Fan-first heat-health protection

Angie Bone[1]
Federico Tartarini[2,3]
Ollie Jay[2]

1 Monash Sustainable Development Institute, Monash University, Melbourne, VIC.
2 Heat and Health Research Centre, University of Sydney, Sydney, NSW.
3 University of Sydney, Sydney, NSW.

angie.bone@monash.edu

doi: 10.5694/mja2.52662

Heat-related illnesses occur when environmental heat stress exceeds the body's physiological limits of heat tolerance. This most often arises when these limits are already constrained by cofactors such as older age, chronic diseases and certain medications.[1] Global heat-related mortality, estimated to be about 489 000 deaths per year,[2] is predicted to increase substantially as climate change progresses.[3]

People in housing with poor thermal performance may be exposed to high indoor temperatures, especially in densely built urban settings. Socially isolated people and those with limited mobility are often unable to engage in heat-avoidance behaviours.[1]

We urgently need low-cost, energy-efficient, and effective cooling interventions that can be implemented at scale to reduce heat-related health impacts.

The challenges of air conditioning

Air conditioning is the leading cooling strategy globally and is widely recommended as the best prevention for heat-related illness and death. Annual sales of air conditioning units have more than tripled globally since 1990 and air conditioning use is projected to triple again by 2050.[4]

Yet, because of high capital, operational, and maintenance costs, air conditioning is often inaccessible. A recent Australian survey indicated that while most respondents had air conditioning, two-thirds did not use it because of cost concerns.[5] Calls to improve the accessibility and affordability of air conditioning are increasing.[6] Some Australian governments now offer subsidies to vulnerable people for energy costs and the purchase of air conditioning units.

Although air conditioning is an effective cooling intervention, its use has significant implications, in addition to these financial and equity considerations.

Electricity used to run air conditioning, if sourced from fossil fuels, contributes to greenhouse gas emissions. Although renewable energy sources are being rapidly introduced, the mounting demand for electricity for cooling may threaten this transition and increase the risk of power outages. Although hydrofluorocarbon refrigerants, which are potent greenhouse gases, are being phased out under the Kigali Amendment to the Montreal protocol, replacing older, inefficient units will take decades.[7]

In operation, air conditioning units generate heat that is released into an already overheated outdoor environment, intensifying the urban heat island effect.[1] Their installation may reduce incentives to consider passive cooling strategies in buildings and urban environments, such as cross-ventilation, shading and greening. Reliance on air conditioning may reduce opportunities for acclimatisation if thermostats are set at lower temperatures than summer norms, increasing vulnerability in the event of power failures.[8]

Using air conditioning as our primary response for managing heat health risks can be seen as a maladaptation to climate change, because it may paradoxically increase long term health risk and vulnerability. Although air conditioning is necessary to protect the health of the most heat-vulnerable people, there are safe and effective alternatives to reduce our over-reliance on it, saving on operating costs and emissions, and increasing our resilience.[9]

The fan-first approach

Fans can increase comfort, reduce cardiovascular strain, and reduce the rise in core temperature. They increase heat loss through convection when air temperature is lower than skin temperature (~35°C) and facilitate the evaporation of sweat or water applied to the skin surface under high humidity conditions. Thermal comfort models show that fan-generated air movement (1 m/s) at 27°C and 50% relative humidity (RH) can provide a reduction in thermal sensation equivalent to an air temperature that is ~4°C lower for a person in still air seated quietly (1.2 met [metabolic rate, measured in metabolic equivalent]) wearing summer clothing (0.5 clo [clothing insulation]).[10,11]

The fan-first approach recommends that as indoor temperatures rise, electric fans are used first, rather than resorting immediately to air conditioning, or suffering discomfort without air conditioning.[5,6] Using electric fans first means that thermostats can be set to start cooling at higher temperatures (eg, ~27°C, as opposed to ~23°C).[11] Thus on warm days, air conditioning units are on for shorter periods — if at all — without reducing thermal comfort or cooling of the body.

