# Experimental investigation of the effects of inlet cooling air temperature on the occupants' local thermal sensation in the under-floor air distribution system

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## ABSTRACT

**In the present study, the effects of inlet cooling air temperature from the diffusers of under-floor air distribution system have been experimentally investigated on the occupants' local thermal sensation. In the experiments, the inlet air temperature is controlled at 12°C, 16°C and 20°C, and the inlet velocity is kept constant. Also, the room thermal conditions have been controlled at the mean temperature of 24±0.5°C and mean relative humidity of 25±2%. During the experiment, 8 healthy male subjects with common office clothing and metabolic rate were exposed to an under-floor air distribution system for 30 min and their thermal sensation and satisfaction were assessed on the basis of thermal comfort standards. Based on the results, the head and chest thermal sensations are not significantly depended on inlet temperature. But, by decreasing the inlet temperature, the thermal sensation and satisfaction of hands and feet are decreased. Moreover, the results indicated that the overall body thermal sensation is significantly depended on the sensation of the body parts with extreme thermal conditions. Also, the results show that the feeling of air movement can be increased during the time; so, the subjects reported about 75% draught discomfort after 30min exposure to under-floor air distribution system.**

## KEYWORDS

**Under-floor air distribution system, Thermal comfort, Local thermal sensation, Experimental study, Ventilation.**



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## 1. Introduction

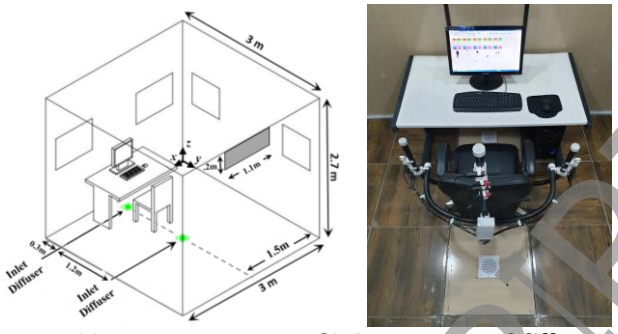
The under-floor air distribution system (UFAD) is a conventional ventilation system which can provide proper indoor air quality and thermal comfort conditions[1]. So far, the numerous studies have been carried out on the performance of under-floor air distribution system. Al-Ajami and Amer[2] analyzed the performance of under-floor air distribution systems in comparison with overhead systems. Based on their results, using the UFAD system can reduce the energy consumption up to 30%. Afzalian et al. [3] numerically investigated the effects of air change rate on thermal comfort, indoor air quality, and local thermal discomfort in a crowded hall with UFAD system. Based on the results, increasing the air exchange rate causes a significant increase in indoor air quality and energy consumption. But on the other hand, the diffusers' arrangement can cause to increase the draught discomfort about 15%. Also, Yao et al. [4] analyzed the performance of UFAD system with swirl inlet diffusers.

The performance of the air conditioning systems is generally influenced by factors such as the arrangement of inlet and outlet diffusers, the air change rate and the inlet air temperature and velocity of inlet air. Therefore, the main aim of this study is to experimentally evaluate the performance of UFAD system in providing the thermal comfort conditions for various body segments.

## 2. Methodology

The experiments conducted in a test room (as shown in Fig 1) with dimensions of 3m×3m and ceiling height of 2.7m which located at the Thermal Comfort Research Group, University of Birjand. In the experiment, 8 healthy male subjects were exposed to an under-floor air distribution system for 30 min and their thermal sensation and satisfaction were assessed on the basis of thermal comfort standards. During the test, the subjects performed sedentary office activity and their metabolic heat production was assessed about 1.2 met. Also, the subjects wore the office clothing with the thermal resistance of about 0.61 clo.

As shown in Fig.1 (a), the air enters the room from two inlet diffusers with dimensions of 15cm×15cm and the air passes through 57 holes with 6mm diameter on each inlet diffuser. Also, an air outlet diffuser with dimensions of 110 cm×20cm is located near the ceiling. On the other hand, the guidelines for designing the cooling UFAD systems have suggested a temperature of about 16°C as the inlet temperature [5, 6]. This temperature is based on the occupants' general comfort and the effect of inlet temperature on local thermal sensation in various parts of the body has not been studied.




**(a) Room geometry** **(b) Arrangement of diffusers**

**Figure 1. Geometry of test room**

Therefore, in this study, the effects of three different inlet temperatures of 12, 16, and 20°C have been investigated on the occupants' local thermal sensation.

