BEDDING TEXTILES AND THEIR INFLUENCE ON THERMAL COMFORT AND SLEEP

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Abstract:

Human comfort perceptions in relation to textiles are influenced by tactile perceptions, moisture and thermal interactions. Studies in the thermal comfort of clothing have been done with instrumental techniques as well as with human subjects. There have also been many studies on influence of thermal comfort and sleep. This paper brings together some specific aspects of bedding textiles and their influence on thermal comfort and sleep.

Key words:

Bedding textiles, thermal comfort, microclimate, sleep.

Introduction

Thermal comfort refers to the condition of the mind which expresses satisfaction with the thermal environment. Thermal comfort charts and thermal indices have been developed with the help of thermal equations designed to predict thermal comfort. The thermal comfort feeling of the human body is influenced by various parameters. The three main factors that influence human thermal comfort are; environmental climate, clothing, and physical activity. Air temperature, thermal radiation, relative humidity, and air movement near the vicinity of the body are some of the environmental factors that influence the comfort status. Clothing factors such as thickness of material, clothing insulation value, type of material, volume of air enclosed in the fibers, resistance to diffusion of water vapour, layers of clothing, body fit, air permeability, etc influence the thermal comfort, apart from the human metabolic rate which is determined by the activity level of the body.

Influence of textiles on thermal comfort

The comfort level changes dynamically with moisture and heat exchanges within the clothing layers and the human body. Heat transfer within the clothing is considered a sum of the dry heat and evaporative heat transfer. The sensitivity to thermal stimulus varies from area to area on the body surface; similarly the distribution of skin temperature across the body is different. This skin temperature distribution is altered by location of clothing insulation on the body, as found in a study (in cooler temperatures) by Nielsen et al. [1]. They also found a correlation between mean body temperature and thermal sensation; however no such correlation was found between change in skin temperature distribution or mean skin temperature to the same (which contrasted with several earlier studies). A considerable amount of research has been done in order to ascertain the influence of various factors of clothing on comfort. Depending on the circumstances, some factors play more important roles than others. For instance, Zhang et al. [2] showed that for conditions when the ambient temperature is below skin temperature, the air permeability of a textile has far more influence on rectal temperature than its moisture regain, and that in conditions where the skin temperature is higher than the surrounding temperature, it is vice versa. Li et al. [3] showed that the hygroscopic natures of clothing materials have significant influence over the human thermoregulation process and comfort feeling during environmental transients. Scheurell D.M et al [4] confirmed that discomfort sensations are influenced by small amounts of moisture in the skin-clothing interface. The type of fabric (next to the skin) plays a role in this moisture buildup and as little as 3% to 5 % added moisture is enough to stimulate sensations of discomfort. We now know that the perception of fabric dampness depends on fabric hygroscopicity, ambient relative humidity, fabric temperature, and pressure distribution of fabric on skin, apart from fabric moisture content. Additionally, Wang et al. also [5] found that the skin temperature drop during contact with a damp textile plays a major role in dampness perception and a 0.8°C to 1° C drop in temperature changes the perception from dry to damp.

Influence of bedding microclimate on sleep

Various studies have been conducted using electroencephalogram monitoring to study the effect of temperature on sleep. The thermoregulation of the body is less active during sleep than in waking state. Studies have been conducted in thermally comfortable ambient temperatures as well as with varying temperatures and with varying degrees of clothing cover. Tests conducted in varying conditions have identified a thermoneutral zone, which is defined as the range of optimum temperatures in which the human body feels thermally comfortable. This thermal comfort zone is determined by clothing and bedding of a sleeping subject. Changes in the ambient temperature have been observed to induce sleep structure modifications, specifically as regards the duration of REM and SWS durations (Rapid eye movement and Slow wave sleep respectively). Muzet et al. [6] states that moving away from the thermoneutral zone increases the number and duration of wakefulness.

It is suggested that the thermoneutrality zone in the bedding microclimate is around 30 °C. In one study, while the ambient temperature changed from 16 to 25°C, the bedding microclimate temperature changed from 28.6°C to 30.9°C. The microclimate temperature remained at 29.6 °C for ambient temperatures of 19°C and 22°C. The preferred ambient temperature was 19°C and test subjects showed discomfort when the room temperature deviated from this. In another study where high nocturnal awakening was noted, an ambient temperature of 13 °C showed 26.1°C temperature in the microclimate [6].

