Establishing Evidence-Based Guidelines on Maximum Indoor Temperatures

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Disclosure Statement

I have no affiliation (financial or otherwise) with a pharmaceutical, medical device or communications organization.

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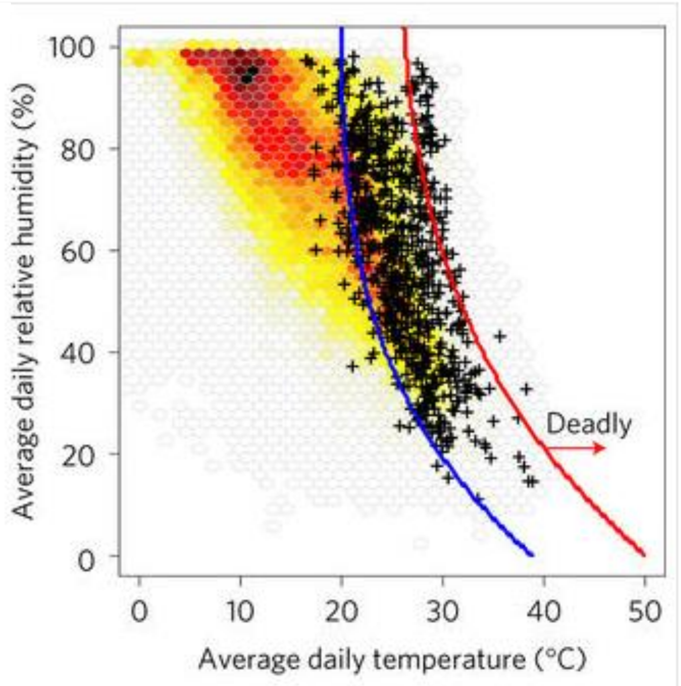
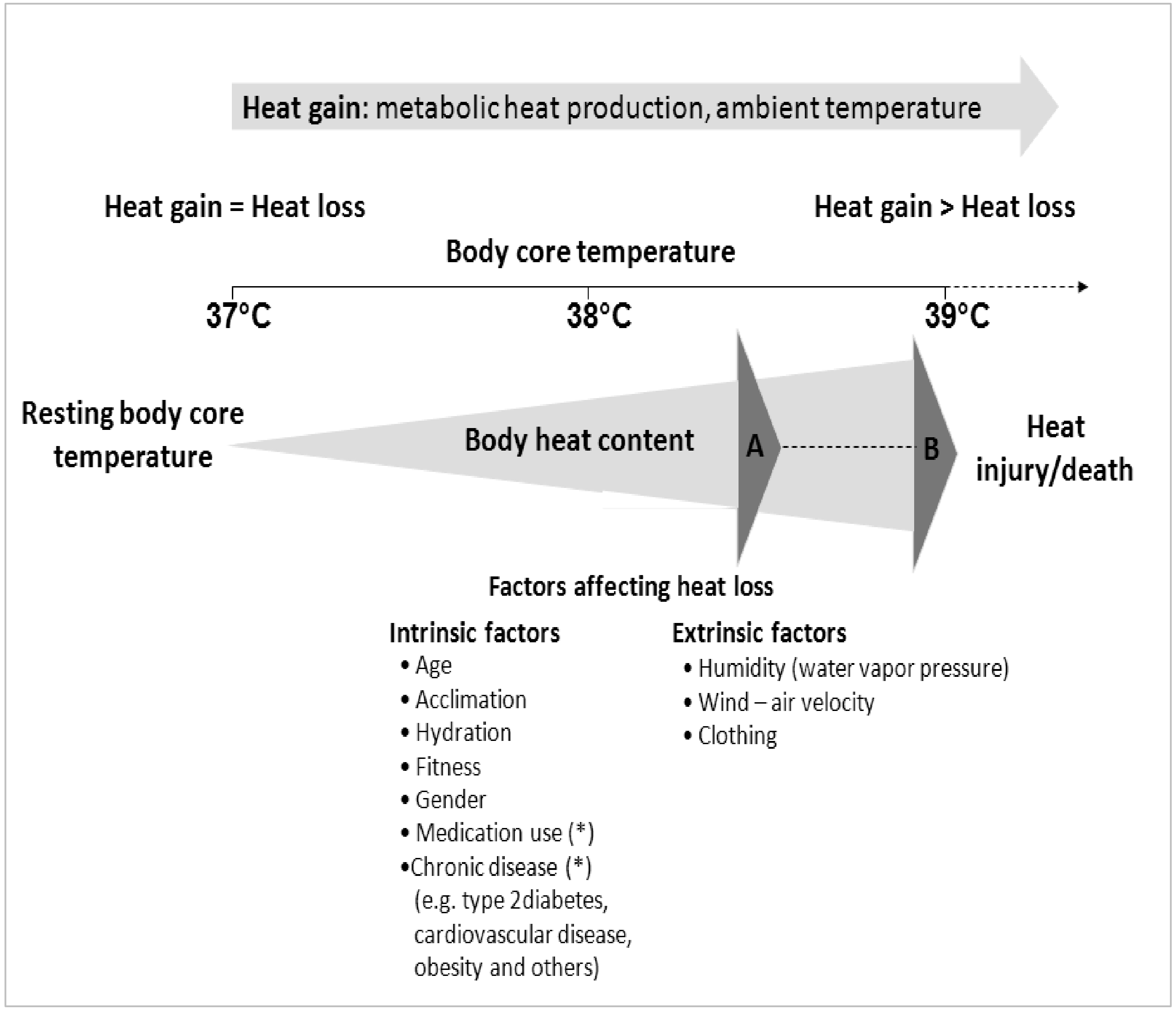
nature climate change

Climate change is considered one of the greatest threats to human health of our time.

Nature Climate Change 7: 501-506, 2017

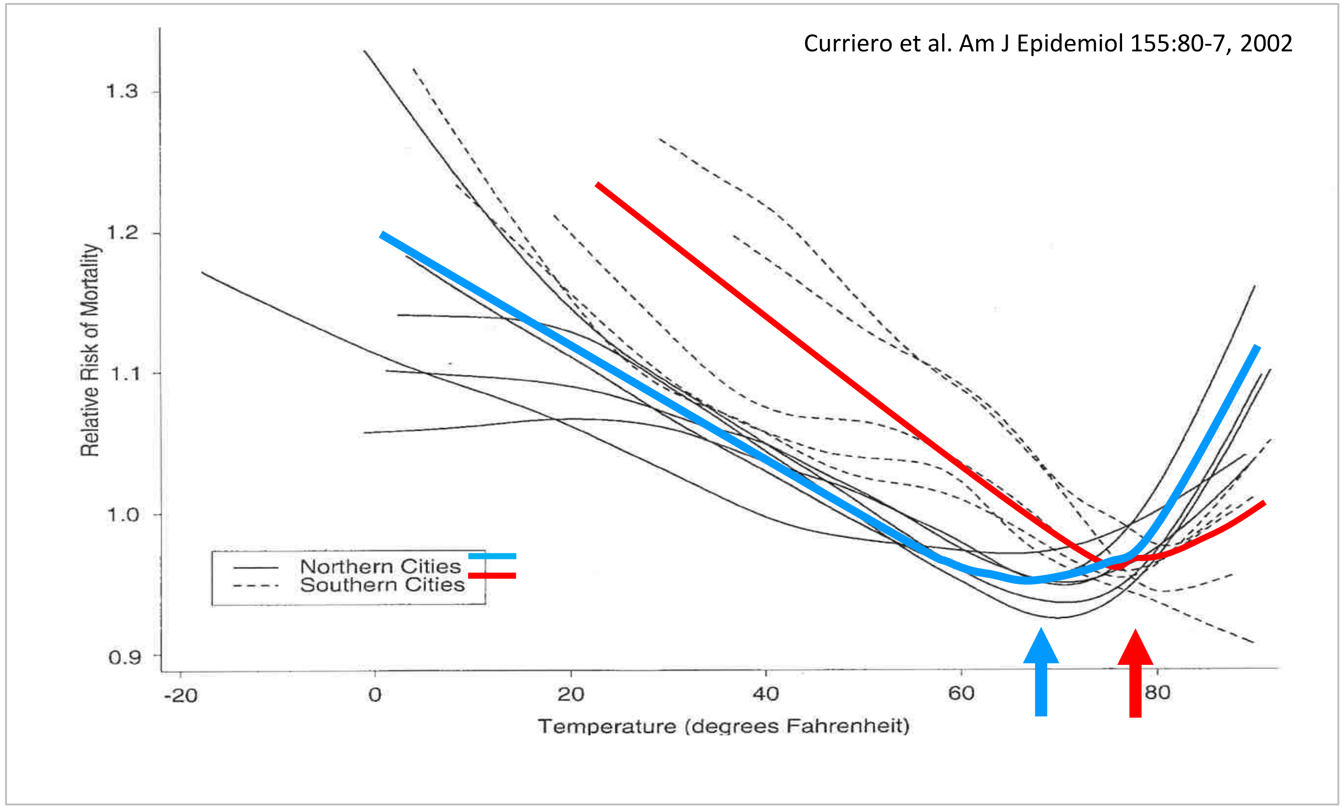
When people are exposed to heat, especially when temperature remains atypically high for several days, they can suffer from potentially deadly illnesses such as heat exhaustion and heat stroke quickly and unexpectedly.





Relationship between outdoor temperature and human health

Assessment of the thermal environment on temperature-attributable mortality serves as a valuable tool to assess the acute health effects of heat exposure that fluctuate over time.



Extrinsic (e.g. geographical location, climate type, seasonal influences, etc.) and ***intrinsic*** (e.g. gender, age, state of health, level of heat adaptation, fitness, behavioral responses, etc.) factors can affect this relationship.

What is the best variable to measure?

Simple (e.g., maximum, minimum or mean temperature, apparent temperature, the humidex and others) to complex methods developed to estimate heat exposure.

- ✓ no consensus on what measure of temperature is the best predictor of mortality across age groups, seasons or region. (Barnett, *Environ Res*. 2010;110(6):604).

What is the best temperature to measure?

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) (Rhomberg, *Crit Rev Toxicol*. 2011;41:651).

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

Indoor temperature and health in the elderly over the summer period

		Mean temperature[a] (Min–Max) °C		
		Outdoor[c] $N=77$	Living room $N=113$	Bedroom $N=113$
Early spring	1–7 May[d]	11.9 (10.9–12.9)	20.9 (17.5–26.6)	19.3 (15.7–25.5)
	21–27 May	21.5 (20.3–22.9)	24.0 (19.9–28.8)	23.6 (19.7–27.9)
	24–30 July	20.4 (19.0–22.4)	24.2 (21.0–29.1)	23.8 (20.1–28.2)
Late summer	14–20 August	23.6 (22.7–24.7)	25.4 (22.3–30.2)	25.1 (20.8–29.3)

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 – the Netherlands = April to August 2012

		Climate perceived as too warm[b] %	
		Living room $N=113$	Bedroom $N=113$
Early spring	1–7 May[d]	1.9	2.9
	21–27 May	28.3	29.2
	24–30 July	36.0	33.0
Late summer	14–20 August	55.3	50.0

(van Loenhout et al. Environ Res. 2016;146:27-34)

During the warmest week of the study period (August 14th to 20th), air temperature (mean temperature: 23.6ºC) was approximately 5ºC above normal conditions with the majority of the residents (n=113) reporting indoor ambient conditions as excessively warm.

