STUDIES ON SWEATING

V. Studies of Quantity and Distribution of Thermogenic Sweat Delivery to the Skin*

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INTRODUCTION

In a previous communication (1) we described a relatively simple method for assaying the quantities of sweat delivered on circumscribed areas of the surface of the human skin. This method, which employes the indicator used by Manuila of the school of Werner Jadassohn (2) for the detection of sweat, consists of the following essentials: Prints are taken of the sweat pattern on the skin by means of filter paper squares prepared with an indicator-powder containing Bromphenol-Blue and are compared with standard prints produced by measured quantities of water or sweat. Unlike the other quantitative technics thus far employed for the purpose of measuring sweat-output, the newly developed method permits examinations on a large scale within relatively short periods of time and without any intricate equipment. Furthermore, in contrast to the other technics, our method assays exclusively the outpouring sweat proper, i.e., the water coming from the sweat organ and collecting on the skin surface.

Because of these advantages, we employed the new procedure in extensive studies of the regional distribution of sweat delivery to the skin surface. As a first step, it appeared desirable to gather data on the quantities of thermogenic sweat in healthy and untreated subjects, in order to secure a new baseline for subsequent clinical or experimental investigations.

We shall also present a few selected examples demonstrating the usefulness of the method for the study of pertinent patho-physiologic questions.

OUTLINE OF PROCEDURE

a. Stimulation of sweating by exposure to heat

The test subjects were exposed to dry heat under standardized experimental conditions. The heat was supplied by two ordinary reflector-type sweat boxes, each provided with twelve (60 watt) incandescent bulbs. The subject was seated on a low stool between the open sweat boxes; one in a vertical position in front of the chest and abdomen; and the other in an analogous position, open towards the subject's back. The boxes were elevated on stools. Great care was taken to obtain equidistance between the bulbs and the same parts of the body in every person under test. During the exposure to heat, a large blanket reaching down to the floor, encompassed both boxes. The subject's head and neck protruded

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through a hole in the blanket. The arms were abducted; the flexed elbows were supported by the upper edge of the anterior sweat box, and the palms directed toward the light bulbs. The temperature of the air between the boxes and the skin of the test subject averaged 108°F. The room was "air-conditioned," with ranges in temperature from 68 to 80°C., in relative humidity from 20 to 46%. The relative humidity of the air in the room was determined with a sling hygrometer before each examination.

As described in the preceding report (1), the sites to be tested were defined by means of a stencil and encircled with a stamp prior to the experiments.

b. "Onset" of the response to heat

Not only the amount of sweat delivered, but also the speed of the response to the heat stimulus was important. In every test session, therefore, we recorded the period of exposure to heat needed to produce the first manifestation of increased outpouring. The first grossly visible sign, the "onset," was the appearance of minute sweat droplets (mostly on the sides of the forehead) which produced a characteristic glistening immediately perceptible to any somewhat experienced observer. When sweat droplets were visible on the skin prior to exposure to heat, the time of heating until "onset" was recorded as "zero" minutes. In addition to the required periods of heat-stimulation, we recorded the site or sites on which the "onset" appeared. It was often helpful to ascertain the findings by placing a glass prism on the skin, as suggested by M. G. Netsky (3). The prism was not used on any of the actual test-sites marked with the stamp, but only in their vicinity.

At this initial stage of the response to heat, the droplets were usually still too minute to produce distinctive prints on our indicator-paper. Furthermore, since different parts of the skin began to sweat visibly at different times, application of the prepared filter paper on any of the test sites was avoided during this early phase, in order not to defeat our purpose, namely, to obtain distinctive and comparable records from all test sites at the same time.

c. "Pre-reading period"

It was important to follow carefully the increase in outpouring after the "onset," in order to ascertain the time when measurable quantities of sweat appeared on all, or almost all areas of the skin surface. In addition to careful inspection of the skin with the naked eye and with the prism, it was found helpful also to take tentative prints with our prepared filter paper from areas adjacent to the encircled test sites.

After a certain interval following the "onset," the sweat droplets on all, or nearly all of the test sites, reached the proper size to produce satisfactory prints. Although the droplets became larger during this interval, they subsequently changed relatively little in size for a period of approximately 3–5 minutes, i.e. they did not become so large as to diffuse and coalesce (especially during absorption by the recording filter paper) and thus obviate the possibility of differentiating the patterns. Later, the confluence of the droplets on a number of test-areas terminated the favorable period for taking distinctive prints. The period of ex-

posure to artificial heat before the indicator-paper actually had to be applied, was regarded and recorded as the "pre-reading period." The latter was defined as the duration of exposure to heat preceding the earliest suitable moment for application of the treated filter paper.

d. Printing and reading of records

As soon as the "pre-reading period" was terminated, squares of the prepared filter paper were applied on all test sites in the manner outlined in our previous report (1).