Electric fans use as little as 3% of the energy used to power air conditioning,[12] making them more accessible and affordable. A simple pedestal fan can be purchased for about $20, requires no special installation and very little maintenance, and can be moved to different spaces. Some fans are equipped with batteries so can be operated during power outages. Fans cool the person directly and the airflow can be adjusted based on an individual's needs, whereas air conditioning cools the whole room, affecting everyone present regardless of their thermal preferences, activities or vulnerabilities, and using energy to cool parts of rooms that are unoccupied.[13]

In an Australian context, fan-first cooling could reduce annual electricity demand and greenhouse gas emissions from air conditioning by more than 70% throughout a typical year.[14] A cost-curve analysis assessing the emissions abatement potential of adopting a fan-first cooling strategy demonstrated a superior net benefit when compared to the switch from incandescent to LED home lighting,[14] which was previously recognised to be one of the most cost-effective measures for emission reduction.[15] For example, raising the air conditioning thermostat from 24 to 26.5°C with supplementary air movement from desk and ceiling fans in a Singaporean office, reduced energy consumption by 32%, without compromising thermal comfort.[13]

Using fans safely where air conditioning is not an option

Where air conditioning is unavailable or unaffordable, fans can protect health in hot conditions, particularly if combined with other cooling interventions such as wetting the skin with water.[16] Physiologists have observed a protective effect of electric fan use alone up to 42°C in settings of high humidity (50% RH) in young healthy adults.[17,18]

However, in very hot (45°C) and dry (< 15% RH) conditions, fans can worsen heat strain as the body cannot produce enough sweat to cool itself and the fan pushes more heat into the body.[19] This creates the paradox that a device typically considered to provide a cooling effect, causes the body to heat at a faster rate. As the benefits of fans depend on the body's ability to sweat, the temperature at which fans switch from cooling the body to heating it, is lower when people are less able to sweat (eg, older age, or taking anticholinergic medications).

The indoor temperature at which fans should be turned off depends on humidity. As most people lack access to reliable humidity data, simplified indoor temperature thresholds have been developed that are protective, irrespective of humidity. These thresholds are 39°C for young healthy adults, 38°C for older adults, and 37°C for older adults taking anticholinergic medication.[20]

Recent human experimental studies have supported these thresholds. At 38°C with 60% RH, fans have been shown to reduce heat-induced cardiac strain by as much as 86% in older adults with heart disease not prescribed β-blockers.[21] At 36°C with 45% RH, no evidence of harm was observed with fans in healthy older adults. A wind speed of 2 m/s significantly reduced the rise in core temperature, blunted heat-related increases in heart rate, and improved thermal comfort after 8 hours of exposure.[22]

At temperatures above these simplified indoor threshold temperatures, electric fans should be switched off because their use may be harmful. If possible, alternative cooling strategies should be employed such as wetting the skin or moving to a cooler environment. Below these temperatures, there is no evidence to support switching fans off, which would otherwise remove an intervention that improves comfort and reduces heat stress during hot weather, with or without air conditioning.

Knowledge and use of fan-first cooling

There are several reasons why the fan-first approach is not widely known or adopted, despite the health, economic and environmental benefits.

Firstly, air conditioning's appeal during hot weather is readily apparent. Many public buildings have air conditioning, and cool environments with still air have become normalised. This has been reinforced by building standards, such as ISO 7730:2005 *Ergonomics of the thermal environment*, which have historically recommended keeping the air still in buildings during summer.[23] It may also be in the commercial interests of air conditioning manufacturers and retailers to promote air conditioning in preference to other cooling interventions.

Secondly, air conditioning is clearly protective for individual health at very hot temperatures; the cooling effect of fans progressively diminishes at higher temperatures and is dependent on humidity. Fans are sufficient to protect health in most indoor conditions in many locations. They can be used as a supplement to air conditioning to reduce operation costs or to provide relief under certain conditions when air conditioning is unavailable or unaffordable. Although air conditioning is often considered a key factor in explaining recent reductions in heat-related mortality in high income countries, its contribution is less than might be assumed (< 20% of the observed attenuation), which could relate to barriers to use.[24]

