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Effects of temperature steps on human skin physiology and thermal sensation response

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ABSTRACT

Air-conditioning is frequently used as a means of adjusting indoor thermal environment in hot-and-humid areas. However, when entering an air-conditioned building from outdoors people may experience thermal discomfort and risk health consequence if the instantaneous change of air temperature exceeds the thermoregulatory capacity. A study was conducted to investigate the alteration in thermal perception and in thermoregulation that simultaneously occurred in response to temperature step in a thermal transient. In this study, two temperature down-steps from 32/28 to 24 °C and an up-step from 20 to 24 °C were created in a climatic chamber consisting of two microclimate-controlled rooms, and subjects were evaluated for change in thermal sensation as well as in skin physiological properties, including skin capillary blood flow (SCBF), skin moisture, transepidermal water loss (TEWL), and skin temperature over the course of acclimation. As the results show, a cold sensation overshot occurred in thermal sensation vote (TSV), skin temperature, and SCBF in 1 min after the temperature dropped from 32 to 24 °C. TSV correlated the best with skin temperature ($r = 0.60$) and moderately with skin moisture and TEWL ($r = 0.42–0.54$) when the temperature down-step reached 8 °C. TEWL acclimated in a two-stage pattern, demonstrating a difference between the sensational change and thermoregulation. The gender-specific influence occurred in thermoregulation but not in subjective sensation. The findings of the study suggest that thermoregulatory burden might be adequately controlled when the temperature step in thermal transition zone is limited to 4 °C or lower.

1. Introduction

1.1. Background

In Taiwan, air-conditioning is the most frequently used means in adjusting the indoor thermal environment to accommodate the hot-and-humid climate. For occupants working or living in the air-conditioned buildings, they constantly encounter a step change in air temperature when entering or leaving the buildings, sometimes at a substantial level in hot summer days. The instantaneous change in temperature can bring discomfort or even risk a thermal stress, such as contracting a cold, to those who have to regularly move across the temperature ramp. To alleviate human physiology from the thermoregulatory shock arising from sudden change in thermal environment, the temperature step in the thermal transition zone of a building, including the entrance area, foyer, atrium, lift lobby, and etc., should be appropriately controlled. The control of transient temperature also allows for an opportunity to decrease the consumption of energy used in air-conditioning the transitional space. Chun and Tamura [1] estimated that the energy used in some transition spaces could be up to three times higher than the level spent in the other enclosed spaces. To better characterize the human responses upon an abrupt thermal challenge, we reported here a study conducted in climatic chamber that evaluated the synchronous modification of subjective thermal sensation and skin physiology in adaptation to up- and down-step changes of air temperature.

1.2. Thermal comfort in thermal transient

The thermal comfort in transient conditions has been a focus of studies and literature reviews [2,3]. de Dear et al. [4] investigated the conscious experience of thermal transients both experimentally and by means of dynamic thermoreception modeling. In their observation, the immediate sensations following temperature up-steps closely resembled the steady-state responses established later in the warmer environment, whereas the initial impressions

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