(van Loenhout et al. Environ Res. 2016;146:27-34)

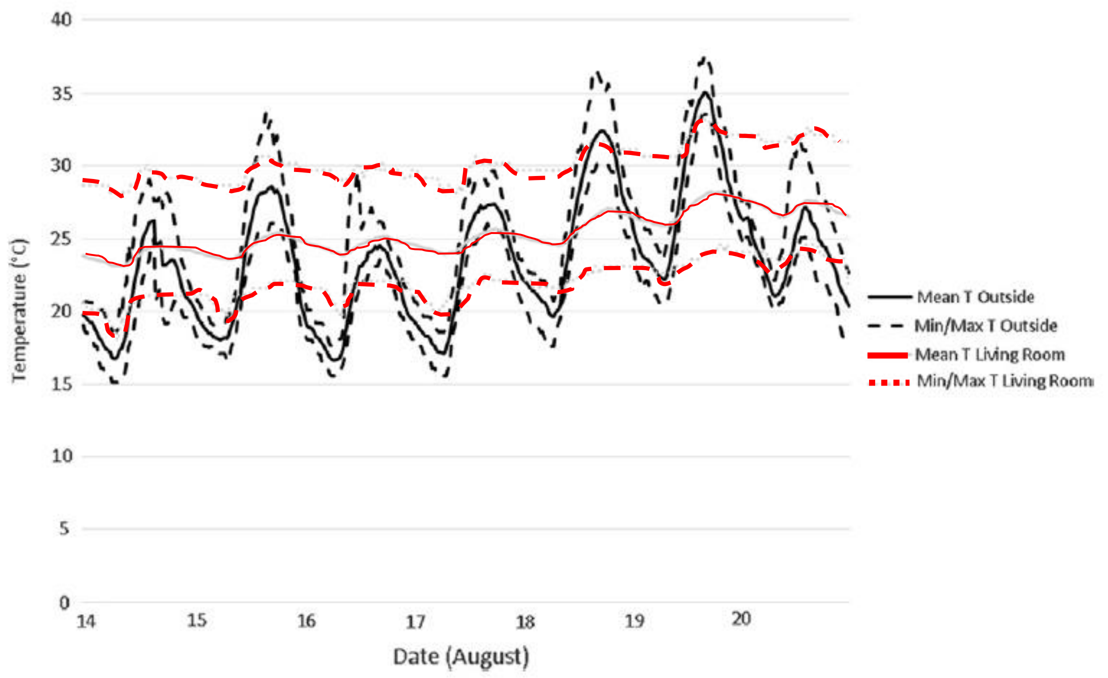


Fig. 1. Mean, minimum and maximum temperature fluctuation between 14 and 20 August 2012 (*N*=113 for living room temperature and *N*=77 for outdoor temperature).

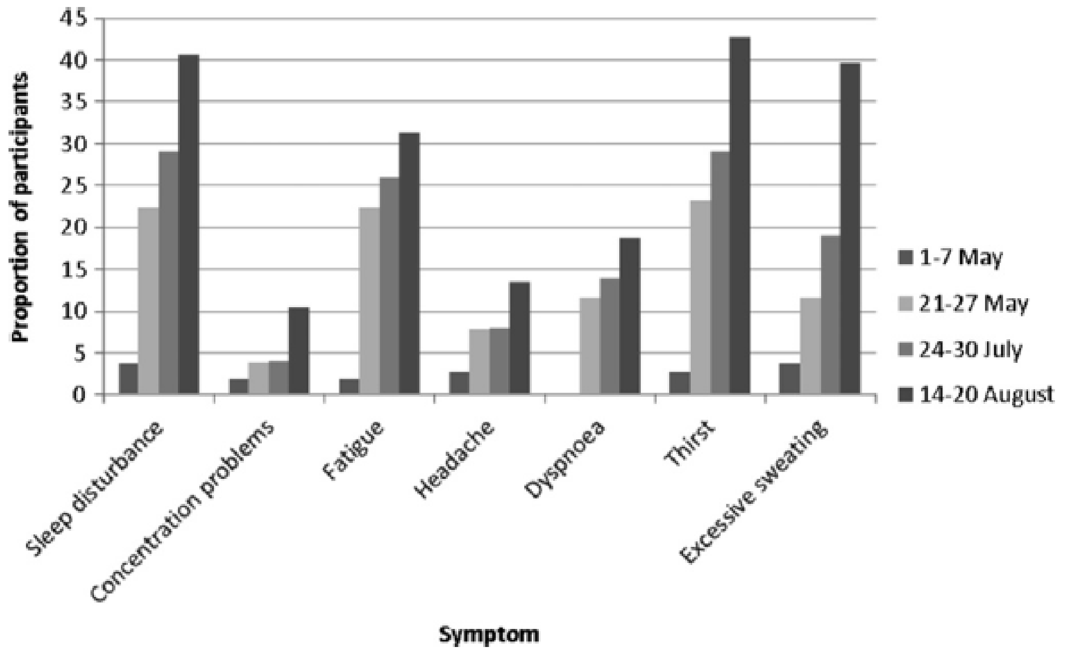


Fig. 2. Proportion of study participants who experienced a certain symptom at some point during each of the study periods.

- many reported symptoms of thirst (43%) and excessive sweating (40%) as well as sleep disturbances (41%).
- *increase in 1ºC of indoor temperature, annoyance due to heat and sleep disturbance increased by 33% and 24% respectively.*

Indoor temperature variations

Heat vulnerable adults not uniformly exposed to the same indoor heat conditions during summer period

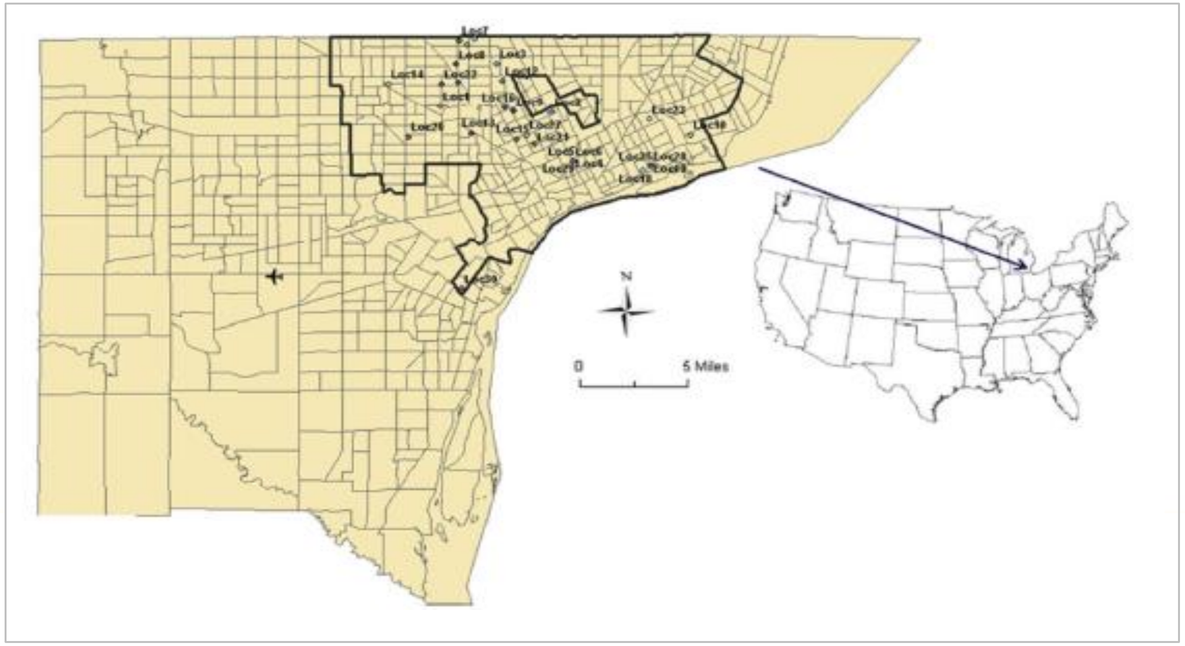
Temperatures in 55 homes (over 79 days) occupied by elderly individuals (>65 years) in Detroit, Michigan, USA.

- ✓ 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; individual rooms for some dwellings reached max of 35ºC.

Dwelling type:

- ✓ Non-high rise dwelling, and in particular, older houses constructed of vinyl paneling or wood siding demonstrated the greatest indoor temperatures whereas houses constructed of brick were more heat resilient.

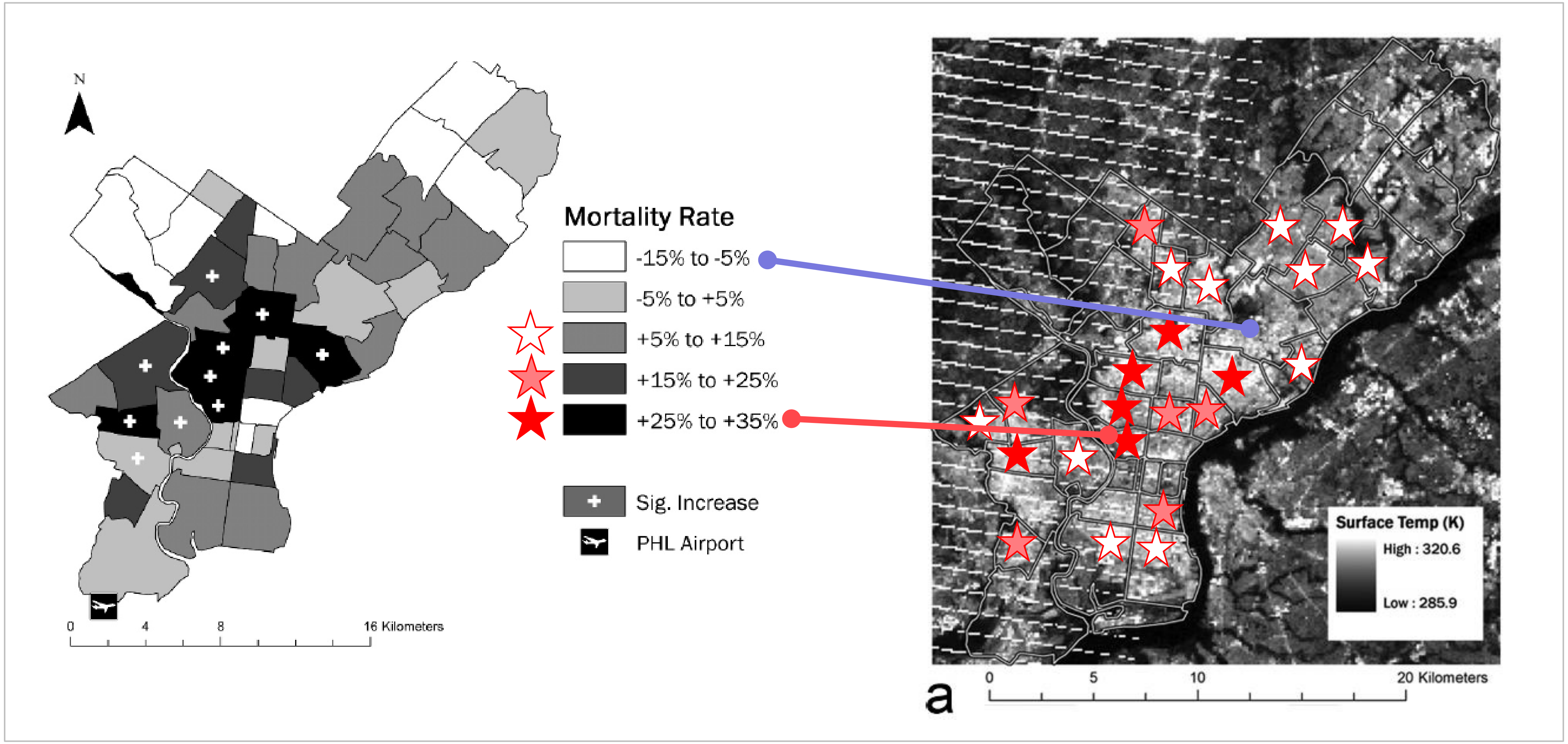
(White-Newsome et al. Environ Res. 2012; 112:20-27)



