ARCTIC AEROMEDICAL Laboratory

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I. INTRODUCTION

The loss of body heat by evaporative perspiration constitutes an important phase of thermoregulation in man. Under arctic conditions, sweating may in addition seriously affect the insulation value of clothing. This may be of vital importance in emergency survival in the Arctic.

Although no data are available pertaining to the rates and distribution of sweating in the Eskimo, a racial difference in sweat rates and sweat patterns between Eskimos and Whites has been suggested on the basis of observations among the Thule Eskimos in northwest Greenland (8), who claim that they sweat less, especially on their feet, than the Whites.

As Ivy (7) has pointed out, there is some evidence indicating that people who live in the tropics (Hindus, Negritos, and certain Polynesians) have a greater concentration of sweat glands per area of skin which can sweat profusely, than people who live in the Temperate Zone.

Kuno (9) made estimations of the total numbers of active sweat glands on various tropic and subtropic races and on Japanese born in or immigrated to the Torrid Zone. He found that the total number of active sweat glands is smallest in Ainos and Russians living in a cool zone and largest in Filipinos living in the tropics. He concludes that the natives of the tropics are provided with a larger number of active sweat glands and consequently they are capable of sweating more intensely. He further concludes that the number of active sweat glands of an individual may be increased considerably only when he has been born in the tropics. His data also suggests that sweat glands may be activated within about two years after birth, but never later. Training of the nervous system governing sweat reflexes in the natives of the tropics has, on the other hand, resulted in a lesser response to stimuli.

Conceivably, a favorable adaptation to a cold environment would be a reduced tendency to sweating during moderate heat loads, which would permit greater body heat storage and reduce the effect on clothing insulation. As part of a broad cold acclimatization study, it was therefore considered desirable to determine if any gross difference in sweat rate exists when Eskimos, generally considered to be exposed to considerable cold, and Caucasians, living a relatively sheltered life, are exposed to identical conditions of ambient temperature, humidity and workload.

A series of experiments were designed to measure the sweat loss in a group of Eskimos, as compared with the same number of White control subjects studied simultaneously at various temperature levels, at rest and while exercising under controlled conditions. The choice of subjects was motivated by the desire to have as widely contrasting groups as possible insofar as previous cold exposure was concerned. For this reason, a random selection of six volunteer Eskimo males from the rather primitive and isolated Nunamiut village at Anaktuvuk Pass in the Brooks Mountain Range was compared with six of our laboratory personnel. All subjects were normal, healthy individuals. The study was conducted in our laboratory during the latter part of the winter to achieve maximum differences in previous cold exposure in the two groups. No dietary restrictions were imposed, except in one experiment when the subjects were examined fasting.

TABLE 1

GENERAL DESCRIPTION OF ESKIMO AND WHITE SUBJECTS
USED IN THIS EXPERIMENT

SUBJECT	AGE (Years)	HEIGHT (Inches)	WEIGHT (Pounds)	SURFACE AREA M^2
ESKIMOS				
1. J. A.	22	66	140	1.72
2. A. M.	24	66	147	1.75
3. J. M.	26	66	139	1.71
4. L. R.	23	61	126	1.55
5. A. K.	22	69	140	1.77
6. F. H.	22	66	143	1.73
MEAN	23	66	139	1.70
WHITES				
7. H. D.*	39	68	152	1.82
8. J. H.	24	73	171	2.00
9. G. S.	28	73	177	2.04
10. J. S.	25	70	130	1.73
11. J. C.	27	68	131	1.70
12. G. S.	26	69	135	1.74
MEAN	28	70	150	1.84

*One White subject became ill shortly after the commencement of the study and was excluded, reducing this group to 5 in number.

II. METHODS

The basic plan of the study was to measure the comparative total evaporative weight loss of these two groups under identical environmental conditions. The experimental design was planned to include three separate environmental conditions.

In the first experiments all the subjects sat quietly, clad only in jockey shorts, for a three-hour period in a room at each of several ambient temperatures. The subjects sat on hard chairs and talked quietly, read, and played cards. Both groups were exposed to a given ambient temperature simultaneously so as to afford a valid group comparison. The temperature range extended from 18° C to 38° C.

The second set of conditions imposed upon these groups was a standard exercise test at a room temperature of 21° C. The subjects were clad only in jockey shorts and walked for 15 minutes on a treadmill at 3.5 mph at an upward inclination of 8.6%. This test was performed in duplicate with very good agreement for a given subject.