Careful lifting of the blanket from the upper border of the sweat boxes provided sufficient access to the sites below the neck.

It was imperative to take the prints in rapid succession, in order to perform the tests before the outpouring droplets became too large. The period during which distinctive patterns were obtainable, i.e. the number of minutes (approximately 3 to 5 minutes) between the end of the "pre-reading period" and the stage of confluence of many droplets, was termed the "reading period."

As was described in our preceding communication (1), the test prints were not evaluated milligram by milligram, but by approximation within 5 mg., after comparison with the best matching standard print, i.e. the best matching pattern produced by a definite quantity of water.

With few exceptions, all our examinations were carried out more than once; many were repeated as often as forty times in the same subjects under the same experimental conditions.

I. EXAMINATION OF "HEALTHY" INDIVIDUALS (NORMALS)

A. Subjects and sites tested

Forty healthy subjects were investigated. Thirty were males between 21 and 67 years of age. Twenty-seven of these were 21 to 29 years old. Four of the males were negroes, 22 to 28 years old. The ten females, including one negress, ranged in age from 22 to 31 years.

The total number of tests in these subjects amounted to 5481, the number of separate sessions to 560.

The following sites were tested: mid-forehead and temporal areas; cheeks; chest, in mid-sternal, right and left midclavicular lines at the levels of the 3rd and 7th costo-chondral junctions; back, in vertebral, right and left midscapular lines at the levels of T4 and T9; axillary vaults; and palms.

In many cases, all these sites were examined at every test session. For technical reasons, however, this was not always possible. Nevertheless, a considerable number of sites were tested in every case but one, with a minimum of 12 sites on the trunk, in addition to the sites on the forehead and the axillary vaults.

The subjects were cautioned not to use any soap or cosmetics on the areas under test from 24 hours prior to the first test-session until the period of the examinations was ended.

B. Results

a. "Onset"

The time of exposure to dry heat required for the "onset" of visible outpouring (table I) averaged 1.9 minutes in healthy males, and 3.58 minutes in healthy females. The number of examinations in females, which are as yet relatively few, will have to be increased to substantiate the significance of the difference of the means.

No difference was noted between the time of "onset" in the few negro subjects tested and that in the white subjects.

Thus far, the period of heating until the "onset" has been rather constant when the tests were repeated in one and the same individual. With regard to the site, the "onset" was noticed in the temporal areas, either exclusively or simultaneously with outpouring on other areas in 30 of the subjects; in the axillary vaults, but not in the temporal areas in 7 of the subjects; and was seen on the chest, and not in the temporal areas in only 3 of the subjects.

TABLE I

"Time of onset" and "pre-reading period"

	NUMBER OF SUBJECTS	NUMBER OF SESSIONS	AVERAGE NUMBER OF MINUTES	RANGE
				minutes
"Onset"				
Males	26	206	1.9	0–9
Females	8	12	3.58	0–8
"Pre-reading Period"				
Males	30	385	13.0	5–30
Females	10	23	26.2	9–35

"Onset." Period of exposure (in minutes) to dry heat required for the visible appearance of outpouring perspiration;

"Pre-reading Period." Period of exposure (in minutes) to dry heat required for obtaining distinctive prints on multiple sites of the body surface.

b. "Pre-reading period"

The average "pre-reading period," i.e. the period of exposure to dry heat required before adequate prints on multiple sites could be obtained, was 13.0 minutes in 30 healthy males, and 26.2 minutes in 10 healthy females. Evidently, the difference between the mean "pre-reading periods" in males and in females is significant.

There was no appreciable difference in the "pre-reading periods" observed in the negroes as compared with the "pre-reading periods" in white test subjects, but the number of negro subjects investigated is still too small to justify any conclusion.

Only very few of the test subjects of the same sex showed major deviations

from our mean values. These exceptional deviations are responsible for the wide ranges indicated on table I. In one and the same subject, the "pre-reading period" hardly ever differed significantly on repeated examination.

c. Quantities of sweat delivered to the skin surface

1. *Correlation between quantity, "pre-reading period," and "reading period."* It appeared important to note that in subjects with relatively small amounts of thermogenic sweat, the "pre-reading period" as well as the "reading period" tended to be long and in persons with relatively large amounts of sweat, both "pre-reading period" and "reading period" tended to be short.

