Heart rate and body temperature responses to extreme heat and humidity with and without electric fans

This item was submitted to Loughborough University's Institutional Repository by the/an author.

Citation: RAVANELLI, N.M. ... et al., 2015. Heart rate and body temperature responses to extreme heat and humidity with and without electric fans. JAMA: Journal of the American Medical Association, 313 (7), pp. 724 - 725.

Additional Information:

- This article was accepted for publication in the Journal of the American Medical Association [© American Medical Association] and the definitive version is available at: http://dx.doi.org/10.1001/jama.2015.153

Metadata Record: https://dspace.lboro.ac.uk/2134/16846

Version: Accepted for publication

Publisher: © American Medical Association (AMA)

Rights: This work is made available according to the conditions of the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0) licence. Full details of this licence are available at: https://creativecommons.org/licenses/by-nc-nd/4.0/

Please cite the published version.
Heart rate and body temperature responses to extreme heat and humidity with and without electric fans

Nicholas M. Ravanelli MSc1, Simon Hodder PhD2, George Havenith PhD2, Ollie Jay PhD3

1Thermal Ergonomics Laboratory, University of Ottawa, 200 Lees Ave, Ottawa, CANADA, K1N 6N5
2Environmental Ergonomics Research Centre, Loughborough University, Leics, UNITED KINGDOM, LE11 3TU.
3Faculty of Health Sciences, University of Sydney, NSW 2141, AUSTRALIA

Revision 1: December 11, 2014
Revision 2: December 18, 2014

Address for correspondence:
Dr. O. Jay
Faculty of Health Sciences,
University of Sydney,
K216, 75 East St,
Lidcombe, NSW 2141.
Australia
+ 61 (2) 935-19328
e-mail: ollie.jay@sydney.edu.au
**Introduction:** Patz et al.\(^1\) described the projected effects of more prolonged and severe heat waves on human health. A simple, low-cost cooling device is an electric fan. A Cochrane review concluded “no evidence currently exists supporting or refuting the use of electric fans during heat waves” for mortality and morbidity.\(^2\) However, public health guidance typically warns against fan use in hot weather. Recommended upper limits range from 32.3°C (90°F) at 35% relative humidity (RH) to the “high 90s” (96-99°F; 35.6-37.2°C, no RH stated\(^2\)). The skin-to-air temperature gradient reverses with rising environmental temperature, causing dry heat transfer towards the body via convection rather than away from it. Fan use would increase this dry heat transfer, potentially accelerating body heating;\(^3,4\) however, the efficiency of sweat evaporation from the skin would be simultaneously increased. Thus, fans could still improve net heat loss. Sweat evaporation declines with increasing humidity, so in more humid environments fans may not prevent heat-induced elevations in cardiovascular (heart rate, HR) and thermal (esophageal temperature, T\(_{core}\)) strain. This study examined the influence of fan use on the critical humidities at which hot environments can no longer be physiologically tolerated without rapid increases in HR and T\(_{core}\).

**Methods:** After University of Ottawa ethics approval, written informed consent was obtained from student volunteers recruited by word-of-mouth. Each participant completed four 135-min trials presented in randomized order and separated by >48 h. Euhydration was confirmed prior to each trial (urine specific gravity <1.025). Wearing shorts and t-shirts, participants sat in a chamber maintained at temperatures equal to (36°C; 97°F) or exceeding (42°C; 108°F) the limits currently recommended for fan use. Each temperature was tested with and without an 18” diameter fan (Whirlpool) facing the participant from 1 m (air speed: 4.0m/s). After 20-min
baseline, RH was increased in 15 equal steps (7.5-min each), from 25% to 95% at 36°C, and from 20% to 70% at 42°C. Heart rate (Polar) and Tcore (Covidien) were measured throughout. Whole-body sweat rate was determined using the 135-min pre-to-post trial change in body mass (Sartorious). The RH values at which an upward inflection in firstly HR and then Tcore occurred were determined (Figure 1) separately for each individual trial using segmented linear regression (Graphpad). These critical RH values and whole-body sweat rates were compared between fan and no fan trials at each temperature using paired-sample t-tests (P<.05, 2-sided).

Results: Eight healthy males (23±3 y; 80.7±11.7 kg) participated between June 5 and November 6, 2013. The critical RH for an upward inflection in HR was higher with fans than without fans at 36°C (83%, 95% CI, 78-87 vs 62%, 95% CI, 56-68; P<.001) and 42°C (47%, 95% CI, 42-51 vs 38%, 95% CI, 33-42; P=.01) (Figure 2). An upward inflection in Tcore at 36°C only occurred in 2 participants with fans but 7 participants without fans (RH=84%, 95% CI, 80-88). At 42°C, the Tcore inflection occurred at a higher RH with fans (55%, 95% CI, 51-59) than without fans (48%, 95% CI, 42-54; P=.04) (Figure 2). Whole-body sweat rate was greater with fans than without fans at 36°C (180 g/h, 95% CI, 173-187 vs 153 g/h, 95% CI, 140-165; P=.01) and 42°C (399 g/h, 95% CI, 381-417 vs 241 g/h, 95% CI, 209-273; P<.001).

Discussion: Our preliminary study is the first to our knowledge to demonstrate that electric fans prevent heat-related elevations in HR and Tcore in healthy young men up to approximately 80% RH at 36°C and 50% RH at 42°C. Thus, contrary to existing guidance, fans may be effective cooling devices for those without air-conditioning during hot/humid heat waves. Only young participants were assessed, so critical RH values must be dervied for other populations (e.g.
elderly with co-morbidities), and those with diminished sweat production. However, sweat rates measured with fans were lower than values previously reported to be achievable in healthy 70 year-olds (440 g/h)⁶. Advice to the public to stop using fans during heat waves may need re-evaluation.
Acknowledgements

No conflicts of interest are declared by the authors. This research was supported by a Discovery Grant from the Natural Sciences and Engineering Research Council (NSERC) of Canada (#386143-2010, held by O. Jay). The funding agency had no input regarding the design and conduct of the study; the collection, management, analysis, or interpretation of the data; the preparation, review, or approval of the manuscript; or the decision to submit the manuscript for publication. O. Jay had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Figure 1. Example of changes in HR and $T_{\text{core}}$ with stepwise increases in relative humidity

Data for one participant at 42°C in “no fan” condition. Each trial consisted of 15 stepwise increases in absolute humidity of 2 mmHg (3.33% RH at 42°C) after an initial baseline period at 20% RH. Each data point represents the average value during the last 1-min of each stage. The RH values at which inflection points occurred for HR and $T_{\text{core}}$ were determined separately for each participant in each of their 4 trials using segmented linear regression.
Figure 2. Influence of fans on critical humidity for heart rate (HR) and core temperature (Tcore) elevations.

Fan (open circles) and no fan (closed circles) trials conducted at 36°C and 42°C. Separate P-values given for comparisons between fan and no fan trials at each temperature. ² indicates no statistical comparison could be performed as an inflection in Tcore was observed in only 2 of 8 participants with fan use at 36°C. Error bars are 95% confidence intervals.
References


