EFFECT OF ALTITUDE ON BASAL PALMAR SWEATING

BY

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Kuno (1934) pointed out that the sweat glands on the palmar surface of the hand are primarily occupied in reflecting emotional changes, during which their output may increase or decrease according to the variety and intensity of the emotion. But the factors which are responsible for palmar sweating under basal conditions, when it is assumed that the emotional state is comparatively constant, are unknown.

Variations in basal palmar sweating have been reported in a number of physiological circumstances, and the reports indicate that it diminishes with age (MacKinnon, 1954a), diminishes during the luteal phase of the menstrual cycle (MacKinnon, 1954b), diminishes in pregnancy (MacKinnon and MacKinnon, 1955a), especially during the first and third trimesters (MacKinnon and MacKinnon, 1955b), and diminishes in summer (MacKinnon and MacKinnon, 1956). In each case the authors have felt that the depression in basal sweat output was linked to increased suprarenal activity and that a stress of some sort was responsible.

The present investigation owes its inception to the thesis that the stress of living at high altitudes would be reflected in basal palmar sweating. It was designed to measure the effect of high altitude on basal palmar sweating by comparing sweat indices of four people living for a period of 12 days in the Swiss Alps, and, in the following year, for a period of 40 days in the Karakoram of West Pakistan, with their sweat indices in London.

Methods

Four mountaineers, three men aged 30–33 and a woman aged 26, all normally resident in London, were involved in the investigation.

Sweating was measured by the number of moist spots situated at the openings of the ducts of sweat glands on an area of skin 4 mm. square immediately distal to the central whorl of the right middle finger, after the finger had been dried with blotting-paper. The number is referred to as the sweat index. It was obtained by preparing a plastic fingerprint (Sutarman and Thomson, 1952) on waking in the morning under conditions which

were as near to basal as possible and subsequently counting the spots in the selected area of skin at a magnification of 10 (Fig. 1).

In the Swiss Alps records were made for 12 days at altitudes of 6,000–13,000 ft. (1,830–3,960 m.) and compared with those obtained in London during the week before and the week after the expedition. In the Karakoram daily records were made for 40 days at altitudes of 8,000–20,000 ft. (2,440–6,100 m.) and compared with daily records obtained in London for a month before and after. While the plastic fingerprints were being prepared oral body temperature was taken with thermometers which were accurate to 0.1° F. Mean sweat indices and mean body temperatures are given in Tables I and II.

On a few isolated mornings of days when major ascents were to be undertaken sweat prints were not

FIG. 1.—Photomicrograph ($\times 10$) of a plastic fingerprint with a sweat index of 79. Each white spot represents a moist sweat-duct orifice.

made, and, unfortunately, on the first day in the Karakoram one subject (Male 3) contracted amoebic dysentery, which lasted for four weeks, and his records for the Karakoram are therefore not included.

TABLE I.—Mean Basal Sweat Index and Mean Basal Oral Temperature (°F.) for 12 Days in the Swiss Alps and for 7 Days in London Before (London 1) and After (London 2)

	London 1. July				Swiss Alps. July				London 2. August			
	Sweat Index	S.D.	Oral Temp.	S.D.	Sweat Index	S.D.	Oral Temp.	S.D.	Sweat Index	S.D.	Oral Temp.	S.D.
Female ..	77	32	97.9	0.6	54	23	97.7	0.8	87	38	98.0	0.4
Male 1 ..	30	19	97.4	0.5	11	9	96.9	0.5	32	17	97.7	0.4
„ 2 ..	45	23	97.3	0.6	12	11	96.8	0.4	82	38	97.3	0.6
„ 3 ..	77	41	97.8	0.4	31	22	96.9	0.6	55	41	97.6	0.5

TABLE II.—Mean Basal Sweat Index and Mean Basal Oral Temperature (°F.) for 40 Days in the Karakoram and for 30 Days in London Before (London 3) and After (London 4)

Subject	London 3. April–May					Karakoram. July–August					London 4. October				
	Sweat Index	S.D.	Oral Temp.	S.D.	C1*	Sweat Index	S.D.	Oral Temp.	S.D.	C2*	Sweat Index	S.D.	Oral Temp.	S.D.	C3*
Female (follicular)	72	22	98.2	0.4	–2.0840	33	19	98.1	0.6	1.1423	69	14	98.1	0.5	1.0243
„ (luteal) ..	84	10	98.5	0.5	1.4924	30	18	98.2	0.4	–2.4271	—	—	—	—	—
Male 1 ..	39	23	97.3	0.5	0.3148	6	7	97.5	0.6	0.2374	25	28	97.1	0.4	–0.0731
„ 2 ..	57	25	97.6	0.3	–1.0318	30	27	96.9	0.6	–0.9765	64	13	97.4	0.5	0.01193

* Indices of correlation between sweat index and oral temperature in London 3, Karakoram, and London 4 respectively, expressed as the ratios of regression coefficients to standard errors.

