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YOUNG

Effect of Exercise and Humid Heat upon Pulse Rate, Blood Pressure, Body Temperature, and Blood Concentration.

By W. J. YOUNG, A. BREINL, J. J. HARRIS, and W. A. OSBORNE.

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(From the Australian Institute of Tropical Medicine, Townsville, Australia.)

The effect of exercise on the human body has been made the subject of much study at different times. Researches have been carried out under atmospheric conditions such as prevail in different parts of Northern Europe, and they have been extended in a few instances to the effects of high temperature and humidity upon the human body. In the latter observations the conditions such as high temperature and varying humidity were produced by artificial means only, and general deductions as to the influence of an actual tropical climate upon the human organism cannot be safely drawn from them. In these experiments the subjects were living in a temperate climate, were exposed to heat and humidity for a short time only, and left the hot chamber at the end of the experiment for an atmosphere of coolness and comfort; in the tropics, on the other hand, the inhabitants are continuously exposed to heat and humidity without respite. Conclusions of real value can thus be drawn only from observations actually carried out in a hot climate, and systematic work in this direction is still lacking.

Although observations have been made in the tropics on body temperature, blood pressure, pulse and respiration rate, and metabolism, yet their object has only been to obtain normal standards for the tropics for comparison with those of Europe.

The following experiments were carried out in Townsville during the hottest months of the year (January to March), during which time the wet-bulb temperature stands between 75° and 80° F., occasionally even above, and the dry-bulb temperature between 80° and 90° F.; the degree of saturation of the atmosphere is very high, and the climate "trying." The climatic conditions—rainfall and temperature—in Townsville correspond, according to Griffith Taylor (1918), to those in Calcutta, with the exception that the humidity is slightly lower.

Methods.

The observations recorded were made on the staff of the Institute (subjects I to VI and VIII), and extended over two wet seasons. During the early part of the second year one of the authors (W. A. O., subject VII),

during a visit to Townsville, joined in the research. The experiments were of three kinds. In a first series the effect of vigorous exercise of short duration was studied. The effort consisted in running up and down a staircase, about 15 feet high, as fast as possible; with few exceptions the feat was repeated 10 times, and the time taken varied from 118 to 150 seconds.

The second series comprised a number of experiments, in which the exercise consisted in walking for a varying period at a moderate pace (three to four miles an hour) during the hottest hours of the day. In one walking experiment on a very hot day (dry bulb 86.4° , wet bulb 81.0°), the observations were taken on three subjects (I, II, and III) at quarter-hourly intervals for two hours (the duration of the walk), and this experiment is treated separately, the observations being plotted in the accompanying chart.

In a third series of observations the effect of extremely high and humid

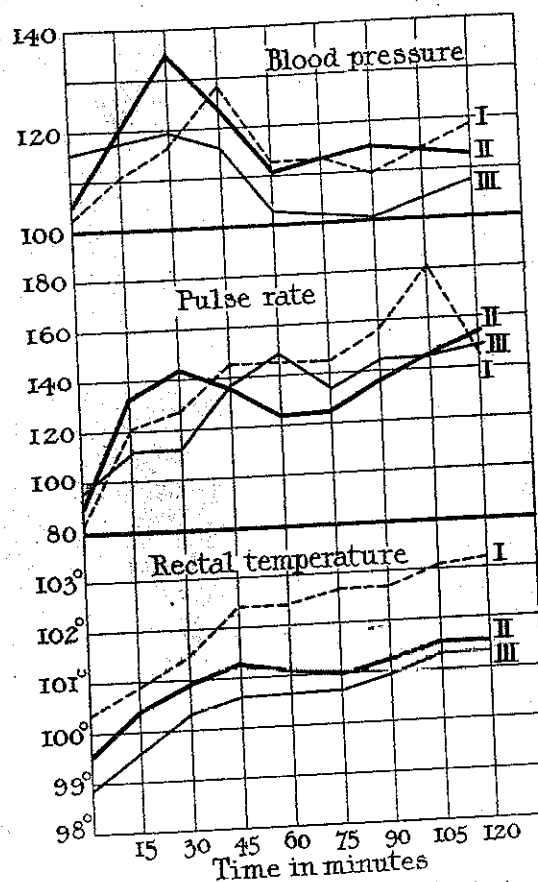


Chart of Walking Experiment. (See text.)

heat was investigated upon three subjects, with a view to comparing the physiological effects produced by external heat alone with that produced by exercise in a hot climate. A small chamber of galvanised iron was used as a hot room. The iron was exposed to the direct sun's rays, and additional moist heat was produced by boiling water within the chamber; on sunny days a wet bulb temperature of about 102° F. could be obtained. The results are tabulated separately in Table VII.

