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PREVENTION OF HEAT CASUALTIES AT MARINE CORPS TRAINING CENTERS

by
C. P. Yaglou and CDR David Minard, MC, USN

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TITLE: PREVENTION OF HEAT CASUALTIES AT MARINE CORPS TRAINING CENTERS

by

Constantin P. Yaglou and CDR. David Minard, MC, USN

Principal Assistants: Paul J. Stonestreet, HMC, USN
Kenneth C. Fennell, HA, USNR
Ann Messer, Biochemist and Analyst

Contractor: President and Fellows of Harvard College

From
The Harvard School of Public Health, Boston, Massachusetts and the Naval Medical Research Institute, Bethesda, Maryland

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PREVENTION OF HEAT CASUALTIES
AT
MARINE CORPS TRAINING CENTERS

OBJECT

To study the conditions under which heat injury occurs in basic and advanced trainees, and to develop safe limits for physical exertion in the heat in order to reduce casualties in hot weather.

SUMMARY

1. The effective temperature on training days between the hours of 1000 to 1600, averaged 80.8°F at Marine Corps Schools, Quantico, Va., 84.3° at Camp Lejeune, N.C., and 85.4° at Marine Corps Recruit Depot, Parris Island, S.C. in the summer of 1954. The climatic heat load on trainees engaged in marching exercises increased at the rate of 21 $Cal/hr/m^2$ per degree rise of effective temperature (ETR) at the threshold tolerance level of 85° ETR.

2. Heat stress on trainees at Quantico was found to be due not so much to strenuous exercises, which generally were of short duration, as to exercises of moderate intensity but of too long duration for warm weather. A good physiological criterion of total heat stress (metabolic plus climatic) was the evaporative sweat loss which correlated well with ETR and with the "wet bulb-globe temperature" index.

3. Heat exhaustion was by far the most common disabling illness encountered at the three Marine Corps Bases. Moderately severe cases occurred in significant numbers at the following ETR's:

- 84° in junior PLC's on six-week basic training at Quantico, Va., 1954
- 85° in new reservists on two-week training duty at Camp Lejeune, N.C., 1954
- 86° in advanced trainees at Quantico, Va., 1954
- 87° in recruit graduates on four-week training duty at Camp Lejeune, 1954
- 87° in recruits on twelve weeks basic training at Parris Island, S.C., 1952 and 1953
- 88° ibid, 1954, with a vigorously enforced preventive program.

4. The progressive increase of heat tolerance from Quantico to Parris Island is ascribed largely to adaptation to a climate becoming progressively warmer. For the same reason, the incidence of heat exhaustion in recruits coming from northern states was three times greater than in those coming from southern states.

5. Incidence rates for heat exhaustion per training day at 88° ETR averaged as follows:

- 126/10000 in new reservists on two-week training duty at Camp Lejeune, 1954
- 60/10000 in junior PLC's on six-week basic training at Quantico, 1954; strenuous exercises suspended at 88° ETR.

43/10000 in recruit graduates on four-week training at Camp Lejeune, 1954
40/10000 in senior PLC's on six-week training at Quantico, 1954
21/10000 in recruits on twelve-week basic training at Parris Island, with quasi preventive measures, 1952 and 1953
2.5/10000 ibid, with rigorously enforced, preventive measures. 1954

6. Most of the casualties occurred on sunny days during field activities when the metabolic and climatic loads were high. In unacclimatized trainees, a significant number of cases occurred while attending outdoor classes in the sun, or during parades.

7. The "wet bulb-globe temperature" was found to be a more practical heat index than the ETR for evaluating climatic heat stress and for predicting the occurrence of heat casualties.

8. The use of preventive measures at Parris Island greatly reduced the number of heat cases, mainly by restricting physical activity according to certain prescribed temperature-humidity limits. Reliability of these limits for predicting occurrence of heat injury can be increased by taking into consideration solar radiation and wind, as by using the wet bulb-globe temperature index, instead of the present temperature-humidity limits which unnecessarily restrict training on cloudy, windy days, but permit training on sunny, windless days when most of the heat casualties occur.

9. The following principal preventive measures are recommended for field trial: When the "wet bulb-globe temperature" (WBGT) rises above 80°, restrict field exercises for new recruits to three hours a day during their first week of training; to between four and five hours a day during the second week, and to not more than six hours a day for the remaining part of the program. Suspend strenuous exercises in new recruits when the WBGT approaches 85°, and halt physical training of all trainees when this index rises to 88°. Hardened troops, after having been acclimatized each summer, can carry on limited activity at WBGT's of between 88° and 90°.

10. Among recommendations made for future studies are (a) determination of total heat loads on trainees while performing strenuous exercises which do not permit direct metabolic measurements, and (b) derivation of specific heat limits for particular exercises.

GENERAL STATEMENT OF PROBLEM

In order to develop a rational program for the control of heat casualties in military training centers it is necessary to know:

(a) the metabolic heat loads due to various exercises,
(b) the climatic heat loads on trainees, due to temperature, radiation, humidity and wind. These four environmental factors must be integrated into a

practical heat index that can be readily measured in the field.

(c) the total heat load (metabolic plus climatic) and resulting heat stress or strain on trainees.

(d) the threshold heat limits at which moderately severe cases begin to appear in basic and advanced trainees, calling for reduction of physical activity.

(e) the upper heat limits beyond which heat injury will occur, calling for a stop of physical activity.

(f) the epidemiology of subclinical and clinical cases of heat diseases.

This report describes work done on items (b) to (f) inclusive, in the summer of 1954 at the three East Coast Marine Corps Training Centers namely:

1. Marine Corps Schools, Quantico, Va.
2. Marine Corps Base, Camp Lejeune, N.C.
3. Marine Corps Recruit Depot, Parris Island, S.C.

Metabolic heat loads of various exercises (item a) were studied separately by Dr. Belding and Commander Minard at Parris Island in July 1955, using volunteer recruit trainees for subjects (1).

HEAT LOADS AND HEAT STRESS ON MARINE CORPS TRAINEES

Meteorological Observations, and Composite Heat Indices Studied. The following meteorologic and environmental observations were recorded manually or automatically at central locations of the camps at a height of 4 ft. above ground:

(a) Shade dry and wet bulb temperature by sling psychrometers.

(b) Globe thermometer temperature for integrating effective radiations from all sources.

(c) Wind velocity by thermoanemometers.

(d) Intensity of direct solar radiation on a horizontal plane at Quantico and Camp Lejeune, using Eppley pyrheliometers.

(e) Intensity of diffuse solar radiation reflected from the sky, and the terrain, at Quantico and Camp Lejeune, using Eppley pyrheliometers.

(f) Mean radiant temperature (long wave) of the sky and ground, at Quantico and Camp Lejeune, using a Hardy radiation thermopile.

Observations made by pyrheliometers and radiation thermopile prove of little practical value to be included in this report. The globe thermometer readings gave all the information needed for integrating radiation and convection.

To begin with, the effective temperature index was used for combining temperature, humidity, radiation and wind into a single value. The radiation component was integrated into the standard effective temperature scale- which normally takes no account of radiation-, by first finding from a psychrometric chart the equivalent wet bulb temperature corresponding to the O.D. globe temperature# and dew-point temperature, and then using this equivalent wet bulb with the O.D. globe temperature and wind velocity for computing the effective temperature from a conventional chart. Determined in this manner, the effective temperature including the radiation component is hereafter designated by ETR.

In order to avoid the foregoing elaborate procedure, for the sake of personnel unskilled in the art, a study was made of a simple substitute for ETR, the so-called "wet bulb-globe temperature" (WBGT), recently developed for practical use in hot environments. This heat index requires no measurement of wind velocity, nor use of complicated charts. It is determined by two simple readings, the wet bulb temperature and the globe temperature, weighted as follows for olive drab shades of military clothing:

WBGT = 0.7 psychrometric wet bulb temp. + 0.3 black globe temp.
or WBGT = 0.7 natural wet bulb temp. + 0.2 black globe temp. + 0.1 air temp.

The natural wet bulb temperature is that shown by an ordinary wet bulb thermometer exposed to the sun and natural wind.

Table 1 summarizes meteorological data at the three Marine Corps Centers for the summer of 1954. The values shown are weekly averages of readings taken between the hours of 1000 and 1600 on training days only. Most of the heat casualties occurred between these hours, excluding isolated cases.

As expected, Quantico was the coolest and Parris Island the warmest of the three stations. The ETR on training days for the hours of 1000 to 1600 averaged 80.8°F at Quantico, 84.3° at Camp Lejeune, and 85.4 at Parris Island. At Quantico there was only one week in the summer of 1954 when the day-time ETR exceeded 85°. At Camp Lejeune this value was approached or exceeded on five weeks, and at Parris Island on 7 weeks (Table 1).

Climatic differences between the three camps were due largely to the natural increase of temperature and humidity with decreasing latitude southward from Quantico to Parris Island. The amount of effective radiation from the sun, sky, and terrain did not differ much, as is indicated in Table 1 by the equivalent increment of temperature## due to net radiation effect (columns 6,12,18) averaging 12.8° at Quantico, 13.6° at Camp Lejeune, and 12.2° at Parris Island, for the summer of 1954.

<u>Total Heat Loads and Stress on Trainees</u>. Gross total heat loads imposed by training exercises and climate combined, were determined by

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Temperature shown by the thermometer of a conventional 6 in. hollow sphere, closely fitted with a sample of the olive drab herringbone twill fabric composing the uniforms worn by Marine Corps Trainees. The absorptivity of this fabric for total solar radiation was found to be approximately 0.74, as against 0.95 for the black globe.

Globe temperature minus shade dry bulb temperature.

measuring the evaporative sweat loss of trainees under various weather conditions. This loss represents the amount of sweat that must be evaporated from the skin, lungs, and clothing in order to maintain body hea balance. With light hot-weather clothing, each Kilogram of water evaporated removes approximately 580 Calories of body heat.

It has been determined that an evaporative sweat loss of 1 Kg./hr, corresponding to a gross total heat load of 580 Cal./hr., is about the maximum that can be safely tolerated by healthy acclimatized young men for 4 to 6 hours a day, when they take a 10 minute rest pause every hour. On the basis of this standard it is possible to assess the total heat loads imposed by exercises and climate in the absence of direct metabolic measurements.

Evaporative sweat loss was measured individually in squad-sized groups of volunteer subjects, undergoing a six-week basic training program at Camp Goettge, Quantico, Va., located about 18 miles inland from the Marine School Headquarters. Four squads totalling 44 men were selected from a group of 268 men who succeeded in completing the training program. The mean weight of the four test squads was 73.7 Kg, the height 178 cm., and the surface area 1.91 m^2. These values differed but little from those of the population of which the subjects were a sample. The group as a whole was composed of young men, between the ages of 19 and 23 (ave. 20), who had completed two years of college. Only a small proportion had had previous military experience.

A total of 74 tests were made in nineteen different training exercises during the period of 29 July to 1 Sept. 1954. Weighings were made before and after each exercise, and at intervals when exercises were long, by means of a large dial Chatillon dynamometer scale suspended from a portable tripod frame, and equipped with a comfortable seat and foot rest. The sensitivity of this scale was about 0.1 lb.

The men were weighed completely dressed, with undershirt, shorts, socks, fatigue uniforms, boots, helmet, cartridge belts, bayonet with scabbard, and full canteen with cup and cover. This equipment had a mean weight of 15 lbs. with field shoes, and 16 lbs. with field boots. Additional loads, not weighed with the subjects but constituting standard equipment for most exercises, were the rifle (10.8 lbs.), steel helmet (2.4lbs.), and ponchos (2.8 lbs.), and in special exercises intrenching tools (3.0 lbs.), light marching pack (7.2 lbs.), or the field marching pack (22 lbs.). Every precaution was taken to make certain that the men drank water only from their weighed canteens; that the men were re-weighed before and after voiding urine, and that the clothing and gear worn in the initial and final weighings were the same.

Heat strain resulting from the total heat stress on trainees was evaluated by the increase of their heart rate and by the rise of rectal or mouth temperature. Reliability of these observations however, was limited because it was not possible to take a sufficient number of readings during or immediately upon cessation of exercises to derive a good average.