Sweat Indices

The mean sweat indices of each of the climbers were lower in the Swiss Alps than in the corresponding London controls (Table I), and lower in the Karakoram than in the corresponding London controls (Table II). From the statistical angle the lowering of the sweat indices in the Swiss Alps was significant and in the Karakoram very strongly significant (Table III).

TABLE III.—Significance of Differences Between Basal Sweat Indices in Swiss Alps and Karakoram and Those in London Before and After. The Probability That Where a Fall in Body Temperature was Registered in the Alps or Karakoram it Arose by Chance is in Parentheses. All Probabilities were Calculated by *t*-Testing (Chambers, 1952)

	London 1		London 2
Female	P<0.05 (P<0.2)	Swiss Alps	P<0.02 (P<0.1)
Male 1	P<0.02 (P<0.01)		P<0.01 (P<0.01)
„ 2	P<0.001 (P<0.05)		P<0.001 (P<0.05)
„ 3	P<0.001 (P<0.001)		P<0.05 (P<0.01)
	London 3		London 4
Female (follicular) ..	P<0.001 (P<0.4)	Karakoram	P<0.001
Female (luteal) ..	P<0.001 (P<0.02)		
Male 1	P<0.001		P<0.001
„ 2	P<0.001 (P<0.001)		P<0.001 (P<0.01)

The day-to-day fluctuations in the sweat indices of the four members of the climbing party followed a similar pattern, and only those of the woman and one man (Male 1) are given (Fig. 2). The graphs illustrate that the characteristic mean sweat index of the individual climbers varied greatly, that the influence of high altitudes on the index was approximately the same in male and female, that the depression in the sweat index was rather less in the Swiss Alps than in the Karakoram, that "acclimatization" did not appear to take place in the Karakoram in spite of the 40 days spent there, and that recovery from the depression in the Swiss Alps appears to have been complete on reaching London 48 hours after leaving the mountains, whereas recovery from the depression of the index by the Karakoram remained incomplete after two months. The last of these did not apply in Male 2, whose sweat indices were slightly higher in London after the Karakoram than in London beforehand (Table II).

Body Temperature

Basal body temperature was lower in the Swiss Alps than in London in all cases (Table I) and lower in the Karakoram than in London in the woman and Male 2, but not in Male 1 (Table II). From the statistical angle the depressions in body temperature were commonly significant (Table III), and it would therefore seem that body temperatures were generally, though not invariably, depressed at high altitudes.

Statistical correlation of sweat indices with body temperature was carried out on three sets of data—those of London 3, those of the Karakoram, and those of London 4—and the low indices which were the result

of the investigation (Table II, C1, C2, and C3) provide convincing evidence that on these occasions the sweat indices were not dependants of body temperature. It was therefore assumed that the sweat indices in the Swiss Alps had also been independent of body temperature.

Discussion

During the luteal phase of ovulatory menstrual cycles body temperature is elevated (Tompkins, 1944) and the sweat index is commonly lowered (MacKinnon, 1954b). Therefore, where the observations on the woman were numerous enough—that is, in the Karakoram and in London before and after—follicular data were separated from luteal data. This could not be done for the Swiss Alps because the total period involved, including the London controls, was only 30 days, and luteal data in the Alps were therefore necessarily compared with follicular data in London (Fig. 2). In 1956 this woman's menstrual rhythm was characterized by luteal elevation in body temperature (Table II) without depression of the sweat index (Fig. 2), and if the rhythm of 1955 bore the same characteristics the fall in her sweat index in the Alps, though it took place in the luteum, was attributable solely to altitude, and the fall in body temperature which took place in the Swiss Alps meant that its depression by altitude exceeded its elevation by the luteum.

Conditions which are encountered at high altitudes, and which could be called upon to account for the very significant lowering of the sweat indices in all the members of the expedition, both in the Swiss Alps and in the Karakoram, are low relative humidity, low environmental temperature, low barometric pressure, emotional changes, or perhaps a combination of some or all of these.

Relative humidity in August in the Swiss Alps is 67% (Morikoffer and Chorus, 1941) and in the Karakoram 51% (Bleeker, 1936), while in London the mean relative

FIG. 2.—Daily indices of basal palmar sweating in female (continuous line) and in male (interrupted line) during expeditions to the Swiss Alps and to the Karakoram, and of daily indices obtained in London before and after the expeditions. M.B.=Bleeding phase in menstrual cycles of female.

humidity at 8 a.m. during the months of May to October is 84% (Meteorological Office, 1958, personal communication), and it would therefore seem possible that the lower relative humidity encountered in the Swiss Alps and the Karakoram could have been responsible for a rapid evaporation at the apertures of the sweat ducts, resulting in a low sweat index. But Venables (1955) saw no "evidence of curvilinearity" in scatter diagrams in

which he related relative humidity to psychogalvanic reflexes measured on the palms of the hands of normal subjects, and, as the electrical resistance of the skin by which the psychogalvanic reflexes were measured was equally the measure of sweat-gland activity, it seems doubtful if the reduction of the palmar sweat index in the Swiss Alps and the Karakoram was due to low relative humidity. Also militating against the theory of causation by relative humidity is the fact that the graphite solution used in the preparation of the plastic sweat prints was applied to, and excluded the air from, the finger within five seconds of drying it.