In all experiments observations were made upon the changes of pulse rate, blood pressure, body temperature, and carbon dioxide content of the alveolar air. The pulse was counted for several quarter-minute periods, and in general the pulse rate of the subject in a lying position was contrasted with that of the subject standing up.

The blood pressure was estimated by means of a Tyco's sphygmomanometer, which instrument had been checked against a mercury manometer. The body temperatures recorded denote invariably rectal temperatures. The alveolar air was sampled by the Haldane-Priestley method.

Pulse Rate.—The pulse rate (Table I) in the subject at rest was within the range considered normal for a temperate climate, varying between 68 and 98 per minute. The pulse rate determined in an upright and recumbent position showed now and again a considerable difference, being lower in several of the subjects when lying down; considerable individual variations in this respect were noted.

The increase caused by exercise corresponded roughly with the violence of the effort, and in those experiments in Table I where the subject raced up and down stairs, the rise accorded with the length of time taken in performing the task. The pulse rate began to fall again immediately the exercise was discontinued, rapidly at first and more slowly afterwards, and after five minutes or so the pulse rate was still above the rate at rest.

In the walking exercises, extending over a prolonged period, the pulse rate at the end of the experiment was, as a rule, high, and it took a much longer time to return to the original rate. In a few instances the pulse rate was determined after half the walk had been accomplished, and it was observed that during the second half of the exertion practically no further rise was produced. In the special walking experiment (see chart) the pulse of the subjects I and II showed a rapid and marked rise at first; afterwards the pulse rate continued to rise at a much slower rate, or exhibited only insignificant variations.

In the hot room experiments the pulse rate rose very slowly and gradually concomitantly with the body temperature.

Blood Pressure.—The results of the estimations of blood pressure are

Table I.

No. Subject.	Nature of exercise.	Pulse rate at rest.		Pulse rate after exercise.			Rate after mins. counted in 15 sec. period.
		Standing.	Lying.	Calculated from first 15 secs.	Counted during first min.	Counted in successive periods of 15 secs.	
I.	Running up and down stairs— 10 times in 155 secs.	80	—	128	124	32, 32, 28, 30, 30, 28, 27, 27	3 mins. 26; 18 mins. 23.
1	10	76	68	148	137	37, 34, 34, 32, 31, 31, 30, 28	5 " 25; 9 mins. 23.
2	10	72	72	136	126	34, 38, 30, 29, 29, 27, 27	5 " 25.
3	10	80	75	138	138	37, 35, 34, 32, 29, 28, 28	10 " 24.
4	10	74	72	148	138	37, 35, 32, 29, 29, 27, 25	6 " 25.
5	10	76	72	160	143	40, 37, 34, 32, 29, 27	5 " 24.
6	10	70	68	176	152	44, 40, 36, 32	5 " 21.
7	10	98	75	164	149	41, 37, 36, 35, 32	5 " 28; 8 mins. 25.
8	10	84	80	172	157	43, 40, 37, 37, 33, 32, 32, 30	5 " 26.
9	10	94	80	168	143	42, 37, 34, 30, 32, 30, 29	5 " 26.
10	10	98	80	164	151	41, 38, 37, 35, 32, 30	5 " 24.
11	10	84	69	144	141	36, 36, 35, 32, 29, 30, 28	5 " 24.
12	10	90	78	164	148	41, 38, 35, 34, 31, 30, 30	5 " 23.
13	10	80	76	164	153	41, 39, 37, 36, 37, 33, 33	4 " 29; 13 mins. 28.
14	7	78	72	172	158	48, 42, 37, 36, 35	5 " 26.
15	8	80	76	160	148	40, 36, 36, 36, 35, 34	5 " 30.
16	8	82	80	172	160	43, 41, 40, 36, 35, 35, 32, 30	5 " 26.
17	8	82	72	160	148	40, 36, 37, 35, 33, 32	5 " 25.
18	8	78	66	164	154	41, 40, 38, 35, 33, 32	5 " 27.
19	9	78	66	160	145	40, 37, 34, 34, 34	5 " 30.
20	10	72	72	140	125	35, 32, 30, 28, 26, 24	5 " 22.
21	10	70	70	140	128	35, 32, 31, 30, 29, 27	5 " 20.
22	10	74	64	148	128	37, 34, 32, 29, 28, 24	5 " 19.
23	10	96	82	120	113	30, 29, 27, 27, 26, 24	5 " 21.
24	10	84	70	152	127	38, 34, 29, 26, 22	5 " 24.
25	10	88	72	166	138	39, 36, 32, 31, 30, 30, 29, 28	5 " 25.
26	10	80	66	144	123	36, 31, 29, 27, 26	5 " 26.
27	10	68	60	152	131	36, 34, 30, 29, 27, 26, 25, 24	5 " 24.
28	10						
II.							
III.							
IV.							
V.							