Indoor temperature and health in the elderly over the summer period

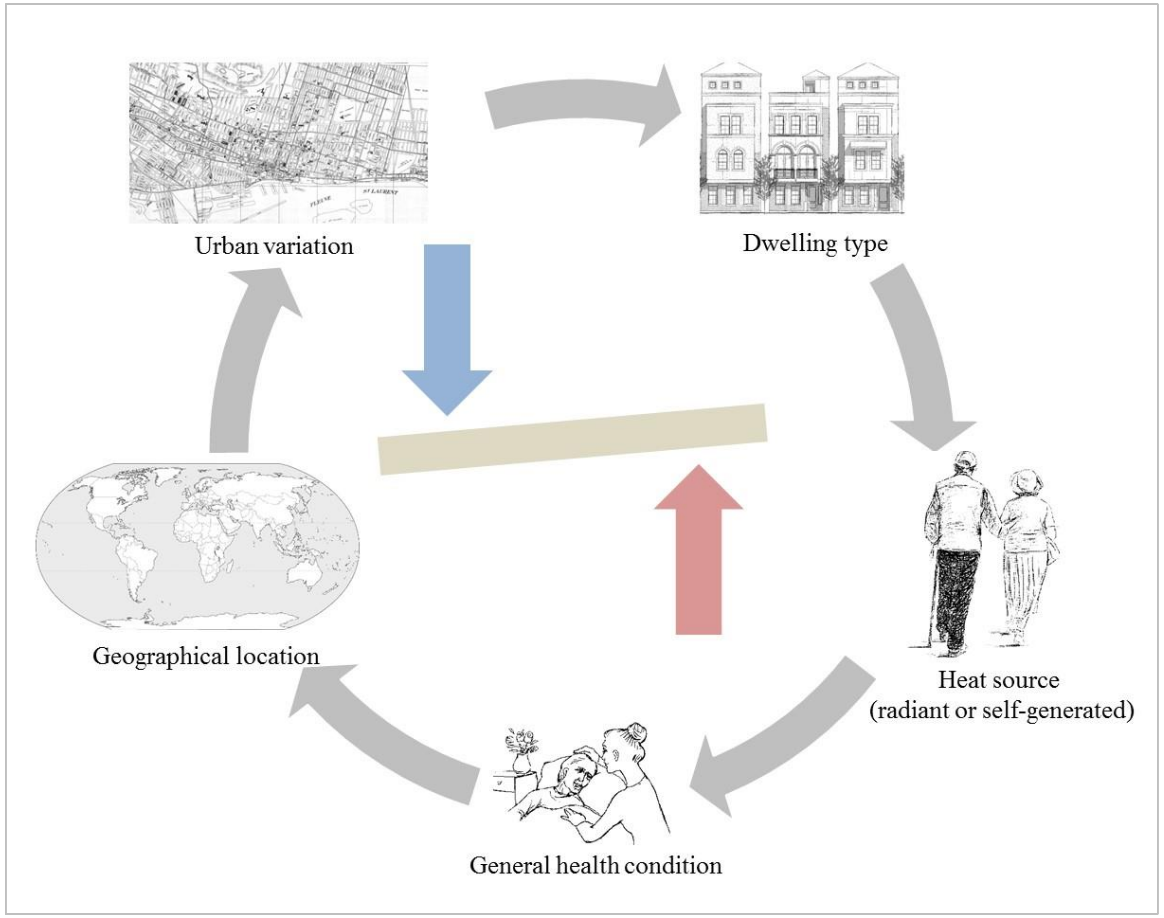
Urban variation: individuals not uniformly exposed to the high heat conditions during hot weather within cities with the urban variation of outdoor temperatures.

Fine-scale variability of heat-related mortality in Philadelphia County, USA (Hondula, Environmental Health, 2012, 11:16)

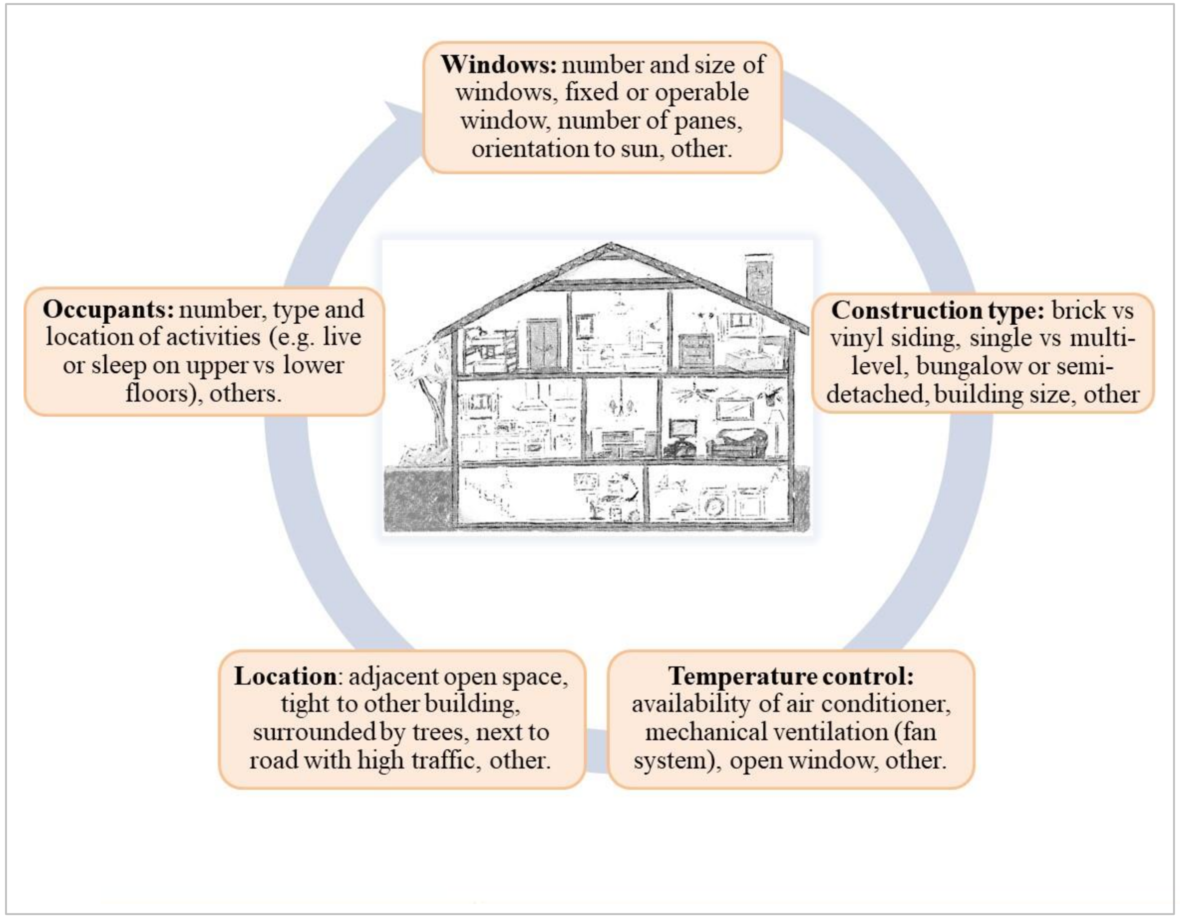


Defining maximum indoor temperature limits

A key **challenge** is quantifying heat exposure levels that can be highly variable between individuals. Factors to consider:

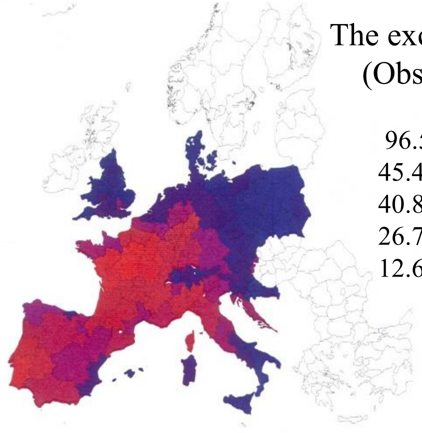


Kenny et al. Temperature (Austin). 2018 May 11;6(1):11-36.



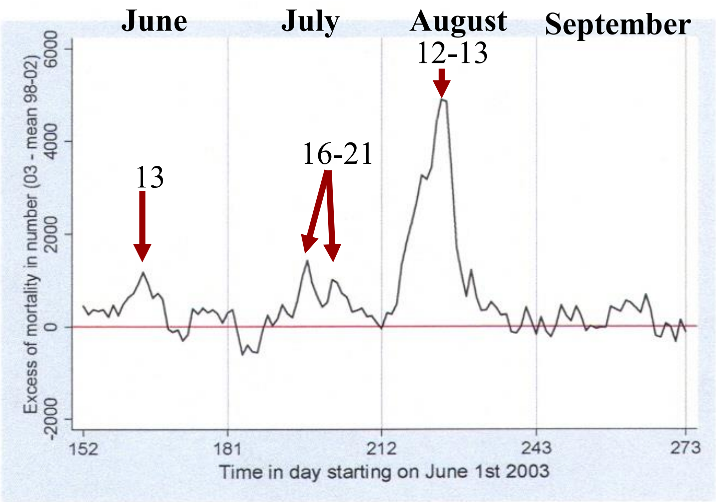
Canadians are not immune from the effects of heat waves

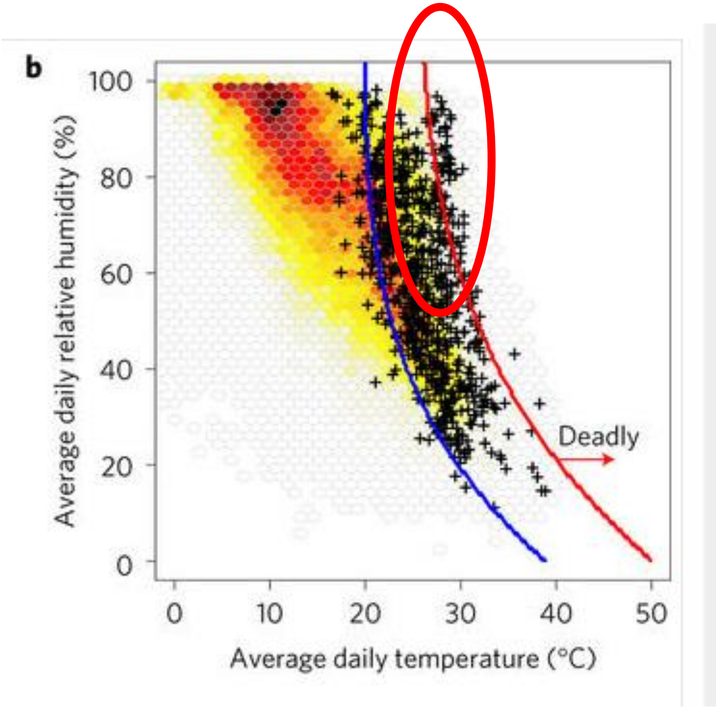
While Canadians may feel immune to the effects of extreme heat due to its more temperate climate, they are at an equally high risk of experiencing the serious health impacts of extreme heat events.