The early morning air temperature in the tents, in both the Swiss Alps and the Karakoram, was around 28–32° F. (–2.2–0° C.), but in spite of this the members of the party felt comfortably warm while the plastic prints were being prepared, because they had been enclosed for six to nine hours in efficient sleeping-bags. Air temperatures encountered later in the day were much higher, and it is true to say that the members of the expedition were only rarely exposed to extreme cold at any time of the day or night. Nevertheless air temperatures in the Swiss Alps and the Karakoram were well below London levels and may have reduced the sweat index in the process of heat conservation, although the primary function of the palmar sweat glands is not thermoregulatory (Kuno, 1934).

Low barometric pressure induces hypoxia, and hypoxia is a potent stimulus to the chemoreceptors in the carotid and aortic bodies in experimental animals (Dripps and Comroe, 1944), thereby giving rise to diverse consequences which include increased activity in the cerebral cortex to a degree that, in dogs, may lead to convulsions (Dripps and Comroe, 1944). If man responds to hypoxia in the same way as experimental animals the hypoxia experienced by the climbers at high altitudes in the Swiss Alps and the Karakoram should have increased their cerebral activity, and, as Netsky and Starr (1948) have demonstrated that precentral corticectomy in man increases palmar sweating as judged by the ferric chloride and tannic acid test (Silverman and Powell, 1944), activation of the precentral cortex by chemoreceptor reflexes induced by anoxia may have contributed to the fall in the sweat index at high altitudes.

Primary emotional changes affect palmar sweating (Kuno, 1934), but it is impossible to judge their influence in the Swiss Alps and the Karakoram. The symptoms—emotional instability, loss of self-reliance, suppressed anxiety, and lack of initiative—usually appear at an altitude of 10,000 ft. (3,050 m.) (Best and Taylor, 1950), or, in the case of experienced mountaineers, at 15,000 ft. (4,570 m.) (McFarland, 1939), but none of these were experienced subjectively by, or seen objectively in, any of the climbers.

Of the factors so far discussed none seems likely to have been the sole cause of the fall in the palmar sweat index in the Swiss Alps and the Karakoram, but a combination of them might constitute a stress (Selye, 1950) involving defensive reactions on the part of the pituitary and suprarenal glands with consequent increase in the blood levels of adrenocorticotrophic and corticoid endocrines, and, as the administration of corticotrophin brings about a fall in the sweat index (MacKinnon, 1957), the fall which took place at high altitudes may have been caused by stress.

Summary

Daily measurements of basal palmar sweating in four people living for a period of 12 days at altitudes of 6,000 to 13,000 ft. (1,830–3,960 m.) in the Swiss Alps, and, in the following year, for a period of 40 days in the Karakoram of West Pakistan were recorded and compared with corresponding data for London. Sweating was found to be significantly less in the Alps and in the Karakoram than in London in all cases. Possible reasons are discussed.

These observations formed a part of the scientific work of the London School of Economics Mountaineering Club Himalaya Expedition, 1956, and we gratefully acknowledge the collaboration of the members of the expedition and the financial support the expedition received from the Mount Everest Foundation, the Medical Research Council, and the Central Research Fund of the University of London. Thanks are due to Mr. J. Durbin, of the London School of Economics, for his advice on the statistical analyses.

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On January 15 Dr. DETLEV W. BRONK, president of the Rockefeller Institute, and Mr. J. R. B. BRETT-SMITH, of the Oxford University Press, New York, announced the establishment of the Rockefeller Institute Press. This will publish books on science and related subjects. Editorial responsibility for the books will rest primarily with the Institute, while the Oxford University Press will be chiefly responsible for design, printing, and distribution. It is expected that the first books will be issued in the autumn of 1959. While many of the books and monographs will be the work of Institute faculty members, works by other scholars will also be published. "Among the objectives of the Press," said Dr. Bronk, "will be to provide an additional and needed outlet for scientific books of highest quality, carefully selected because of their excellence. Further, during this time of rapidly increasing scientific knowledge paralleled by ever mounting costs of publication, the Rockefeller Institute Press, because of its non-profit nature, will make possible the publication of books at costs which will enable the individual to purchase them for his personal library."