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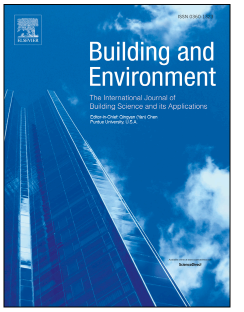

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Experimental study on the variations in human skin temperature under simulated weightlessness

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Abstract: To study the variations in skin temperature in weightlessness, the skin temperatures of 6 male volunteers were measured under simulated weightlessness by head down bed rest (HDBR) experiments. The effects of the air temperature, relative humidity and air speed on the mean skin temperature were scrutinized, and the regional skin temperatures of the subjects under comfortable conditions were investigated. The results showed that the mean skin temperature increased with the air temperature both before and after HDBR in low and neutral air temperatures and that the mean skin temperature was found to be higher before HDBR. However, a higher mean skin temperature was observed after HDBR when the air temperature was high. Moreover, the mean skin temperature in low and neutral air temperatures was found to increase with the relative humidity both before and after HDBR, and a higher mean skin temperature was also observed before HDBR. Additionally, a negative correlation between the mean skin temperature and air speed was observed both before and after HDBR. However, different patterns of the mean skin temperature were observed when the environment changed from low air temperature and humidity to a neutral environment and finally to a high air temperature and humidity. Finally, the regional skin temperature after HDBR showed a different distribution compared with that before HDBR, such as a higher skin temperature in the thorax, forehead and back and a lower skin temperature in the thigh, calf and hand. This indicated that the skin temperature distribution changed greatly under simulated weightlessness by HDBR, which might suggest an altered thermal regulatory mechanism in humans experiencing weightlessness.

Key words: skin temperature; weightlessness; air temperature, relative humidity, air speed, HDBR

1 Introduction

Human skin temperature is an important physiological parameter reflecting human responses to the thermal environment, and it is a direct reflection of the thermal comfort and thermal sensation of the human body. As stated in ASHREA 55-2013, thermal comfort is the condition of mind in which satisfaction is expressed with the thermal environment [1]. This definition of thermal comfort consists of both its physiological and psychological aspects, where skin temperature often plays an important role [2]. Therefore, the skin temperature is often measured as an essential physiological parameter for the evaluation of human thermal comfort.

Human thermal comfort in buildings in terrestrial conditions has been studied for decades, and many sophisticated theories and research models have been advanced. Usually, air temperature, air humidity, air speed, mean radiant temperature, clothing resistance and metabolism are thought to be the 6 major factors influencing human thermal comfort on earth [3]. Additionally, it is easy to judge the comfort level of humans simply by examining their physiological parameters, such as the mean skin temperature. However, what will happen to human skin temperatures when they live and work in a weightless environment? Will the mean skin temperature still be effective to judge thermal comfort? Findings from the recent studies on thermal comfort in terrestrial conditions may not answer these questions because weightlessness was not taken in account in these studies, and there is not a thermal comfort standard applicable to the weightless environment. Therefore, the research in this paper is actually an extension of the studies on human thermal comfort.

Human skin temperature is influenced directly by the skin blood flow and its distribution. The cardiovascular system is the first one to respond to weightlessness when a man is exposed to a weightless environment [4]. Several adaptive changes of the cardiovascular system occur, including but not limited to blood redistribution, altered cardiovascular function and reduced plasma volume, among which blood redistribution has conspicuous effects on skin temperature. The blood flows up to the torso and head from the lower body due to the absence of