Bedding textiles and microclimate

The microclimate in the bedding is determined by the ambient temperature and bedding design, apart from subject clothing cover. Heat loss in bedding occurs through leakage of microclimate air to ambient temperature through bedding upper layers and with the conduction of heat to mattress. Holland et al. [7] tested the rate and volume of air exchange between the microclimate and the ambient environment with different combinations of bedding items and types of tucking in, focusing their study on microclimate ventilation in infant bedding. They found that while the rate and volume of air exchange with ambient temperature was lower with a duvet and in the absence of a duvet, the type of tucking was significant; however, the weave construction of the blankets or the combination of blankets had little influence on the same. According to the European Down and Feather Association [8], as per a study conducted by University of Kiel, the insulating effect of duvet depends on the filling material, the filling quantity, the type of stitching, the capacity of the filling to bind the air and the shape adaptability of the duvet.

Temperature drops within the bedding microclimate can also occur due to the ventilation effect, especially if it cannot adapt to the body shape. The high temperature gradient between the microclimate and the ambient temperature in cooler environments makes sleepers more susceptible to awakening due to the possibility of drastic changes in temperature of bedding microclimate as a result of higher rates of heat loss. Duvets also have tendencies to overheat since, as already mentioned, they allow little heat exchange between ambient temperature and microclimate. Therefore, it is important that a duvet has not only insulating, moisture absorbing and temperature compensating effects, but also the ability to adapt to body shape (due to the frequent change in sleeping position and therefore the ventilating effect which allows the temperature in the microclimate to fall).

Mizuno et al. [9] found that use of electric blankets under low ambient temperatures of 3 °C and relative humidity of 50% to 80 % was beneficial for sleep. Electric blankets can also cause thermal stress in case of higher ambient temperatures, in which case the blanket can be switched off during the night and the heated area can be confined to lower extremities. However, these blankets are not integrated with any dynamic features that adjust according to changing ambient temperatures and thermoneutral microclimate requirements. Merino wool bedding textiles are able to buffer temperature extremes and changes in humidity. These bedding textiles also transport more sweat away from skin as compared to synthetic fabrics and thereby aid quality sleep [10]. In the last few years, many products have entered the garment market that are said to have thermoregulation properties. Garments made of Phase change materials, silver yarns, and chemically modified performance yarns, etc find applications in sportswear and performance fabrics. Bedding textiles that buffer varying levels of temperature and humidity have also been developed by researchers. Phase change material textiles are able to dynamically stabilize temperature changes and improve sleep via microencapsulated waxes [11].

Conclusions

The thermal comfort of a human body is dependent on the complex thermal interactions of the human body and clothing with its surroundings. Thermal comfort prediction softwares have been developed along with climate chamber and thermal manikin tests, in addition to various other instrumentation techniques, in order to access and quantify thermal comfort. Generally, most climate chamber and subjective thermal sensation test analyses rely on the data from the thermal and humidity sensor readings of skin, fabric temperatures, and humidity in the microclimate respectively. However, analyzers also have to consider the significance of correlation between mean body temperature and thermal sensation [1].

Though temperatures above and below the thermoneutral zone have disruptive effects on sleep patterns, cold ambient temperatures tend to be more disruptive to sleep than warm ambient temperatures [12]. Thermoregulation of bedding textiles therefore must be more effective towards cooler temperatures. Heat related sleep disruption tend to concentrate more on initial sleep segments than later [13], which leads us to conclude that the effect of mild heat build up inside the microclimate later in the night will probably have a relatively lesser disruptive effect on sleep than in the case of continued heat stress throughout the night or in the case of a cooler microclimate temperature. This has also been confirmed with tests with electric blankets [9]. The thermoneutral zone has minor variations in various groups, for instance between men and women, elderly and young, and people from different geographical locations. Differences in sensitivity to cold in sleep has been noticed among individuals in sleep tests [12]. Therefore, requirements of bedding textiles may differ from person to person. Especially the elderly and the handicapped have different requirements in regard to comfort. Currently bedding textiles, unlike garments, are not customized specifically as per individual preferences and requirements. This might be a direction for the future development of bedding textiles.

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