Heart Rate and Body Temperature Responses to Extreme Heat and Humidity With and Without Electric Fans

Patz et al1 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 review2 concluded “no evidence currently exists supporting or refuting the use of electric fans during heat waves” for mortality and morbidity. 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 stated2).

The skin-to-air temperature gradient reverses with rising environmental temperature, causing dry heat transfer toward the body via convection rather than away from it. Fan use would increase this dry heat transfer, potentially accelerating body heating3,4; 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 (core temperature) 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 core temperature.

Methods | After University of Ottawa ethics approval, written informed consent was obtained from student volunteers. Each participant completed four 135-minute trials presented in randomized order and separated by more than 48 hours. Euthydration 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-in fan (Whirlpool) facing the participant from 1 m (air speed: 4.0 m/s). After a 20-minute baseline period, RH was increased in 15 equal steps (7.5 minutes each) from 25% to 95% at 36°C and from 20% to 70% at 42°C.5 Heart rate (Polar) and core (esophageal) temperature (Covidien) were measured throughout. Whole-body sweat rate was determined using the 135-minute pre-to-post trial change in body mass (Sartorious).

The RH values at which an upward inflection in first HR and then core temperature 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 (mean [SD] age of 23 [3] years and weight of 80.7 [11.7] kg) participated between June 5 and November 6, 2013. The critical RH for an upward inflection in HR at 36°C was higher with fans (83%; 95% CI, 78%-87%) than without fans (62%; 95% CI, 56%-68%) (P < .001) and at 42°C (47% [95% CI, 42%-51%] vs 38% [95% CI, 33%-42%], respectively) (P = .01; Figure 2).

Figure 1. Changes in Core Temperature and Heart Rate With Stepwise Increases in Relative Humidity for 1 Participant at 42°C Without a Fan

Each trial consisted of 15 stepwise increases in absolute humidity of 2 mm Hg (3.33% relative humidity at 42°C) after an initial baseline period at 20% relative humidity. Each data point represents the average value during the last minute of each stage. The relative humidity values at which inflection points occurred for heart rate and core temperature were determined separately for each participant in each of his 4 trials using segmented linear regression.
Contrary to existing guidance, fans may be effective cool to approximately 80% RH at 36°C and 50% RH at 42°C. Thus, elevations in HR and core temperature in healthy young men up to approximately 80% RH at 36°C and 50% RH at 42°C. This, contrary to existing guidance, fans may be effective cooling devices for those without air conditioning during hot and humid periods.

Only young participants were assessed, so critical RH values must be derived for other populations (eg, 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-old adults (440 g/h). Advice to the public to stop using fans during heat waves may need to be reevaluated.

An upward inflection in core temperature at 36°C only occurred in 2 participants with fans but in 7 participants without fans (RH, 84%; 95% CI, 80%-88%). At 42°C, the core temperature 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 at 36°C with fans (180 g/h; 95% CI, 173-187 g/h) than without fans (153 g/h; 95% CI, 140-165 g/h) (P = .01) and at 42°C (399 g/h [95% CI, 381-417 g/h] vs 241 g/h [95% CI, 209-273 g/h], respectively) (P < .001).

**Discussion** | Our preliminary study is the first, to our knowledge, to demonstrate that electric fans prevent heat-related elevations in HR and core temperature 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 and humid periods.

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**Correction:** This article was corrected on March 4, 2015, to fix the affiliation for Nicholas M. Ravanelli, BSc.

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