2. *Quantity on individual test areas.* The readings of the quantity on a given area in one and the same subject were relatively constant in repeated examinations. For example, in one subject the average amount of sweat obtained on a given site in 36 tests, each performed on a separate day was 12.5 mg./2 cm^2., with a standard deviation of 3.0 mg. Variations in the amount of sweat delivered to a given area in *different individuals* substantially exceeded those obtained in one person on *different occasions.*

3. *Quantities on different sites and regional distribution (in males and females).* Table II shows the average amount of sweat (mg./2 cm^2. surface) found in different regions of the skin surface of 29 healthy males. The corresponding findings in 10 healthy females are shown in table III. Although the individual readings were recorded in 5 mg.-ranges, the results are presented as single figures which were obtained by computation of the mean value.

There were significant and consistent differences in the amounts of sweat delivered to different areas of the skin surface. As shown by tables II and III, more sweat appeared in the temporal areas than in the mid-forehead, whereas considerably larger quantities were found on the medial portions of chest and back than on the lateral parts.

In decreasing order of thermogenic sweat-delivery, the different body areas tested in male subjects can be listed as follows: 1) midsternum at the level of the 3rd costo-chondral junction, 2) temporal areas, 3) midclavicular lines at the level of the 3rd costo-chondral junction, and vertebral line at the level of T4, 4) axillary vaults, and vertebral line at the level of T9, 5) midscapular lines at the level of T4, 6) midsternal line at the level of the 7th costo-chondral junction, 7) midscapular lines at the level of T9, etc.[1], as shown in table II.

In the female subjects (see table III), the axillary vaults showed the greatest amount of outpouring, and the quantity at T4 in the vertebral line exceeded the amount on the temporal areas. In all other respects the order of decreasing magnitude of sweating was about the same for the different test sites as in the male subjects. In both sexes the lowest amounts were present in the palms.

For the purpose of comparison, the mean amounts of thermogenic sweat on different areas of the body surface in males and females are graphically presented

[1] For technical reasons it was impossible to ascertain the actual amounts on the test areas of the face and the relation of the readings obtained on the mid-forehead and cheeks to the other values obtained on the areas of the body surface (see Discussion (C)).

in Graphs I and II. As is evident, *the males showed greater amounts of sweat in all areas* examined,[2] *except in the axillae and on the palms*, where about equal amounts were found in both sexes. The observed differences were significant on nearly all

TABLE II

Regional distribution of thermogenic sweat on the skin-surface of 29 healthy males

REGION	NUMBER OF TESTS	MEAN (MG. SWEAT/2 CM.² SURFACE)	RANGE (MG. SWEAT/2 CM.² SURFACE)
I. *Head*			
a) Left temple	77	17.45	2.5–52.5
b) Mid-forehead	20	14.75	2.5–22.5
c) Right temple	77	16.8	2.5–52.5
d) Left cheek	18	2.5	
e) Right cheek	18	2.5	
II. *Axillae*			
a) Left axilla	276	15.65	2.5–37.5
b) Right axilla	211	14.35	2.5–37.5
III. *Chest*			
1. At the level of the 3rd costo-chondral junction:			
a) Left midclavicular	62	16.5	2.5–32.5
b) Midsternum	51	20.5	12.5–32.5
c) Right midclavicular line	62	17.1	2.5–32.5
2. At the level of the 7th costo-chondral junction:			
a) Left midclavicular line	59	6.4	2.5–22.5
b) Midsternal line	49	11.7	2.5–27.5
c) Right midclavicular line	59	6.15	2.5–27.5
IV. *Back*			
1. At the level of T4:			
a) Left midscapular line	328	11.85	2.5–32.5
b) Vertebral line	49	16.8	2.5–27.5
c) Right midscapular line	245	12.25	2.5–32.5
2. At the level of T9:			
a) Left midscapular line	263	7.2	2.5–42.5
b) Vertebral line	50	15.0	2.5–32.5
c) Right midscapular line	275	7.1	2.5–27.5
V. *Palms*			
a) Left palm	29	2.85	2.5–7.5
b) Right palm	29	3.2	2.5–7.5

the test sites. More examinations in female subjects are desirable to further substantiate these differences.

Thus far, no quantitative differences in sweat delivery were observed in white and negro subjects.

[2] Neither the actual amounts nor the sex difference in sweat quantities could be ascertained for the cheeks (see Discussion (C)).