In Table 2 are presented data on evaporative sweat losses and changes of body temperature and heart rate for nineteen different types of exercises, arranged roughly in descending order of evaporative sweat loss and ETR. The total heat loads in column 7 were calculated by multiplying the evaporative sweat losses in column 6 by 580, the latent heat of vaporization per Kg. of sweat.

Importance of Peak Loads and Long Training Hours on Heat Stress. The fact that in none of the physiological tests (Table 2) did the mean sweat rate approach the upper limit of 1 Kg./hr., does not necessarily imply low heat stress or strain on trainees. Several factors must be considered in evaluating the intensity-time pattern of heat stress. These are:

(a) Average metabolic heat production
(b) peak metabolic heat production
(c) duration of exercise
(d) climatic heat load.

It is obvious that a brief bout of intense exercise is not likely to cause serious strain if it is followed by a relatively long rest period. Heat stored in the body during exercise is dissipated during periods of inactivity. This is the case both in the Obstacle Course exercise and in the Individual Movement by Day. In both of these tasks, exertion is intense leading to pulse rates of between 160 and 220 beats per minute. Peak activity however, lasts for less than 50% of the time, and the exercises are usually conducted in cool weather when the climatic load is low or negative, thus helping to keep the total heat load low.

Exercises of moderate intensity, such as the day marches, may cause severe strain when excessively prolonged even in moderately warm weather. An example of this is the tactical march and administrative bivouac conducted in the afternoon of 25 Aug. when the ETR was 85°F. The march to the bivouac area lasted about 3 hrs., and the men were loaded with their field marching packs weighing about 22 lbs. in addition to their regular gear. On arrival at the bivouac area the men were drenched with perspiration and abnormally fatigued. Their mean heart rate increased 36 points, the body temperature rose 0.8°F, and the evaporative sweat loss averaged 1.68 Kg. in 3 hrs. On the other hand identical marches conducted at night when the ETR averaged only 63° resulted in an evaporative moisture loss of only 0.96 Kg. for 3 hrs. with no apparent distress.

The importance of high climatic loads in association with moderate physical effort of long duration is well illustrated in an exercise called individual cover and concealment. The group left camp at 1230, marched 1.1 miles to the exercise area, sat at a lecture in the shade for 1¼ hours, dug foxholes (1' x 2' x 6') for the next 30 to 45 mins., and then marched back to camp arriving at 1530. The ETR averaged 88 for the period of exercise, the highest recorded during the 6 week test period. Training had been suspended in the camp at 1315 because of the heat, but word had not reached this group until 1430. On arrival in camp all men exhibited signs of severe heat strain. Pulse rates ranged between 132 and 156, and mouth temperatures rose about 2°F, the highest rise recorded in any of the tests. Mean moisture loss was 0.73/Kg./hr., a rate that was exceeded by only two other tests of short duration, and not associated with serious physiological strain. Thus, an exercise which ranks 3rd on the basis of sweat rate, ranks first in physiological strain because of its relatively long duration and the high environmental heat load with which it was associated.

Trainees Reaction to the Training Program. At the end of the training period, each of the 268 trainees successfully completing the course was given a questionnaire. Among the questions was the following:

"Have you felt physically exhausted after any of the exercises in the present program?" One hundred and twenty five, or 46% of the group answered in the affirmative. Seventy nine of the trainees specified one or more exercises after which they felt exhausted. Their responses are presented in Table 3. When two or more exercises were specified, only that first mentioned is listed. Each affirmative answer therefore represents a separate trainee. In many of the affirmative reports, the trainee volunteered a statement attributing the exhaustion experienced to heat and long hours rather than to exercise.

The conclusion to be drawn is that heat strain on trainees at Camp Goettge was due not so much to strenuous exercises as to exercises of moderate intensity but of too long duration for warm weather.

Climatic Heat Loads. In order to determine the climatic heat loads on trainees, 27 tests were selected involving exercises of moderate physical effort conducted at ETR's from 78° to 88°. Tests involving either strenuous or light effort, and tests conducted in cool weather imposing little or no heat stress, were excluded from this analysis. The tests selected are marked in Table 2 with an asterisk. They are plotted in figure 1 using ETR for abscissas and total heat load for ordinates. The test points cluster about three curves, one fitting the data of marching exercises fairly well, and the other two roughly averaging points for miscellaneous exercises involving greater effort than the marches.

Since the metabolic heat load for any given exercise is essentially independent of the climatic load, the slope of the total heat load curves (figure 1) should give the climatic load per degree ETR. For marches conducted in the neighborhood of 85° ETR, the climatic load increased about 40 Cal./°ETR, or 21 Cal/°ETR/m^2 of body surface. This is much greater than a climatic load of 12 Cal/m^2/°ETR found at Yuma (2) in men marching in the sun at 3 mph, but wearing well ventilated, 6 oz. poplin uniforms, with no underclothing, instead of the poorly ventilated herringbone-twill fatigue uniform worn over cotton underclothing by Marine Corps trainees.

Not enough information is available to ascertain whether the climatic heat load varies much with the type of exercise. Figure 1 indicates no great difference for the exercises studied.

Correlation Between Physiological Heat Stress, or Strain Criteria and Physical Heat Indices. The 27 field experiments selected in the previous section for determining climatic heat loads, were also used for testing the relation between physical heat indices and physiological heat stress and strain criteria.

Referring to Table 4, the evaporative sweat loss, shows a high degree of correlation with ETR, "wet bulb-globe temperature", and globe temperature, but a significantly lower correlation with either the dry or the wet bulb temperature. The implication is that of the climatic factors at Quantico, solar radiation is the predominating factors. The wet bulb temperature at Quantico seldom rises to the point of interferring much with evaporation of sweat.

Correlations between increases of body temperature, or heart rate, with weather factors are in all instances low because in most of the tests it was not possible to measure these physiological responses accurately during or immediately upon cessation of exercises.

HEAT CASUALTIES IN MARINE CORPS TRAINEES

The incidence of heat casualties was studied in selected groups of basic and advanced trainees, using the infirmary logs of camps in preference to the BuMed "F" cards which do not show the mild heat cases. Many of these mild cases were allowed to return to duty or to quarters after treatment and do not therefore appear on "F" cards. A smaller number of cases were admitted to sick bay for observation and discharged within 72 hours following treatment. There were only a few severe cases requiring further treatment at a U. S. Naval Hospital. These cases are discussed in the section on epidemiology of heat illness.

Aside from heat rash, the most common heat illness encountered at the three camps was heat exhaustion, characterized by dizziness, incoordination, profuse sweating, pallor, headache, dyspnea, and gastrointestinal disturbances. Heat cramps and heat stroke were relatively rare, as will be seen farther on, and for this reason they were lumped-in with the heat exhaustion cases for the purpose of this study. Cases of heat rash were excluded from this analysis.

<u>Casualties Among Junior and Senior PLC's at Quantico</u>. In the Summer of 1954, Camp Goettge gave a 6 week basic training course to two groups of junior Platoon Leader Candidates (PLC), composed largely of men between the ages of 19 and 23 years who had completed two years of college. Only a few of them had had previous military experience. The first group, consisting of 495 men who succeeded in completing the training program, started field training on 14 June and finished on 23 July. The second group numbering 269 successful candidates started on 26 July and finished on 1 September.

Concurrently with the junior PLC training program at Camp Goettge, a 12 week advanced training program was conducted for senior PLC's at Camp Upshur, located only a few miles from Camp Goettge. These seniors differed from the juniors mainly in having had previous training. There were 906 advanced trainees during the first period, 14 June to 23 July, and 854 during the second period, 26 July to 1 Sept. Of the 854 trainees, 232 were fresh graduates from Camp Geottge.

Figure 2 shows the daily incidence of heat exhaustion in junior and senior PLC's, and the corresponding ETR averaged for the hours of 1000 to 1600 between which most of the heat casualties occurred. Breaks in the ETR graph occur on Saturdays and Sundays when there was no training and no heat cases. Generally, peaks of incidence coincided with peaks of ETR with little lag. Cases occurred with wet bulbs as low as 65 to 70° in clear weather when the solar radiation intensity was high and the wind was low. For the period of 14 June to 1 Sept., the mean daily incidence of heat casualties was 11/10000 per training day in junior PLC's, as against 4/10000 in senior PLC's, or 2.8 times greater in junior than in senior trainees.

Casualties Among New Reservists and Recruit Graduates at Camp Lejeune. At this camp, the incidence of heat cases among 5078 unacclimatized new reservists on two-week training duty, was compared with that of 1246 recruit graduates on four-week advanced training. These seasoned recruits were graduates of Parris Island and had had from 4 to 7 months of active duty. Although the two groups had the same age distribution (17-23 yrs.), they were samples of different populations. Both groups trained with the First Infantry Training Regiment, the former from 7 June to 30 August, and the latter from 1 July to 30 August 1954. The mean strength of the former (new reservists) was 850, fluctuating from week to week between a low of 336 and a high of 1174 men. The strength of the recruit graduates remained constant at 520 men in July and 726 men in August, 1954.

During the period of 1 July to 27 August, which was concurrent in the training of both groups, 148 heat cases developed from among 3940 unacclimatized reservists, but only 31 cases among the 1246 seasoned recruit graduates. The daily incidence and corresponding ETR are shown in figure 3. The highest incidence occurred on 20 and 21 July, with a secondary peak on 4 August, affecting mostly new reservists unaccustomed to work in the heat. The common factors associated with these peaks were high dry and wet bulb temperatures, high solar radiation intensity, and low wind. It is important to point out that the day of highest incidence (July 21), was a cloudy day, with heavy showers in the morning followed by partial clearing in the afternoon. Although the intensity of solar radiation recorded by pyrheliometers was relatively low, the cumulus clouds of the passing warm front emitted enough infrared radiation to raise the mean O.D. globe temperature for that afternoon as much as 18° above the shade air temperature.

The incidence of heat casualties during the period of 1 July to 27 August (1954) averaged 35/10000 per training day in the new reservists on two-week training duty, as against 14/10000 for recruit graduates on four-week training duty. Although the incidence ratio of these two groups at Camp Lejeune ($\frac{35}{14} = 2.5$) is about the same as that of the corresponding two groups of PLC's at Quantico ($\frac{11}{4} = 2.8$), the rates in themselves are not comparable because of differences in weather conditions, intensity of training, and population characteristics between the two camps, as will be seen farther on.

Casualties Among Boot Camp Trainees at Parris Island. This Post offered an opportunity for making a three year study of heat casualties, before and after application of a preventive program. Trainees at this Post were under constant supervision and all but the most trivial cases treated in the field were entered into the logs of infirmaries in 1952 and 1953. However, less complete records of mild cases were kept in the summer of 1954 owing to shortage of medical personnel. This Post maintained two small weather stations of its own in strategic areas, and planned the training according to the weather.

Daily incidence of heat cases for the summers of 1952, 1953, and 1954, appears in figures 4, 5, and 6. Missing weather data for the summer of 1952 were obtained from nearby weather stations, and reduced to local readings by correlation with existing Post data.

June, 1952 was the hottest June on record, with the most extensive and prolonged heat waves dominating most of the country. Parris Island suffered miserably from the heat (see figure 4), which soared to record highs in the last week of June, with maximum dry bulb temperatures of 95 - 103°F, wet bulb temperatures of 80 - 85, and sunshine above normal. The mean ETR for the hours of 1000 to 1600 ranged from 87 to 90° and the heat cases rose to 106/10000 on June 26, the highest rate recorded for any June day at Parris Island. It was not so much the degree of heat as the suddenness with which it struck so early in the season, before the men had had an opportunity to become acclimatized.

The summer of 1953 was nearly normal at Parris Island, although much above normal in the middle southwest. The summer of 1954 was characterized by excessive dryness, but the temperature and sunshine were only slightly above normal. The unusually low incidence of heat cases in the summer of 1954 is due largely to the use of preventive measures.

TOLERANCE LIMITS FOR WORK IN THE HEAT

Heat limits for physical work were determined by noting the weather conditions at which disabling heat symptoms began to appear in the selected groups of basic and advanced trainees. In figure 7 is shown the relation between average incidence of heat cases per day and mean ETR for the hours of 1000 to 1600 local time. In constructing figure 7, the incidence rates including positive, as well as zero rates when no cases occurred, were first classified according to the ETR and then averaged for each degree of ETR before plotting. When the number of training days at any given ETR was less than four, the rates for those days were grouped with rates of the next higher or lower ETR classification, whichever of the two had the lesser number of observations. Dotted lines in figure 7 indicate a preponderance of mild heat cases which were returned to duty or quarters within a few hours following treatment at dispensaries. Solid lines show a preponderance of moderately severe cases confined to bed rest at dispensaries over night, or for periods up to 72 hours. With these cases were also included a few severe ones requiring transfer to regional U. S. Naval Hospitals for further treatment. These cases are discussed in the section on epidemiology of heat illness.