recorded in Table II. The figures indicate that the blood pressure was raised to a greater extent by violent exercise of short duration than by a prolonged and less strenuous effort. In the former series of experiments the blood pressure began to fall immediately after the cessation of exercise, and returned within a comparatively short time (about ten minutes) to the original. In the case of prolonged exercise the blood pressure rose at first considerably, and afterwards continued to rise very gradually or even remained stationary. In some instances the initial rise was followed by a fall to the normal, or sometimes even to a sub-normal figure. The curves in the chart illustrate this fact clearly. This fall in pressure is probably due to the dilatation of the cutaneous blood vessels brought about by the high temperature of the skin.

Table II.

No.	Subject.	Nature of exercise.	Blood-pressure (mm.).		
			Before.	Immediately after exercise.	After n minutes.
1	I	Running up and down stairs—			
2		10 times in 129 secs.	109	152	5 mins. 139; 13 mins. 115.
3		10 " 123 "	105	162	5 " 126.
4		10 " 118 "	108	140	5 " 125.
5	II	10 " 152 "	112	172	8 " 122.
6		10 " 132 "	106	140	5 " 114.
7		10 " 118 "	110	145	5 " 123.
8	III	7 " 90 "	119	143	5 " 122.
		8 " 125 "	112	162	3 " 146; 5 mins. 130 8 mins. 108.
9		8 " 118 "	110	148	5 " 126.
10	IV	10 " 130 "	137	186	5 " 172; 8 mins. 140.
11		10 " 150 "	147	178	2 " 157; 5 mins. 142.
12		10 " 155 "	129	192	5 " 128.
13		10 " 142 "	132	162	5 " 130.
14	V	10 " 135 "	124	148	5 " 130.
15		10 " 180 "	122	170	5 " 135; 10 mins. 128.
16	VI	10 " 117 "	126	185	5 " 152.
17		10 " 110 "	141	176	5 " 132.
18	I	Walking 36 mins.	109	129	15 " 110; 45 mins. 109.
19		" 37 "	119	130	
		Second walk in 33 mins.	—	148	20 " 118.
20	II	Walking 30 mins.	113	137	
		Second walk in 32 mins.	—	130	5 " 112.
21	IV	Walking 34 mins.	139	153	
		Second walk in 36 mins.	—	130	
22	V	Walking 38 mins.	112	132	
		Second walk in 38 mins.	—	128	
23	I	Climbing hill (1000 feet)	109	134	
24	II	Descending same.	—	118	
		Ditto	110	135	
			—	123	
25	III	Ditto	112	102	
			—	102	

The observations upon the effect of humid heat alone upon the blood pressure were only carried out on two subjects, and gave inconsistent results. In some instances the blood pressure of one of the subjects rose, whereas it fell to a slight extent with the other. Hill and Flack (1909) on the other hand, observed a constant and considerable fall in the blood pressure after a stay of fifteen minutes in a hot bath of 100° to 112° F.

Body Temperature.—Previous observers have proved that the rectal temperature may rise to as much as 102° F. in perfectly healthy individuals as the result of moderate exercise in a temperate climate, and Hill and Flack have recorded even much higher temperatures in athletes. In one individual, for example, a temperature of 105° was recorded after a foot-race over a course of three miles, and these authors drew attention to the fact that the temperature rose with the duration of the effort.