The third condition was an attempt to imitate field conditions. The entire group was dressed in the same kind of standard Air Force clothing and walked for three hours through the snow at an ambient temperature of -23° C.

Gross evaporative sweat loss was measured by weighing the subjects nude at the beginning and end of each experimental period, using a Fairbanks-Morse platform scale, accurate to within 5 grams [13, 1]. By metering expired air volume for a 20-minute period and by measuring room humidity, an estimate of total expired air-water loss was possible, the difference between total body-water loss and expired air-water loss being due to sweat evaporation. Expired air was assumed to contain 35 g H_2O/M^3 (100% saturation at 33°C) [15, 3]. The experimental periods were of three hours' duration only and no corrections were necessary for urinary or fecal loss. All weight loss was expressed as $Gm/M^2/Hr$.

For the rough estimation of the regional distribution of active sweat glands, as a supplement to the weight loss data, the sweat print method was used in some instances [12].

Metabolic rates were determined by two indirect calorimetric techniques used at random on all subjects. Either a Benedict-Roth basal metabolism machine was used to measure O_2 consumption directly for two 9-minute periods or the volume and oxygen content of a 20-minute expired air sample was determined, using a dry gas meter and a Beckman oxygen analyzer and applying the formula proposed by Weir [16]. All metabolic rates were expressed as $Calories/M^2/Hr$. Since our objectives were to compare metabolic rates with evaporative heat loss, no attempt was made to compare basal oxygen consumption in Eskimos and Whites. This problem has been the subject of a previous report [14].

During the treadmill experiments, expired air was measured continuously by a dry gas meter. An aliquot expired-air sample was diverted through a Beckman oxygen analyzer for expired air oxygen determinations.

Room temperature and humidity were determined at frequent intervals by a sling psychrometer and the room temperature adjusted as closely as possible ($\pm 2°C$) by manual adjustment of the heaters.

Oral temperatures were taken on the subjects at the beginning and end of each experimental period to obtain a rough estimate of net heat balance.

In a separate series of experiments, the body temperatures of two subjects from each group (J.A., J.M.; H.D. and J.S.) were measured and correlated with evaporative heat loss and metabolic rates at room temperatures from 23° C to 35° C. Each of the observation periods was of three hours' duration. In each experimental period, one Eskimo and one White subject sat on hard chairs, dressed in cotton jockey shorts. They remained quiet throughout the entire period but were allowed to read. Metabolic rates were determined twice during each experimental period as described before. Skin and rectal temperatures were continuously recorded, using copper-constantan thermocouples and a Brown recording potentiometer. The skin temperatures were measured at the following locations: head, trunk, arm, thigh, calf, and foot, and the average skin temperature estimated by using the formula suggested by Hardy and DuBois [6].

III. RESULTS AND DISCUSSION

1. Comparative Resting Sweat Loss and Metabolic Rates of Eskimos and Whites at Temperatures Ranging from 18° C to 38° C.

The room temperature in this series of experiments extended from a level where the subjects were all in a negative heat balance with minimal sudomotor activity, through a range that required increasing sudomotor activity in order to maintain a constant body temperature, and finally to a temperature where maximal or near maximal sweating was still not adequate for thermostasis.

The response of the two groups to this increasing external heat stress is summarized in Table 2 and illustrated in Figure 1. At the lower temperatures there is no difference in evaporative sweat loss. As ambient temperature rises, a divergence is noted in the skin evaporative sweat loss with the Eskimo group having a significantly greater sweating rate. At all temperatures the resting metabolic rate for the Eskimo group exceeds that of the Caucasian group by over 30% under the conditions of this experiment. This difference is highly significant ($P < 0.01$).

TABLE 2

COMPARATIVE RESTING SWEAT LOSS AND METABOLIC RATES OF ESKIMOS AND WHITES

ROOM TEMP. °C	HUMIDITY Gms H_2O/M^3	MEAN SWEAT LOSS (Gms/Hr./M^2)				METABOLIC RATE (Cal/Hr./M^2)	
		ESKIMOS		WHITES		ESKIMOS	WHITES
		Mean	SD	Mean	SD		
17-20	2	15	4	17	2	61	46
21-24	2	31	9	22	5	63	49
27-29	2	44	7	23	5	68	50
35 (with-out blower)	6	75	17	50	11	71	51
32 (plus blower)	5	90	10	40	10	62	45
38 (plus blower)	11	177	12	147	12	69	53
					MEAN	66	46
					STANDARD DEVIATION	6	6

In spite of the elevated metabolic rate of the Eskimos, all subjects were in a negative heat balance at the lowest room temperature as indicated by a decline in oral temperature of several degrees in all subjects. At higher room temperatures there was a rise in oral temperature in all subjects, indicating a positive heat balance.