The excess mortality ratio – Europe 2003
(Observed Deaths/Expected Deaths)

96.5% France	48.9% Portugal
45.4% Italy	41.2% Spain
40.8% Luxembourg	28.9% Germany
26.7% Switzerland	21.6% Belgium
12.6% Austria	~10% other countries





Humidex 47°C
July 1st, 2018, Canada Day

RESEARCH ARTICLE Open Access

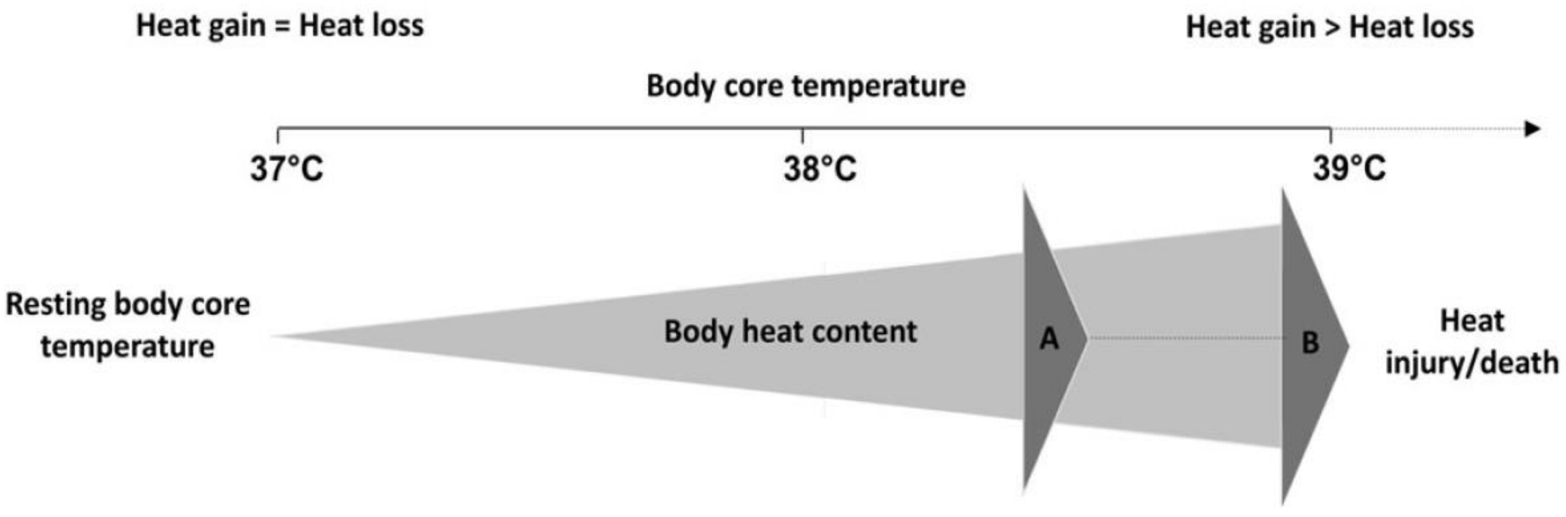
Health impacts of the July 2010 heat wave in Québec, Canada

Table 2 Average temperatures during the heat wave (2010) and the comparison periods (2005–2009), by health region (HR)

HR	Maximum temperatures (°C)		Minimum temperatures (°C)	
	2010	2005-2009	2010	2005-2009
Capitale-Nationale	32.3	24.0	19.7	12.8
Chaudière-Appalaches	32.1	23.6	19.8	11.2
Estrie	32.3	24.8	21.0	12.5
Lanaudière	33.6	25.3	21.2	13.6
Laval	33.4	24.8	24.0	15.8
Montérégie	34.0	24.7	21.6	14.0
Montréal	33.4	24.8	24.0	15.8
Outaouais	33.1	23.9	18.5	12.4

Bustinza *et al. BMC Public Health* 2013, **13**:56
http://www.biomedcentral.com/1471-2458/13/56

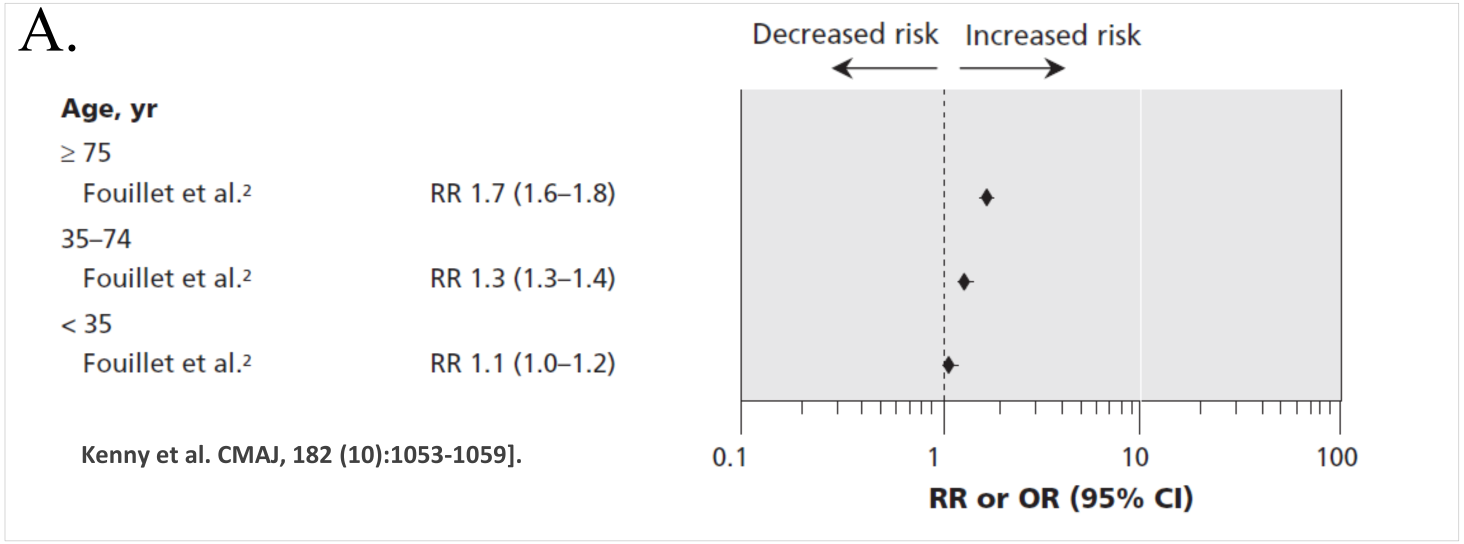
Whole-body heat exchange in vulnerable individuals during a heat exposure

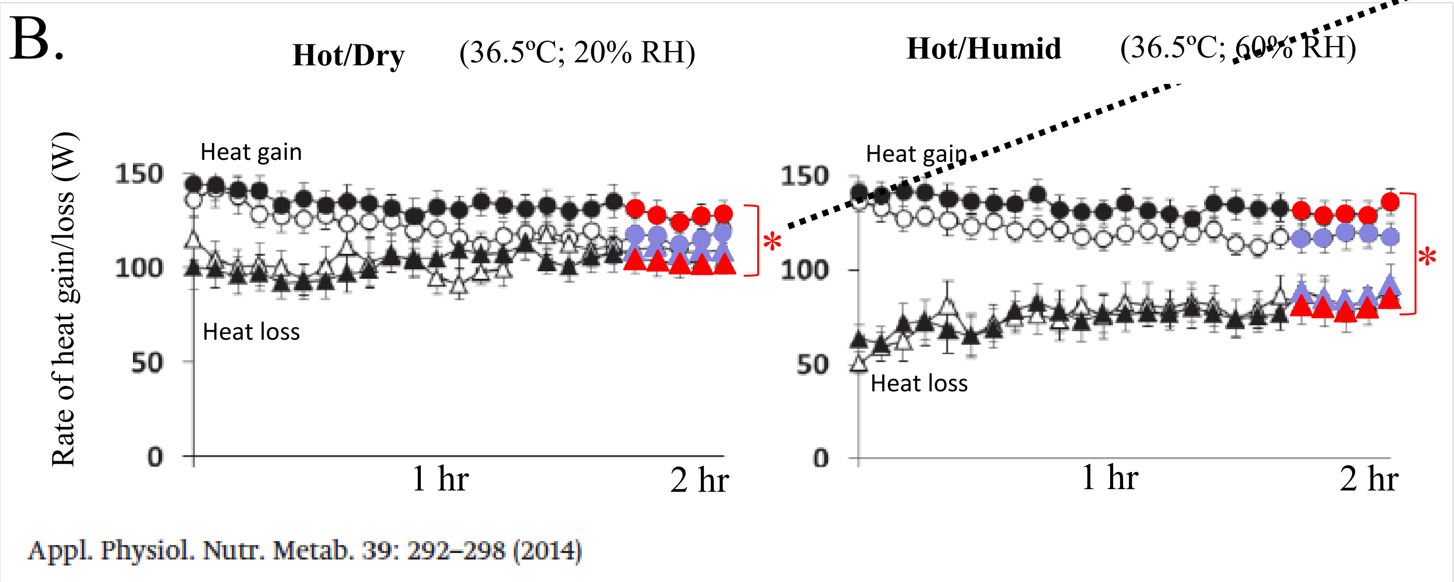


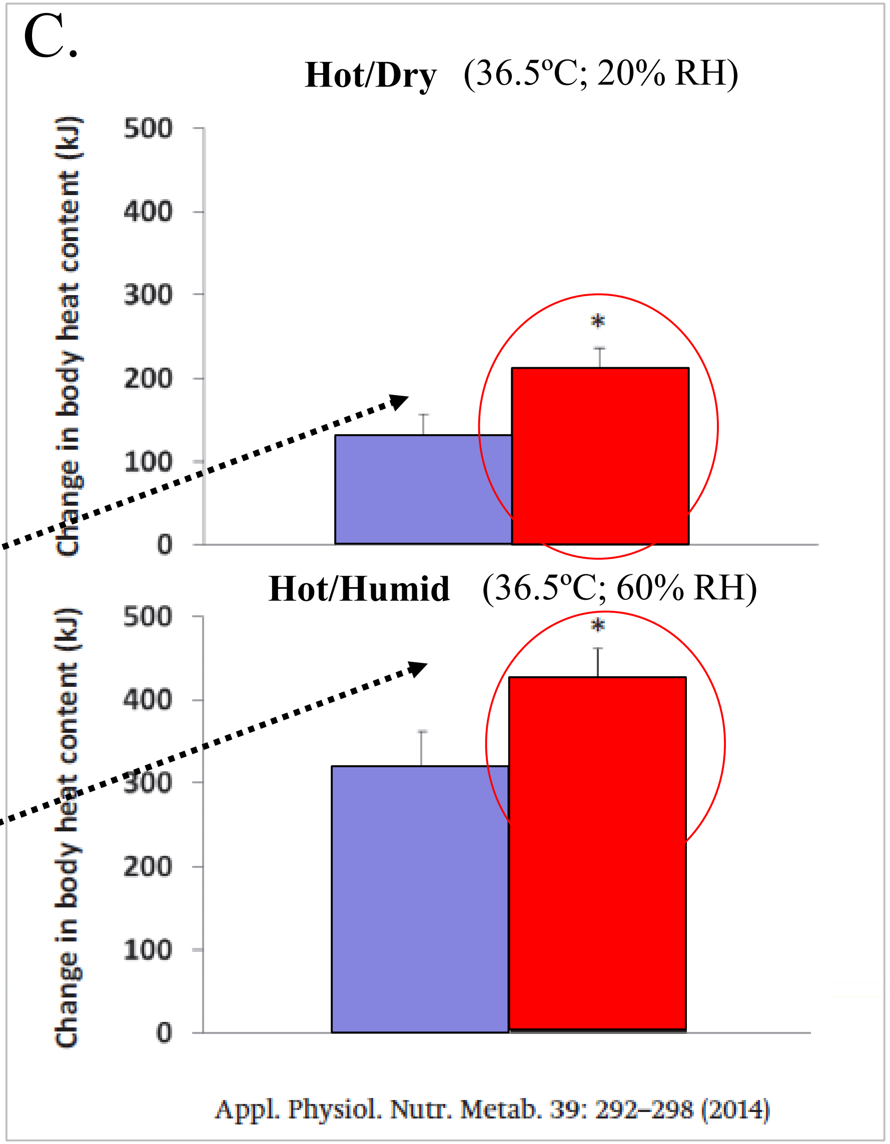
The Snellen air calorimeter permits the very precise minute-by-minute assessment of dynamic human heat balance across a wide range of environmental conditions during rest or exercise.