In the present experiments exertion of short duration did not produce any rise of any consequence; 0.3°–0.8° F. was the usual elevation, and only on one occasion (subject VI) a rise of 2° was found.

Table III.

No.	Subject.	Nature of exercise.	Air temperature.		Rectal temperature.	
			Dry bulb.	Wet bulb.	Before exercise.	After exercise.
1	I	Walking 36 mins.....	86.6	72.2	99.6	100.9
2	I	" 37 "	87.3	76.0	99.4	101.3
3	I	2nd time in 33 mins.	—	—	—	102.0
4	II	Walking 30 mins.....	88.1	79.8	99.7	102.7
5	II	2nd time in 32 mins.	—	—	—	103.0
6	IV	Walking 34 mins.....	85.0	76.2	99.8	101.8
7	IV	2nd time in 36 mins.	—	—	—	102.0
8	V	Walking 38 mins.....	84.2	74.3	99.9	101.3
9	V	2nd time in 38 mins.	—	—	—	101.6
10	I	Walking 2½ hours	80.1	78.2	100.3	101.9
11	I	" 3¼ "	85.2	75.3	99.8	101.4
12	I	" 2 "	86.4	81.0	100.3	103.1
13	II	" 2½ "	80.1	78.2	99.8	101.2
14	II	" 3½ "	85.2	75.3	99.5	100.6
15	II	" 2 "	86.4	81.0	99.5	101.4
16	III	" 2 "	86.4	81.0	98.8	101.3
17	VII	" 2½ "	80.1	78.2	100.0	100.9
18	VII	" 3¼ "	85.2	75.3	99.6	101.0
19	I	Climbing hill (1000 feet).....	86.2	78.1	99.6	102.0
20	II	" " "	86.2	78.1	99.7	102.0
21	II	" " "	85.0	75.5	99.5	101.4
22	III	" " "	86.2	78.1	99.2	103.3

Prolonged and less vigorous exertion—such as walking or hill-climbing during the hot hours of the day—caused much higher rectal temperatures, and the increase was more marked during the first part of the exercise than

later. For example, in the experiments where the rectal temperatures were taken half-way through the walk, the rise during the first part amounted to 2° or 3° F., whereas it was only further increased by two or three-tenths of a degree after the repetition of the effort. The chart contains a graphic representation of the rectal temperatures during a two hours' walk on a hot day, and illustrates the above statement.

In the hot room a continued rise in rectal temperature was noted. This took place in the beginning slowly and gradually, but the rate increased with time and with increased temperature, thus confirming Haldane (1905), and Harvey Sutton's (1908) observations.

Alveolar air.—The percentage of carbon dioxide in the alveolar air has been estimated by a number of observers by the Haldane and Priestley method, and their results on individuals at rest have been found fairly constant. In Table IV are given the averages of 58 observations on seven subjects at rest, whereas Table V gives for comparison averages, maxima and minima, obtained by other workers in Europe. The figures obtained in Townsville are lower than those of the other authors, and this may be attributed to the influence of the higher temperatures of the atmosphere.

Table IV.—Alveolar Air during Rest.

Subject.	No. of observations.	Carbon dioxide percentage.		
		Average.	Maximum.	Minimum.
I.	8	4.58	4.96	4.03
II.	34	5.04	5.45	4.71
III.	4	4.76	5.0	4.60
IV.	3	5.33	5.86	5.01
V.	3	5.08	5.53	4.48
VI.	1	5.25	—	—
VIII.	5	4.77	4.95	4.50
Mean	58	4.99	—	—

Table V.

Observer.	No. of subjects.	Carbon dioxide in alveolar air.		
		Mean.	Maximum.	Minimum.
Haldane and Fitzgerald (1905)	27	5.59	6.34	4.72
Hill and Flack (1909)	17	5.32	6.35	4.05
Cook and Pembrey (1913)	10	5.57	6.11	4.87
Present observations	7	4.99	5.86	4.03

In this connection it has been noticed by Boycott and Haldane (1908) that outer temperatures influence the carbon dioxide in the alveolar air, and that there existed in fact a seasonal variation, higher percentages being found in cold and lower in warm weather. They do not believe, however, that these changes are caused by variations in the body temperature, but are solely due to the effect of contact of the face and hands with cold or warm air. Lower averages than the European figures were obtained by Chapman and Wardlaw (1916) working in Sydney, and Chapman has stated that he has never obtained a maximum higher than 6 per cent., which in his opinion is due to the higher average outer temperatures in Sydney.