As an additional check on comparative sweat rates and in order to evaluate regional sweat rates, the sweat print method was used, demonstrating the relative concentration of active sweat glands. The active

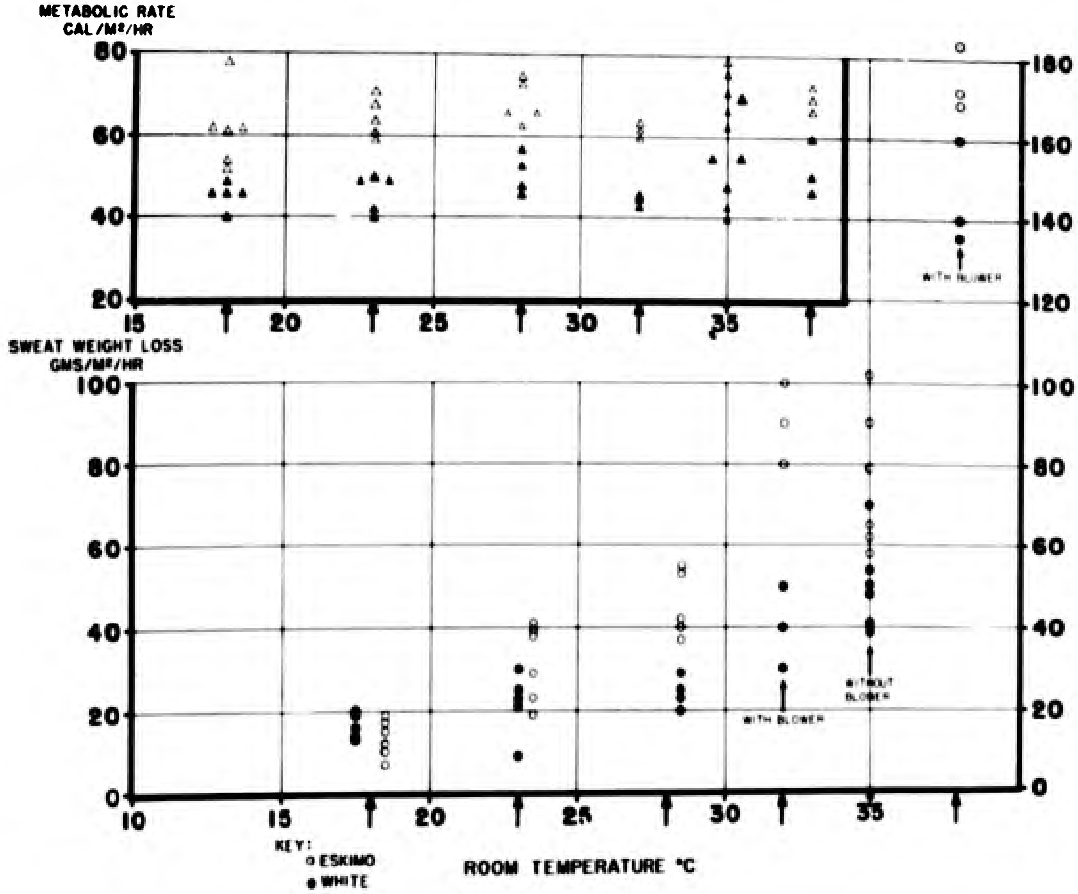

FIGURE 1

The comparative metabolic rates (top) and sweat weight losses (bottom) of Eskimo and White subjects seated quietly at the room temperatures indicated.

glands per square centimeter of skin were counted over different body regions at each of two room temperatures. Table 3 summarizes the mean results. These data substantiate the results obtained from gross evaporative weight loss. The Eskimo skin, particularly of the forehead and back, had a greater concentration of active glands at a room temperature of 33° C. At a room temperature of 28° C, there was no evidence for thermal sweating in either group, although there was some psychomotor sweating in both groups (palms and soles).

TABLE 3

SWEAT PRINTS FROM ESKIMOS AND WHITES
AT TWO DIFFERENT AMBIENT TEMPERATURES

LOCATION	AMBIENT TEMP: 33° C		AMBIENT TEMP: 28° C	
	Eskimos	Whites	Eskimos	Whites
Forehead	7	3	0	0
Chest	1	1	0	0
Back	2	1	0	0
Abdomen	0	1	0	0
Thigh	0	2	0	0
Leg	1	1	0	0
Foot, dorsal	1	2	0	0
Foot, plantar	4	3	2	1
Upper arm	1	0	0	0
Forearm	1	1	0	0
Palm of hand	6	4	4	3

Results are graded 0-10 according to the mean concentration of sweat points per unit area of skin.