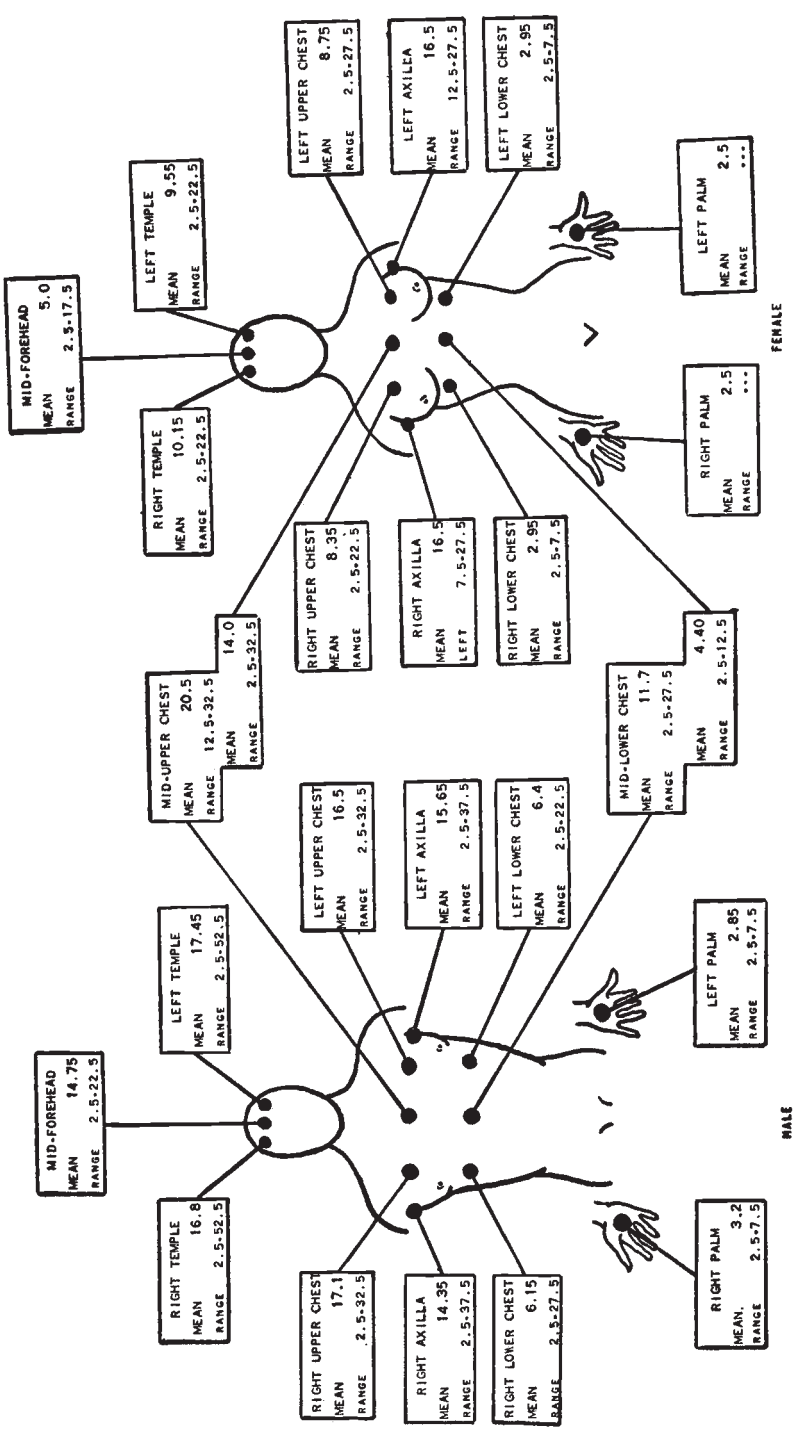
Although the quantity of outpouring sweat was equal on symmetrical sites in the majority of subjects, nevertheless in a substantial minority an asymmetrical sweat-delivery was observed. Such inequality in outpouring on corresponding sites was not recorded by us as an individual peculiarity unless and until the same

TABLE III

Regional distribution of thermogenic sweat on the skin-surface of 10 healthy females