It is clear from figure 7 that no single heat limit can be set to apply to all situations. Although mild heat cases can occur sporadically at ETR's even lower than 80°, when the weather first turns in the season, these cases are of little value in deriving practical limits for work in the heat. It would be not only undesirable but possibly detrimental to set the limits too low, because actual work in the heat is essential, for developing adaptation and maintaining physical fitness in spite of heat stress.

Disabling heat exhaustion symptoms of moderate intensity appeared predominatingly at the following ETR's (see figure 7):

84° in junior PLC's on 6-week basic training in Quantico, 1954
85° in new reservists on 2-week training duty at Camp Lejeune, 1954
86° in senior PLC's on advanced training at Quantico, 1954
87° in recruit graduates on 4-week training duty at Camp Lejeune, 1954
87° in boot camp trainees on 12-week basic training at Parris Island, 1952 and 1953, with quasi preventive measures.
88° ibid, 1954, with a rigorously enforced preventive program for reducing heat casualties.

The progressive increase of heat tolerance from Quantico to Parris Island in basic trainees is ascribed largely to climatic adaptation, for the warmer the climate in which one lives the greater is the degree of heat tolerance he acquires. Basic trainees at Quantico were handicapped not only by the relatively cool and variable climate which made acclimatization to heat difficult, but also by being exercised harder than any of the other groups, in the impression of the authors.

Physical adaptation for work in the heat is held largely responsible for the greater tolerance of advanced than of basic trainees at Camp Lejeune, and to a lesser extent at Quantico where the advanced training program was less rigorous than the basic program.

If a somewhat less strenuous program were adopted for the junior PLC's at Quantico, it would be possible to set only two heat limits applicable to all three camps. These are:

(a) a lower limit of 85° ETR for suspending physical training in new trainees during their first two weeks of summer training, while permitting training on a reduced scale in advanced trainees, and in basic trainees after their second week of training,
(b) an upper limit of 88° for halting physical training of all trainees. Hardened troops, after having been acclimatized each season could carry on limited activity at ETR's of between 88 and 90°.

Heat limits found in studies of the Armed Forces Epidemiological Board at Yuma, Arizona (2,3) fit in well with those of the present study. In all of the AFEB experiments the subjects marched in the sun at 3 to 3½ mph, at ETR's averaging about 4° higher than at Parris Island. The threshold heat limits at which incipient symptoms of heat exhaustion began to appear was 86° ETR during the first two weeks of training, and 88 ETR after 6 weeks of training. Highly motivated civilian personnel, natives of desert climates, were capable of tolerating ETR's between 90 and 92° for six hours a day with a 10 min. rest period in the shade each hour (3).

Not enough information is available to establish heat limits for specific training exercises other than marching at the standard military pace.

EFFECTIVENESS OF PREVENTIVE MEASURES USED AT MARINE CAMPS

Parris Island was first to initiate a preventive program for regulating physical activity, water and salt intake, and clothing of trainees in hot weather. Post training orders issued in 1952, 1953, and 1954 prescribed the following conditions governing physical activity and responsibility of officers and drill instructors for the safety of trainees:

(a) A red flag will be displayed whenever the shade dry bulb temperature-humidity readings, recorded hourly at two strategic areas of the Post, equal or exceed the limits shown in columns 1 and 2 of Table 5. During the time a red flag is displayed, recruits will be given only that type of instruction which can be given to men standing or sitting in the shade.

(b) A yellow flag will be displayed whenever the temperature is between 90 and 100°F, and the relative humidity is lower than that required for displaying the red flag. During the time the yellow flag is displayed, instruction of the type requiring trainees to sit in the sun shall be restricted to a minimum. Instruction involving strenuous physical exertion, such as an infantry drill, crawling on the ground, or bayonet training, will be given only in the shade.

(c) Responsibility of officers and drill instructors "extends not only to the accomplishments but also to the well being of those over whom authority is wielded". "All officers and non-commissioned officers must be especially vigilant to note and immediately correct conditions wherein there are dangers to the lives and health of recruits".

Control of physical activity in the prescribed manner, supplemented with instructions on "how to keep healthy in hot weather", has greatly reduced the incidence of heat casualties in the summer of 1954 by comparison with the incidence in the previous two summers (see figure 7). A part of this reduction is ascribed to less thorough reporting of mild heat cases in 1954 than in the previous two summers, owing to shortage of medical personnel.

At Quantico, application of the Parris Island preventive program helped but little in reducing heat casualties (see figure 7) because the Parris Island heat limits were too high for the climate of Quantico. Most of the heat casualties at Quantico occurred at humidities below the critical levels at which the red flag will fly. There were only a few hot days at Quantico calling for modification of training in accordance with the Parris Island heat limits.

At Camp Lejeune, modification of training in hot weather was largely at the discretion of officers conducting the field training. Insofar as the authors were aware, no specific coordinated program was in force at this camp in the summer of 1954.

Water and salt discipline was adequately stressed at the three camps, and in some instances perhaps overstressed. Nevertheless, cases of dehydration and possibly salt deficiency did occur sporadically at all three camps.

Improving Effectiveness of Preventive Measures. Effectiveness of the temperature-humidity limits now in use at Marine Camps for reducing heat casualties can be increased especially at Quantico by taking into account radiation and wind. These two factors had been overlooked in the past because there was no practical method for measuring the radiation component, and integrating it with the temperature, humidity and wind into a composite heat index, such as the present ETR, Heat Stress Index, WBGT, and others.

The importance of sunshine and wind to heat stress is shown in Table 5, by computing the ETR corresponding to the Parris Island temperature-humidity limits, when the sky is completely overcast, or when the sun is shining, and with low or moderate wind. As can be seen in column 3 (Table 5) the Parris Island limits originally had been based on a constant effective temperature (E.T.) of 85°, which is a sound, conservative limit for moderately heavy work in the absence of solar radiation and wind. But with full sunshine and no wind, the ETR will rise to the potentially dangerous level of 90° or above (Table 5), capable of producing casualties at least as high as the highest recorded at Parris Island in 1954 (see figure 7). The hazard would be even greater at Quantico. On the other hand, with a completely overcast sky and a wind velocity of 5 mph, the ETR will drop to between 81° and 82° (Table 5), which is 3° to 4° below the Parris Island basic E.T. limit of 85°, thus permitting full training when the present Post formula forbids any physical training.

Modification of the Parris Island formula to take into account radiation and wind effects would entail no signficiant loss of training, for time lost on sunny days would be made up by gains on cloudy, windy days, and gains accrued by permitting limited training after the first two weeks at camp until the ETR rises to 88°.

A practical way of taking solar radiation and wind into account is by the use of the "wet bulb-globe temperature" index (WBGT) described earlier in this report. A threshold limit of 85° WBGT would be the criterion for raising the yellow flag to suspend strenuous exercises in basic trainees during their first two weeks of training, while permitting physical training on a reduced scale in advanced trainees until the WBGT rises to 88°. Display of the red flag would be appropriate at this upper heat limit to halt physical training of all trainees.

CORRELATION BETWEEN HEAT CASUALTY RATES AND WEATHER FACTORS

Table 6 gives correlation coefficients between the logarithm of daily heat casualty rates and the daytime (1000 - 1600 hrs.) ETR, WBGT, globe temperature, dry bulb temperature and wet bulb temperature, excluding days in which the ETR was less than 83°. For the purpose of this analysis the logarithm of 0 was taken as 0.001.

Correlation coefficients for Quantico and Camp Lejeune are in all instances insignificant, owing to the small numbers of observations (Table 6), and the many variables besides the weather affecting heat casualty rates, especially the intensity of training exercises.

At Parris Island, on the other hand, with a mean strength of 5000 to 14000 trainees, the heat casualty rates correlate well with all weather factors in the summers of 1952 and 1953 (Table 6). Data obtained at this camp in the summer of 1954 are not comparable, owing to the application of preventive measures which practically have eliminated heat casualties (see figure 7) by reducing or halting physical activity in warm weather.

Although the dry bulb temperature ranks third in Table 6 as an index for predicting heat casualty rates, the possible error of prediction is large enough, especially in small groups, to temper the choice in favor of simplicity. This holds true particularly in regions where the weather varies but little from day to day as in a desert. A composite index must be used where the weather varies much.

The conclusion to be drawn is that, while the occurrence of heat casualties in groups of trainees can be predicted, from a knowledge of environmental thermal factors and physical activity, it is difficult to predict accurately the incidence rates owing to the fact that many other factors are so closely associated (see section on epidemiology of heat illness) as to obscure the relationship between the variables under consideration.

EPIDEMIOLOGY OF HEAT ILLNESS IN THE NAVY AND MARINE CORPS

Recent Statistics for Heat Cramps, Heat Exhaustion, and Heat Stroke. Table 7 presents a summary of heat cases excluding heat rash occurring among Navy and Marine Corps personnel for the twelve-year period 1942-1953. Heat cramps is seen to present low morbidity and no mortality. Heat exhaustion (or heat prostration, according to present Navy nomenclature) is important both because of continued high incidence which has not decreased appreciably during the post-war years, and also because of the number of sick days from this cause. No deaths from heat exhaustion are reported since 1945. Heat stroke (or sunstroke), with a mean yearly incidence of approximately one-tenth that of heat exhaustion, has accounted for all of the six deaths in the post war three-year period 1951-1953. Four of the six deaths occurred among recruits undergoing summer training at Parris Island, S.C., and two among officer candidate trainees at Marine Corps Schools, Quantico, Va., in July 1953.

Analysis of the 1952 statistics indicates that Marine Corps personnel have a higher incidence rate of heat illness than Navy personnel. Also personnel within the Continental U.S. show a higher rate than those stationed aboard ship overseas.

Although reporting of heat stroke by "F" cards reflects the true incidence of this disorder, this is not true of heat exhaustion or heat rash. Mild cases of these disorders are treated and returned to duty within 48 hours and do not appear in Navy Medical statistics. The extent of discrepency between reported heat cases (heat exhaustion and heat stroke) and cases receiving treatment but not reported is seen in Table 8. The reported cases include four cases of heat stroke from Parris Island and one case each from Camp Lejeune and Quantico. The remaining are cases of heat exhaustion.

After 20 June 1954 at Camp Lejeune, and after 10 July at Quantico and Parris Island, special report forms were supplied to Medical services at these bases with a request that this form be filled out for each case of heat disease. This procedure was only partially successful in increasing the number of reported cases, owing largely to limitations of medical personnel, especially at Parris Island.

Heat Rash (Miliaria Rubra). Although heat rash is generally considered to be a minor heat condition, it is important to military populations working and living in warm, moist climates, because of its high prevalence and resulting loss of time and efficiency. Heat rash interferes with sleep leading to cummulative fatigue which may predispose the victim to heat exhaustion. Impaired sweating from this skin disorder is an additional predisposing factor.

At Parris Island, cases of heat rash among recruits began to appear in significant number after exposure for several days to ETR's exceeding 80°, with no let up of sweating. As can be seen in Table 9, the incidence increased cummulatively from May to September, when the mean ETR remained continuously above the sweating threshold of 78° for resting men. However, admission rates were very low.

Experiments at the Naval Medical Research Institute during the last war (4) have shown that heat rash does not occur when the ETR is less than 78°, but may appear after an exposure of a few days to 85° ETR. Exposure to an environment just cool enough to stop sweating, even for a few hours a day, was found to be the most effective method of treating heat rash. By cooling the sleeping quarters to 78° ETR or less, naval personnel were able to work in high heat all day without developing heat rash.

Acclimatization. In military training centers the constant influx of unacclimatized, untrained recruits maintains a group susceptible to risk of heat disease. Of the 598 cases reported on "F" cards in 1952 (Table 7) 397 occurred among recruits undergoing summer boot training at Parris Island, S.C. At Camp Lejeune the incidence of heat casualties among new reservists on two-week training duty was 35/10000 per training day as against only 14/10000 in acclimatized recruit graduates on four-week advanced training.