2. Comparative Sweat Loss and Metabolic Rates of Eskimos and Whites during Treadmill Walk at a Constant Room Temperature (21° C).

Sweat rates during indoor treadmill exercise were obtained in duplicate on all subjects. Sweat losses and metabolic rates for the entire test period are summarized in Table 4. A wide variation in sweat rate is observed within each group and the group differences are not significant.

TABLE 4

COMPARATIVE SWEAT LOSS AND METABOLIC RATES OF ESKIMOS AND WHITES DURING TREADMILL WALK AT A CONSTANT ROOM TEMPERATURE (21° C)

SUBJECT	SWEAT LOSS Gms/M^2	GROSS METABOLIC RATE (Cal/M^2)	CORRECTED METABOLIC RATE* (Cal/M^2)
Eskimos			
1	39	121	111
2	75	126	116
3	65	116	106
4	56	110	101
5	38	116	107
6	64	119	109
MEAN	56	118 SD: 5	108
Whites			
8	92	104	94
9	42	102	92
10	46	101	92
11	52	85	76
12	31	98	89
MEAN	53	99 SD: 9	89

* The corrected metabolic rate refers to heat which is not used to perform useful work and which must be dissipated by the subjects.

The metabolic rate for the Eskimo group is significantly greater than that for the Caucasian group, however. The figures for gross metabolic rate include that expended in performing work which is 16-18 calories in each group. This still leaves a rather large amount of heat to be dissipated, with the Eskimo group having to dissipate 21% more in order to maintain a constant body temperature. Oral temperature rose by a few tenths of a degree in both groups.

It is apparent that the exercise period was too short to adequately demonstrate the difference in sweating rates, which would be inevitable in these groups. The lag period of sweating activity is well documented and should have been allowed for in this experiment.

3. Comparative Sweat Loss of Eskimos and White Subjects during a Three Hour Outdoor Walk, Simulating Field Conditions, at an Ambient Air Temperature of -23^{o} C.

The nude weight losses are summarized in Table 5. Here, again, there was a great difference in sweat response between the Eskimo subjects and the Whites. This suggests that there was an increased sudomotor drive in the Eskimos in a situation where body heat production was high by virtue of exercise and body heat loss reduced due to clothing insulation.

4. Comparative Sweat Loss in Eskimo and White Subjects Correlated with Metabolic Rates and Body Temperatures at Different Room Temperatures.

The body temperatures of two Eskimos and two Whites were measured at several skin sites and rectally during three-hour observation periods. Weighting of the skin temperatures permitted the calculation of average skin temperature, T_S (6). Mean body temperature, θ, was calculated for each half-hour period according to the formula (2) $\theta = 0.6\ T_R + 0.4\ T_S$. From the calculations of θ, it was possible to approximate the net heat balance of a subject throughout an entire observation period. The net

TABLE 5

COMPARATIVE SWEAT LOSS OF ESKIMOS AND WHITE SUBJECTS DURING THREE HOUR OUTDOOR WALK. AMBIENT AIR TEMPERATURE -23° C.

SUBJECT	WEIGHT OF CLOTHING (kilos)	NUDE WEIGHT LOSS (Gms/M²/Hr.)
Eskimos		
1	7.3	91
2	7.4	189
3	7.0	119
4	7.0	183
5	6.7	89
6	7.4	145
MEAN	7.1	136
Whites		
8	8.5	81
9	8.4	31
10	7.9	77
11	7.7	69
12	6.5	59
MEAN	7.8	63

gain or loss of body heat was estimated in Calories by assuming a mean specific heat for the body tissues of 0.83 (4).

In all cases, the subjects achieved thermal equilibrium within the three-hour time limit as indicated by the attainment of a constant body temperature; however, there was either a heat debt or heat storage during the early phases of each period. The average heat debt at the coolest room temperature was 4-6 Calories/M^2/Hr. for all subjects and the average heat storage at the hottest room temperature was 5-7 Calories/M^2/Hr. for all subjects. Data on the thermal state of the subjects as a whole is presented in Table 6. From inspection of the data it is apparent that under these conditions the Eskimos neither store more heat nor lose more heat from body tissues than do the Whites. However, at the cooler room temperatures, the Eskimo subjects maintain a warmer T_S than do the Whites. This, in all probability, is due to their elevated metabolic rates, which also are summarized in Table 6.