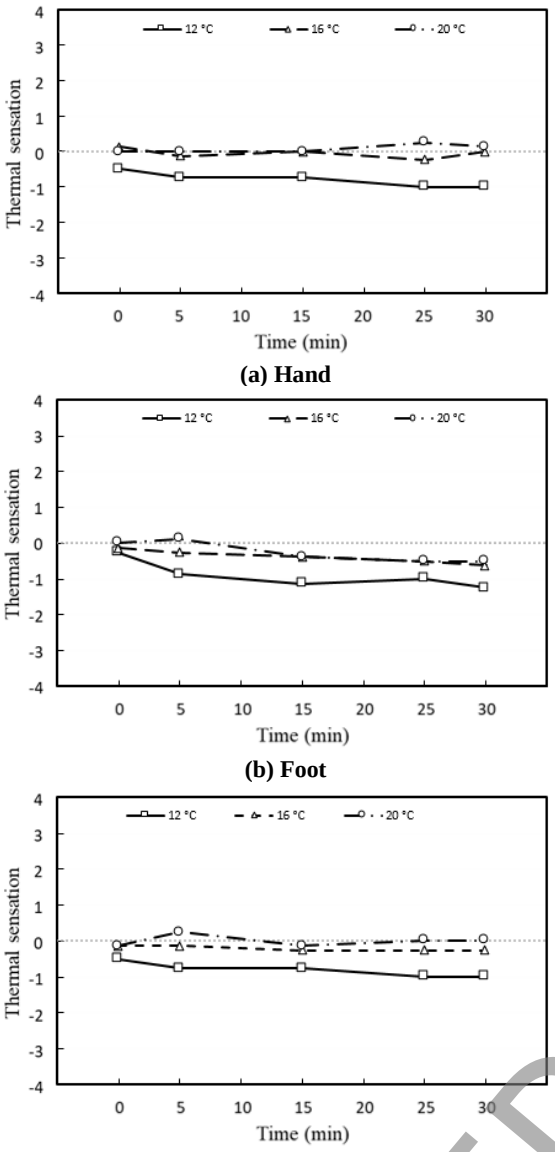
## 3. Results and Discussion

In this study, the effects of changes in the inlet temperature of UFAD system have been investigated on local thermal sensation and satisfaction of hand, feet and whole body. In Figure 2 (a), the subjects' hand thermal sensation is shown. Also, Figs 2 (b) and 2 (c) show the transient thermal sensation of foot segment and whole body during the test. As can be seen, the subjects have noticeably cooler sensation for the inlet temperature of 12 than the temperatures of 16 and 20°C. Also, the results indicate that the body can adapt hands with the environment at inlet air temperatures of 16 and 20°C. So, the body can maintain the hand thermal sensation in the neutral range for up to 15 minutes from initial time. At the beginning of the test, the foot thermal sensation was in neutral range and it decreases over the time and after 30 min, the foot segment has a slightly cool sensation.

Figure 3 (a) shows the hand mean thermal comfort during the test. The subjects are satisfied with the inlet temperature of 20°C during the test; but as the inlet air temperature decreases to 16°C, the subjects' satisfaction decreases significantly. Also, it is observed that the inlet air temperature of 12°C can considerably decrease the level of subjects' comfort. Also, in Figs 3 (b) and 3 (c), the foot and whole body thermal comfort are shown. As can be seen, the whole body thermal comfort level is highly dependent on mean comfort level of critical body segments such as hands and feet.

## 4. Conclusion

In the present study, the occupants' local thermal sensation were studied in a room with UFAD system and with different inlet temperatures of 12,16,and 20°C.

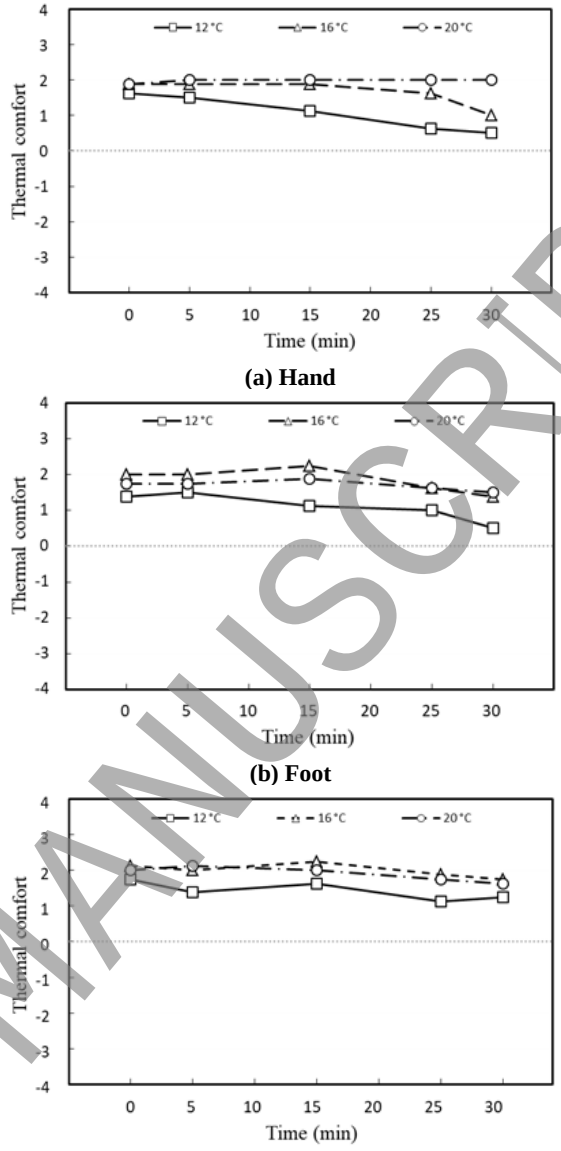



**(a) Hand**

**(b) Foot**

**(c) Whole body**

**Figure 2. The occupants' transient thermal sensation**




**(a) Hand**

**(b) Foot**

**(c) Whole body**

**Figure 3. The occupants' transient thermal comfort**

Based on the results, changing in inlet air temperature can significantly affect the feet and hands thermal sensation.

Moreover, the results indicated that the overall body thermal sensation and thermal comfort level are significantly depended on the sensation of the body parts with extreme thermal conditions such as hands and feet. Also, the results show that the feeling of air movement can be increased during the time; so, the subjects reported about 75% draught discomfort after 30 min exposure to UFAD system.

## 5. References

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