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PERFORMANCE EVALUATION OF AN ENERGY EFFICIENT STAND FAN

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INTRODUCTION

Elevated air speed is an effective method of cooling people in moderately warm indoor environments. In cold climates, elevated air movement can cause draft, defined as unwanted local cooling. In warm climates, on the other hand, enhanced air speeds can allow thermal comfort to be achieved in occupied spaces with elevated temperatures, which can yield energy efficiency benefits (Sekhar, 1995; Olesen and Brager, 2004; Aynsley 2005). A comprehensive review about thermal comfort and air movement pointed out theoretical support for using cooling fans (de Dear et al., 2013). Schiavon and Melikov (2009) introduce the cooling fan efficiency (CFE) index, defined as the ratio between cooling effect (as measured with a thermal manikin) generated by the fan and its power consumption, to objectively compare cooling fans in their ability to energy efficiently cool people. In this paper, an energy efficient stand fan was tested because of its special design of driving motor and fan blades. The three-phase brushless direct current (DC) driving motor can easily realize 24-grade-velocities in an energy efficient way. Specially designed fan blades, based on aerodynamics theories, can reduce flow resistance effectively. The maximum design power for this fan is 18 W, which is only 1/2 or even 1/3 of the power required for a conventional alternating current fan. Because of these advantages, the fan is envisaged to behave better than conventional fans (Schiavon and Melikov, 2009). The performance of the fan was tested and evaluated by manikin-based equivalent temperature, fan power consumption and CFE index.

METHODOLOGIES

Experiments were conducted in a chamber (11.0 m × 7.8 m × 2.6 m) with accurate control of dry bulb temperature (±0.5°C) and relative humidity (RH) (±3%). During experiments, outdoor temperature fluctuated from 31°C to 32.5°C. Room temperature was controlled by a variable air volume (VAV) air conditioning system with low background air velocity. Relative humidity was not controlled but measured. Relative humidity does not affect the thermal manikin measurements described below. One workstation was located at the centre of the chamber for measurement purposes. One commercially available stand fan with 24 speeds was employed, which was driven by direct current (DC) Ⅲ energy efficient motor. The fan was positioned at one of four locations at 1 or 2 m (3 and 6 times the swept diameter) distance in front of or to the side of the dry-heat loss thermal manikin. The height of the fan hub was 1.1 m, the same as the breathing height of a sitting person, which is the target point. The fan consumes from 1.9 W (minimum speed) to 17.3 W (maximum speed), and generates 0.05 m/s to 2.46 m/s at 1 m distance and 0.05 m/s to 1.26 m/s at 2 m distance, respectively. These air velocities at the target points were measured without the thermal manikin. Room temperature and RH were measured by an Indoor Air Quality meter, with 0-60°C (±0.4 °C) temperature range and 5-95% (±3%) for RH range. Air speed was measured by a DanTech System, with a response time of 0.5 s and an uncertainty of 0.01 m/s ±1% of reading. Fan power was measured by a Yokogawa digital power meter with 0-5 kW measuring range and 1 W uncertainty. One dry-heat loss thermal manikin, which can only simulate sensible heat loss from human body, was used to assess the cooling effect of the fan. Performance of the fan was explored at four room air temperatures (24 °C, 26 °C, 28 °C, and 30 °C), six selected speeds (settings 4, 8, 12, 16, 20, and 24), two distances between the fan and thermal manikin (1 m, 2 m) and two directions to thermal manikin (front, side). Cooling fan efficiency (CFE) index was defined as the ratio between the cooling generated by the fan (as measured with the thermal manikin) and its power consumption (Schiavon and Melikov, 2009).

RESULTS AND DISCUSSION

Cooling effect (Δt_{eq}) and CFE were obtained under experimental conditions studied. Whole-body cooling effects vary between -7.9 °C and 0 °C. The resulting CFE index varies between 0 °C/W and 0.83 °C/W). In Figure 1, box-plots are presented of the CFE index versus room temperatures (24 °C, 26 °C, 28 °C and 30 °C), fan grades (4, 8, 12, 16, 20, 24), fan distances (1 m and 2 m), fan position (front and side).