The average rate of total body heat loss is the net rate of body heat produced and body heat lost or stored. Thus, for a subject who has an average metabolic rate of 60 Calories/M^2/Hr. and an average rate of heat storage of 5 Calories/M^2/Hr., the average rate of total heat loss is 55 Calories/M^2/Hr. Figure 2 presents the data graphically for the four subjects. Total body heat loss was greater in the Eskimos, which is a reflection of the fact that they had a higher metabolic rate and the same heat storage as the Whites.

The total body heat loss has been divided into non-evaporative and evaporative heat loss for purposes of this study. The latter, in turn, was fractionated into respiratory water loss and skin evaporative water

TABLE 6

THE AVERAGE RESTING METABOLISM, BODY TEMPERATURE, AND NET HEAT BALANCE OF TWO ESKIMO AND TWO WHITE SUBJECTS DURING SUCCESSIVE THREE-HOUR EXPOSURES TO THE ROOM TEMPERATURES INDICATED

ROOM TEMP. ° C	RESTING METABOLIC RATE (Cal/M^2/Hr.)		BODY TEMPERATURES (° C)						NET HEAT BALANCE (Cal/M^2/Hr.)	
			SKIN (T_S)		RECTAL (T_R)		MEAN BODY (Θ)			
	Eskimos	Whites	Eskimos	Whites	Eskimos	Whites	Eskimos	Whites	Eskimos	Whites
23	65	52	32.3	31.5	36.8	37.1	35.9	36.1	-4.5	-5.5
28	66	51	33.7	33.1	37.0	37.3	36.4	36.5	-0.5	-3.5
30	51	44	34.3	34.0	36.9	37.2	35.9	35.9	1.5	0.0
32	60	53	35.2	35.1	36.7	37.2	36.1	36.3	5.0	5.5
35	65	53	36.1	36.1	37.2	37.4	36.7	36.7	3.5	4.0

