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SENSATION OF DRAFT AT ANKLES FOR DISPLACEMENT VENTILATION AND UNDERFLOOR AIR DISTRIBUTION SYSTEMS

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INTRODUCTION

Draft is defined as an unwanted local convective cooling of the body caused by air movement (Fanger, 1977). The main factors that affect draft are air temperature and velocity (Houghten et al., 1938), air turbulence (Fanger et al., 1988), body parts exposed and clothing insulation level, and overall thermal comfort (Toftum et al., 2003). Historically, the literature on draft has focused on thermal discomfort at the neck, which was considered the most sensitive part of the body, especially as the majority of mechanical systems supplied air from the ceiling. Now, owing to the widespread use of floor-level air distribution systems (underfloor air or displacement) and dress customs in which ankles could be uncovered, the need to assess draft risk for the ankle has emerged (Sekhar and Ching, 2002). The purpose of the present study is to experimentally evaluate local draft risk for uncovered ankles associated with displacement ventilation and underfloor air distribution.

METHODS

Thirty female subjects (age = 24.1±6.8 y, BMI = 21.2±2.2) participated in nine double-blind and fully randomized climatic chamber tests. Only female subject were selected because according to meta-analysis by Karjalainen (2007) females are more likely than males to express thermal dissatisfaction. The subjects were instructed to dress in typical summer office clothes (around 0.6 clo) with their lower legs bare. They wore flip-flop sandles without socks.

The experiments were carried out in a well-insulated environmental chamber (5.5 m × 5.5 m × 2.5 m). Three workstations (WS) were established so that three subjects could be tested at the same time. Custom-build displacement diffusers were positioned behind the subjects at minimum distance of 0.71 m away from the legs. The subjects were allowed to move their feet within a marked area of 0.71 × 0.51 m. The subjects were instructed to keep the feet flat on the floor throughout the tests. A dedicated spot cooling system supplied conditioned air through the three diffusers while an underfloor air system was used to keep the whole space at a desired room temperature. Air temperature was measured at heights of 0.1 and 1.1 m and at no more than 0.5 m from each person at each of the three workstations. The air temperatures were monitored continuously using thermistors. A multichannel low velocity thermal anemometer with omnidirectional velocity transducers was used to measure mean velocity, turbulence intensity and air temperature at 0.1 m height, near the ankles, during the tests. All the sensors comply with the standards requirements (ISO, 1998; ANSI/ASHRAE, 2013).

The room was maintained at a relative humidity of around 50%. The operative temperature was kept at 24 °C. The measured air temperatures and velocities at the feet are reported in the *x*-axis of Figure 1. Each test took 3 hours. At the beginning of each test, the subjects sat for 30 minutes in a mesh chair to let their body to adapt to the chamber temperature. After this preconditioning time, the subject sat on the chair under the influence of the diffuser for 30 minutes and then rested outside the influence of the jet for 30 minutes. Subjects were allowed to adjust their clothing to keep their whole body thermal sensation neutral during the entire duration of the test, but they were not allowed to change their clothing in the lower part of the body during the test.

A survey was given before and after 1, 5 and 27 minutes measured from the start of each test condition. The survey questionnaires include six parts: (1) overall thermal acceptability; (2) thermal comfort, thermal preference, and thermal sensation on a 7-point ASHRAE scale; (3) air movement acceptability at ankles and preference; (4) thermal sensation at the hands, torso, ankles and feet; (5) air movement acceptability at hands, torso, ankles and feet; and (6) air quality acceptability.

RESULTS AND CONCLUSIONS

The average operative temperature measured at 1.1 m was stable during the experiments at 24.1 °C (SD = 0.16 °C). The temperature at the ankle was different at each workstation, varying with the supply air setpoint and air speed. In Figure 1 is shown the overall thermal acceptability vote at the end of each test. Between 20 and 37 percent of the subjects found the thermal environment not acceptable. The maximum percentage of dissatisfied people due to draft in European and International standards is 10%. The values obtained here are above the maximum limit set by ISO 7730 and EN 15251. The number of dissatisfied subjects is higher than expected. To have less than 10% of dissatisfied occupants, the air temperature should be higher and/or the air velocity should be lower than the cases tested here. With an air temperature at the ankles of 21.7 °C and an air velocity of 0.16 m/s we still observed 6 out of 30 (20%) dissatisfied subjects. The results show that the subjects were more sensitive to draft than expected.