Do older adults experience greater thermal strain during exposure to heat?

Epidemiological evidence demonstrates a 2-5% increase in all-cause mortality for a 1°C increase in average daily temperature during hot temperature periods. Int J Biometeorol. 2012;56(4):569-581







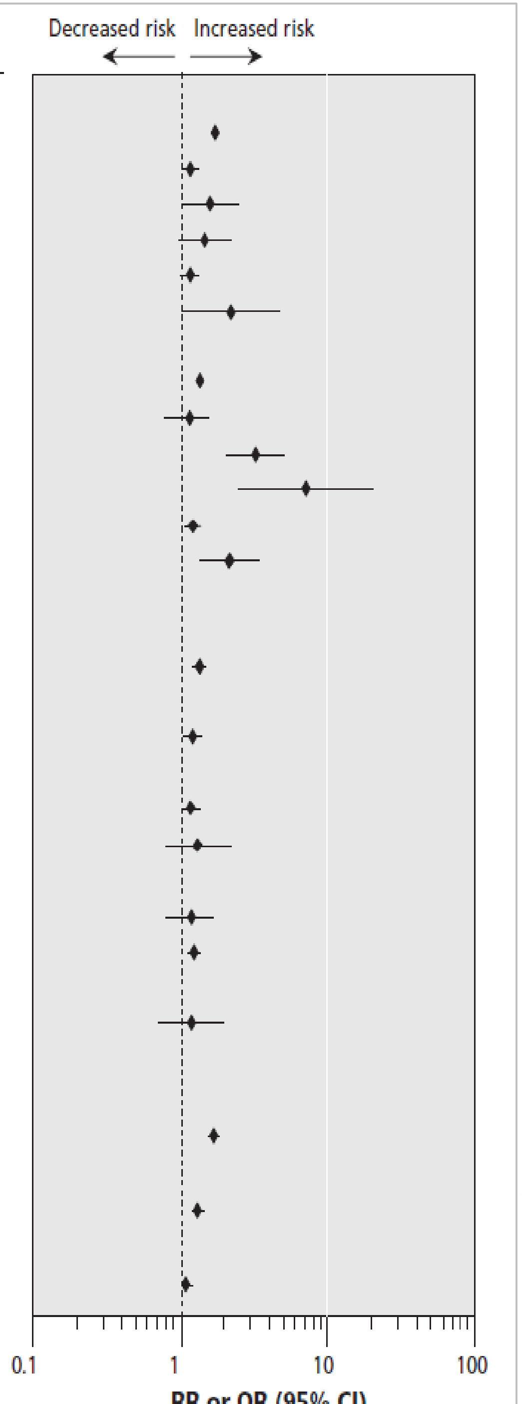
Heat stress in older individuals and patients with common chronic diseases

Key points

- Normal aging causes marked reductions in the body's capacity to dissipate heat resulting in a greater heat storage and therefore increase in thermal (core temperature) and cardiovascular strain during heat exposure at rest and during physical activity.
- This maladaptive response occurs in adults as young as 40 years of age and is worse in individuals with chronic medical conditions such as type 2 diabetes and hypertension.
- Recent work however shows that age- and disease-related impairments are heat-load dependent.

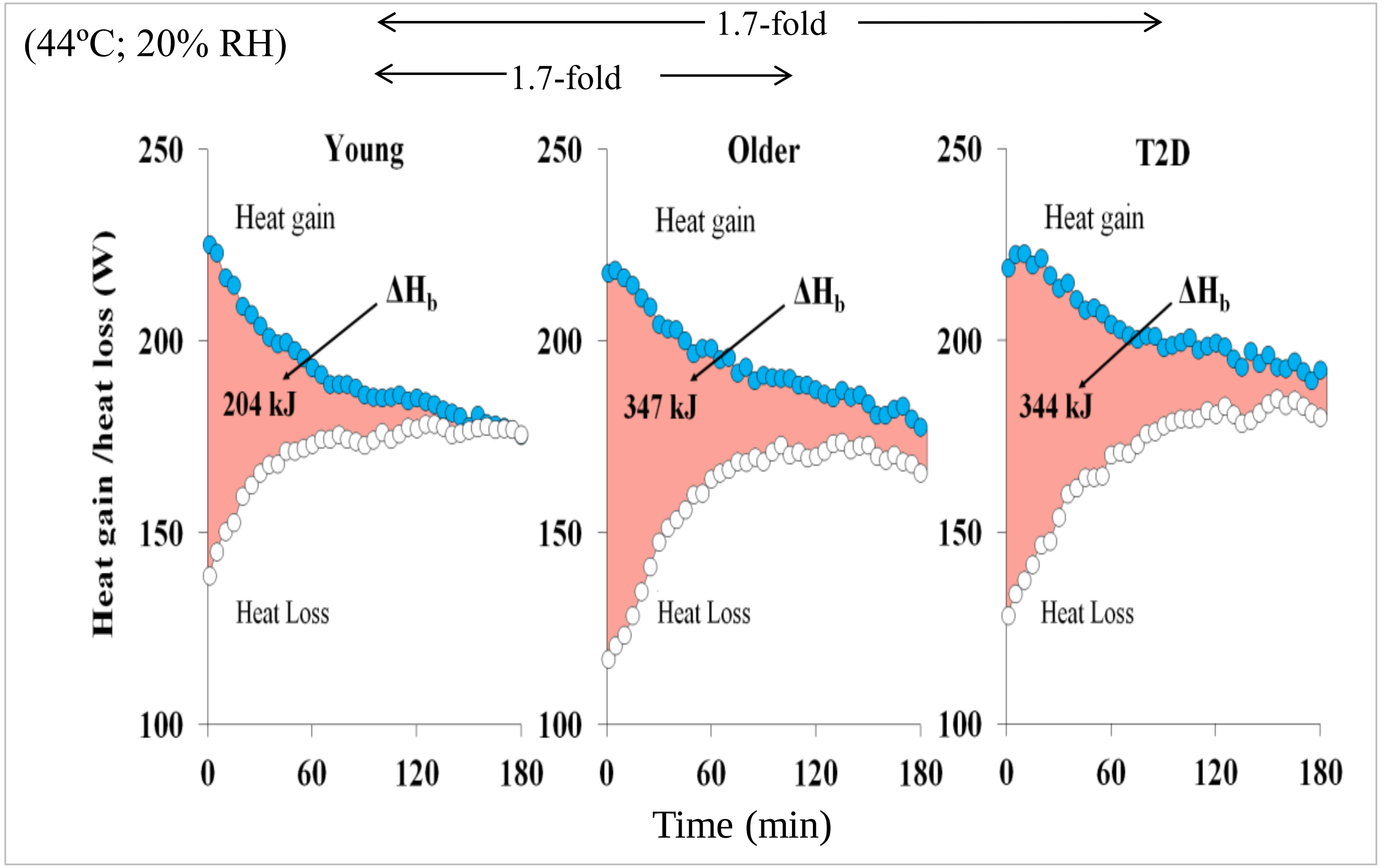
See references: J Appl Physiol (1985). 2015 Feb 1;118(3):299-309; PLoS One. 2013 Dec 12;8(12):e83148; Diabetologia. 2019 Apr 2. doi: 10.1007/s00125-019-4858-5; Med Sci Sports Exerc. 2013 Oct;45(10):1906-14

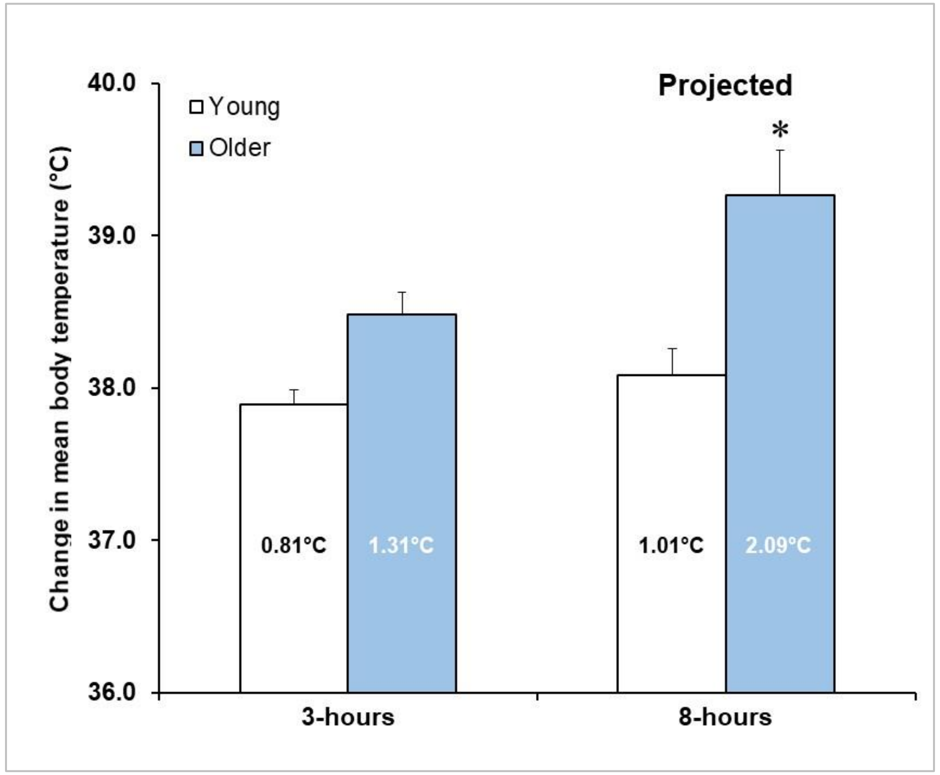
Characteristic	OR or RR (95% CI)
Respiratory diseases	
Hoffmann et al.[18]	RR 1.61*
Schwarz et al.[19]	OR 1.13 (1.00–1.26)
Lorente et al.[15]	OR 1.6 (1.0–2.5)†
Bretin et al.[17]	OR 1.48 (0.96–2.26)
Semenza et al.[9]	RR 1.13 (0.99–1.26)
Semenza et al.[8]	OR 2.2 (1.0–4.9)
Cardiovascular disease	
Hoffmann et al.[18]	RR 1.30*
Lorente et al.[15]	OR 1.1 (0.8–1.6)†
Bretin et al.[17]	OR 3.19 (2.08–4.90)
Naughton et al.[16]	OR 7.17 (2.5–20.8)‡
Semenza et al.[9]	RR 1.23 (1.18–1.28)
Semenza et al.[8]	OR 2.3 (1.5–3.6)
Diabetes	
Type 2	
Semenza et al.[9]	RR 1.33 (1.21–1.45)
Type 1	
Semenza et al.[9]	RR 1.22 (1.08–1.36)
Type not specified	
Schwarz et al.[19]	OR 1.17 (1.04–1.32)
Lorente et al.[15]	OR 1.3 (0.8–2.3)†
Hypertension	
Lorente et al.[15]	OR 1.2 (0.8–1.7)†
Semenza et al.[9]	RR 1.24 (1.19–1.29)
Obesity	
Lorente et al.[15]	OR 1.2 (0.7–2.2)†
Age, yr	
≥ 75	
Fouillet et al.[2]	RR 1.7 (1.6–1.8)
35–74	
Fouillet et al.[2]	RR 1.3 (1.3–1.4)
< 35	
Fouillet et al.[2]	RR 1.1 (1.0–1.2)