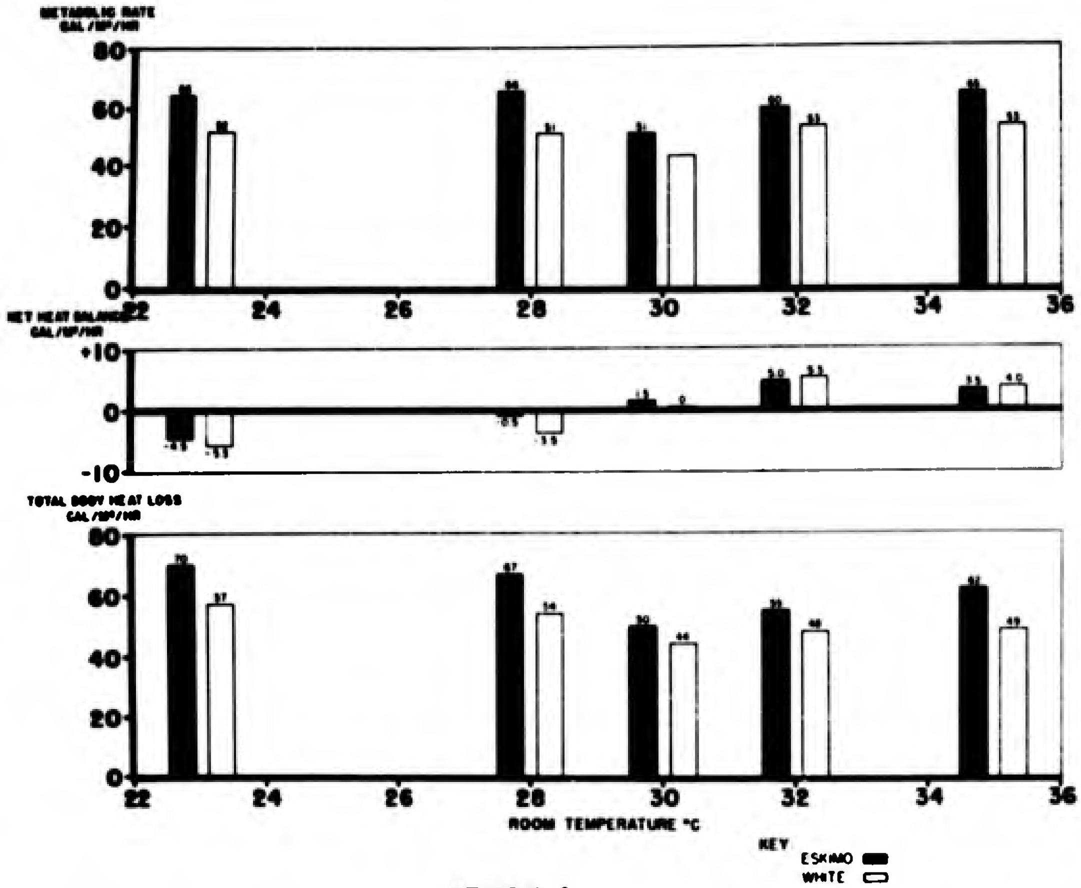

FIGURE 2

The comparative metabolic rates, net body heat balance and total body heat loss of Eskimo and White subjects seated quietly at the room temperatures indicated.

loss. The data on these three avenues of heat loss are summarized graphically in Figure 3. Respiratory heat loss was consistently higher in the Eskimos because of their higher respiratory minute volume (Eskimo mean: 5.1 Calories/M^2/Hr., SD 1.3; White mean: 3.4, SD 0.4). Non-evaporative heat loss was not significantly different between the Eskimo and White groups. Skin evaporative heat loss was consistently greater in the Eskimo group at all room temperatures, particularly in the intermediary temperature zone. This confirms the more numerous data reported on in the first phase of this study.

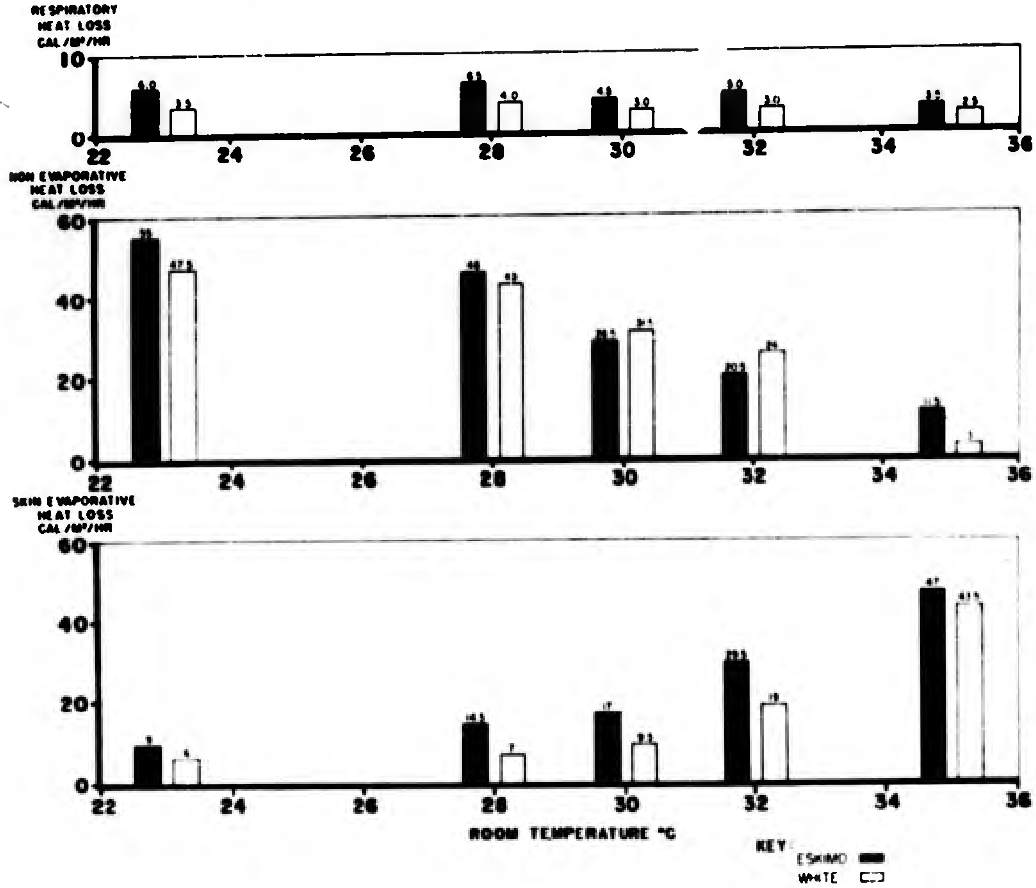

FIGURE 3

The comparative respiratory heat loss, non-evaporative heat loss and skin evaporative heat loss of Eskimo and White subjects seated quietly at the room temperatures indicated.

