Dehydration in Man in a Semi-arid Climate

by

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INTRODUCTION [o]

The extremely high temperatures and the small amount of precipitation which prevail during the spring and summer months in the semi-arid areas of southwestern United States suggested the problem of attempting to determine whether or not an erythrocytosis or concentration of the body fluids obtains in the blood of normal, human males during these months. Certainly the concentration of blood, its chemical relationships and the physical qualities such as viscosity are of considerable importance to the well-being of the individual.

It has been pointed out in an Editorial from the Journal of the American Medical Association (1928), that desiccation of the blood to even a slight degree results in impairment of the circulation, and, as a result, in secondary functional disturbances of almost every part of the body. Since the physiologic effects of loss of water are referable to blood concentration, the condition of the blood serves as an index to the degree of dehydration of the body

[o] The writer wishes to express his thanks to Dr. G. T. Caldwell, under whose direction this study has been carried out, for his helpful suggestions and advice.

as a whole. The problem of fatigue at high temperatures has been studied in connection with men working on the Hoover Dam in Arizona, reported by Zwalenburg (1933). Treatment of this fatigue was based on the assumption that heat exhaustion resulted from a concentration of tissue fluids and loss of chlorides by dehydration; the consumption of an abundance of table salt with large amounts of water reduced the death rate at the Dam caused by heat exhaustion from 17 in 1931, to no deaths in 1932. Dragstedt and Ellis (1930), found that gastric secretion was profoundly affected by alterations in the water content of the blood. Loss of water in the blood showed the chloride ion to be of great importance, and where there was sufficient deficiency of this ion in the blood to cause illness of their experimental dogs, they found that intravenous injections of Ringer's solution did considerable to correct the condition of loss of appetite and general debilitation. Jordon (1931), and Peters and Van Slyke (1931), state that profuse perspiration results in an increase in the number of red corpuscles per cubic millimeter of blood. Clough (1929), and Wintrobe and Miller (1929), consider such relative polycythemic conditions transient phenomena and differentiate this type from other secondary polycythemias such as increases due to changes in altitude or conditions of shock where the total number of red corpuscles in the body may be increased within a relatively short time.

Previous workers who have experimentally investigated this primary type of erythrocytosis have had their subjects perform quite vigorous work to produce sweating, or else the subjects were sweated by hot,water baths. It is not unreasonable to assume that such unusual muscular exertion might introduce factors which could not be controlled. An example of such a factor would be the alteration of the chemical constituents of the blood fluid and salts because of the greater respiratory and muscular activity thereby necessitated. With the knowledge of the fact that the spleen serves as a reservoir for red corpuscles, it has been shown by Barcroft (1930) that various physiological states such as emotion, exercise, etc., will cause an increase in the number of red corpuscles in the circulating blood. Barcroft, working with dogs, found that the exteriorized spleen was reduced in size by 50 per cent when the dog heard a cat mew in an adjacent room. It may be seen then that there is every necessity for controlling physiological factors in an experiment of this type. Under the conditions of these experiments, the individuals were leading a normal existence but subject to the high temperatures and low humidity which prevail throughout a considerable portion of the year.

The subjects selected for these experiments were mainly students and instructors in the University of Arizona. They led a normal life physically, were not engaged in any heavy labor in the sun, and had access to free water at all

times. The ages ranged from nineteen to about forty years; neither very corpulent nor very thin men were selected as subjects. Initial erythrocyte counts and hemoglobin determinations were made on all subjects selected to eliminate any who might have been anemic.

In this study, erythrocyte enumerations and hemoglobin determinations were made on 20 normal, healthy, adult males at intervals of approximately 30 days for the period of June 1932 to June 1933. Refractive indices of the blood plasma of 14 of the same individuals were made monthly for a period of six months in 1933 and 1934 in an effort to determine whether the plasma of the blood would show concentration by this method. Unfortunately it was not possible to continue these determinations throughout the summer months. Hemoglobin determinations, erythrocyte enumerations, and refractive indices were compared with each other and with mean temperatures and total evaporation values in an effort to find a possible explanation for any variation in the concentration of body fluids that might exist.