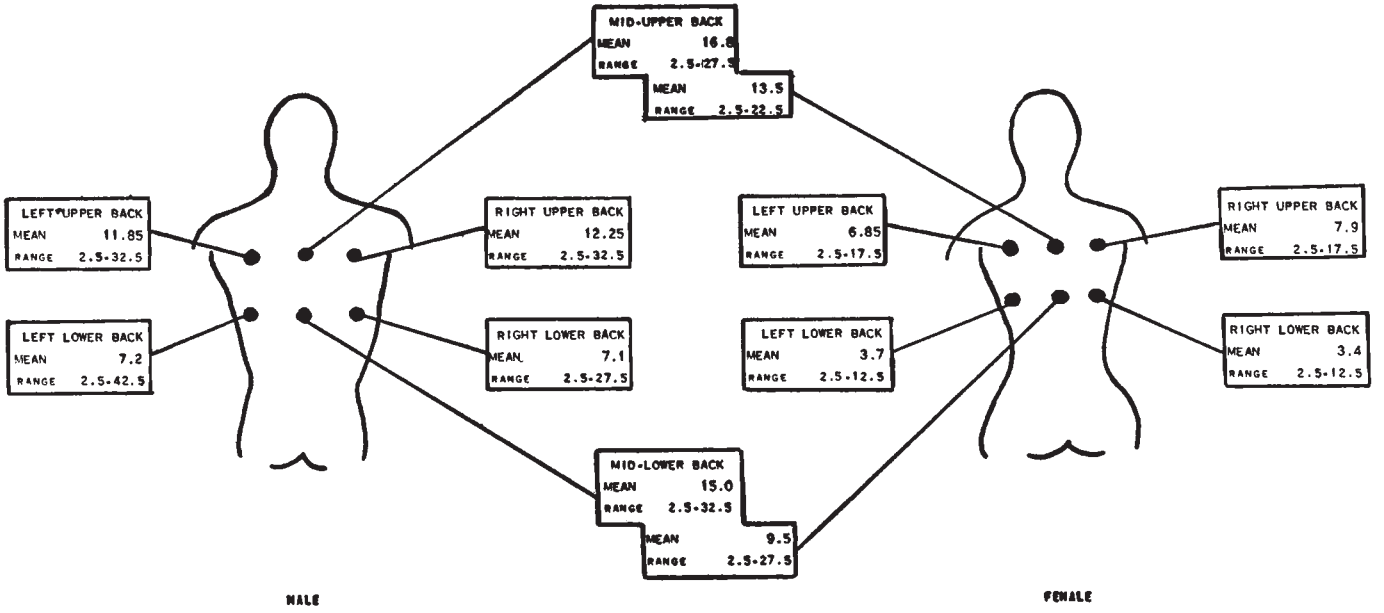
REGION	NUMBER OF TESTS	MEAN (MG. SWEAT/ 2 CM.^{2} SURFACE)	RANGE (MG SWEAT/2 CM.^{2} SURFACE)
I. *Head*			
a) Left temple	17	9.55	2.5–22.5
b) Mid-forehead	6	5.0	2.5–17.5
c) Right temple	17	10.15	2.5–22.5
d) Left cheek	3	2.5	
e) Right cheek	3	2.5	
II. *Axillae*			
a) Left axilla	5	16.5	12.5–27.5
b) Right axilla	5	16.5	7.5–27.5
III. *Chest*			
1. At the level of the 3rd costo-chondral junction:			
a) Left midclavicular line	12	8.75	2.5–27.5
b) Midsternum	10	14.0	2.5–32.5
c) Right midclavicular line	12	8.35	2.5–22.5
2. At the level of the 7th costo-chondral junction:			
a) Left midclavicular line	11	2.95	2.5–7.5
b) Midsternal line	8	4.40	2.5–12.5
c) Right midclavicular line	11	2.95	2.5–7.5
IV. *Back*			
1. At the level of T4:			
a) Left midscapular line	23	6.85	2.5–17.5
b) Vertebral line	10	13.5	2.5–22.5
c) Right midscapular line	23	7.9	2.5–17.5
2. At the level of T9:			
a) Left midscapular line	17	3.7	2.5–12.5
b) Vertebral line	10	9.5	2.5–27.5
c) Right midscapular line	17	3.4	2.5–12.5
V. *Palms*			
a) Left palm	7	2.5	
b) Right palm	7	2.5	

or a similar deviation was encountered more than twice in the same symmetrical areas. In the axillary vaults, consistently asymmetrical outpouring was observed in 5 of 27 healthy males, and in none of 5 healthy females, i.e. in 15.6% of all the subjects; in the midscapular region, 9 of 29 healthy males (31%) and 1 of 10 healthy females (10%) showed asymmetrical sweat delivery.



DISTRIBUTION OF THERMOGENIC SWEAT (MEAN AMOUNTS IN MGM/2CM² SURFACE)
IN 29 MALES AND 10 FEMALES

GRAPH 1



DISTRIBUTION OF THERMOGENIC SWEAT (MEAN AMOUNTS IN MGM/2CM^2 SURFACE)
IN 29 MALES AND 10 FEMALES

GRAPH II

C. Discussion of results in healthy subjects

The fact that at one and the same site and in one and the same subject rather constant amounts of thermogenic sweat were found in repeated examinations appears to indicate that the results obtained under our experimental conditions are reliable.

The validity of our findings was further apparent when comparative assays (1) of thermogenic sweat were performed with the recently introduced gravimetric method of M. E. Cohen[3] (4) and with our method. We obtained very similar values when both procedures were performed at the same time on symmetrical sites, as well as in examinations which were carried out in one and the same area on different occasions.

