The Skin Interface - Meeting Point of Physiology and Clothing Science

George Havenith[1*], Caroline Smith[1], Takako Fukazawa[2]

[1] *Loughborough University, Dept. Human sciences, Ashby Road, Loughborough, LE11 3TU, UK*
[2] *Fukuoka Women's University, Dept. of Living Environmental Sciences, Fukuoka-shi, Japan*

Abstract: This paper describes the relevance of knowledge of processes that happen at the skin for sports clothing design. It looks at skin temperature distribution while cooling, relevant e.g. to outdoor winter sports and mountaineering, at sweat distribution over the body while running, relevant e.g. to clothing designed for running in general and more particularly for exercise in warm and hot climates, and finally it looks into regional skin sensitivity, relevant for all fields of sports clothing design. As these areas interact heavily, the sports clothing designer needs to be aware of their influences and their interactions in order to optimise the clothing for the specific type of sport at hand.

Keywords: clothing, skin, comfort, sweating, evaporation, cooling

1. Introduction

A person at rest typically regulates their body temperature around 37°C, though this is by no means an exactly fixed temperature for all humans. Exercise will cause an increase in body temperature, which for many climatic conditions is unrelated to the temperature. Body temperature increases even with light to moderate exercise to values around 38°C, and up to 39 and occasionally above 40°C for heavy exercise (e.g. marathon) are

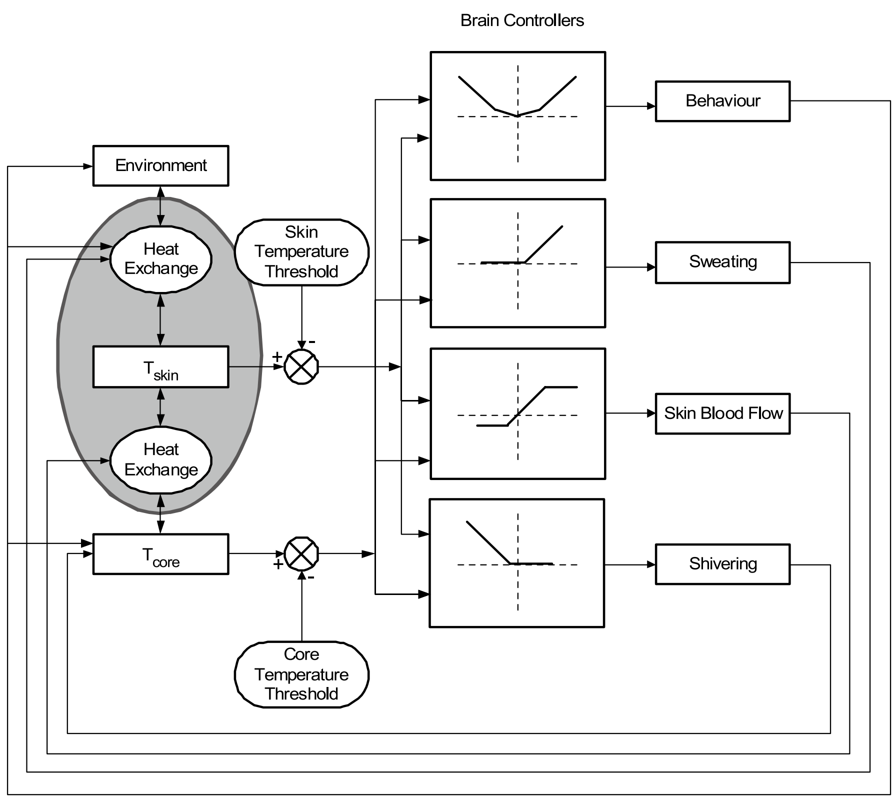

Figure 1, Schematic representation of the thermoregulatory control system. Tcore = body core temperature; Tskin = mean skin temperature; brain controller graphs show reaction of effector (Y-axes) to error signal (x-axes) (adapted from [3]). Grey area denotes the focus of present paper.

* Corresponding author's email: G.havenith@lboro.ac.uk

not uncommon, even in cool climates. Increases up to 39°C are seldom a problem to the body and should be considered a normal phenomenon in thermoregulation[1][2].

An example of how the body's temperature regulation could be represented is given in Figure 1 [3]. Here we have a body, which is represented by a body core temperature and by a skin temperature. Afferent signals representing these body temperatures are relayed to the control centres in the brain. There they are compared to a reference signal, which could be seen as a single thermostat setpoint, or as a number of thresholds for initiating effector responses. Based on the difference between actual temperature and the reference value (the error signal), various effector responses can be initiated.

For the present paper, the focus will be on the interface between the body and the environment: the skin (i.e. the grey area in Figure 1). Of the effector mechanisms, the internal ones are vasodilation of skin vessels (if body temperatures are higher than the reference, i.e. a positive error) and shivering and vasoconstriction (negative error). Shivering will increase heat production and heat the core, and vasodilation and constriction will regulate the heat transport between core and skin, and via skin temperature also the dry heat loss to the environment. The one that influences the exchange of heat externally (between skin and environment) most is sweat production. The evaporation of this sweat will cool the skin. Of course Figure 1 is a simplified model, as many different thermo-sensitive regions of the body have been identified, and other and more complex models are possible [3].

When we think of clothing we can think of it as an additional, behavioural effector response. Where possible we adjust our clothing levels to the climate we live in, providing the right amount of insulation to allow the other effector responses to stay within their utility range. The main effect of clothing will be its influence on the heat exchange between the skin and the environment. It will affect the heat loss of the body and will also impact the thermal sensation experienced by a person. Both are highly relevant to an individual's performance in sports.

Sports clothing can be worn for different reasons. In many sports protective clothing is worn, e.g. hockey gear protects against certain impacts. Clothing may also protect against the weather (mountaineering, skiing, sailing clothing). In many sports clothing is minimized however, in an attempt to limit any negative impact on heat loss and motion (e.g. running). These various applications all relate to heat exchanges at the skin, either limiting or promoting it. Hence a good understanding of what happens at this interface is important for optimal sports clothing design.

2. Thermal Insulation and Sports Performance - Cold Environments

For optimal sports performance the temperature of the muscles needs to be slightly raised. E.g. after warming the legs in a 44ºC water bath there was an increase of 11% in maximal peak force and power [4], which has been repeatedly shown for various muscle groups. Warm up, is considered beneficial [5][6] through temperature-related mechanisms (decreased stiffness, increased nerve-conduction rate, altered force-velocity relationship and increased lactic energy provision [5]), though other mechanisms have also been proposed. Only where warm up increases the overall heat load (warm up in warm and hot environments) negative effects are expected through its contribution to overall heat strain. Thus, for exercise in cool environments it is of the utmost importance to prevent excessive cooling of the body pre- and during exercise. This requires clothing to be adjusted in a way to prevent excessive heat loss. One option is to provide extra insulation overall, but a better solution may be found when this insulation can be targeted specifically at body regions with high heat loss.

When we think of cold protection, the initial thought goes to reduction of dry (radiative and convective) heat loss. This heat loss is defined by

$$Heat\ Loss = \frac{T_{skin} - T_{air}}{Insulation} \tag{1}$$

JFBI Vol.1 No. 2 2008 doi:10.3993/jfbi09200802