CORRELATION BETWEEN DIFFERENT FORMULAS FOR MEAN SKIN TEMPERATURE AND THERMAL COMFORT

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INTRODUCTION

Mean skin temperature (MST) and core temperature both influence thermal sensation and thermal comfort (1). Thermal sensation may be defined as how humans subjectively perceive their thermal environment. Thermal comfort is defined as that state of mind which expresses satisfaction with the thermal environment (2). Behavioural thermoregulation, which may play a dominant role in the maintenance of thermal equilibrium, is affected by thermal sensation and thermal comfort (3). By giving the different areas of the body different weighting factors according to their sensitivity one can obtain different formulas for MST and body temperature (BT) (rectal temperature (T_{re}) + MST). The purpose of this study was to find whether there exists a correlation between some selected formulas for MST/BT and thermal sensation and thermal comfort on clothed subjects working and resting at 3 ambient temperatures.

METHODS

6 men exercised at 40% workload of maximal aerobic work capacity at three different ambient temperatures (T_a); -25°C, -10°C and +10°C. The experiments were conducted in a climatic chamber and included twice repeated bouts of 40 min cycle exercise followed by 20 min rest. A 3-layer clothing ensemble was used in all experimental conditions with an extra woollen pullover and a pair of polyamid/polyester trousers at -25°C. T_{re} and skin temperatures (T_{skin}) were measured at 13 points on the body (see formula F) and recorded continuously. Every ten minutes the subjects evaluated thermal sensation and thermal comfort for the body as a whole. The subjective scales ranged from "very hot" to "very cold" on a 9-point scale, and "comfortable" to "very uncomfortable" on a 4-point scale, respectively. The different formulas for MST and BT used were:

A) $MST = 0{,}35 \cdot T_{abdomen} + 0{,}19 \cdot T_{thigh} + 0{,}14 \cdot T_{lower\ arm} + 0{,}13 \cdot T_{lower\ leg} + 0{,}07 \cdot T_{forehead} + 0{,}07 \cdot T_{foot} + 0{,}05 \cdot T_{hand}$ (4)

B) $MST = 0{,}5 \cdot T_{chest} + 0{,}36 \cdot T_{lower\ leg} + 0{,}14 \cdot T_{lower\ arm}$ (5)

C) $MST = 0{,}3 \cdot T_{chest} + 0{,}3 \cdot T_{upper\ arm} + 0{,}2 \cdot T_{thigh} + 0{,}2 \cdot T_{lower\ leg}$ (6)

D) $MST = 0{,}34 \cdot T_{chest} + 0{,}33 \cdot T_{thigh} + 0{,}18 \cdot T_{lower\ leg} + 0{,}15 \cdot T_{lower\ arm}$ (7)

E) $MST = 9{,}429 + 0{,}137 \cdot T_{forehead} + 0{,}102 \cdot T_{hand} + 0{,}290 \cdot T_{back} + 0{,}173 \cdot T_{lower\ leg}$ (8)

F) $MST = (T_{forehead} + T_{neck} + T_{chest} + T_{back} + T_{abdomen} + T_{upper\ arm} + T_{lower\ arm} + T_{hand} + T_{anterior\ thigh} + T_{posterior\ thigh} + T_{anterior\ lower\ leg} + T_{posterior\ lower\ leg} + T_{foot})/13$ (modified from 9)

G) $BT = 0{,}9 \cdot T_{re} + 0{,}1 \cdot F_{MST}$ (10)

T_{skin} and T_{re} at minute 40 and 100 during the working period, and T_{skin} and T_{re} at minute 60 and 120 during the resting period were picked out. MST and BT were calculated from these temperatures. A linear regression analysis was performed, with temperatures as independent variables and thermal sensation and thermal comfort as dependent variables. Each ambient temperature was treated alone either at work or at rest. Significance was set at the 0,05 level of confidence. Differences with $0{,}05<p>0{,}1$ will be referred to as a tendency in the data.

RESULTS AND DISCUSSION

In general, some correlation were found between formula A, C, F and G and thermal sensation or comfort. The C-formula showed a tendency to correlate with thermal sensation at -10°C (y=17,8-0,5x, r=0,52) during rest. The

G-formula correlated during rest at +10°C (y=77,7-2,0x, r=0,69), while the A- and F-formula showed a tendency to correlate at -25°C (y=21,6-0,6x, r=0,57) and (y=19,3-0,5x, r=0,52), respectively. During exercise the C-formula correlated with thermal sensation at -25°C (y=17,4+0,8x, r=0,61). The F-formula showed a tendency to correlate with thermal comfort at -10°C (y=17,3-0,5x, r=0,51) and -25°C (y=-15,7+0,6x, r=0,55) during rest. The studies (4, 5, 6, 7, 9, 10) the selected formulas are based on involve resting, naked subjects. One exception (8), (formula E), is a study where the subjects exercised and rested in a cold environment (+10°C) in two different clothing assemblies: One in which the insulation was placed mainly over the trunk, and one in which the insulation mainly covered the limbs. Formula A had an agreement of at least 70% within ±0,5°C with the results from a reference MST involving 13 skin temperatures according to studies by (8). The purpose of another study (11) based on the same methods was to compare thermal sensation and distribution of skin temperatures for these subjects. The correlation between the G-formula and thermal sensation during rest are in agreement with these results, but in contrast to their study we found no correlation during work.

CONCLUSIONS

The best correlation found were between the A-, C-, F- and G-formula and thermal sensation and thermal comfort during rest. The formulas involved different number of individual skin temperatures. Prior studies (7, 8, 9) have shown better correlation between different formulas for MST the more skin temperatures taking part. This is in accordance with our study (except from the C-formula). The C-formula is not very different from the D-formula, where we found no correlation, but the different skin areas are given different weighting factors.

The highest correlations were between MST/BT and thermal sensation and thermal comfort during rest. During work, only formula C correlated with thermal sensation or comfort. This may be due to other factors than temperature, such as sweating, influencing thermal sensation and thermal comfort during work.

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ACKNOWLEDGEMENTS

This study was supported by the Branch Development Program for Textile Industries, represented by Norwegian Clothing and Textile Institute. The authors wish to express their appreciation to the program committee.