Whereas great care was taken to maintain uniform experimental conditions. it may—at first glance—appear somewhat paradoxic that the sweat-prints were not taken in every test subject after the same, standardized period of heating. However, uniform exposure to heat would have failed to disclose important findings in all those subjects who needed a longer exposure before test-prints were obtainable, as well as in those in whom a fast and profuse response would have prevented distinctive printing. Although the "pre-reading periods" (similarly to the "onset" and sweat quantities) were fairly constant in reapeated examinations of the same individual, the rare variations encountered in subjects of the same sex and in particular the great discrepancy between the "pre-reading periods" in the two sexes, called for individual determination of the proper timo for taking the prints.

The risk of obtaining erroneous results (i.e. of low sweat quantities simulated by "premature" printing, and of high quantities simulated by "belated" printing) was obviated by the fact that subjects with relatively short "pre-reading periods" usually show large amounts of thermogenic sweat and those with long "pre-reading periods" show small amounts.

The great differences in sweating observed between the male and female subjects conform with unpublished results we obtained in earlier investigations, with a Quinizarine indicator-powder in Carbowax (5). These investigations also revealed slower and weaker thermogenic sweating in females than in males. It is interesting that no difference in the quantity of thermogenic sweating was noticeable in the axillae or on the palms of the two sexes, i.e. in areas of predilection for emotional sweat response (6). To our knowledge, sex-differences in the quantity of "sensible" thermogenic sweating have not been reported by previous investigators,[4, 5] although S. Scaglione (7) observed decreased "insensible per-

[3] The only deviation from M. E. Cohen's original technique (devised for assays of palmar sweating) was an abbreviation of the contact of the blotting-paper with the skin, from 60 to 10 seconds.

[4] We do not here identify thermogenic sweating with the sweating induced by topically applied acetyl-choline; according to D. Kahn and St. Rothman (20) and Th. E. Gibson and W. B. Shelley (21), this drug induces a stronger sweat response in males than in females.

[5] We are greatly indebted to Dr. W. B. Shelley for calling our attention to the report of J. D. Hardy and collab. (22), that vaporization from skin and lungs in males exceeds that in

spiration" during pregnancy. Regarding the differences, it appears of interest that the metabolic production of heat (B.M.R.) per square meter of body surface in males physiologically exceeds that in females. Since one of the most important functions of thermogenic sweating is its regulatory influence on body temperature and one of its principal purposes is to prevent the accumulation of heat in the body, one might well expect males to show more thermogenic sweating than females.

Our observation that natural asymmetry in sweat delivery occurred on one or another area of the body surface in about 20% of the subjects examined, appears to deserve special attention. This asymmetry might be regarded as an already established fact, but as far as we know, it has neither been demonstrated quantitatively nor discussed by previous investigators. The possibility of such asymmetrical outpouring must be taken into account in evaluating studies of the influence of various medicaments on sweating, especially in studies of topically applied agents. Preliminary control investigations are necessary for the detection of pre-existing differences between symmetrically situated areas. For instance, such preliminary examinations are indispensable for studies of the local action of antiperspirants in the axillary vaults. In our experience, most of the test subjects with asymmetrical sweating spontaneously volunteer the information that they sweat preponderantly in one or the other armpit.

The relevant results of other investigators and our findings are in agreement in many respects. Thus, Y. Kuno (6) and J. S. Weiner (8) also found the smallest amounts of thermogenic sweat invariably on the palms (and soles). In addition, we can substantially confirm the results of these investigators indicating that the amount of sweat found in the temporal areas exceeds the quantities found in the other regions of the skin surface. As the head and neck were not enclosed in the heating apparatus in our experiments, these parts were not only distant from the source of radiation, but they were also subject to free evaporation. The amounts of sweat found in the temporal areas of *male* subjects were not significantly below those found in the mid-sternal area. It seems probable, therefore, that in our studies too, the greatest amount of sweat was in the male subjects actually present in the temporal areas rather than in the upper sternal area (despite the highest value recorded on the latter site, see table II). For similar reasons it appears safe to conclude that the amounts in the mid-forehead and on the cheeks were also higher than those recorded by our prints. The recorded values for the cheeks were about as low as the figures obtained on the palms. But since of these two areas only the latter were enclosed by the heating apparatus we employed, the actual quantity of thermogenic sweat on the cheeks presumably exceeded the amount on the palms. Our conclusion is further borne

females, and that in males the onset of sweating occurs at a lower environmental temperature. These investigators presented an explanation for their findings similar to our comment regarding the sex-difference in the quantity of "sensible" heat-sweat, inasmuch as they had shown a lower metabolic rate in females, necessitating less dissipation of heat through evaporation.

out by the relatively high values obtained on the cheeks by Kuno (6) and Weiner (8) in heated rooms. On the other hand, there was certainly less sweat present on the cheeks than on the temples. W. C. Randall's printing patterns (19) are consistent with our low readings in the zygomatic area.