Table VI contains the details of analyses of alveolar air after various forms of exercise. The percentage of carbon dioxide in general was greatly increased. After prolonged exercise the increase was much less marked than after vigorous exercise, and in experiments where an analysis was made halfway through the experiment the increase was more marked in the first than in the second half. In several experiments the analysis after exercise showed an actual decrease when compared with the figure at rest, which decrease may be attributed, as previously explained by Cook and Pembrey

Table VI.

No.	Subject.	Nature of exercise.	CO ₂ per cent. in alveolar air.	
			Before.	After.
1	I.	Short vigorous 121 secs.	4.56	7.16
2		" 125 "	4.39	7.28
3		" 127 "	4.86	6.98
4	II.	" 133 "	4.82	6.08
5		" 138 "	5.02	5.63
6		" 133 "	4.83	5.43
7	III.	" 105 "	4.62	5.38
8		" 120 "	4.60	5.40
9		" 141 "	4.82	6.15
10	IV.	" 151 "	5.12	7.12
11		" 149 "	5.01	6.96
12		" 148 "	4.48	8.32
13	V.	" 135 "	5.53	8.16
14		" 117 "	5.25	9.05
15	VI.	Walking 36 mins.	4.66	5.38
16		" 37 "	4.82	5.27
17		2nd time in 33 mins.	—	5.44
18	II.	Up and down hill 48 mins.	4.40	4.15
19		Walking 30 mins.	5.03	4.26
20		2nd time in 32 mins.	—	4.65
21	III.	Up and down hill 48 mins.	5.01	4.08
22		" "	5.0	3.50
23	IV.	Walking 34 mins. "	5.86	6.58
24		2nd time in 36 mins.	—	5.95
25		Walking 37 mins.	5.23	6.52
26	V.	2nd time in 38 mins.	—	6.62

(1913) to the washing out of carbon dioxide from the lungs by the vigorous ventilation.

In the hot room experiments the percentage of carbon dioxide did not show any constant variation, whereas Hill and Flack (1909) in their hot-bath experiment, observed a marked decrease in the carbon dioxide tension, owing to the increased rate of respiration due to the heat.

Loss in body weight.—The temporary loss in body weight brought about by exercise, and which is mainly due to loss of water, is naturally considerable in the tropics, on account of the increased perspiration. As shown in Table VII the loss bears relationship to the effort, time, and external heat. It was quite a common occurrence to lose as much as 1 kgm. in weight during a walk of one hour at a moderate pace, and in one instance as much as 3200 grm. (Experiment No. IV in Table) was lost during a two hours' walk. The loss of weight in the hot room amounted to between 500 and 1200 grm. in one hour. In several exercise experiments quoted in the Table, the subjects were weighed in their clothing so that the loss represents only the water evaporated and not the total water lost from the body.

The loss of weight represents in the main loss of water secreted as perspiration; a certain amount of water is lost in the expired air, but as the air inspired is not far from the saturation point this amount is small. The loss in weight due to respiratory exchange may be neglected.* In the hot room, where the humidity was very high, practically the total loss in weight is due to perspiration.

The question as to the source from which the perspiration is derived has been discussed by Hunt (1912), who estimated the percentage of hæmoglobin in the blood before and after prolonged sweating in a hot room. He found that the hæmoglobin figures remained constant, and concluded from this that no concentration of the blood had taken place and that therefore the water excreted in the sweat was derived from the tissues and not from the blood serum. A similar experiment was carried out by Haldane and Priestley (1916)

* In the course of another investigation by one of us (W. J. Y.) the respiratory exchange of two of the subjects was determined by means of a Zuntz portable meter, during a walk of 15 minutes at a rate of 3 miles per hour, and the figures obtained may be quoted here to show that only an insignificant portion of the weight lost is accounted for in this way.

In this experiment carbon dioxide was evolved at the rate of 107 and 119 grm. per hour by the two subjects respectively, and oxygen absorbed at the rate of 96 and 108 grm. per hour. The loss in weight due to respiratory exchange was therefore only 11 grm. per hour in each case.

