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The relationship of skin temperatures of clothed adults to ambient temperature in a warm environment

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Summary

In forty-one apyrexial adult male patients, who were clothed in light-weight cotton pyjamas, mean skin temperature was determined and, simultaneously, ambient temperature and the temperature of air space under clothing were measured. Both mean skin temperature and the temperature of the air space under clothing showed a linear increase with ambient temperature.

Heat loss by vapourization of water is known to have a curvilinear relationship to ambient temperature. Application of the temperature relationships obtained in this study to the vapourization curve indicates that clothing shifts the point of sharp upward inflection of the curve to the left; and, if ambient temperature is to be employed to predict the amount of cutaneous water loss in clothed individuals, the extent of this shift must be determined. The data obtained in the present study have been applied to studies of evaporative water loss in Lagos.

Résumé

Dans quarante et un malades (tous hommes) sans fièvre, vêtus de pyjamas en coton léger, la temperature moyenne de la peau etait determinée et, en même temps, la temperature ambiante et la temperature de l'air sous le vêtement etait mésurée. La temperature et de la peau et sous le vêtement montrait une augmentation linéaire avec la temperature ambiante.

La perte de chaleur par la pulvérisation d'eau a été etablie d'avoir un rapport curviligne à la temperature ambiante. L'application des rapports de la temperature obtenus dans cette étude à la courbe de la pulvérisation démontre que le vêtement déplace à gauche le point d'ascension aiguë de la courbe et, s'il faut employer la temperature ambiante pour prédire la quantité d'eau perdue a travers la peau dans des individus en vetements, la limite de ce déplacement doit être determinée. Les data obtenus dans cette étude ont été appliqués dans des études de la perte d'eau par la pulvérisation à Lagos.

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Introduction

Skin temperature is one of the major determinants of cutaneous evaporative water loss. Both diffusional water loss through the skin and ecrine sweating are related to mean skin temperature (Pinson, 1942; Wyndham, 1965). Mean skin temperature, in turn, varies with ambient temperature as well as other environmental factors such as relative humidity and air movement; the magnitude of the effects of these environmental factors on mean skin temperature depends on whether the subject studied is nude or clothed (Hall & Klemm, 1963).

Most studies of evaporative water loss have been carried out under artificial conditions in which environmental factors are controlled, usually in a climatic chamber. When studies of cutaneous water loss are carried out under natural conditions it is important to quantitate the relationship of environmental factors to skin temperature under the particular climatic conditions prevailing where the studies are conducted. The present paper reports the relationship found between ambient temperature and mean skin temperature of adult male patients hospitalized in Lagos. These patients were usually clad in light-weight cotton pyjamas, and, in order to find out the effect of this clothing on the temperature of the environment surrounding the subjects, the

relationship of ambient temperature to the temperature of the air space under the clothing was studied.

Materials and methods

Forty-one adult male Nigerian patients were studied on one of the surgical wards of Lagos University Teaching Hospital. All patients were apyrexial, as indicated by oral temperature, at the time of the study. Each subject was clothed in light-weight pyjamas and lay on his bed either covered with a cotton sheet or with no extra cover, whichever he found thermally comfortable. In order to obtain as wide a spread of environmental conditions as possible, the studies were distributed evenly between the morning period when temperatures are relatively low and the afternoon when temperatures are closer to the maximum for the day.

At the time of each study ambient temperature was read from an autographic thermometer* and relative humidity from a hygrograph,† both instruments being situated in the ward. Skin temperatures were measured with the aid of an electrical thermometer‡ from the forehead, trunk, arm, forearm, hand, thigh, leg and foot and mean skin temperature ($\bar{T}_s$) was calculated from the following formula of Hardy & Dubois (1938a):

$$\bar{T}_s = (0{\cdot}07T_{head} + 0{\cdot}35T_{trunk} + 0{\cdot}14T_{arm} + 0{\cdot}05T_{hand} + 0{\cdot}19T_{thigh} + 0{\cdot}13T_{leg} + 0{\cdot}07T_{foot})$$

In order to measure the temperature of the air space closest to the subject's skin, the temperature of air under the pyjama shirt was taken, irrespective of whether the patient had extra cover or not. This temperature was measured with the aid of the electrical thermometer using a probe which was supported under the pyjama without its touching either the cloth or the patient's body.