In the *female* subjects, the regional distribution of thermogenic sweating differed from the pattern in males. Further evidence is required before it can be concluded definitely that in females the greatest quantity of thermogenic sweat is actually present in the axillae[6] and not in the temporal regions.

Though Y. Kuno (6) did not describe a distinctive regional sweat pattern for the trunk, his observation (by ocular inspection) of profuse sweating in "some larger areas" and "slight or moderate" sweating in the remaining areas could be explained by the results of our regional analysis. However, some of the other results described by Y. Kuno (6), differ from the findings obtained under our experimental conditions. Thus, for example, our results did not conform with Kuno's observations of a weak sweat-response of the axillae to heat stimulation; nor with his observations of a simultaneous "onset" of thermogenic sweating in all areas of the skin surface (except for palms and soles).

A regional pattern of thermogenic sweating which differs somewhat from the results obtained in our experiments was described by G. E. Burch and W. A. Sodeman (9) (10) who determined the water loss from the skin by passing a stream of dry oxygen over the test area through a closed system. There was, however, a considerable difference in the sites selected for testing by these authors and by us and most other investigators. The results of W. A. Sodeman and G. E. Burch (9) (10) differ from our observations also with regard to the fairly uniform amounts of sweat we found in a given area in repeated examinations of the same subject, while these authors obtained considerable fluctuations "from time to time."

In separate communications (11) (23), we called attention to the striking parallelism in the regional distribution of thermogenic sweat and of ether-soluble substances on the skin surface. The data submitted in these reports and the present study show that this parallelism exists in all areas with the exception of the axillae[7], and probably the mid-forehead (in relation to the amounts on the temporal areas) and the cheeks.

A further parallel in the delivery of thermogenic sweat and ether-soluble substances, is the relative constancy of the quantities of both these materials delivered to the surface of a given skin area in one and the same individual. In other words, the amounts of thermogenic sweat as well as of ether-soluble material ("casual" or "retained" levels (10)) determined by repeated examinations of any given area of the skin under standard conditions nay be regarded as characteristic of the individual under test.

A small number of our experiments resulted in findings comparable with the

[6] Apparently, the apocrine glands are considerably more numerous in females than in males. Thus, H. Homma found about twice as many in females (24).

[7] Assays of the amounts of ether-soluble material in the axillae were continued after our previous report (11) on the amounts of ether-soluble film; in 20 examinations, the level of ether-soluble material averaged 0.68 mg./10cm^2. (range: 0.35 to 0.95 mg./10cm^2.).

undisputed observation (12) (13) (14) (11) that the delivery of ether-soluble material to the skin surface is automatically inhibited once a certain level is reached: in the few experiments in which consecutive prints were taken during *continuous* exposure to heat, the "pre-reading periods" grew progressively longer after early periods of accelerated outpouring. We believe that this may be explained by a physiologic regulation automatically preventing excessive delivery of sweat, and thus perhaps analagous to the mechanism regulating the accumulation of ether-soluble substances. Comparable findings were also obtained by S. D. Gerking and S. Robinson (15a) (15b) who observed a drop in the average rate of thermogenic sweating from 1.3 kg. sweat per hour during the first two hours of a six-hour exposure, to 0.89 kg. per hour during the sixth hour. A somewhat similar observation was made by Y. Kuno (6) who noted that considerable (experimental) elevation of the environmental temperature causes increased sweating, "until the function of the sweat glands reaches about its maximum."

As suggested in our previous report on the assay of ether-soluble substances on the skin (11), the intimate correlation between the amounts of outpouring sweat and of ether-soluble material, may at least in part, be caused by the formation of "oil in water"—and "water in oil"—emulsions from the two categories of biologic products delivered to the skin surface. Studies of this correlation are being carried out in subjects with acne vulgaris; these findings will be reported in a separate communication (23).

II. SOME OBSERVATIONS OF PHARMACOLOGIC OR CLINICAL SIGNIFICANCE

Quantitative examination of thermogenic sweating by means of our relatively accurate and convenient procedure has been extended to further studies, dealing with various pharmacologic and clinical questions.

Thus, the method proved to be suitable for assays of the effects of different externally applied or systemically administered agents on thermogenic sweating: the results we obtained after the administration of ACTH or cortisone-acetate, for instance, have been described elsewhere (16) (17).

