Journal of Fiber Bioengineering and Informatics 10:1 (2017) 1–12
doi:10.3993/jfbim00252

The Effect of Clothing on Thermoregulatory Responses of Human Body in a Hot Environment

Jelka Geršak*, Milan Marčič

University of Maribor, Faculty of Mechanical Engineering, Research and Innovation Centre for Design and Clothing Science, Smetanova 17, SI-2000 Maribor, Slovenia

Abstract

Studying the effect of clothing on thermoregulatory responses of human body is highly complex because clothing, resp. a clothing system, as a heat exchange layer between the body and the environments must ensure a balance between heat production and heat dissipation within different environments and during various activities. The problem becomes more complex in the case of protective clothing, which requires liquid penetration resistance or impermeability of the material, restricting thus the dry heat flux by conduction, convection, and radiation, as convection and conduction transfer of heat caused by sweat evaporation and condensation. This paper deals with the study of the impact of clothing as baseline clothing, made from different functional materials, on thermoregulatory responses of human body in the limited heat and moisture transfer context. The results of the investigation show that the effect of baseline clothing, as an interface layer, worn under impermeable protective clothing, on thermoregulatory responses of human body, is limited during wearing in a hot environment.

Keywords: Clothing; Clothing Material; Cooling Effect; Thermoregulatory Response; Heat and Moisture Transfer

1 Introduction

The effects of clothing on thermoregulatory responses of human body have been studied by many researchers. Several reports show that heat transfer through clothing is significantly affected by human body and four climatic parameters: ambient air temperature, relative humidity, mean radiant temperature and air speed [1-6]. The clothing, designed on the basis of anthropometric requirements from two-dimensional textile surfaces, joined in a 3-D form, which covers the body as a shell [6], is not just passive cover for the skin; it interacts with and modifies the heat regulation function of the skin, and its effects are modified by the environment. Clothing, which mediates convective, as well as radiative and evaporative heat exchange, must be interpreted within the complete context of human physiological and psychological response. Therefore, the fact should not be neglect that the type, construction and structure of clothing, resp. clothing system worn can have an important impact on heat dissipation during different activities.

*Corresponding author.
Email address: Jelka.Gersak@um.si (Jelka Geršak).

In terms of thermophysiological comfort, which is characterized by three divergent processes (during normal wear, under transient wear conditions, and under specific wear condition), the behaviour of clothing in these three different domains may be treated as a complex system. Namely, clothing comfort is determined by a number of clothing properties that affect the thermal conditions of the skin. During normal wear, the human body continuously generates low amount of perspiration, meaning that human body produces some sweat or saturated water vapour, which must be progressively dissipated to maintain thermoregulation and a feeling of thermal comfort. The clothing becomes a part of the steady state thermoregulatory system [7]. Under transient wear conditions, characterized by heavy sweating caused by strenuous activity or climatic conditions, noticeable amount of perspiration and liquid sweat occur und must be rapidly managed by the clothing, resp. clothing system, in order to maintain thermal regulation [7]. Contrary to normal wear and transient wear conditions, under specific wear conditions, characterized by heavy sweating caused by impermeable protective clothing, the effect of clothing, as an interface between the skin and the environment, is passive, and health and safety are priorities to comfort.

2 Problem Formulation

Clothing, i.e. clothing system, which is a heat exchange layer between the body and its environment, plays an important part in the thermoregulation process. This means that clothing provides a microclimate between the body and external environment, and the microclimate is very important to the process of heat and vapour transfer from the skin to the external environment.

Clothing acts as a barrier for heat and vapour transfer between the skin and the environment. This barrier is formed both by the clothing materials themselves (from physical, structural and matter properties of the fabric to design and structure of the clothing assembly as a clothing system) and by the air they enclose as well as the still air that is bound to its outer surfaces [6]. The problem becomes more complex in the case of protective clothing, which is designed to provide protection against one or more hazards, and requires liquid penetration resistance or impermeability of the materials. The clothing interferes with the evaporation of sweat from the skin, increases skin temperature and core temperature, while reduction in cooling efficiency can also be observed.

2.1 The Influence of Clothing on Thermal Load

Heat transfer from human body, through the microclimate between the body and the clothing system and the clothing system itself, to the environment, is a complex process. Heat production and heat loss as heat exchange between human body and the environment are described by following equation of heat balance:

$$M - P_{ex} = \pm Q_R \pm Q_K \pm Q_C - Q_{res} - Q_E \pm S, \tag{1}$$

where, M is the energy created by metabolic processes; P_{ex} is mechanical (external) power, needed to perform activities; Q_R is heat absorbed (+) or released (−) from the skin through radiation; Q_K is heat absorbed (+) or released (−) from the skin through convection; Q_C is heat absorbed (+) or released (−) from the skin through conduction; Q_{res} is heat released through respiration; Q_E is heat released through sweat evaporation, and S is the accumulation of (+) or loss (−) of heat in the body (for heat balance $S = 0$).