Thirdly, there may be concerns about the safety of electric fans, either because the fan-first recommendation is misunderstood as implying complete substitution of air conditioning, or because fans can increase heat gain in certain conditions. A threshold of 35°C, above which fans should be turned off, became commonly used in public health guidance from the early 2000s. This was based on the theory that above 35°C (normal human skin surface temperature), fans could increase heat gain by blowing hot air at the skin. However, this neglected to consider the ability of fans to increase evaporative heat loss from sweating. Much public health guidance retains this threshold, despite the role that fans play in enhancing evaporative cooling and the absence of any empirical evidence of harm from fans at 35°C, including a 2012 Cochrane review,[25] which was unable to find any eligible studies. Since then, rigorous biophysical modelling and laboratory-based heat exposure studies have established the higher temperature thresholds described above. Population-level evaluation of the impact of fan use up to these higher temperature thresholds is still to be completed, although electric fans have been in common use for decades by 100s of millions of people in countries that regularly experience indoor temperatures above 35°C.

Lastly, effective public health communication requires simple messages that can be easily understood by all. The fan-first approach must communicate the relationship between fans, air conditioning and other cooling interventions, as well as temperatures at which fans are no longer safe to use. This is not insurmountable, and analogies could be made with medication dosages, but is clearly more complex than a "use air conditioning" message. Personalised advice, such as that provided by the HeatWatch smartphone application (currently being trialled),[26] may help people determine the best cooling recommendations for their circumstances, including the safe use of fans.

Recommendations

- Electric fans can be used in conjunction with air conditioning to improve thermal comfort while minimising energy consumption and cost, by setting the air conditioning thermostat to about 27°C.
- Electric fans are cheap to buy, operate and maintain. Where air conditioning is unavailable or unaffordable, electric fans provide an effective alternative, increasing comfort, reducing cardiovascular strain, and reducing core temperature in most hot and humid conditions, especially when used while wetting the skin with water.
- Electric fans are safe to be used in indoor temperatures of up to 37°C for older adults on anticholinergic medications, 38°C for older adults, and 39°C for younger adults. At higher temperatures, fans may worsen heat stress and should be switched off. Alternative cooling strategies should be employed where possible, such as wetting the skin or moving to a cooler environment.
- In advising patients about heat-health protection, health professionals should consider both the patient and their ability to keep their home cool, and include advice on the use of fans, with and without air conditioning.
- Public communications and behaviour change campaigns for heat-health protection should highlight the individual and community benefits of electric fans, with air conditioning used only when indoor temperatures exceed about 27°C, particularly for the young and healthy.
- Air conditioning should continue to be part of heat-health protection, particularly for population groups and settings where it is most warranted, including hospital wards, aged care facilities, and community safe havens. This should include the use of fans in these settings to enhance thermal comfort while reducing the building energy consumption.
- Further research is warranted to evaluate the effectiveness of the fan-first approach at the population level and to understand how the fan-first approach can be most effectively communicated to the public.

Acknowledgements: Ollie Jay acknowledges funding from the National Health and Medical Research Council (NHMRC) Investigator Grant (2021/GNT2009507).

Open access: Open access publishing facilitated by Monash University, as part of the Wiley - Monash University agreement via the Council of Australian University Librarians.

Competing interests: Angie Bone is a Board Member of Doctors for the Environment Australia.

Provenance: Not commissioned; externally peer reviewed. ■

1 Ebi KL, Capon A, Berry P, et al. Hot weather and heat extremes: health risks. *Lancet* 2021; 398: 698-708.

2 Zhao Q, Guo Y, Ye T, et al. 2021 Global, regional, and national burden of mortality associated with non-optimal ambient temperatures from 2000 to 2019: a three-stage modelling study *Lancet Planet Health* 2021; 5: e415-e425.

3 Chen K, de Schrijver E, Sivaraj S, et al. Impact of population aging on future temperature-related mortality at different global warming levels. *Nat Commun* 2024 15: 1796.

4 International Energy Agency. The Future of Cooling. Paris: IEA, 2018. https://www.iea.org/reports/the-future-of-cooling (viewed Sept 2024).

5 Albanese V, Shah S, Hammet T, et al. 2024 Summer Survey Report v1.3. Sweltering Cities, 2024. https://swelteringcities.org/2024/04/04/summer-survey-2024/ (viewed Sept 2024).

6 Australian Council of Social Service. ACOSS Summer Heat Survey 2024. ACOSS, 2024. https://www.acoss.org.au/wp-content/uploads/2024/03/ACOSSHeatSurveyReport2024.pdf (viewed Sept 2024).