Incidence of Heat Exhaustion by States. Of the 181 cases of heat exhaustion in reservists training with the 1st Infantry Training Regiment at Camp Lejeune, 150 occurred in reservists on two-week training duty. These reservists were attached to units from various midwestern, eastern, and southern states.

Table 10 shows the incidence of cases by state for the three summer months. The difference between northern and southern states is statistically significant, and indicates that a trainee from a northern state is more prone to develop heat exhaustion than a trainee from a southern state. Basic to this difference in heat tolerance is the degree of physiological acclimatization to heat and the know-how of living in hot climates which the trainee brings with him to camp.

Time of Onset. About 20% of the heat casualties at the three Marine Corps Camps occurred in the forenoon, and the remaining 80% in the afternoon, including sporadic cases reported after duty hours. The peak incidence was reached between the hours of 1230 and 1430 local time, and seemed to be affected to some extent by the noon meal.

Activity at Time of Onset. In Table 11 is compared the activity at time of onset in 150 cases occurring among reservists on 14 days training duty, with 31 cases occurring among recent recruit graduates on 4-week advanced training with the 1st Infantry Training Regiment at Camp Lejeune.

In unacclimatized trainees a significant number of cases occurred in outdoor classes where exposure to the sun imposed a large heat load. Fewer such cases occurred in hardened personnel. In this group field exercises accounted for the majority of cases.

Types of activity which were probably incidental rather than causally related to heat illness, were grouped into a miscellaneous classification (Table 11) including activities in which only one or two cases occurred. The proportion of such incidental activities was less among the recruit graduates.

Other Factors. At Camp Lejeune, 21% of the 150 heat casualties among reserve trainees gave a history of one or more incidents of heat illness. Only 8% of a somewhat comparable group of trainees at Quantico gave a similar history.

A relation between obesity and susceptibility to heat was not evident in these 150 cases. However, these included no cases of heat stroke. Of the four cases of heat stroke among recruit trainees at Parris Island in 1954 three were obese. All four cases were serious enough to be transferred to the U.S. Naval Hospital, Beaufort, S.C. for further treatment.

The Negro trainee population was too small to study racial susceptibility.

Although the need for adequate water and salt intake in hot weather was properly stressed at the three camps, the use of salt tablets was unnecessarily overstressed.

Among other factors worth mentioning were lack of adequate sleep due to long training hours, possible febrile reactions to innoculations capable of adding to the heat load on trainees, and too much emphasis upon the appearance of dress resulting in excessive climatic heat loads on trainees from poorly ventilated clothing.

Treatment of Heat Casualties. Treatment of the 150 cases of heat exhaustion in reserve trainees at Camp Lejeune consisted chiefly in cessation of activity, rest in the recumbant position in the shade, and administration of intravenous or oral saline after evacuation of the heat victim to a field dispensary.

Prompt recovery of unconscious or stuporous patients usually followed the intravenous administration of 1000 ml 5% glucose in saline.

It was reported that in most instances normal alertness had been restored by the time half of this amount had been received. Mild cases were allowed to return to quarters. More severe cases remained at bed rest overnight in the dispensary. Four of the 150 cases were transferred to the U.S.N.H. Camp Lejeune for further treatment.

PREVENTION OF HEAT CASUALTIES

On June 15, 1954, the Bureau of Medicine and Surgery, Department of the Navy has issued Instruction 6200.7, providing information and guidance for the prevention of heat diseases. This instruction appears in full in Appendix 1.

Supplementary information and recommendations based on the present study are outlined below:

Measures Directed at the Host. - (a) Training programs for new recruits should be geared to their capacity by allowing a "breaking-in" period of one to three weeks with progressive degrees of heat exposure and physical exertion.

(b) Consideration should be given to a program of special training for obese trainees, and possibly for other groups suspected of heat susceptibility.

(c) No attempt should be made to harden short-time trainees to heat by unnecessary exposure to sun or by prolonged physical exertion.

(d) Training schedules should allow a siesta of one hour after the noon and evening meals, and an adequate amount of night sleep, between 7 and 8 hours.

(e) Consideration should be given to mechanical cooling of a barracks at Parris Island on experimental basis, as a means of insuring restful sleep for heat rash victims, and for the treatment of febrile conditions.

Measures Directed at the Agent and Environment. - (a) Training programs in hot weather should be planned on the basis of some simple heat index, such as the "wet bulb-globe temperature" (WBGT), combining air temperature, humidity, radiation, and wind into a single value.

(b) When the WBGT rises to 80°, field exercises for new trainees should be limited to 2 hours in the morning and 1 hour in the afternoon during their first few days of training; to between 2 and 3 hours in the morning and 2 hours in the afternoon during the second week, and to not more than 6 hours a day for the remaining part of the program, with the usual 10 min. rest period each hour in all instances.

(c) When the WBGT approaches 85°, physical exercises should be suspended in basic trainees during their first two weeks at camp, while permitting training on a reduced scale in advanced trainees and in basic trainees after their second week at camp.

(d) All physical training should be halted when the WBGT reaches 88°. Hardened troops, after having been acclimatized each season, could carry on limited activity at ETR's between 88 and 90°, for periods not exceeding 6 hours a day, barring emergencies.

(e) Prolonged day-time marches, or double time marching or drilling, should be avoided when the WBGT exceeds 80°.

(f) Exercises involving crawling on the ground, digging, or running the obstacle course, should be conducted in the morning when the WBGT is below 80°.

(g) Outdoor classes in the sun should be avoided when the WBGT exceeds 85°. Adequate shade and ventilation should be provided for this purpose.

NEED FOR FUTURE STUDIES

1. An important immediate problem is the determination of total heat loads and climatic loads on trainees while performing exercises which do not permit direct metabolic measurements. This information is needed in order to formulate heat limits for specific training exercises. An indirect method of determining total and climatic heat loads for difficult exercises has been described in this report.

2. Factors controlling the rate of recovery from heat stress should be studied with a view to arriving at the proper length of rest pauses for controlling fatigue and improving performance.

3. There is need for additional research leading to a better understanding of the mechanism of acclimatization and of the physiological bases underlying individual variability in susceptibility to heat.

4. The role of innoculations in rendering recruits susceptible to heat should be evaluated.

ACKNOWLEDGEMENTS

Grateful appreciation is expressed to the Commanding Generals of the three Marine Corps Training Centers and the Surgeons and Officers under their command, for their support and cooperation in the performance of this study.

Much credit is also due to the many Marine Corps trainees at Quantico who voluntarily participated in the physiological phase of this study.

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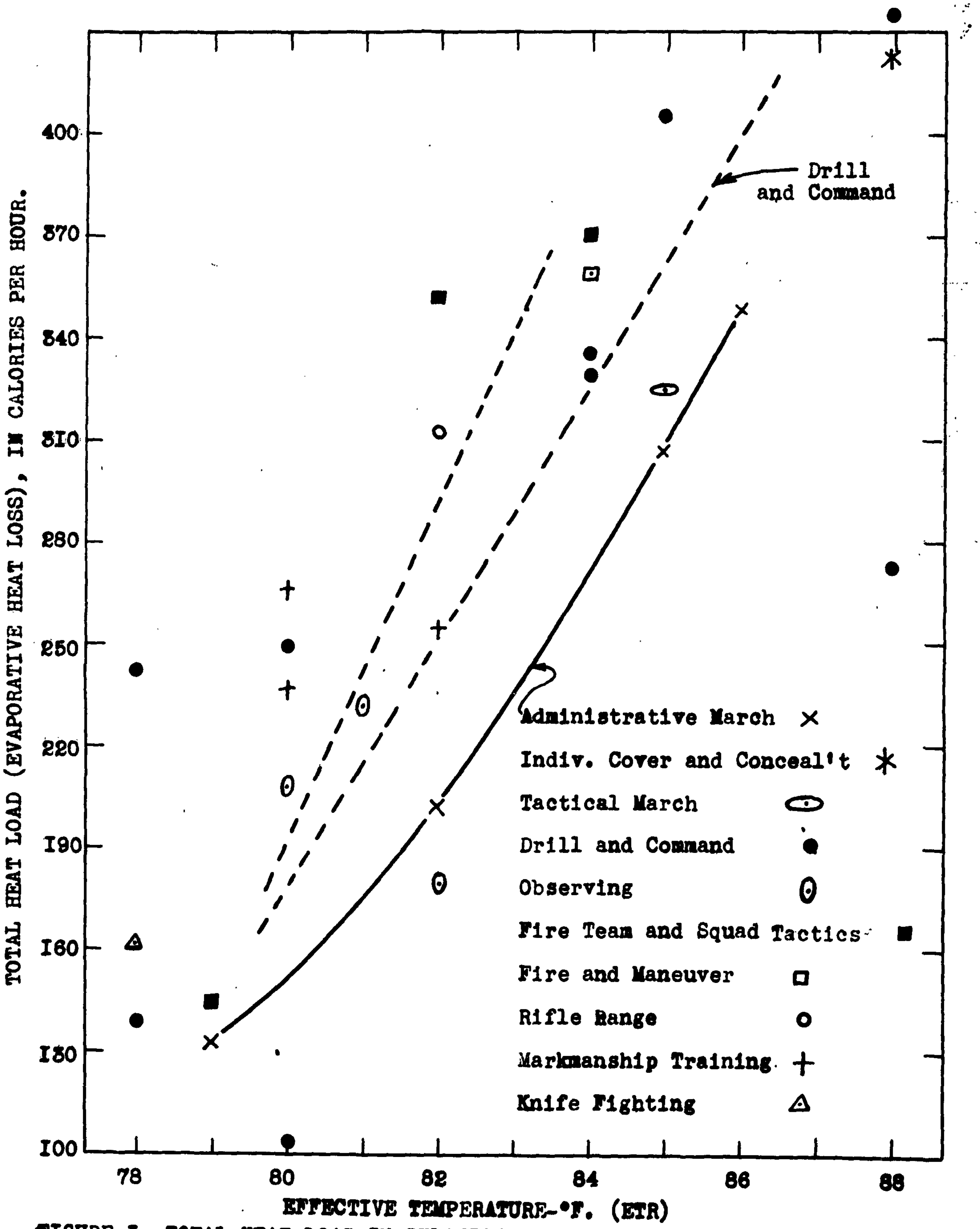

FIGURE I. TOTAL HEAT LOAD IN RELATION TO ETR AND TYPE OF EXERCISE.
Slope of lines gives climatic heat load per degree ETR.

