6 Thermal comfort: A review of recent research

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Thermal comfort is defined as that state of mind that expresses satisfaction with the environment. From the classical studies of comfort and the environment by Houghton and Yaglou, the recognition of relationships between physiology and subjective response by Winslow, Herrington and Gagge and on to the present, research continues to strive to heighten the understanding and quantification of parameters affecting our satisfaction with the environment. While the steady state comfort response to uniform thermal environments is not completely understood, it can be reliably predicted and recent efforts have been directed toward non-uniform thermal environments. Asymmetric radiation, spatial temperature variation, and drafts are examples of non-uniformities that can cause physiological strain on the individual and discomfort in an otherwise neutral environment. Progress has been made in defining the relationship between subjective responses and these non-uniformities and work is continuing. Other work has explored the human response to physiological non-uniformities produced by clothing. Asymmetric clothing insulation may make the wearer less sensitive to changes in mean skin temperature. Physical fitness also affects thermal sensitivity but further studies are needed in this area. In a related matter it has been shown that though women often experience less discomfort in warm environments than men, when the subjective data is plotted against skin wettedness the sex differences disappear, implying the discomfort difference is due to differences in the physiological (sweating) response rather than sensory differences. The sweating response has been shown to depend on fitness and conditioning. Recently, it has been deomonstrated that skin moisture can be monitored by various types of miniature humidity sensors. This is enabling skin wettedness measurements to be made under a wider variety of clothing and activities and the correlation with warm discomfort to be better defined. Interestingly this work indicates that people are very good at sensing skin moisture as their perceived skin wettedness between dry and soaking wet has a high correlation to measured skin wettedness. How skin moisture is actually sensed is still unknown, however. Additionally, skin wettedness above about 30% increases the friction between skin and clothing, contributing further to the discomfort of warm situations. Clothing research and new materials are leading to a better quantification of clothing parameters that affect comfort. In addition, it is being shown that furnishings and ambiance can influence the thermal judgements of occupants. Recent studies of subjective response have confirmed the usefulness of the operative temperature concept to characterize and control complex environments.

7 Physiological strain caused by work clothing at muscular work in dry and humid heat

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In 213 climatic chamber experiments four young, healthy, acclimatized men performed light (260 W) and moderate (335 W) work on a treadmill and were exposed successively to combinations of ambient temperature and air humidity varying within the range of 15°C to 55°C and 10 to 98% relative humidity with a constant air speed of 0.3 m/s. The effect of two sets of work clothing with an I_{cl} of 0.7 and 1.0 clo on heart rate, sweat loss and body temperatures were studied. Each subject performed a control series of experiments at a given work rate wearing only shorts with an insulation value of 0.1 clo. The combinations of the work, clothing, and the thermal parameters were selected in such a way that the subjects were able to tolerate the conditions for as long as 4 hours.

Compared with the nearly nude, 0.1 clo, condition, the 0.7 clo clothing caused practically no physiological effects in the men in neutral room temperature, and only slight physiological strain occurred in a warm climate in dry air with a light work rate, but the strain increased as the vapour pressure and work rate increased The effects of 1.0 clo clothing were also relatively small in an elevated room temperature in dry air, but clothing caused considerable super-elevation of all the physiological responses as a

result of increasing vapour pressure already in a moderate warm environment with a light work rate. Further elevation was seen in humid heat, especially with a moderate work rate. The heat strain due to clothing did not increase linearly with the insulation in clo-unit; instead the increase was exponential.

The results indicate that it is not possible to consider clothing independently of other heat stress factors. The physiological effects of a specific set of clothing are always dependent on the combinations of the thermal parameters and the activity level.

8 Cardiac output of children during submaximal exercise under different ambient temperatures

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The present study measured cardiac output ($\dot{Q}$) in children during exercise at different ambient temperatures in order to investigate the effects of ambient temperature on this parameter. The values obtained were compared with the same measure in adults to clarify any differing characteristic features of $\dot{Q}$ in children.

Ten boys and nine girls, aged 10-11 years old, participated in the present experiment. All studies were carried out in a climatic chamber kept at 20, 30, and 40°C, with a relative humidity of 50%. Subjects exercised on a Monark bicycle ergometer for 8 minutes, each at loads of 300 and 450 kg.m.min^{-1}. Oxygen uptake ($\dot{V}O_2$) and carbon dioxide elimination ($\dot{V}CO_2$) were determined by the Douglas bag method during 5-7 minutes of exercise. At the same time, heart rate (HR) was counted from a bipolar chest lead ECG. Q was estimated by the CO_2 rebreathing method during the last seconds of an exercise period. The fraction of CO_2 was measured by a rapid infrared CO_2 meter (Godart Capnograph). The experiment was undertaken during fall and winter for boys, and during summer and fall for girls.

For a given $\dot{V}O_2$, stroke volume (SV) tended to be reduced and HR increased in a 40°C environment in both sexes. Accordingly, $\dot{Q}$ at 40°C was maintained at a level similar to that in cooler conditions. A lower HR and a higher SV at a given $\dot{V}O_2$ in boys was found to be similar to that in girls. The values of $\dot{Q}$ in relation to VO_2 in the children studied were compared with those in children and adults who had been previously studied. The children in the present study were found to have a $\dot{Q}$ response corresponding to those of children of similar age already reported in the literature and to have a lower Q compared with most adults.

9 Aerodynamic and thermoregulatory characteristics of running apparel

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The aerodynamic drag associated with three types of commercially available running apparel (SS: nylon singlet and shorts; L: lycra/nylon bodysuit and RS: nylon rainsuit) and two bodysuits of newly developed stretchable, water vapour permeable fabrics (T and K) was measured in a wind tunnel on a human mannequin at four velocities (4.7, 7.1, 8.8 and 9.7 m.sec^{-1}). Commercially available running apparel provided consistently higher drag than the T and K bodysuits. Under all conditions the high sheen and tight fit of the K fabric allowed drag reductions of between 17.5 and 7.4% at running speeds. At sprint speeds a hood over the hair was responsible for 6 of the 7.4% reduction in drag noted with the K suit. It is estimated that reductions in drag of this size provide real time savings of between 1.05% in the marathon to 2.75% in the 100m dash. A field trial of the K suit with 16 male subjects (mean age: 22 yr) revealed a significant ($p<.025$) decrease in 100m running time amounting to a time saving of 1.17% at a velocity of 7.43 m.sec^{-1}. The thermoregulatory properties of the SS, L and K suits and a suit of stretchable, membrane porous fabric (B) were investigated at