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Thermal Physiology and Local Responses of Human Body During Exercise in Hot Conditions

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Abstract

Body temperature is maintained by effective thermoregulation, which depends on heat balance that includes heat production and heat loss. Skin moisture and water evaporation from the body play an important role in heat transfer, especially during exercising or in hot conditions. The regional skin evaporation can significantly affect the heat release of the each body part, the pattern of skin temperature distribution and the thermoregulation. Indeed, the distribution of sweat evaporation and skin temperature can also be applied as a means of managing the body thermoregulation. This study reviews the thermoregulation of human body, local skin evaporation and the skin temperature distribution. It also highlights the implication of local skin evaporation and skin temperature in the development of sportswear and the prevention of heat disorder in hot conditions.

Keywords: Heat Balance; Thermoregulation; Regional Sweat Evaporation; Regional Skin Temperature

1 Introduction

The body temperature is maintained by effective thermoregulation, which balances the interaction of air, clothing and skin temperature via the process of heat production and heat loss. In hot conditions, the rate of heat loss by convection and radiation decreases due to a decrease in the gradient of skin-to-environment temperature. However, the skin evaporation increases which contributes about 80% of total heat release of the body [1, 2]. Skin evaporation is regarded as the primary mechanism which affects thermoregulation in hot conditions. Due to the differences between sweat gland density and sensitivity of the body, the skin surface has non-uniform sweat evaporation on each part of the body. Meanwhile, distribution of skin temperature is not constant because of the variation of anatomic structures and tissue thickness as well as the distribution of blood flow. During the past five decades, the skin temperature and evaporation distribution of human body has been investigated by several research groups. Despite different applied research

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protocols and measurement methods, the skin temperature and evaporation mapping patterns have not been systematically highlighted. It is necessary to analytically summarize sweat evaporation distribution and the mapping pattern of skin temperature, because of their effects on thermoregulation, as well as the potential benefits on the development of functional sportswear.

This study presents the findings from the literature of the heat balance of human body and the mechanism of thermoregulation. The details of the distribution of sweat evaporation and regional skin temperature as well as the summary of the mapping pattern of human body are also presented. After that, the interaction between the local skin evaporation and skin temperature are discussed. Based on the researches reviewed, the implication of skin temperature and evaporation are generally explored in the development of sportswear and prevention of heat disorder.

The framework of this review is illustrated in Fig. 1.

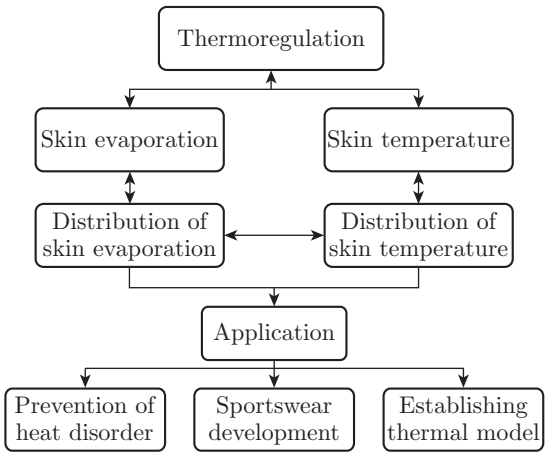

Fig. 1: Framework of this paper

2 Heat Balance and Thermoregulation

Normally, the core temperature of a healthy adult human is 36.8 ± 0.4℃ [3, 4]. The heat balance of the human body can be expressed as equation 1 [1, 2, 5, 6]

$$S = M - (\pm W) - (\pm E) - (\pm K) - (\pm C) - (\pm R)(W/m^2)$$

where:

S is the rate of storage of heat (positive = increase in body heat content, negative= decrease in body heat content);

M is the rate of metabolic heat production (always positive in a living animal, during rest, M = metabolic heat production);

W is the rate of work (positive = external work accomplished, negative = mechanical work absorbed by the body);

E is the rate of evaporative heat transfer (positive = evaporative heat loss, negative = evaporative heat gain);

C is the rate of convective heat transfer (positive = transfer to the environment, negative = transfer into the body);