27-34

Daylong exposure to extreme heat (40°C)

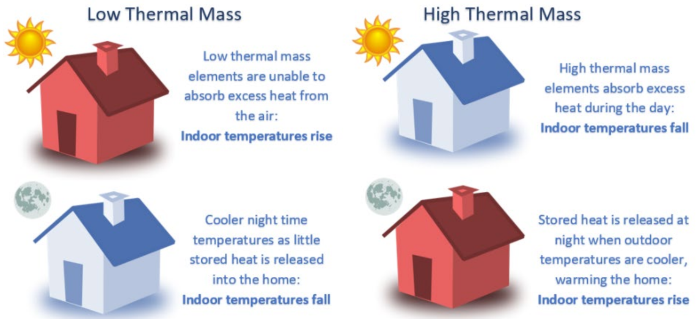


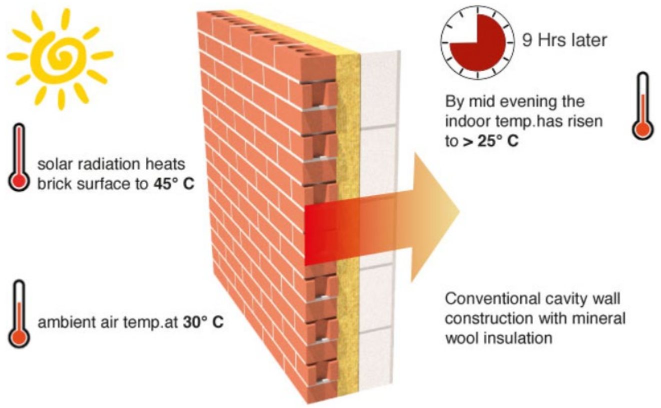


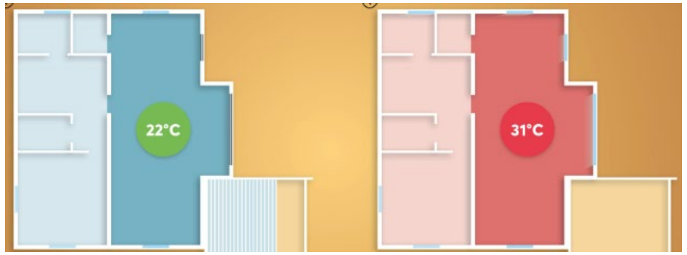
While brief air conditioning exposure is effective for reducing the physiological burden of extreme heat, the benefits are short-lived.

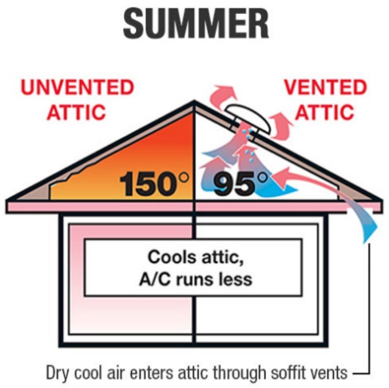


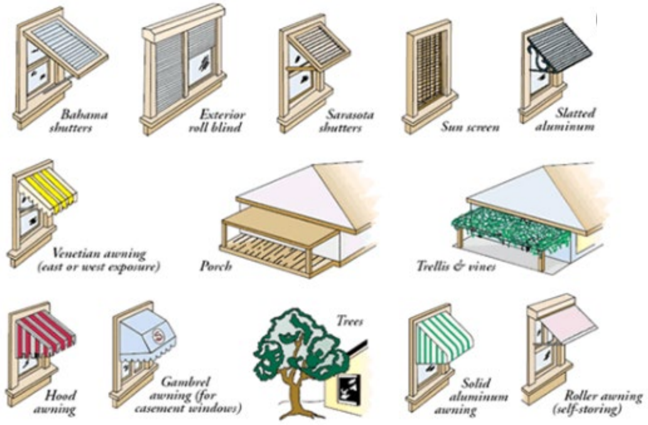
Options to Reduce Overheating in Your Home – preparing for the next extreme heat event











Heat Reduction Actions

Immediate	Check that all windows that can be opened are functional to permit airflow. This includes the ability to open windows on opposite sides of the house to create a draft (cross ventilation) during cooler nighttime periods. For personal safety, avoid leaving your window opened for extended periods, especially at night.
Short Term	If possible, create a temporary summer living space in a cooler area such as the lowest level of the house (e.g., basement). If you don't have a thermostat or direct access to a thermostat for your home, consider installing a temperature and humidity monitoring unit to track overheating in your home. Purchase a pedestal fan or portable air conditioning unit to enhance air circulation in your home.
Moderate	Consider permanent internal (e.g. blinds, drapes) or external (e.g. awnings, shutters, canopies) shading solutions to block the sun. Install a ceiling fan in your primary living spaces. Remove or relocate any reflective material (e.g., metal sheds) and glass barriers (e.g., outdoor greenhouses) around your home that can absorb and reflect the sunlight. If you have an attic, make sure it is properly insulated and ventilated so that excess heat can escape. Keep your yard as green as possible (e.g., grass, bushes and trees), as large asphalt, concrete or paved driveways can absorb and radiate more heat.
Long Term	Plant trees in areas that would provide the most coverage to the primary living space of your home. If you have many and/or large windows, consider solar control coatings to reduce the amount of solar radiation that can enter your living space. Install a central air conditioner if you have existing ductwork or consider a ductless wall-mounted air conditioner. If it is time to change your shingles consider a light-coloured roof as it can reduce the amount of heat absorbed by your home. Replace single-paned windows with more energy-efficient double or triple-paned windows. Install external solar control coatings to reduce heat gain from the sun. Renovate your basement to create a permanent bedroom and living space in this cooler area of your home.

Together….Creating Heat-Resilient Communities

Health Canada Santé Canada

We would like to thank the many volunteers who have participated in our studies.

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Any
Questions