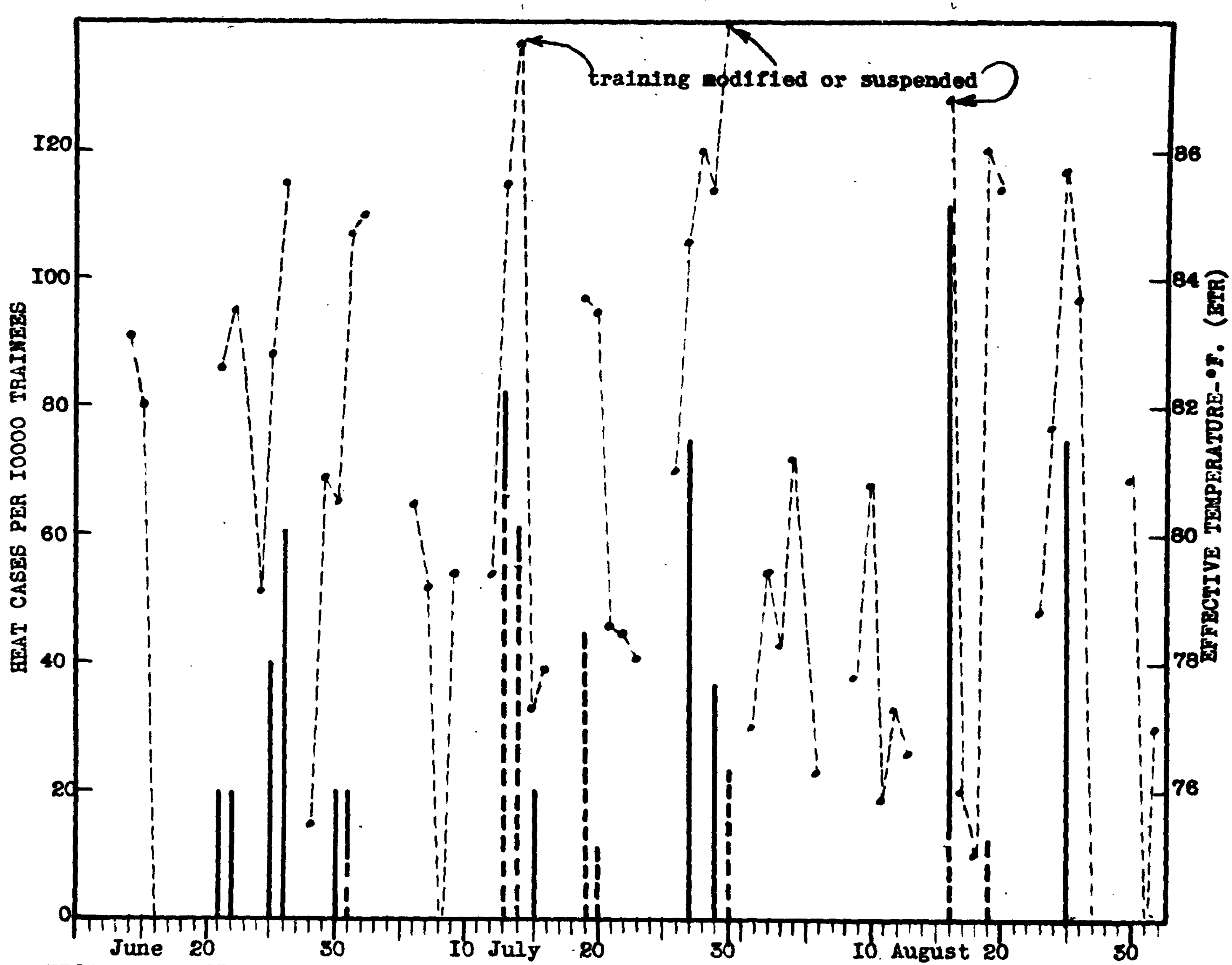

FIGURE 2. INCIDENCE OF HEAT CASES AND EFFECTIVE TEMPERATURE-°F. (ETR), QUANTICO, VA.1954. Solid bars show incidence in junior PLC's on 6-week training duty. Broken bars show incidence in senior PLC's. Points show ETR.

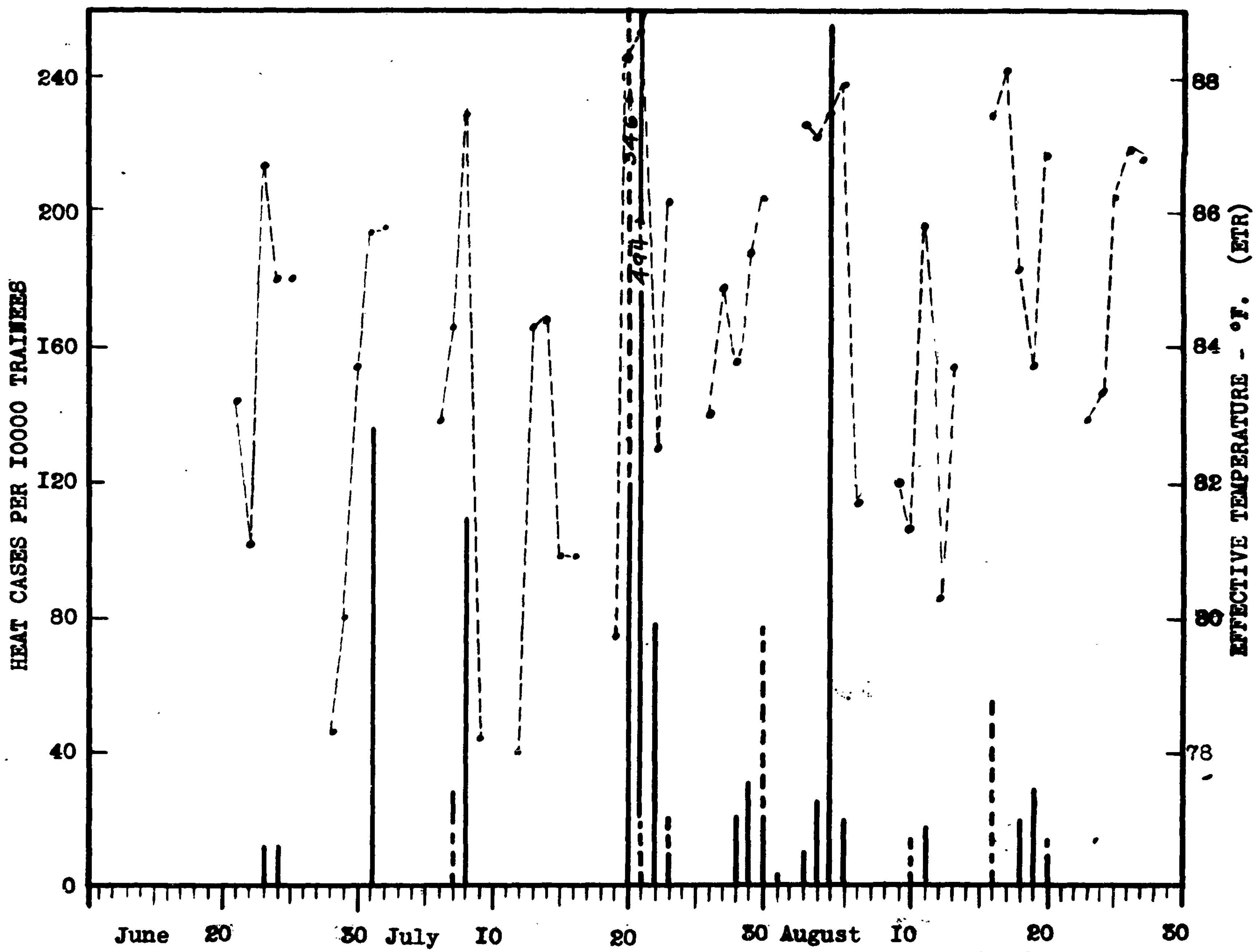

FIGURE 3. INCIDENCE OF HEAT CASES AND EFFECTIVE TEMPERATURE -°F. (ETR). CAMP LEJEUNE, 1954. Solid bars show incidence in new reservists on two-week training duty. Broken bars show incidence in recruit graduates on four-week training. Points show ETR.

