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

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**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\(_{\text{core}}\)) 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\(_{\text{core}}\).

**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.\textsuperscript{5} Heart rate (Polar) and T\textsubscript{core} (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 T\textsubscript{core} 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 T\textsubscript{core} 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 T\textsubscript{core} 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 T\textsubscript{core} in healthy young men up to approximately 80% RH at 36°C and 50% RH at 42°C. Thus, contrary to existing guidance\textsuperscript{3,4}, 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.
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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 ($T_{core}$) 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 $T_{core}$ was observed in only 2 of 8 participants with fan use at 36°C. Error bars are 95% confidence intervals.
References


