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HEAT-STROKE.

FURTHER OBSERVATIONS ON AN ANALYSIS OF FIFTY CASES.

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AN analysis of the reports of fifty cases of heat-stroke among British troops in India was given in a recent number of this Journal.[1] It was a preliminary paper and the discussion dealt chiefly with the influence of: (1) Exposure to a high and moist atmosphere; (2) muscular work, and (3) conditions which increase the effects, such as unsuitable clothes, heavy loads, and debility due to alcohol or other causes. It was stated that the direct action of the sun's rays, sweating, treatment, the after-effects, the loss of efficiency and the causes of death would be considered in a subsequent paper. In the present article an attempt is made to fulfil that promise.

Action of the Sun's Rays.—There has been, and is still, a widely prevalent view that serious disorder or death may be produced by the direct action of the sun's rays. This view is the basis for the distinction, which is generally made, between "sun-stroke" and "heat-stroke"; thus in the "Nomenclature of Diseases," issued by the Royal College of Physicians of London, in 1906, will be found the following classification: Heat-stroke, coup de chaleur, Hitzschlag; sun-stroke, coup de soleil, Sonnenstich. The term

[1] August, 1913.

"heat apoplexy" is no longer included in the list. In the "Manual of the International List of Causes of Death," 1912, the following are grouped together: Coup de soleil, heat apoplexy, heat exhaustion, heat prostration, heat-stroke, insolation, solis ictus, sun-stroke, thermic fever, thermoplegia.

The divergence of opinion in the Service may be indicated by the following quotations from recent issues of this Journal. Major Leonard Rogers, I.M.S. [1], says "there are two different conditions produced by exposure to the sun or excessive heat: firstly, syncopal attacks, usually induced by the action of the direct rays of the sun, often aided by excessive exertion, such as when troops march on a hot day; and secondly, hyperpyrexia, following prolonged high atmospherical temperature, with or without exercise, and usually without actual exposure to the sun, such as attacks stokers in ships in hot climates. Intermediate conditions combining some degree of both the above states also occur. As a rule, the syncopal form, or sun-stroke proper, is rapidly recovered from under suitable treatment; but true heat-stroke, with hyperpyrexia and loss of consciousness is a much more serious, and often fatal, condition of common occurrence in certain tropical climates." On the other hand, Colonel R. J. S. Simpson [2] has pointed out that "in practice, at least in the Service, it appears to be the custom to apply the term sun-stroke to the pathological state arising within a comparatively short time after actual exposure to the sun, and the term heat-stroke when this antecedent is absent. . . But there is so much confusion in the nomenclature of these pathological states that a comparison of the relative proportions of each type of disease in each of the various groups does not appear to be profitable." A more forcible expression of opinion is that of Major W. H. Ogilvie, I.M.S. [3], "If the victim was bowled over in the sun, the case is sun-stroke, if he was in the shade it is heat-stroke, the symptoms being identical in both cases."

These quotations are sufficient to show the unsatisfactory condition of a question which has been complicated still further by the view of Sambon [4] and Manson [5] that heat-stroke is an infective disease. The question must be settled by observation and experiment. There is no doubt that the sun's rays have a direct action upon the body, but sunburn and other inflammatory conditions of the skin are of an order different from sun-stroke. The actinic power of the sun is greatest at high altitudes, or in dry localities in the Tropics, whereas sun-stroke is most prevalent in atmospheres which are both hot and moist. The pigmentation of the skin

protects the body against the injurious action of certain rays of the sun. A negro can withstand exposure to intense sunlight which would be intolerable to a white man unprovided with clothing. This is not a simple question of exposure to heat, for it has been found that as stokers on board ship coloured men are not superior to the white man in resisting the combined effects of heat and moisture. Comparative experiments made by Eijkmann [6] upon the skins of Europeans and of Malays living in the Tropics, show no difference in the radiation of heat, but a greater absorption of heat in the case of the brown skin of the Malays. These results receive confirmation from the observations of Aron [7], who points out that the greater absorption of heat by the pigmented skin appears to evoke an earlier activity of the sweat glands. There is little doubt that the pigment gives protection against the ultra-violet rays, but not against the heat rays. Pieces of frog's skin placed over sensitive photographic plates demonstrate that the pigmented tissue is very effective in absorbing the chemically active rays of light.

The question of clothing in the Tropics has attracted considerable attention, and orange-red material has been used to exclude the actinic rays of the sun. Comparative tests [8] have been made with orange-red and white clothes by the United States Army in the Philippines. One group of 500 soldiers wore the special underclothing and a similar number were supplied with white underclothing for the purpose of control. The orange-red clothing was heavier than the white and increased the discomfort produced by heat. The conclusions drawn from the experiments were that the effects of the climate in the Philippines can be, and probably are, produced by moist heat, and even if the actinic rays of the sun had any influence they were sufficiently excluded by the khaki uniform and the campaign hat.