At room temperatures of 28°C to 32° C, the Eskimos' skin evaporative heat loss averaged 8.5 Calories/M^2/Hr. more than the Whites'. Their total heat loss at this temperature range was 9.3 Calories/M^2/Hr. more than the Whites', so that the sweating mechanism accounted for 91% of the difference. As was stated earlier, the elevated metabolism of the Eskimos required that they increase total body heat loss in order to maintain thermal equilibrium, and an enhanced sweating activity was the major mechanism employed.

The skin evaporative sweat losses of the Eskimo and White groups have been plotted as a function of rectal and average skin temperatures

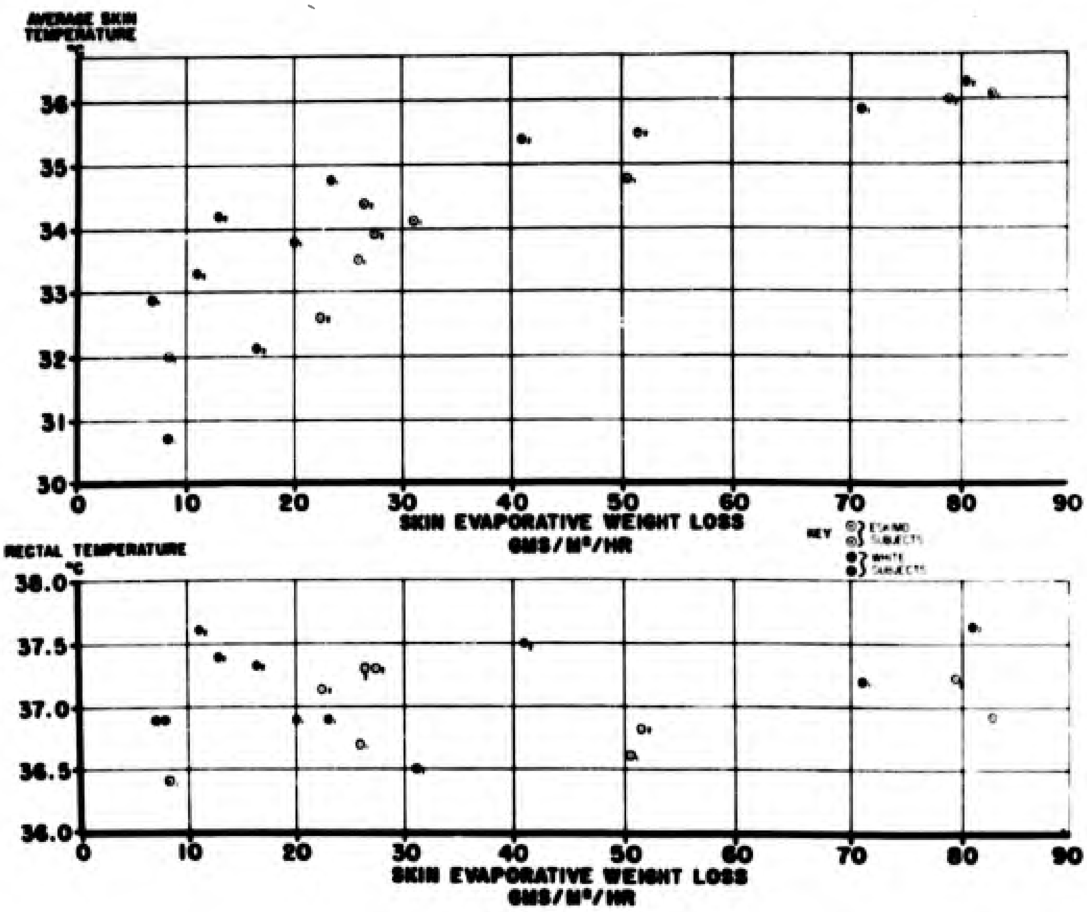

FIGURE 4

Plots of the skin evaporative weight loss of Eskimos and Whites as a function of rectal temperature (bottom) and average skin temperature (top). Correlation coefficient (r') for rectal temperature sweat loss relationship is 0.16; r' for skin temperature-sweat loss relationship is 0.89.

in Figure 4. The sweat rate data were correlated with the temperature data using a rank correlation coefficient (r') [5]. There was no correlation between the sweat rates and rectal temperatures (r' = 0.16). The correlation of sweat rates and skin temperatures for the combined Eskimo-White group was high (r' = 0.89). The Eskimo sweat rate-average skin temperature correlation was 0.96; the correlation for the Whites was 0.88.

