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INFLUENCE OF ENVIRONMENTAL FACTORS ON SWEATING RATE OF SEDENTARY SUBJECTS

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ABSTRACT

Results of a comparative study on the influence of various thermal indices on the sweating rate of sedentary subjects have been reported in this paper. Superiority of dry-bulb temperature of air over other indices for rough assessment of water requirement in relatively dry heat has been demonstrated, and a simple prediction chart for the same has been worked out. The results have thus been found to lend support to the idea that sweating rate alone cannot serve as an index of comfort. Limitations of such field trials have also been discussed.

Object

The object of this investigation was to estimate fluid loss from acclimatised Indian subjects under different grades of thermal stimuli in hot weather as available in Delhi. Correlation of total fluid loss with various thermal indices, namely air temperature, globe temperature, E. T. and C. E. T. were also made.

Method

Total fluid loss due to sweating and pulmonary evaporation, was determined from nude body weights recorded before and after the exposure. Exposure to climatic condition was made in ordinary tropical summer clothing for one or two hours. The subjects were in sitting posture during the time of exposure.

Meteorological data were recorded and E. T. and C. E. T., were calculated according to the method suggested by Bedford.

In a previous investigation approximate sweating for different tasks like marching, sentry duty and drill etc. was assessed and the present report is a continuation of the work in the same line.

Experimental data

The findings on various days of experiment along with meteorological data are shown in Table I, and Fig. I shows the fluid loss at various thermal levels as indicated by air temperature, globe temperature, E.T. and C E. T.

Table II shows computed values of approximate total water requirement of an average Indian subject (Body surface $1 \cdot 6$ meter^2).

The data shown in Table I include rate of total water loss, W, in oz. per hour per square meter of body surface, globe reading Tg°F, air temperature T_a ° F, air velocity V in ft./mt., corrected effective temperature

TABLE I

EVAPORATIVE WATER LOSS

Sitting Quiet in Normal Summer Clothing

(1 met)

Serial No.	No. of Subjects	Rate of water loss W oz/m²/hr.	Globe Reading T_g °F	Air Temp. T_a °F	Air Velocity V ft/mt.	Relative Humidity (Per-cent)	C.E.T. T_c	E.T. T_e
1	5	5·52	106·2	100·5	310	23	83·1	81·3
2	5	7·80	113·5	104·8	479	21	85·1	82·7
3	7	7·70	108·0	97·1	165	20	82·9	79·8
4	7	4·72	94·0	94·5	20	47	83·7	83·8
5	6	4·53	88·0	87·2	20	72	83·0	82·7
6	2	5·49	101·7	98·9	133	50	87·0	86·2
7	4	5·68	99·3	96·4	56	48	86·1	85·3
8	4	4·32	96·6	94·4	112	49	83·9	83·2
9	4	3·14	103·3	89·3	383	41	82·0	76·3
10	4	3·89	102·0	92·0	665	59	83·6	79·5
11	5	1·54	82·8	81·3	80	66	76·4	75·6

TABLE II

Water Requirement in Shade for a Standard Indian Subject (Body Surface 1·6 m²).

(Sitting Posture)

Dry Bulb Temp. °F	Water Requirement in oz. per hour of exposure
80	2·4
90	6·2
100	10·1
110	13·9

C.E.T.) T_c and Effective Temperature (E.T.), T_e respectively. W was determined in each case by averaging over a number of individuals, the number of subjects for each observation being shown separately in Table I. All the observations, except No. 1 were taken under indoor condition, so that T_g and T_a never differed greatly from one another. The humidity was below 50 per cent except in observations No. 5, 10 and 11.

Discussion of Results

The experiments were conducted in various thermal environments prevailing under ordinary indoor conditions. As such, it was not possible to vary the environmental factors according to any set plan, as could have been achieved with a climatic chamber. Nevertheless, the present type of field experiment is evidently useful in the sense that it does enable us to judge the relative merits of the various thermal scales in use, for the prediction of total water loss from the body (*i.e.* evaporated water from sweat and lungs, and unevaporated sweat) under actual working conditions.

The straight lines in figure 1, (a—d) are represented by the following regression equations :—

$$W = 0{\cdot}24\,T_a - 17{\cdot}7 \;..\; \text{(i)},\ \text{S.E.} = \pm 0{\cdot}88$$

$$W = 0{\cdot}16\,T_g - 10{\cdot}7 \;..\; \text{(ii)},\ \text{S.E.} = \pm 1{\cdot}13$$

$$W = 0{\cdot}44\,T - 32{\cdot}0 \;..\; \text{(iii)},\ \text{S.E.} = \pm 1{\cdot}31$$

$$W = 0{\cdot}29\,T_e - 18{\cdot}5 \;..\; \text{(iv)},\ \text{S.E.} = \pm 1{\cdot}12$$

The sitting-resting metabolic rate M for the subjects under observation was found to be 43 cals/hr. m^2 on the average, with a standard deviation of $\pm 5{\cdot}4$. This may be one of the important factors influencing the scatter of the points about the regression lines.