The data collected during these studies were analysed statistically with the aid of an IBM370 computer situated at the Institute of Computer Sciences of the University of Lagos. A product moment correlation matrix was developed between mean skin temperature ($\bar{T}_s$), ambient temperature (T_a), and the temperature of the air space under the subject's clothing (T_s). The level of significance of the correlation coefficients was read from the statistical tables of Fisher & Yates (1963).

* Bimetallic thermograph Mk3, Short & Mason, London.
† Hair hygrograph manufactured by Wilson, Warden & Co. Ltd, London.
‡ Type TR8, manufactured by Ellab, Copenhagen, Denmark.

Results

The mean of $\bar{T}_s$ calculated for all forty-one studies was 34·67°C ± 0·80°. During the studies, ambient

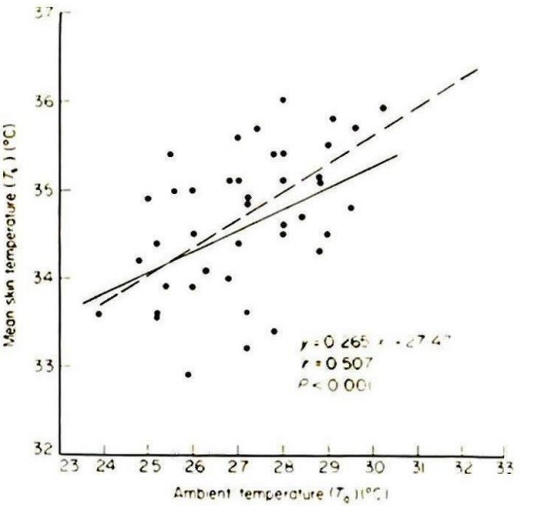

FIG. 1. Regression of mean skin temperature ($\bar{T}_s$) on ambient temperature (T_a). The hatched line represents the relationship reported by Hall & Klemm (1963).

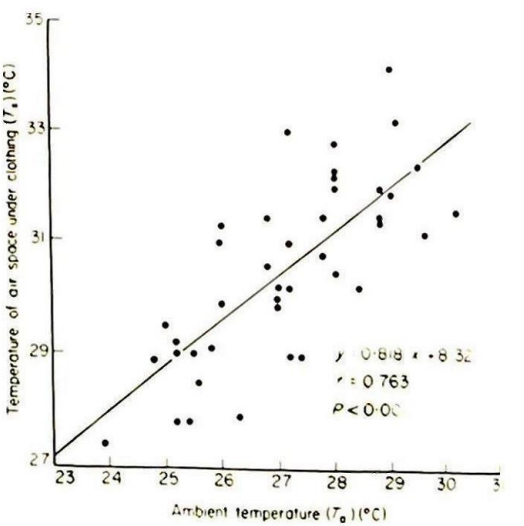

FIG. 2. Regression of temperature of air space under clothing (T_s) on ambient temperature (T_a).

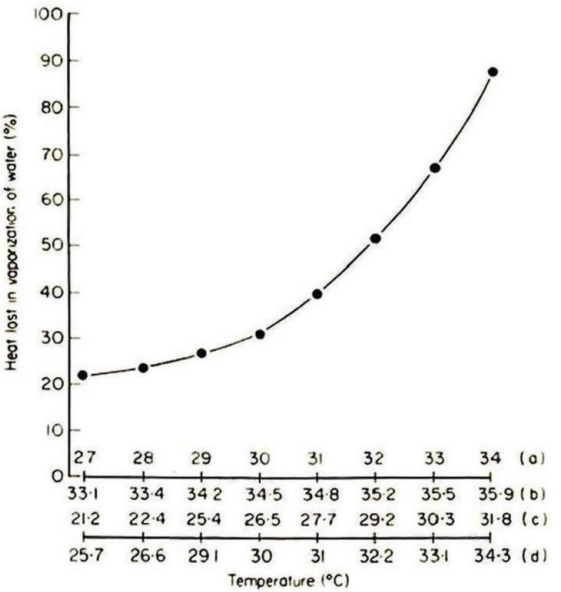

FIG. 3. Superimposition of the vapourization curve of Dubois *et al.* (1952) on temperature data recorded in the present studies. (a) and (b) are the ambient and mean skin temperatures, respectively, recorded during the studies of Dubois *et al.* (1952). (c) presents the ambient temperatures which correspond during the present study with mean skin temperatures shown in (b) (as calculated from regression equation shown in Fig. 1). (d) presents the temperatures under clothing which correspond with ambient temperatures charted in (c) (as calculated from regression equation shown in (Fig. 2). Note the shift of the curve to the left in relation to (c) as compared with (a), and the similarity between the temperatures charted in (a) and (d).