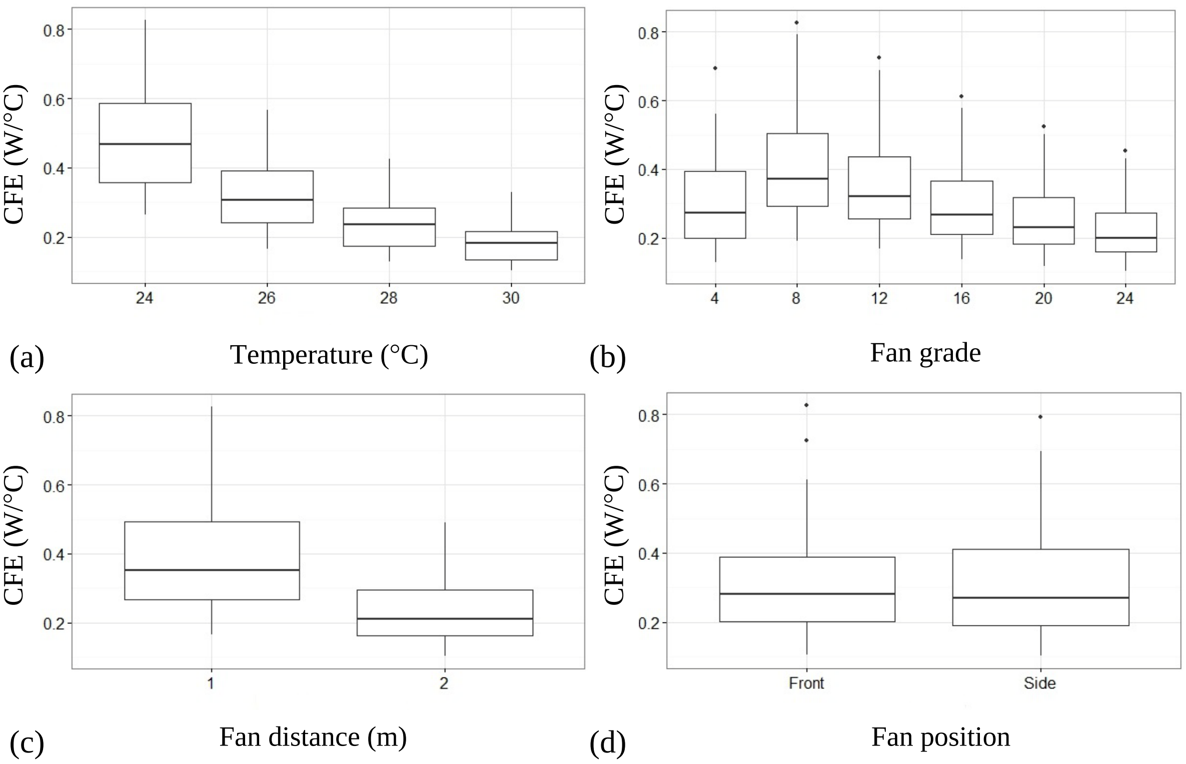

Figure 1. Box plots for CFE index versus (a) temperature, (b) fan speed, (c) fan distance and (d) fan position.

The influence of room temperatures on the CFE index is obvious. When room temperature is 24 °C, the median CFE index is 0.47 °C/W. When the room temperature increases to 30 °C, the median changes to 0.18 °C/W. It makes sense that air motion is less effective in providing convective cooling at higher air temperatures. The influence of fan speed on the CFE index is also evident from Figure 1(b), with the highest index achieved at a relatively low speed setting (grade 8). Figure 1(c) shows, as expected, that the fan is more effective at 1 m spacing than at 2 m from the manikin. The orientation between the fan and the manikin does not play a significant role in the CFE value (Figure 1(d)).

CONCLUSIONS

Cooling effect and CFE index have been evaluated for an energy efficient stand fan with a seated thermal manikin. The assessment was completed at four room temperatures, six fan speeds, two fan-manikin distances and two fan positions. Whole-body cooling effects vary between -7.9 °C and 0 °C corresponding to fan power varying between 1.9 W and 17.3 W. The CFE index was measured to be in the range 0 °C/W to 0.83 °C/W. As compared with previous testing results regarding stand fans, the unit tested here used lower fan power and produced correspondingly higher CFE index values for comparable whole-body cooling effect. Apart from head and chest regions, cooling effects for arm and thigh region are also enhanced because of the widely distributed airflow generated by the fan. Responses from human subjects are needed to be explored. The influence of fan generated airflow on convective cooling is stronger with lower room temperatures. For a given room air temperature, the influence of fan speed on cooling effect varies obviously when fan grade is lower than 16. For pursuing same cooling effect, it is more energy efficient to locate the fan in shorter distance using lower fan grade which has high CFE instead of locating the fan in longer distance using higher fan grade. If the location is occupied by indoor furniture, fan can be moved to side direction by keeping the same distance.

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