Kenny et al. CMAJ 182 (10):1053-1059]

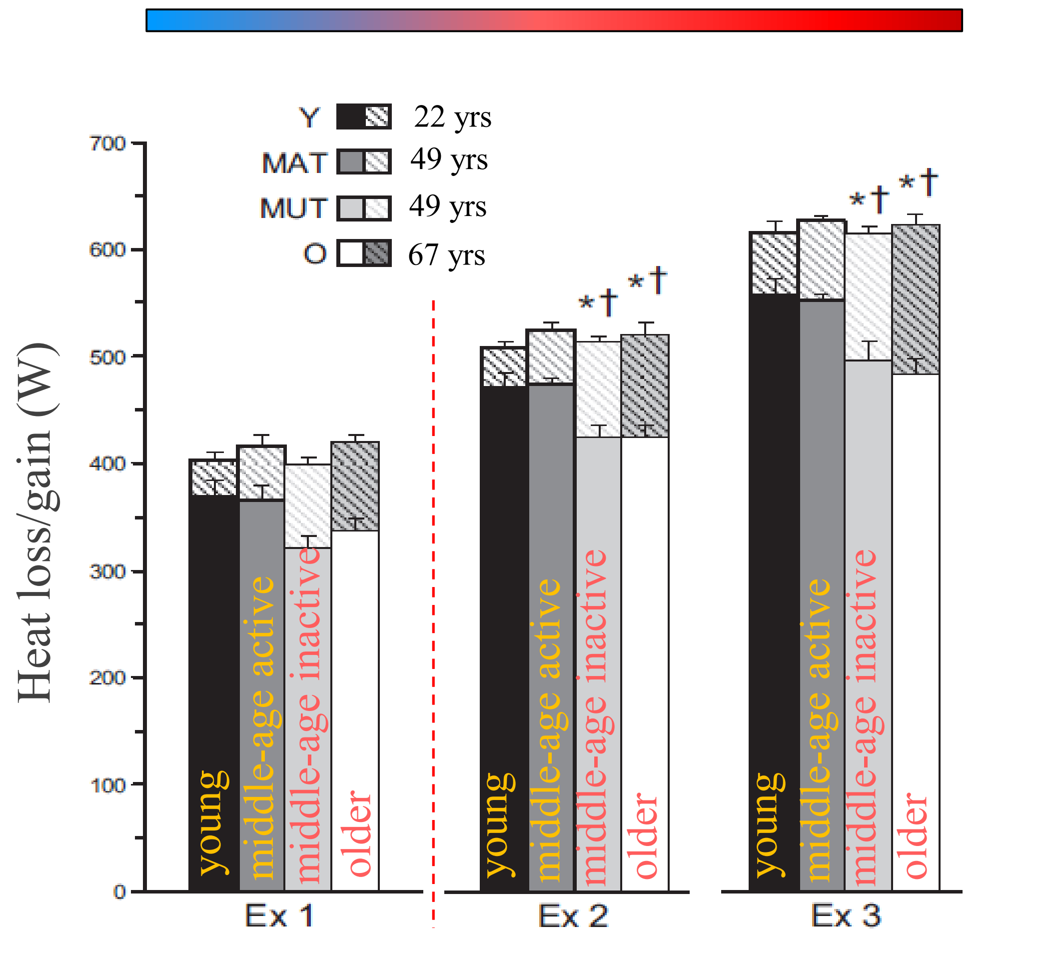
Heat strain during an extreme heat exposure in older adults with and without type 2 diabetes (T2D)





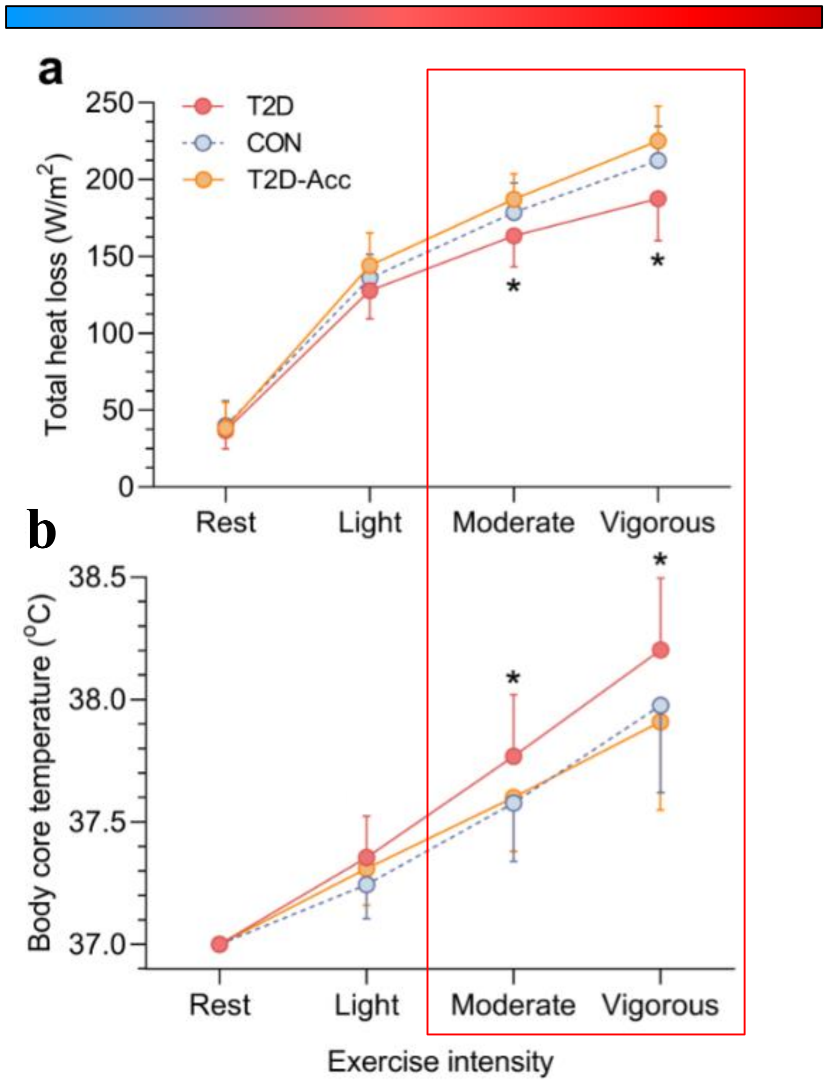
Kenny et al. Temperature 2017, 4(1):79-88

Age- and disease-related impairments in heat loss are heat-load dependent



Mean ± SE values for evaporative heat loss (solid bars) and heat gain measured over a 2-hour intermittent exercise bout in hot-dry heat (40°, 20% relative humidity). Young (20 yrs): black bar; middle-aged trained (49 yrs): dark grey bar; middle-aged untrained (49 yrs): light grey; Older (65 yrs): white bar. *, significant difference in evaporative heat loss from young. †, significant difference in evaporative heat loss from middle-aged trained.

Stapleton et al. J Appl Physiol 2015, 118:299-309.



Change in whole-body heat loss (A) and core temperature (B) for older males with (T2D, n=16) and without (Control, n=16) Type 2 diabetes during three 30-min bouts of cycling during low, moderate and vigorous rate of metabolic heat production. *, significant group differences, P≤0.05.

Poirier et al. JAMA 2019, in review.

How important is indoor temperature to human health

- Rising environmental temperatures represent a major threat to human health.
- It is estimated that people spend the majority (>90%) of their time indoors. This raises important concerns about the validity of employing outdoor measures to define heat-related risks for human health.
- Exposure to high indoor temperature was an underlying cause of many heat-related fatalities in the 2003 European heatwave. During the 1995 & 1999 Chicago heat waves, those who did not leave their homes at least once a day had higher mortality.
- Although the relationship between weather and human health has been widely defined by outdoor temperature, corresponding increases in indoor temperature during heat events can also be harmful to health especially in vulnerable populations.

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https://doi.org/10.1080/23328940.2018.1456257

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PRIORITY REVIEW

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Towards establishing evidence-based guidelines on maximum indoor temperatures during hot weather in temperate continental climates

Glen P. Kenny[a], Andreas D. Flouris[b], Abderrahmane Yagouti[c] and Sean R. Notley[a]

The next steps

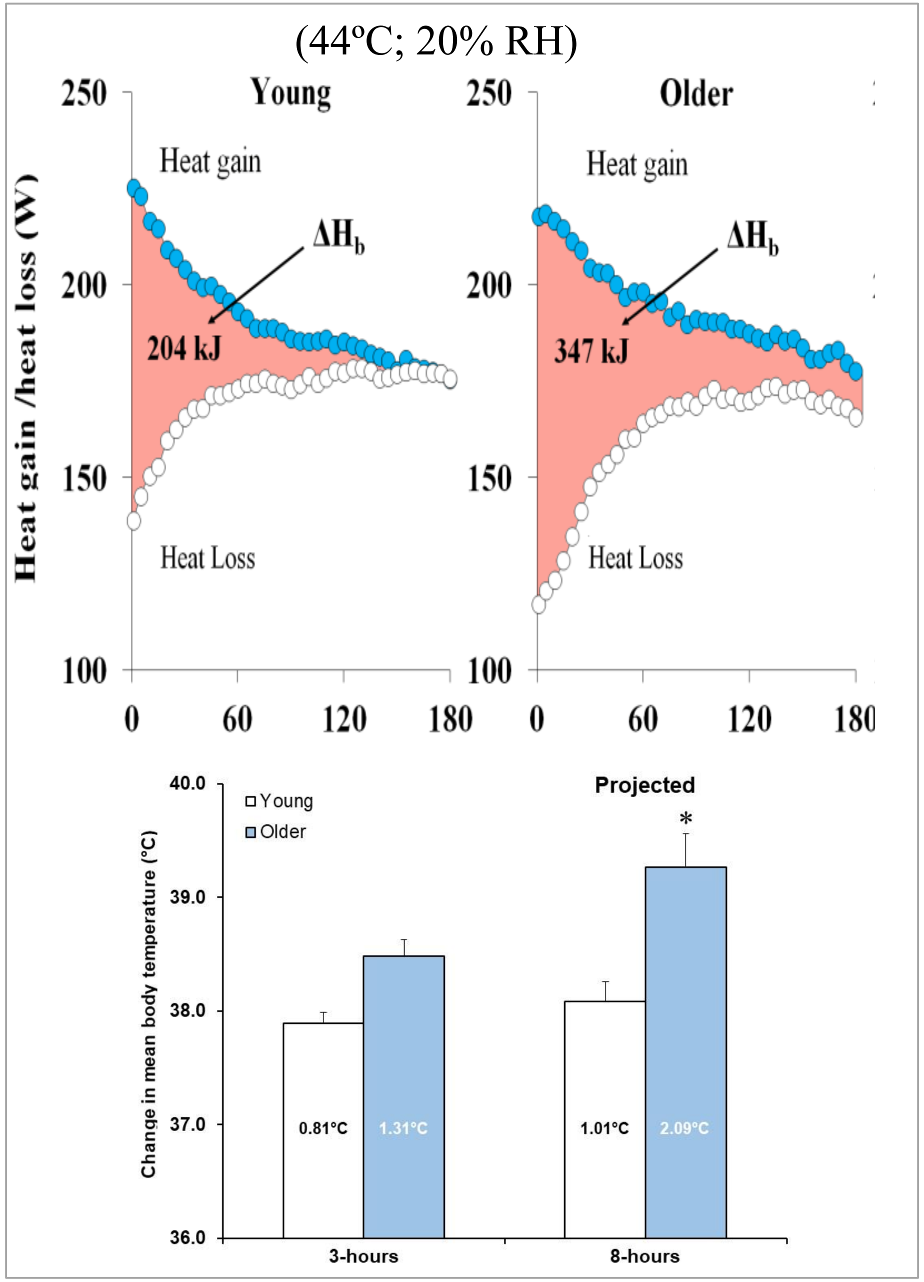
On separate days, we will measure WBHL and body heat storage during a 4-hour exposure at 21, 26, 31 and 36°C (all at 50% RH) in young (18-25 years) and older (75-80 years)*.