In another experiment, one subject during an hour in the hot chamber lost about 7 grm. in weight due to the respiratory exchange.

Table VII.

No.	Subject.	Temperature of room.		Rectal temperature.		Pulse rate.				Blood-pressure.		Alveolar CO ₂ .		Duration of experiment.
		Dry bulb.	Wet bulb.	Before.	After.	Before lying.	Before standing.	After lying.	After standing.	Before.	After.	Before.	After.	
1	I	100.1 to 101.2	95.8 to 98.0	100.1	102.2	—	76	—	124	120	123	4.96	4.04	mins. 60*
2		100.1 „ 100.8	96.1 „ 97.3	100.3	102.7	84	88	89	123	109	100	4.03	4.05/4.23	70†
3		100.1 „ 107.0	98.7 „ 102.0	99.8	102.0	—	—	—	132	—	—	—	—	40‡
4		98.0 „ 95.0	88.5 „ 92.0	99.8	100.2	—	—	—	—	—	—	—	—	60
5		98.2 „ 97.1	91.2 „ 95.2	99.5	100.4	66	74	62	78	110	103	—	—	60
6	II	94.8 „ 100.3	98.2 „ 96.0	99.5	103.0	72	72	112	168	112	142	—	—	78§
7		102.1 „ 104.1	93.0 „ 96.2	99.5	100.8	—	88	—	116	—	—	—	—	45
8		100.3 „ 99.0	93.0 „ 96.7	99.2	101.4	—	86	—	132	—	—	—	—	60
9		101.4 „ 99.8	96.1 „ 98.8	99.8	102.8	—	98	—	130	103	118	—	—	60
10	VII	106.0 „ 108.0	92.0 „ 95.0	99.7	100.8	—	90	—	128	—	—	—	—	60

* Throbbing in head.

† S.G. of blood—before 1.0535, after 1.0567.

‡ Fainting.

§ S.G. of blood—before 1.0515, after 1.0552.

who failed to detect any alteration in the percentage of hæmoglobin in the blood after a net loss of 1.07 kgrm. in body weight.

Experiments were undertaken to ascertain whether the estimation of the specific gravity of the blood might yield further information on the source of the sweat. Observations on the specific gravity of the blood were carried out some time ago in this Institute by Hammerschlag's chloroform-benzene method and yielded figures well within the range of European estimations. The same method was employed to estimate the specific gravity of the blood before and after profuse sweating, in order to ascertain whether any concentration could be detected by this means. Although the estimations showed a very slight increase in the specific gravity of the blood after sweating in the hot room, the differences were within the range of experimental error, which is considerable. Unless a mixture of the same specific gravity as that of the blood were hit upon immediately it was difficult to obtain a constant behaviour of a drop of blood; moreover the size of the drop had an undoubted effect upon the result. For the above reasons this method was abandoned, and in the later experiments the total solids of the blood before and after the sweating and the refractive index of the blood serum were estimated.

For the total solids a few drops of blood oozing out freely from a deep puncture wound in the lobe of the ear were collected on a small piece of thick blotting paper, previously dried and tared. It was quickly weighed and dried to constancy at 110° C. The amount of blood collected weighed about 120 mgrm. to 130 mgrm., and the weighings were done by a specially constructed micrometer balance, designed and made by Messrs. Felton, Grimwade and Company of Melbourne, accurate to 1 mgrm., which enabled the paper to be weighed in a few seconds; the whole determination could thus be completed in 15 to 20 minutes. All estimations were done in duplicate.

The method was not found altogether reliable on account of the possible sources of error. If the blood did not flow freely from the puncture wound and pressure had to be resorted to, the estimations of the blood solids gave inconsistent results. In addition, there was always the possibility of a small amount of sweat being taken up simultaneously with the blood by the paper.

In spite of these possible errors, after a few preliminary experiments duplicate estimations gave fairly consistent results, and the calculated percentage of the total solids in the blood (about 20 per cent.) from two separate estimations did not differ by more than one.