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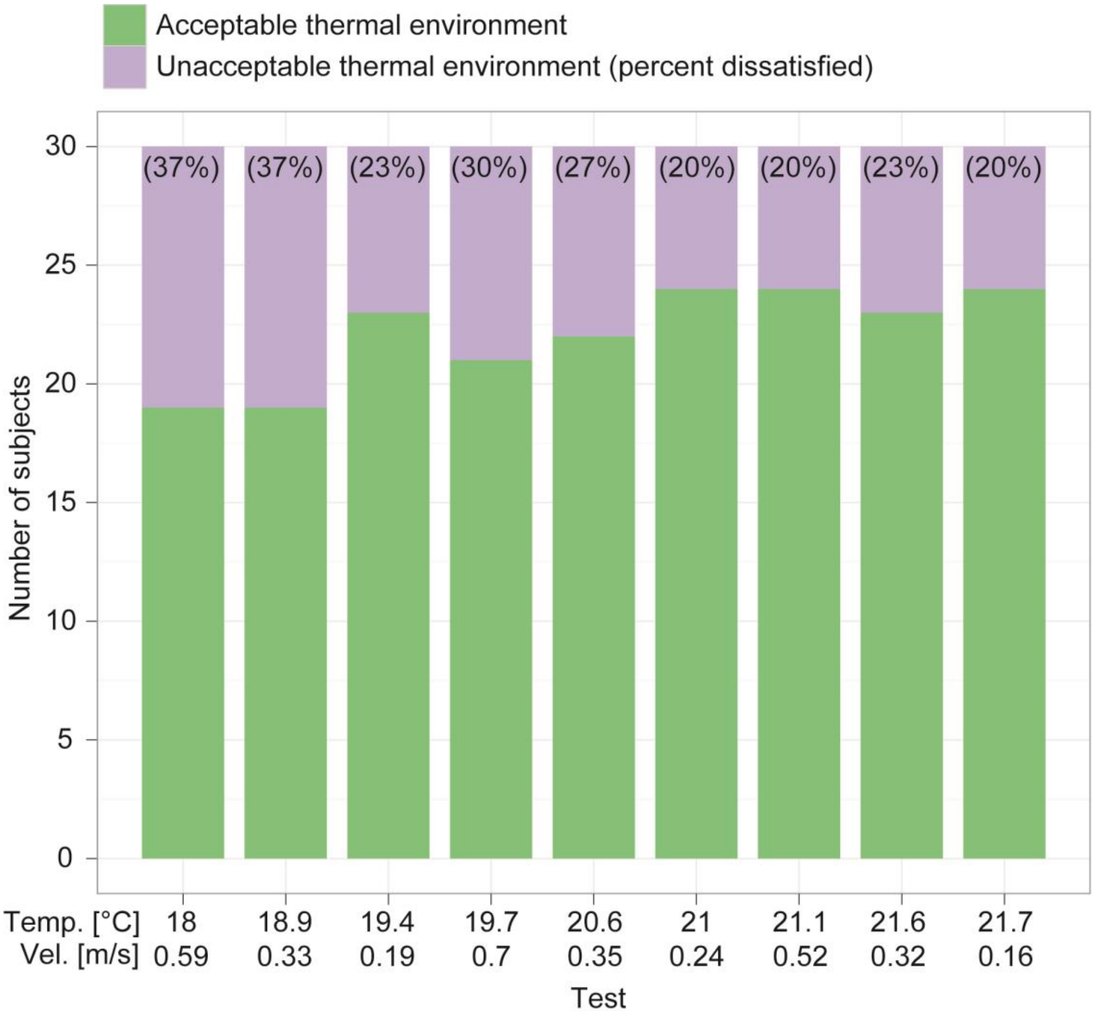

Figure 1. Overall thermal acceptability of the environment for the nine tests. Tests are identified with the dry-bulb air temperature and air velocity at the ankles.

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