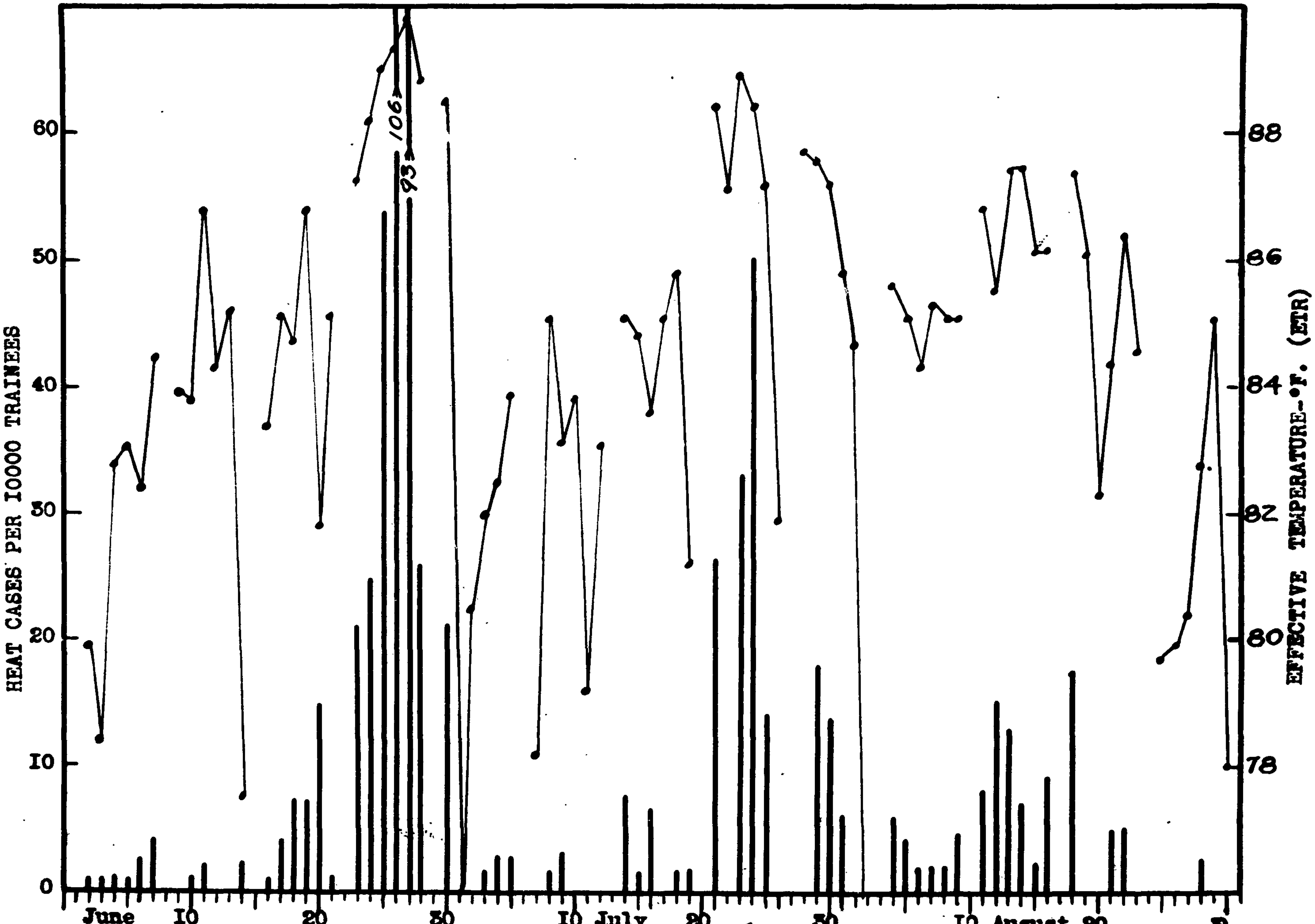

FIGURE 4. INCIDENCE OF HEAT CASES AND EFFECTIVE TEMPERATURE-°F. (ETR). PARRIS ISLAND, 1952

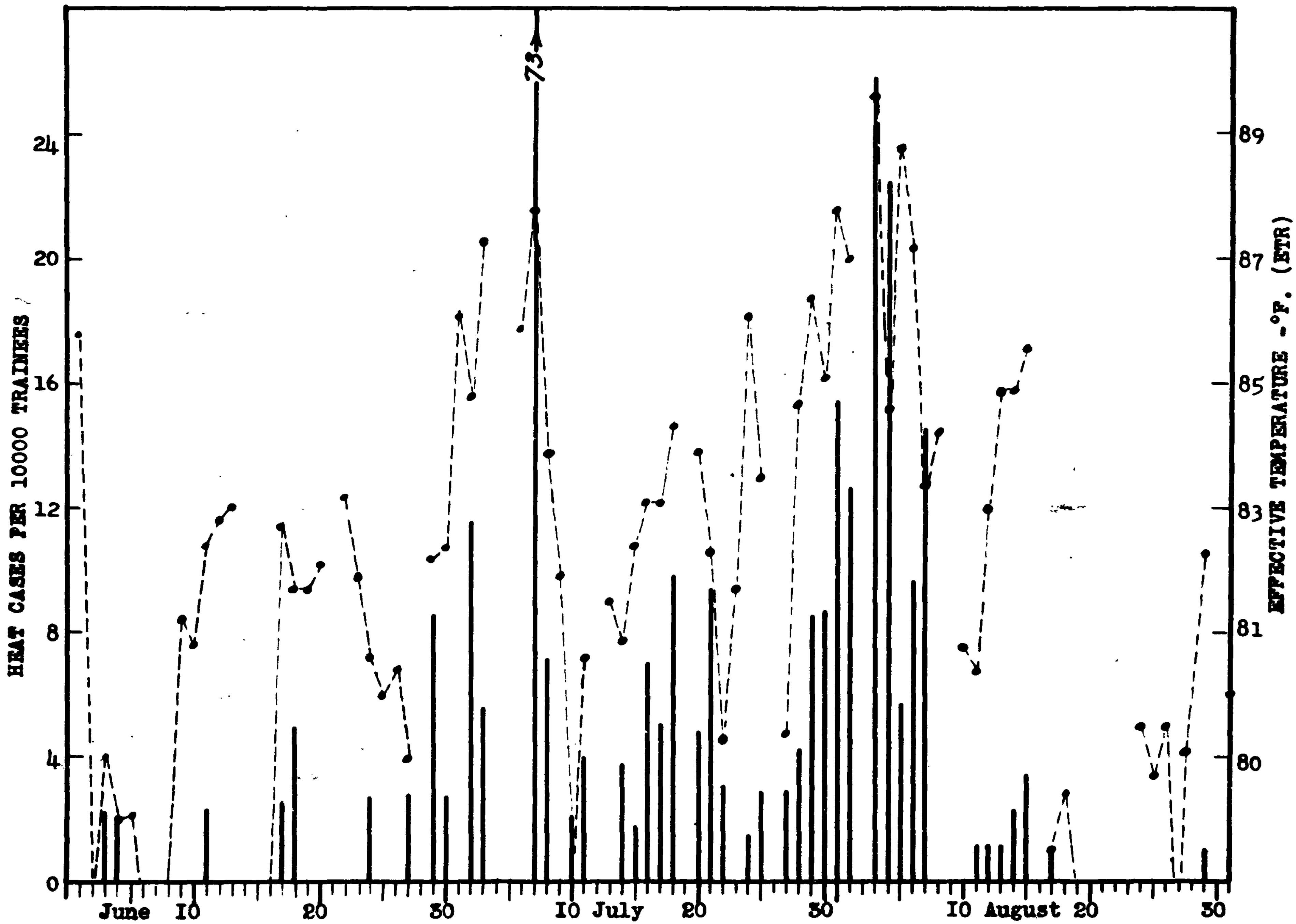

FIGURE 5. INCIDENCE OF HEAT CASES AND EFFECTIVE TEMPERATURE-°F. (ETR), PARRIS ISLAND, 1953

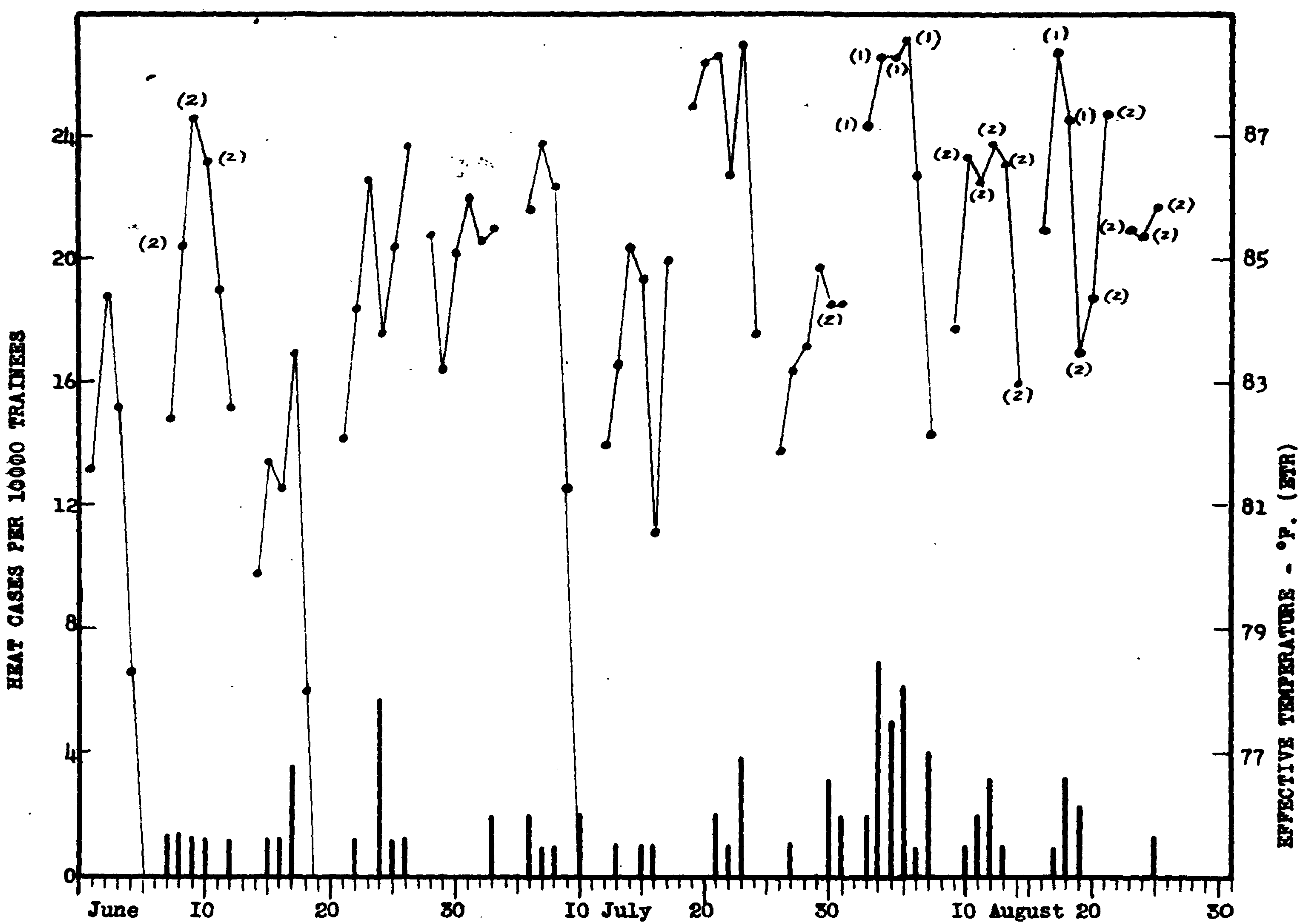

FIGURE 6. INCIDENCE OF HEAT CASES AND EFFECTIVE TEMPERATURE-°F. (ETR), PARRIS ISLAND, 1954
(1) Training suspended because of the heat. (2) Training modified.

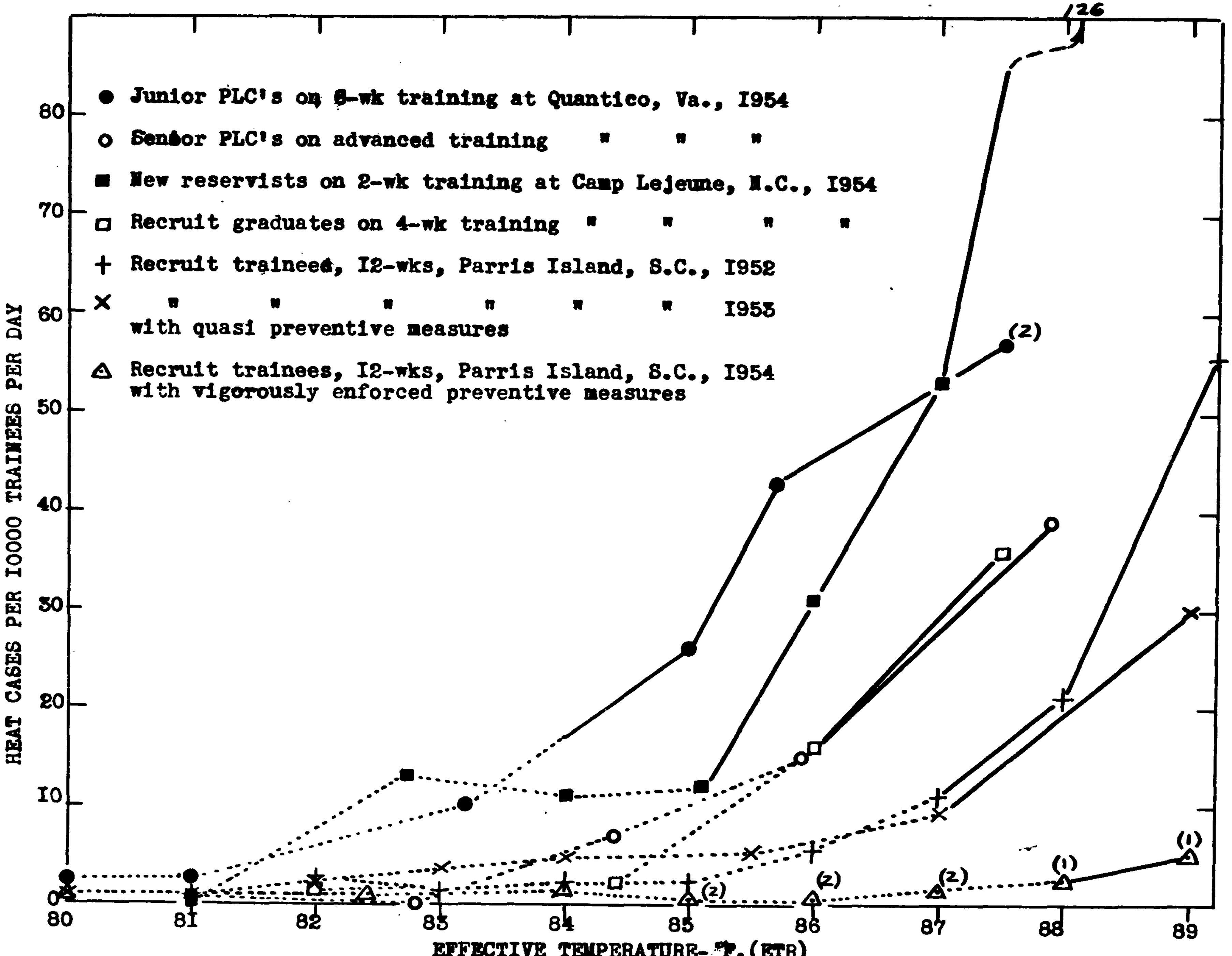

FIGURE 7. INCIDENCE OF HEAT CASES IN MARINE CORPS TRAINEES IN RELATION TO ETR.
(1) Training suspended because of the heat. (2) Training modified.

TABLE 1

WEEKLY AVERAGE DAY-TIME (1000-1500 hrs.) WEATHER DATA, AT EAST COAST MARINE TRAINING CENTERS, JUNE - AUGUST, 1954 -- ALL TEMPERATURES IN °F.

Weeks of 1954	QUANTICO, VA. Dry Bulb	Wet Bulb	Black Globe	O.D.(1) Globe	Rad'n (2) Increment	E.T.R. (3) (O.D. Globe)	CAMP LEJEUNE, N.C. Dry Bulb	Wet Bulb	Black Globe	O.D.(1) Globe	Rad'n (2) Increment	E.T.R. (3) (O.D.Globe)	PARRIS ISLAND, S.C. Dry Bulb	Wet Bulb	Black Globe	O.D.(1) Globe	Rad'n (2) Increment	E.T.R. (3) (O.D.Globe)
June 14-19	75	68	68	84	9	74	--	--	--	--	--	--	83	72	96	92	9	79
21-26	86	71	105	99	13	82	87	74	107	101	14	84	88	76	107	101	13	85
28- 3	84	69	104	98	14	82	85	73	104	98	13	83	89	76	108	102	13	85
July 6-10	78	67	94	89	11	77	86	76	102	97	11	83	86	77	102	97	11	84
12-17	85	70	104	98	13	82	84	75	98	94	10	82	88	74	105	100	12	84
19-24	82	70	100	95	13	81	87	78	106	100	13	85	93	79	111	106	13	87
26-31	92	71	115	108	16	86	86	73	110	103	17	85	88	73	107	101	13	84
Aug. 2- 7	80	68	93	89	9	77	90	76	111	105	15	86	95	78	112	107	12	87
9-14	80	65	97	92	12	78	84	72	105	99	15	83	91	76	110	104	13	86
16-21	84	71	104	98	14	82	89	78	109	103	14	87	92	77	109	104	12	86
23-28	82	71	100	95	13	81	88	75	108	102	14	85	90	80	104	100	10	86
MEAN June 21 Aug. 28	83.3	69.3	101.6	96.1	12.8	80.8	86.6	75.0	106.0	102.0	13.6	84.3	90.0	76.6	107.5	102.2	12.2	85.4

(1) Temperature shown by globe thermometer closely fitted with O. D. herringbone twill fabric.
(2) Globe temperature minus dry bulb temperature.
(3) Effective temperature including radiation component based on O. D. globe readings.