For several years the therapeutical use of different rays of light has been extensive, but no case showing symptoms resembling those of sun-stroke has been recorded.

Aron has shown by interesting experiments upon animals and by observations on men, both white and coloured, that exposure to the direct rays of the sun will raise the temperature of the skin above the internal temperature of the body. Monkeys indigenous to the Tropics can be killed by exposure to the sun and death appears to be due solely to the abnormal rise in the temperature of their bodies, for if a sufficient ventilation is maintained over the body the animal shows no bad effects even if its head be exposed for hours to the full force of the sun's rays.

A critical examination of the evidence indicates that the actinic rays of the sun are only an indirect factor in the causation of heat-stroke. The white man is forced to protect his skin from the action of the sun's rays by clothing, and thus, as regards the loss of heat from his body, places himself at a disadvantage; he sweats extravagantly, for much of the moisture is absorbed by his clothing and is not directly used for cooling the body by evaporation. The coloured man sweats economically owing to his scanty clothing; he can be placed at a disadvantage by unsuitable uniform, and it is well known that native troops in India are liable to heat-stroke when they are wearing uniform and marching in close order on a hot day.

The effect of the glare of the intense sunlight upon the eyes may be a contributory factor, for in many people intense head-ache is produced thereby. In this respect subjects with blue eyes appear to suffer more than those with dark eyes.

Sweating.—For many years it has been known that a man can maintain his normal temperature when he is living in a dry atmosphere, the temperature of which is above that of his body. Under such conditions he does not lose, but gains heat by radiation and conduction. His temperature does not rise; it follows, therefore, that he must possess some efficient means of cooling his body, for in addition to the heat gained from the air he must, as long as he lives, produce heat by the essential processes of combustion within his tissues. A man receiving an adequate diet and doing moderate work produces about 3,500 calories in twenty-four hours: in order to neutralize this heat by evaporation alone he would require to drink about 6 litres (1¼ gallon) of water to replace the water lost from his body.

On these points Hunt [9] made observations in the Deccan, where during the hot weather the daily maximum temperature of the air is about 100° F. (38° C.) and in some parts is as high as 110° F. (43° C.) for long periods. The temperature indicated by the wet bulb thermometer was generally between 65° and 70° F. (18° to 21° C.), showing a very low percentage of moisture. No great discomfort was felt by healthy Europeans, and fairly hard muscular work was possible in the open air, even when the temperature in the shade was 110° F. (43° C.). The average amount of liquid taken daily by each of three men who were observed while living an active outdoor life during very hot weather was 13½ litres (3 gallons) or more. In such extremes of dry heat the cooling produced by the evaporation of sweat is the safeguard against heat-

stroke and it is interesting to note that Hunt did not see, during his duties as medical officer, any case of pure heat-stroke or sun-stroke.

As an example of the importance of sweating may be given the following data taken from the reports [10] of the experiments performed at Aldershot. Four men during a march of seven miles in drill order lost by sweating an average of over 3 pints (1,816 grm.) of water, the maximum loss being over 4 pints (2,390 grm.) and the minimum over 2 pints (1,200 grm.). It was a hot day in September when the temperature of the air by the dry and wet bulb thermometers was 79° F. (26·1° C.) and 67·5° F. (19·7° C.) respectively, and there was at times a south-west breeze. In the same series of experiments the influence of load, clothing, and training, as well as the effects of different conditions of external temperature, moisture, and wind, were determined. Further reference to these subjects will be made when the question of the prevention of heat-stroke is considered.

The healthy body maintains its percentage of water at a constant level, and any excessive loss by sweating must be compensated sooner or later by drinking. According to Hunt's observations the percentage of water in the blood is not appreciably diminished, even when several litres of water have been lost by sweating. The reserve of water in the body appears to be stored in the muscles and skin and is only slowly replenished by drinking. It is unwise, therefore, to restrict drinking; a normal thirst is the call for water to maintain the reserves in the tissues.

It has been noted over and over again that in cases of heat-stroke the skin is dry, whereas in cases of heat-exhaustion the skin may be covered with sweat. The regulation of sweating, which is an active secretory process, appears to be controlled by the nervous system and the temperature and chemical composition of the blood. The secretory system may be paralyzed and in such cases increased vascularity and temperature of the skin are not accompanied by sweating. In some fevers this condition appears to be due to the action of the toxic products of pathogenic micro-organisms, and it is possible that some unusual product of metabolism acts in this way in heat-stroke.

Treatment.—There is general agreement that the most successful treatment of heat-stroke is the application of cold by means of baths, douches or sponging with cold or iced water, by the wet pack, and iced enemata. The credit of the introduction of these methods appears to be due almost entirely to the Medical Service of the Army.