One of our clinical findings which might have appeared predictable was a distinct increase in the quantity of thermogenic outpouring in the skin areas surrounding certain grossly diseased or atrophic areas where the sweat delivery was absent or greatly reduced. Such "compensatory hyperhidrosis," i.e. sweat delivered in distinct and measurable excess of the amounts delivered to the surface of more distant, and grossly healthy parts of the skin of the same person, was observed in 7 patients with very different lesions causal of deficient outpouring (atrophic areas in consequence of Atabrine-dermatitis; discoid lupus erythematosus; acne indurata; psoriasis; atopic dermatitis; miliaria rubra). In an additional subject, who voluntarily took Atabrine (18), a strongly increased sweat delivery was noticed on the forehead during a period when outpouring on most other parts of the skin was very poor. The increased outpouring around certain skin lesions appears analagous to a "spontaneous" hyperhidrosis observed by Ake Nilzen[8]

[8] We are indebted to Dr. Ake Nilzen, Dermatol-University Clinic, (Karolinska Sjukhuset; Hud Klinik,) Stockholm, for permitting us to report these as yet unpublished findings.

which occurs in the immediate surroundings of experimentally produced cantharidin-blisters.

Another finding of clinical, as well as of physiologic interest was clearly demonstrated in two subjects who complained of excessive "cold" sweating in the palms during emotional tension. In these subjects, exposure to dry heat did not noticeably increase the considerable quantity of sweat already present on the surface of the palms prior to heating. Moreover, the thermogenic sweat-delivery in the other areas of the skin was within normal ranges. In contrast, the palms of three other patients, with generalized thermogenic hyperhidrosis as well as vesicular eruptions, recurring each summer all over the hands, showed an unusually high increase in sweat upon heating. As might again have been anticipated, the results of these assays lend renewed support to the concept that emotional and thermogenic sweating are separate functions, probably due to different mechanisms. In addition they support and to a degree elucidate the concept of dysidrotic eczematous eruptions of the hands.

SUMMARY

1. Quantitative assays of the delivery of thermogenic sweat were carried out on different sites of the skin in 30 healthy males and 10 healthy females. These studies employed a recently described method (1) for quantitatively measuring the outpouring sweat by means of prints on filter paper prepared with the Bromphenol-Blue indicator, which was introduced for the detection of sweat by the school of Werner Jadassohn (2). The time of exposure to heat (minutes) after which the first droplets were visible is here defined as the period to the "onset" of sweat delivery. Distinctive prints were obtained only at a somewhat later time. The period between the beginning of artificial heating and the earliest moment found suitable for taking prints of the sweat pattern is here designated as the "pre-reading period."

2. Our results suggest that the "onset" may occur sooner in males than in females; and demonstrated that the "pre-reading period" is on the average considerably shorter in males than in females. In the white and the few negro subjects tested, no significant difference was noted in either "onset" or "pre-reading period."

3. Although the "pre-reading period" was fairly constant in the same individual and in the same sex, persons who responded to heat stimulation with large amounts of sweat tended to show relatively short "pre-reading periods" and vice-versa.

4. The amounts of sweat delivered to a given site were relatively constant on repeated examinations in one and the same individual, but varied from one test subject to another.

5. Regional variations in the distribution of thermogenic sweat were observed (tables II and III). A characteristic pattern for this regional distribution was observed in all individuals tested. Except for the quantities in the axillae and on the palms, corresponding regional amounts of sweat in healthy females averaged below the values obtained in the males. Thus far, no quantitative difference was noted in the sweat delivery of white and negro test subjects.

6. Asymmetrical readings were regularly obtained in a considerable percentage (approx. 20%) of the individuals under test. The possibility of such differences on symmetrical sites requires careful consideration in studies of sweating in pathologic conditions as well as in various pharmacologic investigations, especially in those dealing with externally applied agents.

7. There was a striking parallelism in the amounts of sweat and of ether-soluble material (mainly sebum) delivered to the skin surface. The amounts of both materials encountered on a given site were relatively constant in the same individual; and the quantitative variation of both thermogenic sweat and ether-soluble material was similar.

8. Mention is made of some results of pharmacologic or clinical interest which can be conveniently obtained by the new method for the quantitative assay of secretory sweating.

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DISCUSSION

DR. DAVID KAHN, *Lansing, Michigan:* Dr. Herrmann's finding of greater thermogenic sweating in males than in females confirms the sex difference that Dr. Stephen Rothman and I observed in the local sweat response to intradermally injected acetylcholine (J. Invest. Dermat. **5:** 431 [Dec.] 1942).

Similar findings were subsequently reported by Gibson and Shelley (J. Invest. Dermat. **11:** 137 [Aug.] 1948).

Although the sex difference noted by Dr. Herrmann in his excellent report refers to sweating produced by heat, I think there is little doubt but that thermal sweating is mediated by the acetylcholine that is liberated.

F. HERRMANN (*Conclusion of Discussion*): We are sorry not to have mentioned the report of Kahn and Rothman (20), nor the subsequent report of Gibson and Shelley (21) indicating that males show stronger sweating at the site of acetylcholine application than do females. This omission was due to our opinion that thermogenic sweating is not necessarily identical with the sweating induced by the topical application of acetylcholine.