



## Evaluation of calculation methods of mean skin temperature for use in thermal comfort study

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### ABSTRACT

A method was established to evaluate calculation methods of mean skin temperature, in order to find appropriate ones for use in human thermal comfort study. In this method three indexes, including reliability, sensitivity and number of measurement sites, were proposed. Under air temperatures of 21 °C, 24 °C, 26 °C, and 29 °C, 22 subjects' local skin temperatures (21 sites) and electrocardiograms were measured, and their thermal sensation and thermal comfort were inquired. Human heart rate variability indicated the physiological relation between mean skin temperature and ambient temperature for the sensitivity evaluation. Adopting the evaluation method, 26 types of mean skin temperature calculation methods were evaluated based on the experimental data. The results indicate that a calculation method of mean skin temperature with 10 sites is the most appropriate one, due to its high reliability, excellent sensitivity and fewer measuring sites. When it was applied to reflect thermal comfort, the performance was good.

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### 1. Introduction

Mean skin temperature (MST) is an important physiological parameter reflecting human response to cold or thermal stimulus and states of heat exchange between human body and a thermal environment. Human thermal comfort is defined as being “that condition of mind in which satisfaction is expressed with the thermal environment” [1]. As indicated in both of its thermophysiological definition [2] and energetic definition [3], MST plays a dominating role [4]. Therefore MST is often measured as an essential physiological parameter relating with thermal comfort (e.g. [5–8]).

Values for MST are obtained by summing the products of a finite number of local skin temperatures and the corresponding weighting factors. Up to now, many MST calculation methods have been established from the field of physiology, distinguished by the number of skin temperature sites and weighting factors. In the studies on thermal comfort, subjects' MST was measured with one of these MST calculation methods. For example, Bulcao used a 10-site weighed MST calculation method [5], Gagge adopted an average of 10 sites as mean skin temperature [6], and Hasebe and

Huizenga chose a 7-site method [7,8]. The MST calculation methods themselves cause differences in the MST values. That is to say if different one was used, the results might be distinct. However, in these studies no reason was given to explain why the MST calculation method was chose. Considering the importance of an appropriate MST calculation method in obtaining a reasonable result, it is necessary to compare various MST calculation methods and find out which are suitable for use in thermal comfort study.

In the present work, a method was established to evaluate different MST calculation methods considering the effect of ambient temperature on skin temperature, which is the most important environmental factor affecting human thermal comfort. And also, the most appropriate one for future use in study on thermal comfort was discussed.

### 2. Methods

#### 2.1. Subjects

12 male and 10 female college students (mean  $\pm$  SEM of age: 23.9  $\pm$  0.4 years, height: 170.6  $\pm$  1.1 cm, weight: 61.2  $\pm$  1.6 kg) were recruited for the experiment. All subjects were healthy non-smokers who were not taking prescription medication and had no history of cardiovascular disease. All protocols were approved by the university's ethics committee and conformed to the guidelines

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