In all but four of the fifty cases now under review this treatment was employed; of the exceptions two were found dead, another was a cardiac case with definite post-mortem evidence of endocarditis, and another died a few minutes after admission to the hospital. In many cases a dose of calomel was given on admission. It is interesting to note in confirmation of previous results that diaphoretics failed.

The iced enemata, originally suggested by Parkes, appear to be especially useful in those severe cases in which the circulation of the blood through the skin is so defective that the blood cooled at the surface is not exchanged rapidly enough for the heated blood of the internal organs. The application of ice to the head and neck seems to give prompt results owing probably to the fact that the high temperature especially affects the brain.

The success of the treatment by cold is strong evidence in favour of the view that heat-stroke is due to a disordered regulation of temperature produced by heat; the failure of antipyretic drugs can be considered as evidence against the bacterial theory of Sambon.

The After-effects.—The records of the fifty cases relate to the period spent in hospital; for this reason they are too short to serve as a correct guide to the after-effects of heat-stroke. In the reports of thirty-eight out of the forty patients who survived it is stated that there were no after-effects: in one an absence of sweating is noted, and one man showed such marked wasting of muscles with double ankle drop that he was invalided.

The widely prevalent idea that the nervous system is more unstable after heat-stroke would appear to be supported by what is known of the effects of a high bodily temperature upon the nerve-cells.

Loss of Efficiency.—The records of these fifty cases give an estimate of the loss of efficiency from heat-stroke, but it is an underestimate. There were ten deaths, and it is of interest to note the age, service, and rank of the men.

It will be noted that the fatal cases are not among the young men of short service in India. From the physiological point of view this might be expected, for there appears to be no reason why a young healthy man should not accommodate himself to the effects of heat as readily as, or even more readily than, older men.

The minimum value for the days lost by the forty men who recovered is 605, giving an average of fifteen days for each man;

the shortest time was two days, the longest with recovery thirty-nine, the longest before invaliding ninety-three days. In as many as twenty-seven cases it is mentioned that the men were sent to the Hills after discharge from the hospital and this excellent precaution at first sight suggests an additional loss of efficiency.

Rank	Age	Service	
		Total	In India
Drummer	35 years	Not given	$3\frac{5}{12}$ years and $3\frac{4}{12}$ in South Africa
Bombardier	28 ,,	9 years	Not given
Saddler	32 ,,	7 ,,	4 years
Sergeant	30 ,,	$12\frac{1}{2}$,,	$10\frac{1}{2}$,,
Private	21 ,,	Not given	$2\frac{1}{12}$,,
Private	25 ,,	,,	$4\frac{9}{12}$,,
Lance-Corporal	28 ,,	9 years	$5\frac{10}{12}$,,
Corporal	27 ,,	13 ,,	$2\frac{1}{2}$,,
Private	41 ,,	14 ,,	$2\frac{7}{12}$,,
Private	32 ,,	13 ,,	Not given

The present fifty cases were reported in the British Army in India between June 24, 1909, and August 22, 1910. The table on pp. 636 and 637, prepared by the War Office at the suggestion of Sir Alfred Keogh, shows the returns for the ten years 1902-1911 and gives more extended data for an estimation of the serious loss from heat-stroke.

Causes of Death.—The ordinary methods of a post-mortem examination do not show any characteristic condition in the bodies of those who have died from heat-stroke, and owing to the rapidity of decomposition in the tissues a microscopic examination is beset with sources of error. Some observers [11] have found marked changes in Nissl's granules and in the nuclei of the nerve cells of the central nervous system. Halliburton and Mott [12] showed by experiments that the globulin of these cells will coagulate at 42° C. if that temperature be maintained for some time.

Death appears to be due to the effect of the high temperature upon the nervous system and the heart. The proteins of the nerve cells may be coagulated and a partial coagulation of the proteins of the respiratory and cardiac muscles may assist in the production of failure of respiration and of the heart.

If exact knowledge is to be obtained an examination directly after death is necessary. Further experiments upon animals will be needed if progress in the knowledge of the condition is to be more rapid.

Prevention.—If heat-stroke is a disordered regulation of temperature, due to exposure to a high temperature, the methods of prevention are clearly those directed to diminish the production and increase the loss of heat. Muscular work increases the production of heat and the activity of the heart; the greater the load the greater the effect. Unsuitable clothing by preventing the cooling effect of sweating diminishes the loss of heat. A man can work hard on a hot day if the air be not too moist, but he must cool his body by sweating freely and must drink copiously in order to maintain the reserves of water in his tissues. Progressive training results in the economical performance of work