The total solids in the blood showed a decided tendency towards increase after perspiring; out of 11 experiments, in six the increase was larger than

the experimental error, varying between 1.5 and 3.1. In three experiments there was an increase, but within the error limit, and an actual but small decrease was observed in two experiments. The increase in the blood solids in the different experiments was not proportionate to the loss in body weight. In the detailed Table a column is given indicating the loss of water from the blood, which would correspond to the increase in the solids actually observed. Considering the small actual difference in the weighings, these calculations are only very approximate, and only the one conclusion is justified—that there is a tendency to increased blood solids brought about by copious sweating.

The refractive index of the serum was measured before and after copious perspiration. The blood was collected from the ear by means of a Wright's tube, allowed to clot and centrifugalised, and the serum examined by means of a Zeiss-Abbé refractometer. In a few instances serum of blood obtained from the ear and from the finger were compared and yielded identical results. In every case the refractive index of the serum was higher after profuse sweating, whether brought about by exercise or merely by exposure to excessive moist heat as shown in Table VII.

In the Table a column of figures is given which represents the percentage of water lost from the blood, calculated from the increase in the refractive index. The figures were arrived at in the following manner: A series of weighed quantities of goat's blood was allowed to evaporate slowly in a desiccator over sulphuric acid, and the increase in the refractive index of the serum was then plotted against the corresponding loss of water from the blood, and a curve smoothed through the points. From this curve the percentage of loss of water from the blood corresponding to the increase in the refractive index of the serum could be obtained.

On comparing the total loss in body weight with the calculated loss of water from the blood, based on the refractive index of the serum, it is clear that the greater part of the sweat must be derived from other sources than the blood, although the experiments show that at least part of the fluid lost is derived from the blood plasma.

It will be observed also from the Table that the quantity of water lost from the blood, as calculated from the refractive index, and that estimated from the increase in the total solids of the blood, do not agree, but, as pointed out previously, the errors in estimating the total solids were too great to consider this method more than a qualitative one.

The estimation of the refractive index gave such constant results that one must conclude that a definite concentration of the blood does take place as the result of copious sweating. The percentages, however, seem rather high.

Table VIII.

No.	Subject.	Nature of experiment.	Air temperature.		Body weight.	Loss.	Refractive index of serum.				Blood solids.			
			D.B.	W.B.			Before.	After.	Increase.	Water loss.	Before.	After.	Change.	Water loss.
1	I.	Walking 36 mins.	86.6	72.2	69	gram.								
2	I.	" 37 "	87.3	76.0	68.8	750								
3	I.	2nd time in 33 mins.	86.2	78.1	69	610								
4	I.	Climbing hill, 1000 feet	86.4	81.0	68	550								
5	I.	Walking 2 hours	88.1	79.8	48	950								
6	I.	" 30 mins.	86.2	78.1	47.6	3200								
7	I.	2nd time in 32 mins.	86.2	78.1	47.6	300								
8	I.	Climbing hill	86.4	81.0	44.8	440								
9	I.	Walking 2 hours	86.4	81.0	44.8	560								
10	I.	Walking 34 mins.	85.0	76.2	61.25	1500								
11	I.	2nd time 36 "	84.2	74.3	59.95	1030								
12	I.	Walking 38 "	100.6	96.9	67.25	2500								
13	I.	2nd time in 36 mins.	100.3	96.8	67	400								
14	I.	Hot chamber 50 mins.	100.3	97.7	45.4	1540								
15	I.	" 80 "	99.6	93.5	45	2000								
16	I.	" 80 "	80.1	78.2	67	650								
17	I.	Walking 2 1/2 hours	85.2	75.3	67	500								
18	I.	" 3 1/2 "	85.0	75.5	45	1530								
19	I.	Climbing hill	80.1	78.2	45	2783	1.3477	1.3481	0.0004	4.2	20.2	21.0	+0.8	3.8
20	I.	Walking 2 1/2 hours	85.2	75.3	45	700	1.3469	1.3485	0.0016	8.8	22.2	22.2	+3.0	13.5
21	I.	" 3 1/2 "	85.0	75.5	45	693	1.3470	1.3479	0.0009	6.9	22.2	20.7	-1.5	
22	I.	Climbing hill	80.1	78.2	45	1265	1.3468	1.3478	0.0010	7.2	20.3	19.4	-0.9	10.8
23	I.	Walking 2 1/2 hours	85.2	75.3	45	1502	1.3474	1.3482	0.0008	4.2	18.1	20.3	+2.2	
24	I.	" 3 1/2 "	85.0	75.5	45	1265	1.3476	1.3480	0.0004	4.2	20.4	21.9	+1.5	6.9
25	I.	Climbing hill	80.1	78.2	45	1440	1.3467	1.3475	0.0008	6.7	20.3	21.3	+1.0	4.7
26	I.	Walking 2 1/2 hours	85.2	75.3	45	2780	1.3460	1.3480	0.0020	9.5	20.3	21.4	+2.4	11.2
27	I.	" 3 1/2 "	85.0	75.5	45	1220	1.3473	1.3482	0.0009	6.9	19.0	20.2	+1.0	5.0
28	I.	Hot chamber 35 mins.	107.0	100.3	67	595	1.3475	1.3480	0.0005	5.0	19.2	20.6	+2.1	10.2
29	I.	" 60 "	102.9	94.6	45	506	1.3462	1.3470	0.0008	6.7	18.5	20.6	+3.1	14.8
30	I.	" 45 "	101.0	93.5	89	970	1.3469	1.3481	0.0012	7.8	17.5	20.6	+3.1	14.8
31	I.	" 60 "	101.0	93.5	89	970	1.3469	1.3481	0.0012	7.8	17.5	20.6	+3.1	14.8