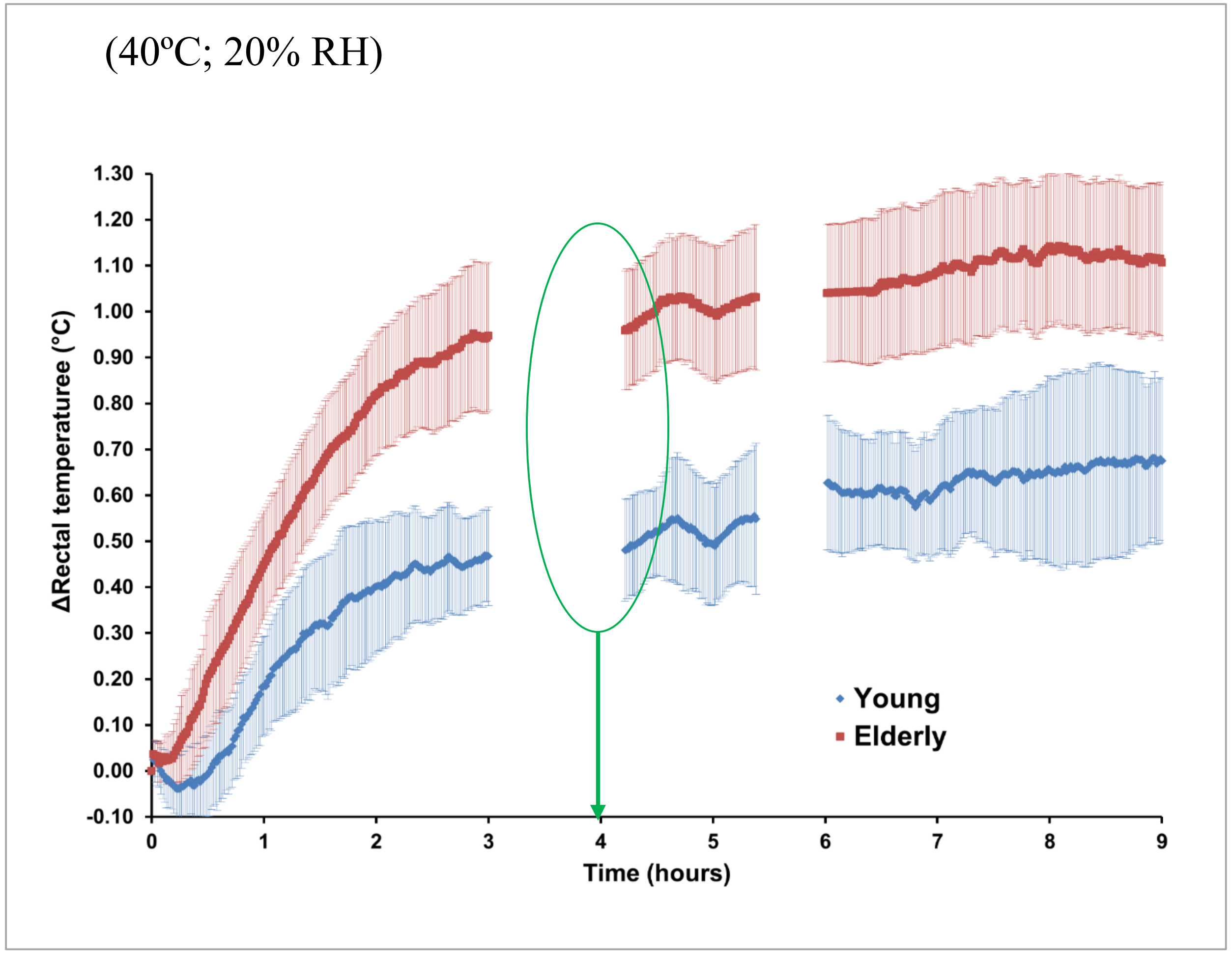
- 21°C (normal room temperature) (Humidex 22°C),
- 26°C (recommended indoor temperature limit by Toronto Public Health) (Humidex 30°C),
- 31°C (average daytime temperature during hot weather events) (Humidex 38°C), and;
- 36°C (average peak summer temperature in some Canadian cities) (Humidex 46°C).

Defining indoor maximum temperature limits based on whole-body heat exchange

Direct calorimetry represents the gold standard method to measure whole-body heat loss (evaporative ± dry) and body heat storage

The experimental model – defining indoor maximum temperature limits based on whole-body heat exchange