	1902						1903						1904						1905					
	Heat-stroke		Sun-stroke		Heat apo-plexy*		Heat-stroke		Sun-stroke		Heat apo-plexy		Heat-stroke		Sun-stroke		Heat apo-plexy		Heat-stroke		Sun-stroke		Heat apo-plexy	
	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths
United Kingdom	7	—	7	—	—	—	—	—	4	—	2	—	4	—	17	—	2	—	9	—	8	1	1	—
India	107	22	24	2	40	22	193	20	52	9	58	24	109	19	169	1	87	14	304	29	99	3	66	23
Colonies	13	3	45	2	4	1	24	2	40	1	17	5	28	3	41	1	—	—	18	3	11	—	1	1
Total whole Army	127	25	76	4	44	23	217	22	96	10	77	29	141	22	227	2	89	14	331	32	118	4	68	24
Total admissions	247						390						407						517					
Total deaths ..	52						61						38						60					

* The classification under "Heat apoplexy" was dropped after 1906.

even under adverse external conditions which are beyond the control of man. The countermanding of marches on a hot day is not the height of efficiency, for in warfare it may be imperative to perform a forced march on a hot day. Efficiency is found in the recognition of dangers and the capacity to escape or mitigate them by intelligent precautions. The guidance afforded by the wet bulb thermometer is more important than that of the dry bulb. Further attention might be drawn to its indications, which would serve as a warning for special precautions by night as well as by day. There is no doubt that a hot, moist, and stagnant atmosphere is especially distressing at night; it would seem that the nervous control of the temperature of the body is less perfect during

sleep, especially in those who are unwell or under the influence of alcohol.

These are old-fashioned truths, which have always received recognition in the Medical Service of the Army. In discussing the question of the prevention of heat-stroke, Sir James Ranald Martin [13] wrote: "Parades, formalities, the majestic English march, 'Regulations,' and appearances, must here be utterly and at once discarded, for it is a question of life and death. The open, disorderly looking order of march, however slovenly it may seem to the lieutenant-colonel, must here be used, the close order being nothing short of stifling and sickening the men 'by Regulation.'

1906						1907				1908				1909				1910				1911			
Heat-stroke		Sun-stroke		Heat apo-plexy		Heat-stroke		Sun-stroke		Heat-stroke		Sun-stroke		Heat-stroke		Sun-stroke		Heat-stroke		Sun-stroke		Heat-stroke		Sun-stroke	
Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths	Admissions	Deaths
33	2	15	—	—	—	5	—	8	—	26	—	17	1	6	—	2	—	5	—	7	—	45	—	7	1
186	32	143	—	22	7	111	13	51	—	157	36	46	1	75	15	30	—	78	7	15	—	200	23	54	1
67	2	9	—	1	—	73	1	5	2	34	2	2	—	55	2	6	—	39	—	1	—	15	—	7	1
286	36	167	—	23	7	189	14	64	2	217	38	65	2	136	17	38	—	122	7	23	—	260	23	68	3
476						253				282				174				145				328			
43						16				40				17				7				26			

The genius of pipeclay must here concede something." Close order means a hot moisture-laden atmosphere, and an uneconomical expenditure of muscular and nervous energy in maintaining rank.

Unfavourable comment appears to be justified in only three of the cases now under discussion. Three soldiers, convalescents for the Hills, were marched at 1.15 p.m. in full marching kit (without overcoat) from the barracks to the railway station, a distance of about a mile and a half. The temperature of the air was 109° F. (42·8° C.) by the dry bulb, and 85° F. (29·4° C.) by the wet bulb thermometer. After arrival at the railway station these men collapsed with heat-stroke. Men who are slightly unwell are liable to heat-stroke. In twenty of the cases the reports show that

the men had been in this condition before the attack. Alcohol appears without doubt to be a factor, and this opinion of the older writers is confirmed by the present reports.

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[6] Eijkmann. *Arch. f. Path. Anat. u. Physiol.*, 1895, cxl, 125.
[7] Aron. *Berlin. klin. Wochenschr.*, 1911, 48 (i), 1115.
[8] *See* Abstract in Journal of the Royal Army Medical Corps, 1911, xvi, 109.
[9] Hunt. *Journ. Hyg.*, 1913, xii, 479.
[10] "Committee on Physiological Effects of Food, Training and Clothing of the Soldier," Second and Fourth Reports, 1908, Journal of the Royal Army Medical Corps, 1909, xii. 211, and 1909, xiii, 592.
[11] Marinesco. *Revue Neurologique*, 1899; Scagliosi, *Arch. f. Path. Anat. u. Physiol. u. klin. Med.*, 1901, clxv, 15; Amato, *ibid.*, 1909, cxcv, 544.
[12] Halliburton and Mott. *Arch. of Neurology*, 1903, ii.
[13] Martin. "The Influence of Tropical Climates in producing the Acute Endemic Diseases of Europeans," 2nd edition, 1861, p. 409.

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Further Observations on an Analysis of Fifty Cases

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Notes