In order to determine if any difference existed between the frequency distribution of the Eskimo and White sweat rate-skin temperature relationship, this was tested by the application of Olds' t-test [11] and Lord's t-test [10]. Both tests indicated that there was no significant difference between the two groups.

The increased sweat activity in the Eskimo group may be accounted for by their relatively warmer skin (see Table 6) stimulating their thermosensory receptors to a greater extent. There is no reason to postulate that the Eskimo has a different thermosensory threshold than the White.

IV. SUMMARY AND CONCLUSION

Comparative sweat rates and metabolic rates were measured in Eskimos and Whites under three separate conditions. In addition, thermometric studies were performed on two individuals from each group in order to permit correlations with body heat balance, body temperatures, etc. The evidence indicated a greater heat production in the Eskimo group at rest and during standard comparative exercises. Under conditions favoring body heat debt, no difference in insensible water loss occurred between the two groups. In the "comfort zone" and under conditions favoring body heat storage, the Eskimos responded by sweat activity which was greater than the Whites' and which was in proportion to their increased heat production. Body heat debt and heat storage under the above conditions were the same for both groups, which indicated that the thermoregulatory "set" of the Eskimo was the same as for the White.

The average skin temperature of the Eskimo did tend to be elevated above the Whites' at all environmental temperatures below 35° C. This, undoubtedly, was due to the increased heat production of the Eskimo group and the resultant increased heat flux to the skin.

A high correlation existed between the average skin temperature and sweat rates of both the Eskimo and White groups, and the frequency-distribution of the data was the same for both. ~~This indicates that~~ the thermosensory receptors in the skin of the Eskimo were stimulated relatively more under these conditions because of their warmer skin. The increased thermosensory activity from skin receptors would account for the increased sweat activity of this group.

The fundamental difference in the groups from the standpoint of thermal regulation appears to center upon the increased metabolism of the Eskimo. In the absence of any demonstrable difference in heat storage, an elevated skin temperature and consequent increased sweat activity are logical mechanisms to permit an increased dissipation of heat in the Eskimo group. There is no evidence to indicate that the Eskimo differs from the White in any way as far as this heat loss mechanism is concerned.

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V. REFERENCES

1. Adolph, E. F., et al, Physiology of Man in the Desert. New York: Interscience Publishers, Inc., 1947.

2. Bazett, H. C., "The regulation of body temperatures" in Physiology of Heat Regulation and Science of Clothing, edited by L. H. Newburgh, Page 128. Philadelphia: W. B. Saunders Co., 1949.

3. Burch, G. E., "The rates of water and heat loss from the respiratory tract of patients with congestive heart failure, who were from a subtropical climate and resting in a comfortable atmosphere." Am. Heart Journal, 32; 1-12, 1946.

4. Burton, A. C., "Human calorimetry: the average temperature of the body." J. Nutr., 9; 261, 1935.

5. Edwards, A., Statistical Method for the Behavioral Sciences. Pages 193-195. New York: Rinehart & Co., Inc., 1954.

6. Hardy and Dubois, "Basal metabolism, radiation, convection and vaporization at temperatures of 22° C to 35° C." J. Nutr., 15; 477, 1939.

7. Ivy, A. C., "Physiological differences produced by race and diet other than Vitamin and mineral deficiencies." Proceedings of the Hawaii Med. Association, April 1956.

8. Johansen, J., Danish physician at Thule, Northwest Greenland. Personal communications, 1952.

9. Kuno, Yas, Kyoto, Japan. Personal communication, 1955.

10. Lord, E., "The use of range in place of standard deviation in the t-test." Biometrika, 34; 41-67, 1947.

11. Olds, E. G., "Distribution of sums of squares of rank differences for small numbers of individuals." Ann. Math. Statis., 9; 133-148, 1938.

12. Randall, W. C., "Quantitation and regional distribution of sweat glands in man." J. Clinical Invest., 25; 761-767, 1946.

13. Robinson, S. and A. H. Robinson, "Measurement of Sweating," Methods in Medical Research, 6; 100-120. Chicago: Year Publishing Co., 1954.

14. Rodahl, K., "Basal metabolism of the Eskimo." Arctic Aeromed. Lab. Tech. Report, 22-1301-0001, Part 2, 1952.

15. Webb, Paul, "Air temperatures in respiratory tracts of resting subjects in cold." J. Applied Physiology, 4; 378-382, 1951.

16. Weir, J. B. de V., "New methods for calculating metabolic rate with special reference to protein metabolism." J. Physiology, 109; 1, 1949.

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