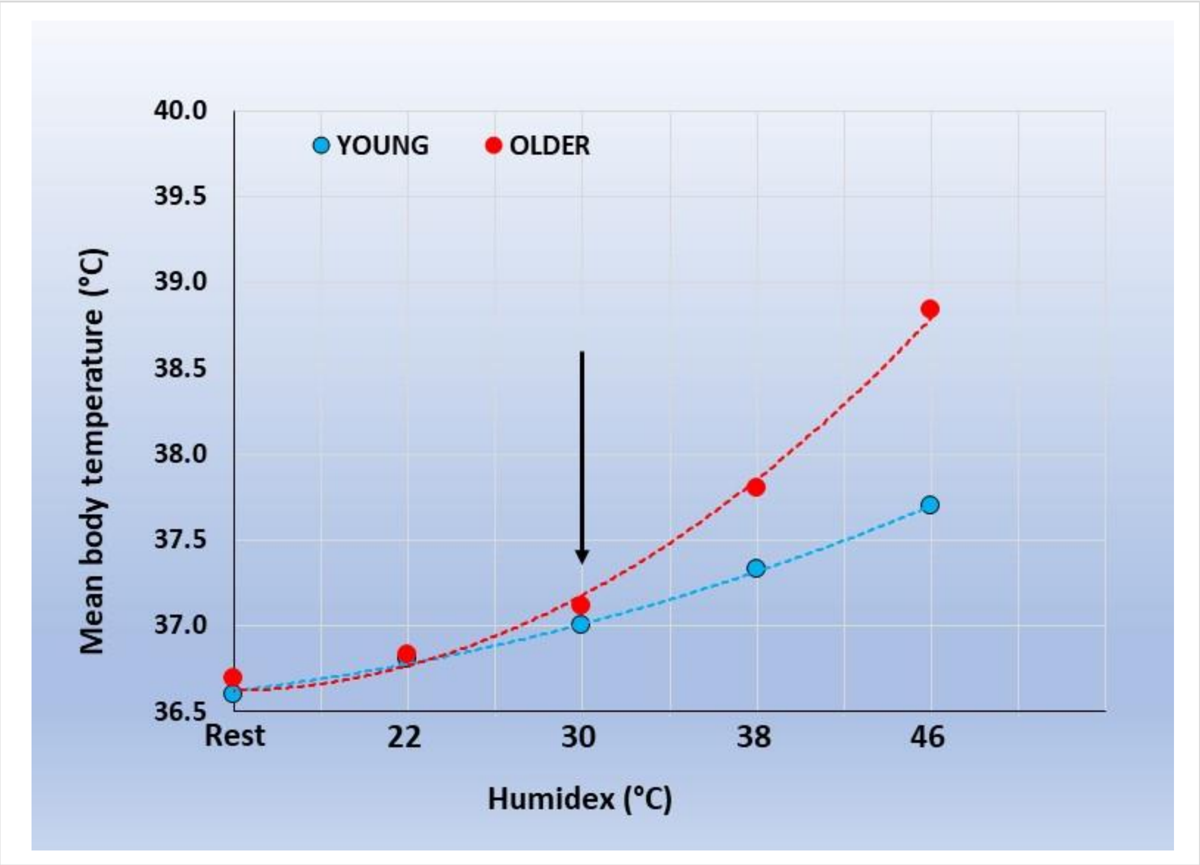


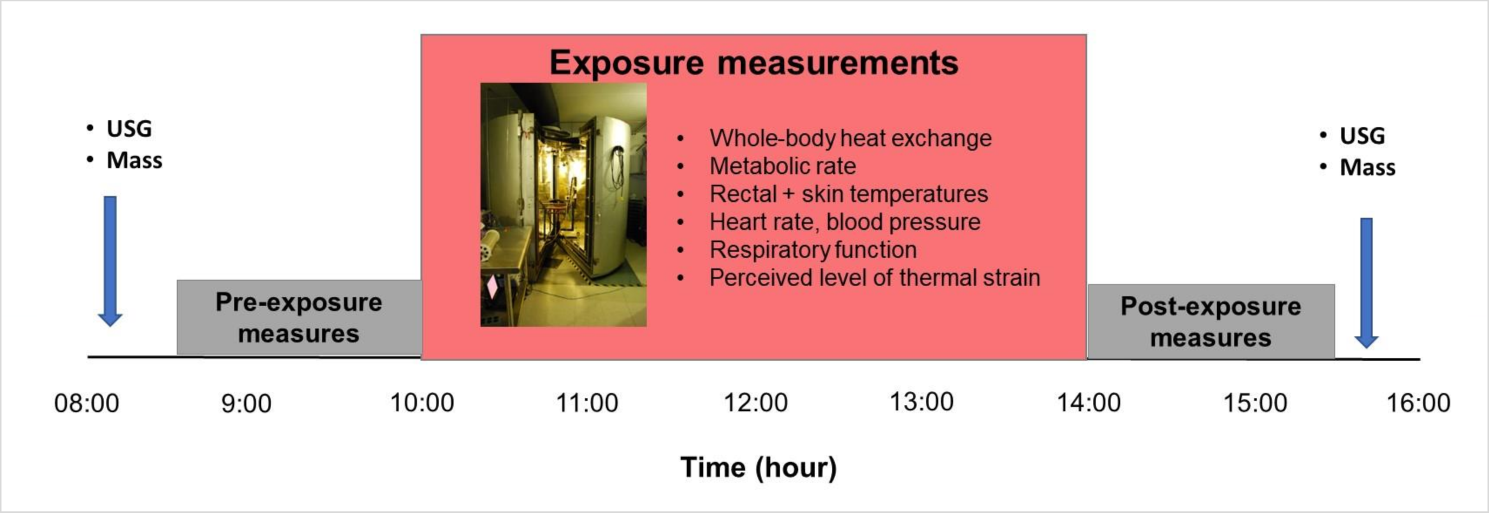


Unpublished data

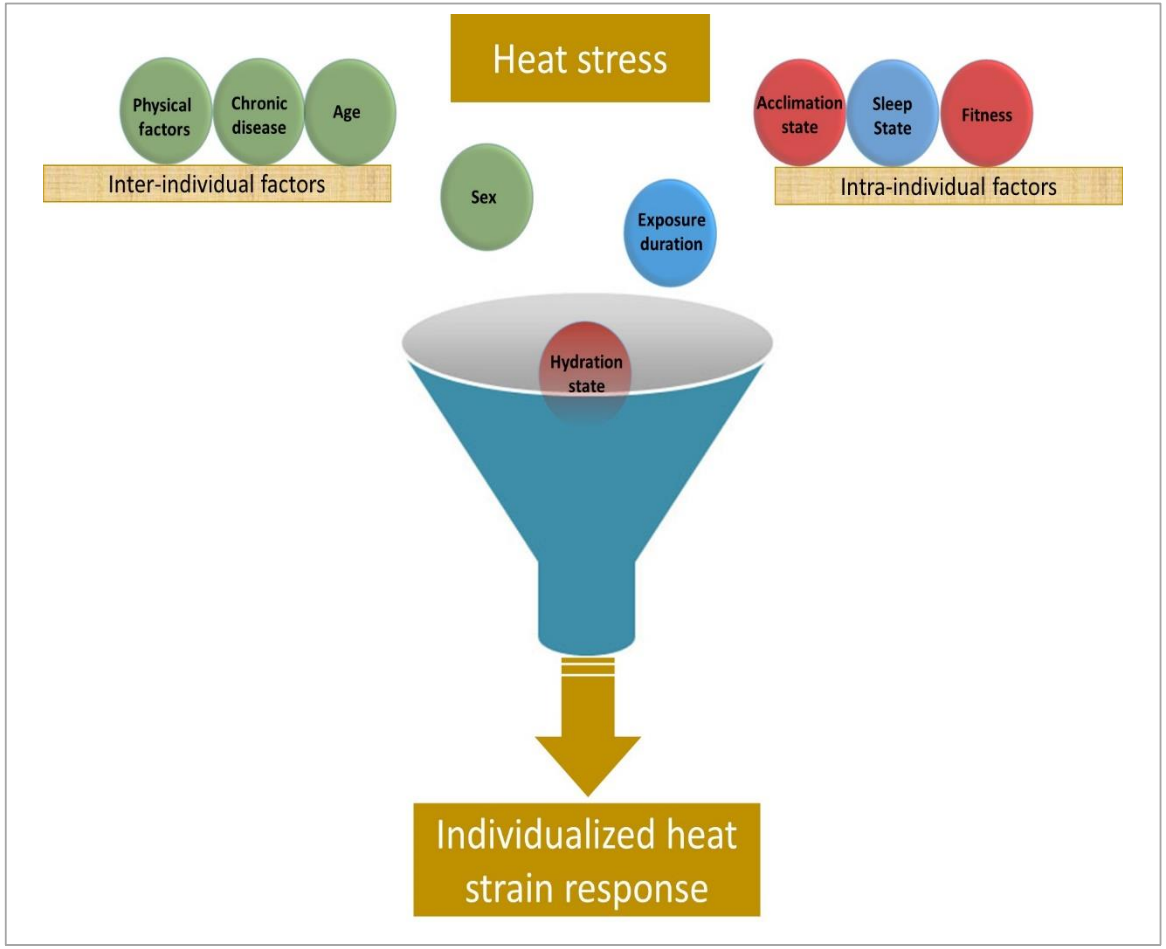
Kenny et al. Temperature 2017, 4(1):79-88

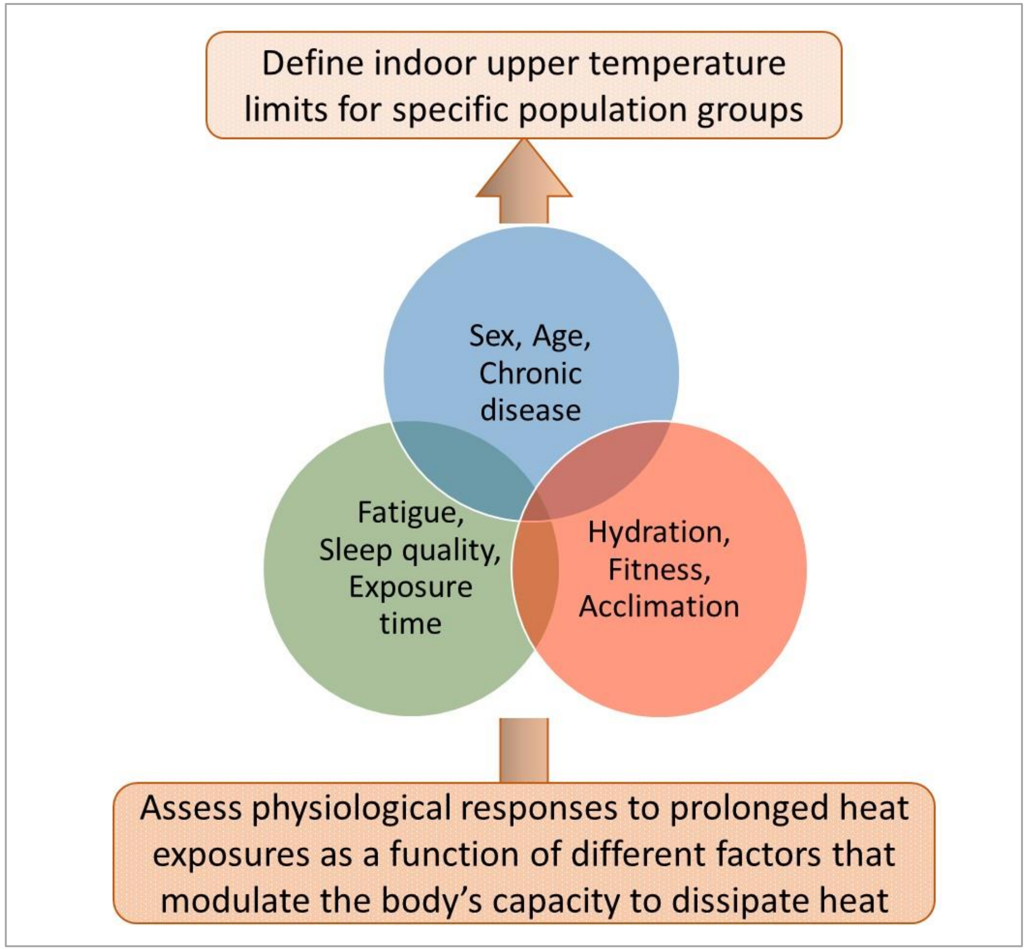
The experimental model



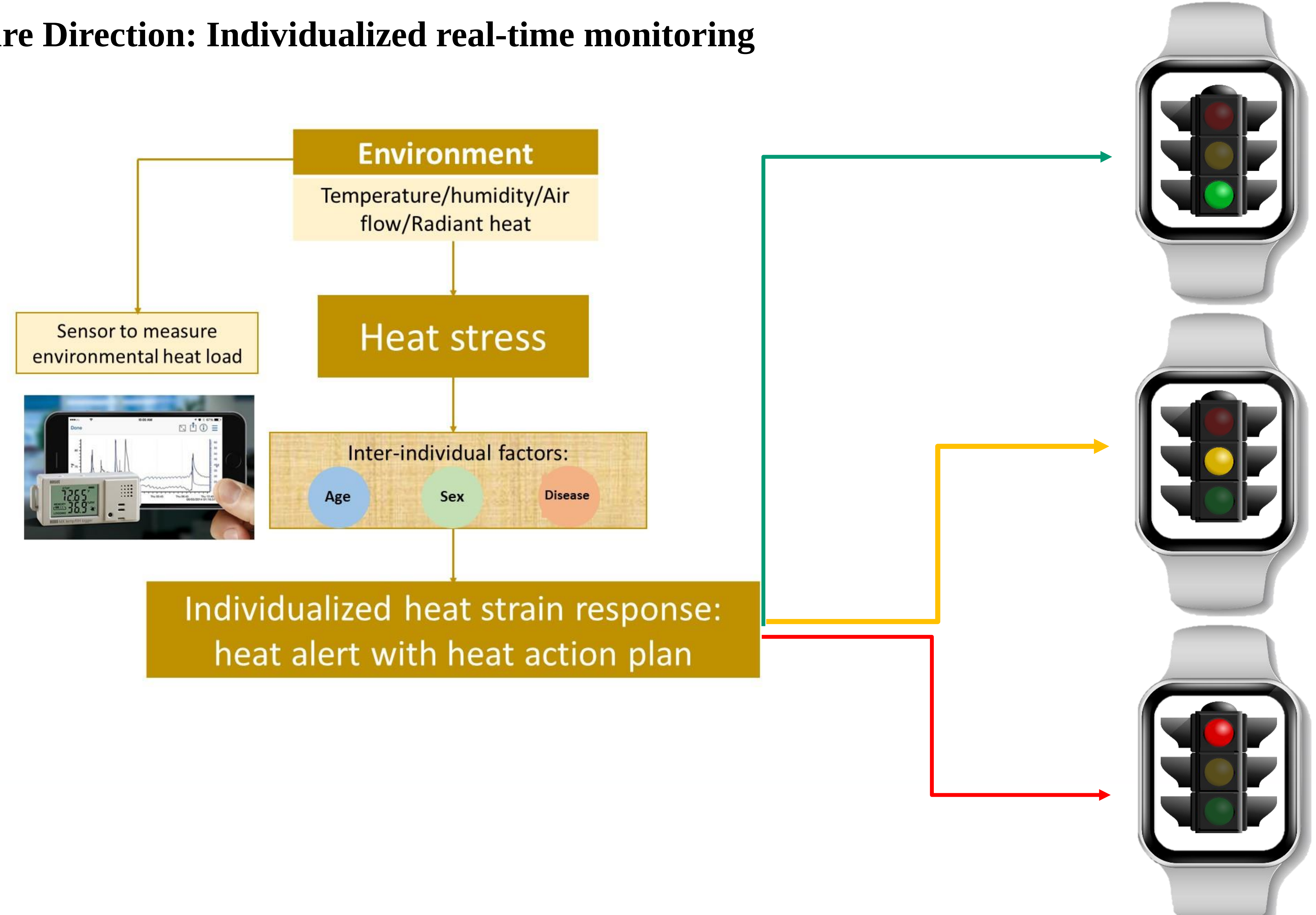


Adjusting indoor maximum temperature limits for specific population groups - Consideration for inter- and intra-individual factors that modify heat tolerance





Future Direction: Individualized real-time monitoring



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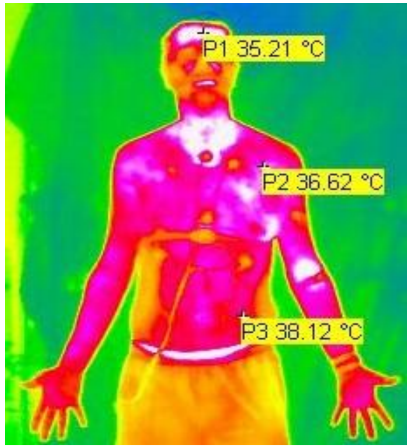

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