and in all probability the calculated percentages can only be regarded as rough approximations.

These results thus differ from those of Hunt, who was unable to detect any loss of water from the blood by means of hæmoglobin estimation, but bear out his contention that the bulk of water in the sweat is derived from the tissues. As an additional source of water, the intestinal canal must be kept in mind.

Summary.

1. Vigorous exercise of short duration caused—
 - (a) An increase in the pulse rate and blood pressure, both of which rapidly fell to normal after discontinuation of the exercise.
 - (b) An increase in the carbon dioxide percentage of the alveolar air.
2. The alveolar air at rest in inhabitants of tropical Queensland showed a lower carbon dioxide content than the European average.
3. Prolonged exercise led to a rapid increase in the pulse rate and temperature at first, which increase became more gradual afterwards, and in the case of blood pressure even fell on occasions below normal, on account of the profuse sweating. Prolonged exercise had but little effect on the alveolar air.
- The body temperature during the exercise continued to rise slowly, but, considering the light nature of the exercise, the rise in temperature was considerable.
4. A considerable loss of water from the body was observed as the result of prolonged exercise. Blood estimations showed that this water was mainly derived from other sources in the organism than the blood plasma; a small concentration of the blood plasma, however, had taken place.
5. The hot room experiments gave results similar to those caused by prolonged exercise, with this difference, that the pulse rate and body temperature rose more gradually at first, but a quicker rise took place afterwards.
6. The results point to the fact that both exercise and humid heat play a part in producing a rise in blood pressure, pulse rate, and rectal temperature. The degree of rise, however, is controlled by atmospheric conditions which influence the rate of cooling of the body.

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CROONIAN LECTURE.—*The Biological Significance of Anaphylaxis.*

By H. H. DALE, C.B.E., M.D., F.R.S.

(Lecture delivered May 29, 1919.—MS. received October 21, 1919.)

MR. PRESIDENT, LADIES, AND GENTLEMEN,—I am deeply sensible of the honour conferred upon me by the invitation to deliver the Croonian Lecture before this Society. In conveying that invitation the Council did me the further service of indicating a desire that the lecture should deal with "The Biological Significance of Anaphylaxis." From the wording of the title thus suggested, and from their choice to deal with this subject of one whose own activities have lain outside the conventional limits of immunological study, I gather that the Council's intention was that the lecture should deal with the interest of the phenomena of anaphylaxis for a wider field of biological enquiry than that to which their investigation primarily belongs.

You will not expect or desire that I shall attempt a detailed review of the enormous literature which has grown up, with almost unique luxuriance, round the study of anaphylaxis. I shall deal with the history of the investigation in summary fashion, mentioning few of the participants by name, and giving only such broad outlines as will serve to make clear the nature of the problem to any who may be imperfectly familiar with it. In presenting some of my own experiments in somewhat fuller detail, I am guided by what I believe to be the Council's desire, that I should put before you a personal and individual view, rather than embark on the hopeless endeavour to compress