temperature (T_a) varied from 23·3° to 30·2° with a mean of 27·16°C ± 1·52°. The mean of the temperature of the air space under clothing (T_x) was 30·54°C ± 1·63°. The mean temperature gradient between the skin and the ward environment was 7·52°C ± 1·30°, whilst the mean temperature difference between the air space under clothing and the ward environment was 3·40°C ± 1·07°. The mean relative humidity during the studies was 82·10% ± 18·30%.

$\overline{T}_s$ correlated significantly with Ta ($r = 0{\cdot}507$; $P < 0{\cdot}001$) and with T_x ($r = 0{\cdot}445$; $P < 0{\cdot}01$). Fig. 1 presents the regression line of $\overline{T}_s$ on Ta. T_x also correlated significantly with Ta ($r = 0{\cdot}763$; $P < 0{\cdot}001$). Fig. 2 shows the regression line of T_x on T_a.

Discussion

In this study, mean skin temperature ($\overline{T}_s$) showed a linear increase with ambient temperature (T_a). A similar relationship has been recorded in clothed subjects by Hall & Klemm (1963). The line for the regression of mean skin temperature on ambient temperature in this study is very similar to Hall & Klemm's (1963) line. Whilst $\overline{T}_s$ rose from 33·7°C at T_a of 23·9°C to 36·3°C at T_a of 32·2°C in the studies reported by the latter authors, the present studies showed a rise from 33·8°C at T_a of 24°C to 35·7°C at T_a of 31°C (Fig. 1).

The early studies of Benedict & Root (1926) established the relationship between insensible weight loss and metabolism but did not show that environmental temperature influenced the contribution of water vapourization to heat loss. This was due to the fact that ambient temperatures during their studies were limited to the range 16–26°C. Later studies by Hardy & Dubois (1938b); Dubois, Ebaugh & Hardy (1952) showed that vapourization loss was virtually uniform up to 30°C ambient temperature and then increased rapidly so that at 34·7°C nearly all body heat was dissipated by this means. At the point of sharp inflection of the vapourization curve, mean skin temperature was found to be 34·0–34·5°C.

The studies of Hardy & Dubois (1938b), and Dubois *et al.* (1952) were conducted on nude subjects. If their vapourization curve for male subjects is superimposed on the temperature data obtained from clothed subjects in the present study whilst its relationship to mean skin temperature is presumed to be the same in both their subjects and ours, the point of sharp inflection of the curve would be shifted to the left in relation to ambient temperature (Fig. 3). However, the relationship of the curve to the temperature of the air space under the clothing worn by our subjects would be very similar to its relationship to ambient temperature during the studies of Hardy & Dubois (1938b) and Dubois *et al.* (1952) on nude subjects. Hall & Klemm (1963) recorded a shift of the vapourization curve to the left in clothed subjects and stated that the mean skin temperature at which the sharp inflection of the curve occurred was unaltered by clothing.

There is a linear relationship between ambient temperature and the temperature of the air space under clothing. The differential between these two temperatures largely accounts for the effect of clothing on the vapourization curve described above. In a series of studies of evaporative weight loss carried out on male lightly clad hospitalized patients in Lagos, the mean of mean daily temperature was 28·75 C and the mean evaporative loss was 1730 g per day (Elebute, 1973). If the corresponding point on the vapourization curve prepared for male subjects by Dubois *et al.* (1952) was used to predict evaporative weight loss in these patients, a value of 868 g per day would have been obtained, an under-estimation by about 49%. T_x corresponding with T_a of 28·75°C on the regression line shown in Fig. 2 is 31·8°C. If the latter was taken as the 'environmental temperature' of the patients and the corresponding point on the graph of Dubois *et al.* (1952) was used to estimate their evaporative weight loss, there would be an underestimation by only 7%. It may therefore be presumed that in clothed individuals the temperature of the micro-environment under their clothing gives a more direct indication of the level of evaporative water loss than ambient temperature. If ambient temperature is to be employed to predict the amount of cutaneous water loss in clothed individuals, the extent to which the particular set of clothing shifts the vapourization curve to the left must be determined.

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