TABLE 2

EVAPORATIVE SWEAT LOSS, TOTAL HEAT LOAD, AND CHANGES OF BODY TEMPERATURE AND HEART RATE DURING TRAINING EXERCISES UNDER VARIOUS WEATHER CONDITIONS
Marine Corps Schools, Quantico, Va., July - Sept. 1954

Date 1954	Time Start	Time Finish	Number of Trainees	Remarks	Evaporative Sweat Loss Kg/hr	Total Heat Load Cal/hr	Change Body Temp °F	Change Pulse Rate	ETR °F	Dry Bulb °F	Wet Bulb °F	Wind mph	Black Globe °F	WBGT °F
	1. INDIVIDUAL MOVEMENT BY DAY													
8/17	1300	1336	5		.77	447			79	79	65	2.2	100	76
8/16	1250	1425	15	lecture and march to qtrs.	.62	360			88	90	75	2.3	118	88
	2. OBSTACLE COURSE													
9/1	1240	1325	11		.52	302			78	78	63	4.4	100	74
8/27	0645	0605	9		.39	226			61	65	63	1.8	65	64
8/23	0650	0815	7		.39	226			64	66	63	0.7	67	64
8/26	0645	0745	2		.27	157			73	75	70	1.5	81	73
8/25	0655	0825	8		.25	145			71	72	70	0.9	74	71
	3. INDIVIDUAL COVER AND CONCEALMENT													
8/16	1150	1540	11*		.73	423	1.9	31	88	94	76	2.5	117	88
	4. FIRE TEAM AND SQUAD PRACTICE													
8/24	1530	1609	11*	defense	.64	371	.6	30	84	87	74	3.6	106	84
8/24	1155	1330	11*	defense	.61	353		-11	82	83	71	3.5	103	81
8/23	1145	1515	11	defense	.42	243			81	79	67	2.0	105	78
8/24	1330	1530	11	lecture	.35	203			84	87	74	3.1	107	84
8/25	0645	1052	11*	attack	.25	145	1.5	53	79	79	73	1.5	91	79
	5. FIRE AND MANEUVER													
8/19	1010	1040	11*		.62	360	1.4	49	84	82	73	1.7	105	82
8/19	0645	1010	11		.24	139			75	72	68	1.9	86	73

* Tests selected for studying climatic heat loads on trainees.

Date 1954	Time Start	Time Finish	Number of Trainees	Remarks	Evaporative Sweat Loss Kg/hr	Total Heat Load Cal/hr	Change Body Temp °F	Change Pulse Rate	ETR °F	Dry Bulb °F	Wet Bulb °F	Wind mph	Black Globe °F	WBGT °F
	6. RIFLE RANGE													
8/10	1412	1515	9*	butts	.54	313	-.1	-5	82	87	70	2.2	103	80
8/10	1015	1120	11		.31	180			80	79	70	2.8	98	78
8/10	0930	1145	9	mostly recumb't	.22	129			80	79	70	2.8	98	78
	7. CALESTHENICS WITH RIFLE													
8/11	0708	0755	10		.41	238			68	67	63	0.6	72	66
8/9	0700	0825	11		.21	122			67	74	66	4.4	77	70
	8 and 9. MARKMANSHIP TRAINING, OR M.T. PLUS DRILL AND COMMAND													
8/9	1410	1645	11*	exercise 9	.46	267	.4	6	80	86	74	3.3	94	80
8/4	1420	1600	11*	" 8	.44	255	.2	8	82	89	68	4.4	107	80
8/4	1200	1420	10*	" 8	.41	237	-.2	8	80	87	67	2.8	102	78
8/6	0915	1020	11	" 9	.29	168			72	74	64	3.6	87	71
8/9	0825	1000	11	" 8	.25	145			72	76	68	4.8	85	73
8/6	0655	0915	10	" 8	.14	82			70	69	65	2.8	82	70
	10. DRILL AND COMMAND													
8/20	1406	1510	18*		.75	435	.5	21	88	91	76	1.7	118	89
7/29	1205	1250	9*		.70	406	.4	23	85	95	69	2.5	117	83
8/20	1008	1056	9*		.58	336	.1	12	84	81	74	1.1	103	83
7/29	1430	1602	11*		.57	330	1.0	41	84	97	69	4.8	114	82
8/18	1455	1600	9		.52	301			78	79	68	4.7	99	77
7/30	1255	1355	12*		.47	273		16	88	96	75	2.5	118	88
8/23	1312	1406	12		.47	273			81	79	67	1.9	105	78
8/12	1420	1630	14	and ceremonies	.46	266			80	83	64	3.0	105	76
8/20	0908	1008	10*		.43	249	.1	16	80	77	73	0.9	92	79
8/9	1510	1615	9*		.42	243	.4	25	78	86	73	3.8	92	79
8/9	1000	1045	11		.41	237			74	78	69	3.8	86	74
8/27	0825	0900	5		.39	226			66	68	64	2.2	73	67
9/1	0959	1127	8		.33	191			75	75	63	3.3	95	72
8/14	0920	1100	12		.32	186			79	78	64	2.6	102	75

*Tests selected for studying climatic heat loads on trainees.

Date 1954	Time Start	Time Finish	Number of Trainees	Remarks	Evaporative Sweat Loss Kg/hr	Total Heat Load Cal/hr	Change Body Temp °F	Change Pulse Rate	ETR °F	Dry Bulb °F	Wet Bulb °F	Wind mph	Black Globe °F	WBGT °F
9/1	0737	0915	10		.28	162			72	66	60	1.1	87	68
8/27	1511	1628	11		.26	151			74	72	69	1.2	82	73
8/3	1520	1610	12*		.24	139	.6	24	78	87	68	3.5	97	76
7/30	0717	0857	11*		.18	104	1.2	-3	80	79	70	0.9	96	78
	11.	INDIVIDUAL CAMOUFLAGE AND MARCHING												
8/13	1150	1515	12		.47	273			78	79	62	3.2	100	73
8/12	0640	1015	8		.28	162			69	68	57	2.5	84	65
	12 and 13.	KNIFE FIGHTING, OR BAYONET DRILL AND MARCHING												
8/20	0650	0815	7*	exercise 13	.28	162	.4	35	78	73	71	0.9	89	76
8/18	0800	0925	5	ex. 12, dem. & drill	.26	151			66	67	63	2.4	74	66
8/18	0655	1055	10	ex. 12, lect.& drill	.19	110			66	67	63	1.8	72	66
8/18	0650	0800	6	ex. 12, " " "	.19	110			64	66	62	1.2	69	64
	14.	ADMINISTRATIVE MARCH BY DAY												
8/17	0935	1050	20		.66	383			72	72	64	3.3	86	71
8/16	0855	1055	5*		.60	348	.6		86	87	76	2.5	107	85
8/16	0900	1050	9*		.53	307	.6	32	85	87	75	2.5	107	85
8/24	0640	0900	18		.46	267			66	66	63	2.2	74	66
8/23	0640	0940	11		.44	255			71	70	64	0.9	80	69
8/16	0650	1100	9*		.35	203		36	82	82	74	1.9	99	81
8/16	0640	0900	8*		.23	133			79	76	72	1.4	90	77
8/17	0650	0935	20		.21	122			72	72	67	2.4	84	72
	15.	TACTICAL MARCH AND ADMINISTRATIVE BIVOUAC												
8/25	1235	1550	20*		.56	325	.9	34	85	90	75	2.4	105	84
8/26	1130	1605	16		.41	237			84	88	74	3.1	106	84
8/26	1130	1245	8	resting	.25	145			87	88	73	2.7	116	86
	16.	TACTICAL MARCH NIGHT												
8/4	1820	2300	11		.38	220			67	77	65	1.9	74	68
8/31	1825	2225	5	10 miles	.38	220			60	67	60	1.5	65	61
8/12	1935	2215	9		.35	202			60	68	57	1.9	66	60

*Subjects selected for studying climatic heat loads on trainees

Page 4 - Table 2

Date 1954	Time Start	Time Finish	Number of Trainees	Remarks	Evaporative Sweat Loss Kg/hr	Total Heat Load Cal/hr	Change Body Temp °F	Change Pulse Rate	ETR °F	Dry Bulb °F	Wet Bulb °F	Wind mph	Black Globe °F	WBGT °F
8/18	1825	2245	10		.31	180			63	69	65	2.2	68	66
8/3	1950	2305	12		.25	145			68	73	64	1.1	73	67
8/11	1845	2300	11		.25	145			60	68	57	1.9	66	60
	17. COMBAT SIGNAL AND FORMATION													
8/18	1440	1550	6		.42	243			78	79	68	4.7	99	77
	18. OBSERVING													
8/30	1420	1525	10*		.40	232			81	83	71	4.8	101	80
8/30	1525	1555	9*		.36	208	-.2	31	80	84	70	2.2	98	79
8/30	1150	1420	10*		.31	180			82	83	73	3.6	102	82
8/31	0650	1104	9		.13	76			63	67	59	5.1	76	64
	19. CEREMONIES													
9/1	1330	1625	6		.33	191			79	79	63	3.7	103	75
9/1	1327	1525	12		.28	162			79	79	63	3.7	103	75

*Tests selected for studying climatic heat loads on trainees.

TABLE 3

TRAINEES REACTIONS TO TRAINING PROGRAM
Marine Corps Schools, Quantico, Virginia, July - September, 1954

Written response to question "Have you felt physically exhausted after any of the exercises in the present program"

Affirmative		No. of Trainees
Obstacle course		23
Individual cover and concealment		16
Tactical march and administrative bivouac		15
Marching double time		14
Tactical and administrative marches		8
Calisthenics		3
Exercise not specified		46
	Total affirmative	125
Negative		143
	Total responding	268

When two or more exercises were specified only that first mentioned is listed. Each affirmative answer therefore represents a separate trainee.

TABLE 4

CORRELATION BETWEEN HEAT INDEXES
AND
PHYSIOLOGICAL HEAT STRESS AND STRAIN CRITERIA
Twenty-seven training exercises
Marine Corps Schools, Quantico, Virginia, July - September, 1954

Heat Indexes	Mean Evaporative Sweat Rate	Mean Change in Body Temp.	Mean Change in Heart Rate
Effective Temperature including radiation (ETR)	.799 ± .071	.317 ± .201	.076 ± .212
0.7 wet bulb + 0.3 black globe temperature (WBGT)	.783 ± .076	.360 ± .195	.158 ± .208
Black globe temperature	.766 ± .081	.226 ± .186	.005 ± .213
Standard Effective Temperature (ET)	.722 ± .093	.348 ± .197	.146 ± .209
Dry bulb temperature	.617 ± .121	.165 ± .218	.005 ± .213
Wet bulb temperature	.406 ± .164	.339 ± .198	.287 ± .196

TABLE 5

LIMITS OF TEMPERATURE AND HUMIDITY GOVERNING SUSPENSION
OF
PHYSICAL TRAINING AT MARINE CORPS RECRUIT DEPOT, PARRIS ISLAND
Summer of 1954

Dry Bulb Temp. °F	Relative Humidity %	ETR corresponding to limiting values in columns 1 and 2, with overcast sky and no wind	with overcast sky and 5 mph wind	with full sunshine and no wind	with full sunshine and 5 mph wind
90	70	85	81	91	88
91	68	"	81	91	88
92	63	"	81	92	88
93	60	"	82	92	88
94	55	"	82	92	88
95	50	"	82	91	87
96	45	"	82	91	87
97	40	"	82	90	87
98	38	"	82	90	87
99	34	"	82	90	87
100	30	"	82	90	87