Indirect assessment of true sweating rate was attempted as follows: Assuming that the evaporative loss in respiratory passages and as insensible perspiration is equivalent to 25 per cent of the metabolic rate (0·25M), the true sweating rate W_s can be expressed as,

$$W_s = W - \frac{0{\cdot}25M}{0{\cdot}58 \times 28{\cdot}4}\ \text{oz/m}^2\,\text{hr}.$$

Here latent heat of evaporation of water at body temperature = 0·58 Cals per gm. and 1 oz = 28·4 gms. The equations (i) to (iv) may now be rewritten as :

$$W_s = 0{\cdot}24\,(T_a - 76{\cdot}4) \ldots\ldots\ldots \text{(v)}$$

$$W_s = 0{\cdot}16\,(T_g - 72{\cdot}3) \ldots\ldots\ldots \text{(vi)}$$

$$W_s = 0{\cdot}44\,(T_c - 73{\cdot}7) \ldots\ldots\ldots \text{(vii)}$$

$$W = 0{\cdot}29\,(T_e - 66{\cdot}6) \ldots\ldots\ldots \text{(viii)}$$

The critical values of the variables above which sensible sweating should occur, are, according to the above equations, $T_a = 76{\cdot}4°F$, $= T_g = 72{\cdot}3°F$, $T_c = 73{\cdot}7$, $T_e = 66{\cdot}6$.

The quality and quantity of the experimental data do not justify elaborate statistical analysis. Nevertheless some important and useful information emerge from the discussions outlined above. The values of the standard errors of the regression equations together with the critical values of the variables lead us to the conclusion that the air temperature T_a is most likely to be the best index for sweating rate prediction under indoor conditions. Some of the assumptions underlying the foregoing treatment may be subject to criticism, but a look at the experimental graphs (Fig. 1, a—d) leaves no room for doubt as to the superiority of air temperature over other thermal measurements as an index for sweating rate prediction under indoor conditions. However, correlation with T_g does not seem to be much inferior, because T_a and T_g do not differ appreciably under such conditions, provided there is no local source of radiation present.

Since a clothed human body is not equivalent to a black globe, so far as radiative exchange with the surroundings is concerned, it is quite likely that under the sun or in places containing additional sources of radiation, globe temperature in the case of clothed individuals will give much poorer correlation than above, although it may be of greater use for nude subjects. This point however needs experimental confirmation. It is probable, that a properly weighted mean of T_a and T_g will show better results for subjects in normal summer clothing, but the present data are not adequate for that purpose.

In addition to individual variation in metabolic rates, air movement also was found to vary considerably during the periods of exposure, and the mean of the values noted at the beginning and end of the exposure periods, cannot be taken to be truly representative of the actual conditions.

It may be pointed out that more useful results can be derived if such observations are repeated under controlled conditions, as in a climatic chamber, with facilities to vary the various environmental factors within a reasonably wide range.

From the present experimental work, the rate of total water loss of acclimatised subjects at various thermal levels can be assessed within reasonable limits. A chart for prediction of water requirement for standard Indian subjects has been worked out and presented in Table II. It is also suggestive that for rough assessment of water requirement of soldiers in dry tropics under indoor conditions simple estimation of dry-bulb temperature is fairly satisfactory.

In a previous experiment, it was however found that the subjective sensation of comfort is better related to C.E.T. than dry bulb temperature alone in summer months, especially when appreciable radiation from surroundings is present. It is, therefore, worthwhile to undertake further work in this line, with a view to test one of the conclusions derived from the present work, namely sweating alone is not an index of comfort. Possibly it is the effective evaporation or the fraction of total water evaporated, which accounts for the difference.

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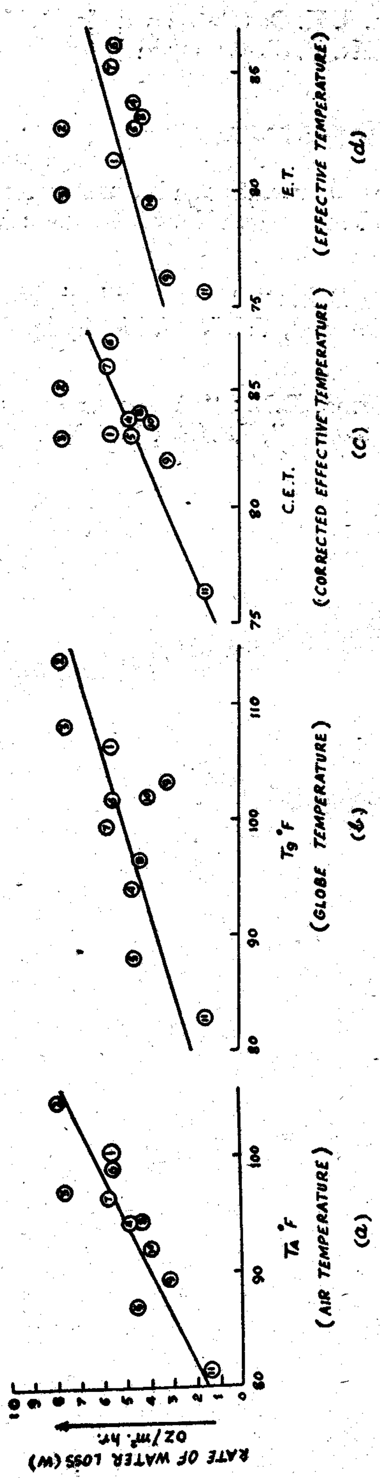

THE NUMBER AT EACH POINT DENOTES THE SERIAL NO. OF OBSERVATIONS.

FIG. 1. RATE OF WATER LOSS IN RELATION TO VARIOUS ENVIRONMENTAL FACTORS