7 United Nations Environment Programme. About Montreal Protocol [website]. https://www.unep.org/ozonaction/who-we-are/about-montreal-protocol (viewed Sept 2024).

8 Lundgren-Kownacki K, Hornyanszky ED, Chu TA, et al. Challenges of using air conditioning in an increasingly hot climate. *Int J Biometeorol* 2018; 62: 401-412.

9 Tartarini F, Schiavon S, Jay O, et al. Application of Gagge's energy balance model to determine humidity-dependent temperature thresholds for healthy adults using electric fans during heatwaves. *Build Environ* 2022; 207: 108437.

10 Zhai Y, Zhang Y, Zhang H, et al. Human comfort and perceived air quality in warm and humid environments with ceiling fans. *Build Environ* 2015; 90: 178-185.

11 Tartarini F, Schiavon S, Cheung T, Hoyt T. CBE Thermal Comfort Tool: Online tool for thermal comfort calculations and visualizations. *SoftwareX*, 2020; 12: 100563.

12 Jay O, Hoelzl R, Weets J, et al. Fanning as an alternative to air conditioning – a sustainable solution for reducing indoor occupational heat stress. *Energy Build* 2019; 193: 92-98.

13 Kent MG, Huynh NK, Mishra AK, et al. Energy savings and thermal comfort in a zero energy office building with fans in Singapore. *Build Environ* 2023; 243: 110674.

14 Malik A, Bongers C, McBain B, et al. The potential for indoor fans to change air conditioning use while maintaining human thermal comfort during hot weather: an analysis of energy demand and associated greenhouse gas emissions. *Lancet Planetary Health* 2022; 6: e301-e309.

15 McKinsey & Company. Pathways to a low-carbon economy: Version 2 of the global greenhouse gas abatement cost curve [website]. McKinsey & Company, 2009. https://www.mckinsey.com/capabilities/sustainability/our-insights/pathways-to-a-low-carbon-economy#/ (viewed Sept 2024).

16 Jay O, Capon A, Berry P, et al. Reducing the health effects of hot weather and heat extremes: from personal cooling strategies to green cities. *Lancet* 2021; 398: 709-724.

17 Suresh Bhuvad S, You R, Chen Q. Evaluation of physiological and thermal comfort effectiveness of ceiling fan and table fan during a heat wave. *Energy Build* 2024; 322: 114706.

18 Ravanelli NM, Hodder SG, Havenith G, Jay O. Heart rate and body temperature responses to extreme heat and humidity with and without electric fans. *JAMA* 2015; 313: 724-725.

19 Morris NB, English T, Hospers L, et al. The effects of electric fan use under differing resting heat index conditions: a clinical trial. *Ann Inter Med* 2019; 171: 675-677.

20 Morris NB, Chaseling G, English T, et al. Electric fan use for cooling during hot weather: a biophysical modelling study. *Lancet Planet Health* 2021; 5: e368-e377.

21 Chaseling GK, Vargas NT, Hospers L, et al. Simple strategies to reduce cardiac strain in older adults in extreme heat. *N Engl J Med* 2024; 391: 1754-1757.

22 O'Connor FK, Meade RD, Wagar KE, et al. Effect of electric fans on body core temperature in older adults exposed to extreme indoor heat. *JAMA* 2024; 330: 1752-1754.

23 International Organization for Standardization. ISO 7730: 2005. Ergonomics of the thermal environment. Analytical determination and interpretation of thermal comfort using calculation of the

PMV and PPD indices and local thermal comfort criteria. Edition 3. ISO, 2005. https://www.iso.org/standard/39155.html (viewed Sept 2024).

24 Sera F, Hashizume M, Honda Y, et al. Air conditioning and heat-related mortality: a multi-country longitudinal study. *Epidemiology* 2020; 31: 779-787.

25 Gupta S, Carmichael C, Simpson C, et al. Electric fans for reducing adverse health impacts in heatwaves. *Cochrane Database Syst Rev* 2012; 7: CD009888.

26 Tartarini F, Jay O. Heatwatch [website]. Sydney: University of Sydney, 2024. https://heatwatch.sydney.edu.au/ (viewed Sept 2024). ■