TABLE 6

CORRELATION COEFFICIENTS BETWEEN THE LOGARITHM OF HEAT CASUALTY RATES AND HEAT INDICES, FOR ETR'S OF 83°F AND ABOVE

Heat Index	Quantico 1954 Junior PLC's	Quantico 1954 Senior PLC's	Camp Lejeune 1954 New Reservists	Camp Lejeune 1954 Recruit Graduates	Parris Island 1952-53 Recruit Trainees	Weighted Mean
Dry bulb temp.	.519 ± .183	.271 ± .225	.340 ± .159	.194 ± .185	.625 ± .064	.470
Wet bulb temp.	.000 ± .250	.454 ± .193	.242 ± .169	.245 ± .181	.527 ± .076	.146
Black globe temp.	.335 ± .222	.049 ± .243	.323 ± .161	.192 ± .185	.567 ± .071	.402
WBGT(1)	.274 ± .231	.388 ± .206	.390 ± .152	.329 ± .172	.660 ± .059	.505
ETR(2)	.511 ± .185	.398 ± .204	.367 ± .155	.332 ± .171	.635 ± .063	.511
No. of observations	16	17	31	27	91	182

(1) WBGT = 0.7 wet bulb temp. + 0.3 black globe temperature

(2) ETR = Effective temperature including the radiation component

TABLE 7

INCIDENCE AND RATES, DEATHS AND SICK DAYS FOR SELECTED DIAGNOSES
Navy and Marine Corps: 1942 - 1953

YEAR	HEAT CRAMPS				HEAT PROSTRATION				SUN STROKE			
	Incidence		Deaths	Sick Days	Incidence		Deaths	Sick Days	Incidence		Death	Sick Days
	Number	Rate			Number	Rate			Number	Rate		
1942	21	2.5	-	246	366	43.8	-	1557	64	7.7	3	362
1943	68	3.2	-	286	832	39.5	4	3999	191	9.1	2	1077
1944	105	3.1	-	546	1246	37.2	4	6166	212	6.3	3	1458
1945	76	2.1	-	383	1013	27.6	1	4759	155	4.2	2	1090
1946	29	2.2	-	155	212	16.0	-	801	25	1.9	-	114
1947	11	1.9	-	102	97	16.5	-	337	23	3.9	-	91
1948	13	2.6	-	46	101	19.9	-	422	19	3.7	-	74
1949	13	2.4	-	72	121	22.6	-	466	12	2.2	-	44
1950	14	2.6	-	56	127	23.6	-	415	9	1.7	-	203
1951	18	2.0	-	94	355	38.8	-	1098	25	2.7	1	242
1952	24	2.3	-	71	598	56.8	-	1247	16	1.5	2	113
1953	20	1.9	-	84	235	22.3	-	1113	18	1.7	3	211
Mean rates per 100,000		2.4				30.3				3.8		

TABLE 8

HEAT CASES: NUMBER ADMITTED TO SICK LIST COMPARED WITH TOTAL CASES
Marine Corps Bases, June - August, 1954

	Admitted to Sick List	Total Cases
MCRD, Parris Island, S.C.	9	84
MCB, Camp Lejeune, N.C.	9	188
MCS, Quantico, Va.	15	96
Total	33	368

TABLE 9

MONTHLY INCIDENCE OF HEAT RASH
U.S. Marine Corps Recruit Depot, Parris Island, S.C.
Rates per 10,000 Average Strength
Parentheses show number of cases

Month	1952				1953				1954 (1)			
	Average Strength	ETR °F	Total Rate	Admiss. Rate	Average Strength	ETR °F	Total Rate	Admiss. Rate	Average Strength	ETR °F	Total Rate	Admiss. Rate
May	13720	80	11 (15)	0 (0)	5985	81	53 (32)	0 (0)	8645	75	3 (3)	0
June	8955	85	232 (208)	0 (0)	4110	81	95 (39)	0 (0)	8315	83	14 (12)	0
July	6140	85	682 (419)	1.6 (1)	5615	84	223 (125)	1.8 (1)	10080	85	169 (170)	4 (4)
Aug.	4505	85	1040 (468)	4.5 (2)	4680	82	930 (437)	4.3 (2)	9410	86	195 (184)	0
Mean	8330	84	491	1.5	5098	82	325	1.5	9112	82	95	1.0

(1) Preventive measures in full force for reducing heat casualties.

TABLE 10

INCIDENCE OF HEAT EXHAUSTION BY HOME STATE
Marine Corps Reserve Trainees on Two Weeks Active Duty
at
Camp Lejeune, N.C., June - August, 1954

	Northern States				Southern States		
	Men	Heat Cases	Rate per 10,000		Men	Heat Cases	Rate per 10,000
Del.	39	4	1025	Ga.	277	13	469
N.J.	178	17	955	Ky.	140	4	285
N.Y.	590	36	610	S.C.	126	1	79
Ill.	51	3	588	Ala.	34	0	0
Ind.	245	12	489	Fla.	95	0	0
Mass.	569	25	439	N.C.	161	0	0
Minn.	28	1	357	Tenn.	294	0	0
Iowa	35	1	285	Va.	197	0	0
Ohio	309	8	258	W.Va.	82	0	0
Penna.	675	17	251				
Md.	46	1	217				
Mich.	373	5	134				
Wis.	114	1	87				
Conn.	118	1	84				
D.C.	234	0	0				
Maine	37	0	0				
Vt.	16	0	0				
N.H.	35	0	0				
TOTAL	3692	132	357	TOTAL	1406	18	128

TABLE 11

HEAT CASES: ACTIVITY AT TIME OF ONSET IN 181 MARINE CORPS TRAINEES
MCB, Camp Lejeune, N.C., June - August, 1954

Activity	Reserves on Two Weeks Training Duty (%)	Recruit Graduates (%)
Outdoor class	29	19
Marching	20	6
Field problem	16	48
Infiltration course	6	13
Miscellaneous	29	14
	100	100

APPENDIX 1

Guide to Aid in Prevention of Heat Casualties

1. Body Heat and Environment. Body temperature is the resultant of the rate of heat production and heat loss. Muscular activity greatly increases heat production. Loss of body heat by radiation and convection, two important methods, diminishes and eventually ceases as the environmental temperature approaches that of the body. Dissipation of body heat by the evaporation of sweat, the most important mechanism under exercise conditions, is greatly reduced when the relative humidity is high. Serious heat illness is rare at wet-bulb thermometer readings of less than 75°F.; above this level the likelihood of dangerous heat injury parallels the temperature. Careful assessment of physical demands on personnel, particularly those who are unacclimatized and unconditioned, should be continuous at temperatures above this reading.

2. Nature of Heat Injury. The two most serious types of heat injury are heat prostration (heat exhaustion) and heatstroke (sunstroke). In heat prostration the heat-dissipating mechanisms of the body are overactive; in heatstroke they are completely overwhelmed.

a. Heatstroke, a serious threat to life, occurs incident to vigorous physical activity or after prolonged exposure to high temperature, particularly if accompanied by high humidity and lack of air movement. Diminution or even cessation of sweating may occur in advance of obvious symptoms and should serve as a warning. Other warning symptoms are weakness, headache, giddiness or dizziness, and loss of appetite or nausea or vomiting. Actual apparent onset is usually sudden. The skin will be flushed, hot, and dry. In addition to diminution or cessation of sweating the victim will experience weakness, fatigue, possibly shortness of breath, faintness, and even collapse. Delirium, progressing to unconsciousness, will appear if exposure is continued and may occur shortly even with rest if relief of high temperature of body is not provided. Convulsions may occur.

b. Heat prostration also occurs under conditions of heat stress. There may be warning symptoms such as a general feeling of illness, headache, dizziness, weakness, poor vision, and nausea or vomiting for some time before the actual onset. When the injury becomes manifest the appearance of the person is that of shock, with pallor and a cold, clammy, wet skin.

3. Susceptibility of Personnel. Personnel who are not accustomed to physical activity under conditions of high temperature, especially when high temperature is accompanied by high humidity, are particularly susceptible to heat injury. This is especially true of individuals who are 10 or more pounds over standard weight. A period of approximately 2 weeks with gradually increasing exertion or physical training is necessary for conditioning and acclimatization. During this period the physical workload should be increased gradually, but

should not be such as to lead to exhaustion or to cause personnel to awaken unduly fatigued on the following day. Until acclimatized, greater-than-normal quantities of water and salt are lost as perspiration, and particular attention must be paid to their replacement.

4. Preventive Measures. The following measures are of value in the prevention of heat injury. Use of any or all of them may be necessary during periods of heat stress:

a. Meals. The heavy meal of the day should be served in the evening and following a rest period rather than at noon, unless activities involving considerable physical exertion are scheduled following the evening meal. An hour of rest following the noon meal is beneficial.

b. Clothing. Clothing and equipment should be worn so as to permit free circulation of air between the uniform and the body surface. Wearing shirt collars, shirt cuffs, and trouser bottoms open will aid in ventilation. In the presence of full sunlight, keeping the body covered by clothing aids in reducing the solar heat load. Where exposure to sunlight is not a factor, removal of clothing assists in reducing body temperature.

c. Water. Water and salt are required in quantities sufficient to replace amounts lost in sweat and urine. The belief that individuals can be taught to adjust to decreased water intake is incorrect. Under conditions of heavy sweating 1 quart or more of water per individual per hour will be required. This is best taken in small quantities at rather frequent intervals, such as every 20 or 30 minutes. The optimum temperature for this drinking water is 65°-70°F.

d. Salt. While the diet ordinarily provides 10-15 grams (2-3 level teaspoons) of salt daily, increased intake is almost certainly necessary under elevated temperatures where there is excess sweating. (This may not apply equally in some individuals, particularly in older age groups, who may tend to retain excessive salt in the body.) This is best supplied at mealtime. However, it may be furnished by provision in drinking water as a 0.1 per cent solution or by supplying salt tablets. Excess salt should be avoided as it may cause increased thirst, nausea, diarrhea, and vomiting.

e. Rest Periods. When conditions are severe or activity strenuous, and particularly when personnel are not yet fully conditioned short periods of work alternated with short periods of rest are to be followed except under emergency conditions.

f. Predisposition. One attack of heatstroke presages the occurrence of a second. Individuals who have been affected should be reexposed to the precipitating conditions with caution, and especially observed during exposures. Severe prickly heat results in decreased ability to perspire in the afflicted skin areas for an indefinite period of time. Such individuals are more prone to develop heatstroke.

g. Training Schedules. Modification of training schedules may be necessary. This may consist of amending schedules to place the most strenuous activities during the cooler portions of the day or of substituting activities calling for less physical activity on particularly hot days. It may also require a slowup in a training program in hot, humid weather. These modifications should not deprive personnel of normal amounts of sleep. Those poorly conditioned individuals who do not gain normal or average recuperation from sleep may require a slower conditioning program.

h. General Health. Maintenance of good physical condition and avoidance of undue fatigue are important. In acclimatizing personnel, they should not be so fatigued that they do not awaken refreshed after a night of rest. Mild illnesses such as respiratory infections, diarrheas, or reactions to immunizations which do not ordinarily interfere with duty may increase susceptibility to heat injury. Also, poor physical condition, lack of muscular firmness, overweight, alcoholic indulgence, lack of sleep, and relatively poor cardiovascular response to exertion (manifested as unduly rapid pulse rate or poor pulse rate response to exercise) tend to increase susceptibility to heat injury and constitute warning signs requiring special individual attention and possibly a slowing up in the individual training program.

5. First Aid. It is essential that leaders of small units carefully observe their personnel when under conditions of heat stress. Flushing of the skin is often the first sign noted, and while it may not by itself signify that injury is imminent, men presenting this appearance should be carefully observed. If, in addition, dizziness, headache, stumbling or other signs of weakness, undue fatigue, stomach upset, or changes of the skin such as those mentioned in paragraphs 2a and b, appear, the person so affected should be removed from further exposure and receive rest, and, if necessary, first aid. Mild cases will become serious if continued activity is permitted. First-aid measures include cessation of physical activity, removal to a cool, shady location, if available, and loosening of clothing and equipment. If the case appears to be one of heatstroke, the person should be sponged with ice or ice water, if available, otherwise with cold water; movement of air should be instituted by fanning, such as with a shirt, if necessary; and medical aid summoned. If heat prostration is suspected and the patient is conscious, he should drink salted water, cool if possible (0.1 per cent solution). Individuals suffering from heat prostration or heatstroke should be handled as litter cases. Ambulances and hospital corpsmen properly instructed in the symptoms and care of heat injury should accompany units training at any distance from fixed medical facilities when conditions which may cause heat injury exist. Ambulances should be adequately ventilated or cooled to prevent further insult to patients in transit. Fixed medical installations should be prepared to render prompt emergency care to heat-injury patients evacuated to them.