MATERIALS AND METHODS

Trenner automatic pipettes graduated to 0.5 and 201 were used for erythrocyte enumerations. Filtered Hayem's solution was used as the diluting fluid throughout all the experiments. The counting chamber was of the Improved Neubauer-Levy type and this same hemocytometer with its cover slip was used for all counts. Eighty squares of the counting chamber were counted. Two counts were made from each pipette and the average of these two counts was taken as the final result. It was observed that when making the counts during the summer months only one minute could be allowed for the corpuscles to settle to the floor of the chamber, instead of the three minutes that Kolmer and Boerner (1931) suggest, because of the rapid evaporation and concentration of the diluted blood. Otherwise, the technique as outlined by the co-authors just mentioned was followed throughout. It was noted that during the summer months coagulation occurred much more rapidly than during the cooler seasons.

A Newcomer-Williamson colorimeter was used for making all the hemoglobin determinations. This instrument was fastened to a stationary base as was the lamp which illuminated it, for if light came from even slightly different angles, different readings would be obtained from the same sample. The mirror of the colorimiter was likewise made stationary.

All other light except that from the colorimeter was excluded by making the readings at night in a darkened room. A 1 per cent solution of hydrochloric acid was made up in sufficient quantity to last throughout the entire group of experiments and was stored in sealed bottles. The preparation of the hematin solution was made according to the directions given by Newcomer (1930). The solution was allowed to stand at least 24 hours and was usually read before 48 hours had elapsed, although according to Newcomer (1930), "..... under the above conditions of preparation the hematin solution assumes in an hour a spectrophotometric condition which remains nearly constant for several days and even for several weeks". Results were recorded in grams of hemoglobin per 100 cubic centimeters of whole blood. An attempt was made in all these experiments to standardize methods of collection of blood and the subsequent handling in so far as was possible. Distilled water from the same source was used for all the hemoglobin determinations. All samples of blood were drawn from the subjects at approximately the same hour of the day to control any possible diurnal variation which according to Dreyer, Bazett, and Pierce (1920) may amount to a considerable per cent of the average contents.

Refractive indices of the blood plasma were obtained by the use of the Abbe refractometer [o]. Because of the limited

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[o] The writer is indebted to Dr. R. S. Hawkins, Head of the Department of Agronomy, University of Arizona, for use of the Abbe refractometer.

amount of blood that could be withdrawn from a skin puncture of the subject's finger, a special tube was constructed from glass tubing for use in centrifugalization of the blood. The tube was 6 centimeters long with an outside diameter of 3.5 millimeters and an inside diameter of 2 millimeters. One end of the tube was left open and the other end drawn out so that a number 28 wire could just be inserted. Both ends were smoothed by grinding with FFF carborundum so that a perfect seal could be made with a rubber band in order that no blood would be lost in the process of centrifugalization. A solution of 10 milligrams of heparin to 1 cubic centimeter of an 0.85 per cent solution of sodium chloride was used as an anti-coagulant. This solution was heated to thirty degrees Centigrade and when the heparin was completely dissolved the solution was filtered. Reed (1929) found that the use of heparin as prepared according to Howell and Holt (1918) had no detectable effect on any physical or chemical property of the blood, so far as could be determined, except coagulation time, and approved its use as an anti-coagulant agent in the preparation of blood samples for chemical or physical analyses. Finger punctures made with a spring lancet provided blood for all samples used in the different determinations.

Heparin solution was drawn into the plasma tube and blown out before filling it with blood. After the tube was filled about three fourths full of blood, a wire loop 1.5 millimeters in diameter was dipped into the heparin solution and then

mixed with the blood. This completely prevented coagulation during centrifugalization. The centrifuge, with the tubes balanced and in place, was adjusted to an approximate speed of 4000 revolutions per minute and allowed to revolve for 20 minutes at this rate. The narrow opening of the tube was so placed that it was toward the periphery of the plane of centrifugal force. A small bore glass tube similar to a bacteriological Pasteur pipette was drawn out and served to transfer the plasma layer to the prism of the refractometer; this arrangement provided more than sufficient plasma for the determinations. Three series of determinations were made on the author's blood at various temperatures within the range of the experimental determinations, to formulate a curve for temperature corrections, since it did not prove practical to bring the temperature of the plasma in the refractometer to a constant for each sample of blood. The determinations which formed the basis for temperature corrections were taken three times and the averages plotted (Fig. 1). All experiments were referred to this curve for correction to 20 degree Centigrade. In gathering samples for refractive index determinations, care was taken to obtain them under comparable conditions with respect to time elapsed since the last meal, exercise, etc., as suggested by Tranter and Rowe (1915). The finger puncture was made deep enough and wide enough so that a large drop of blood welled up of its own accord; squeezing the finger was not resorted to as this might have forced out

tissue fluids other than blood.

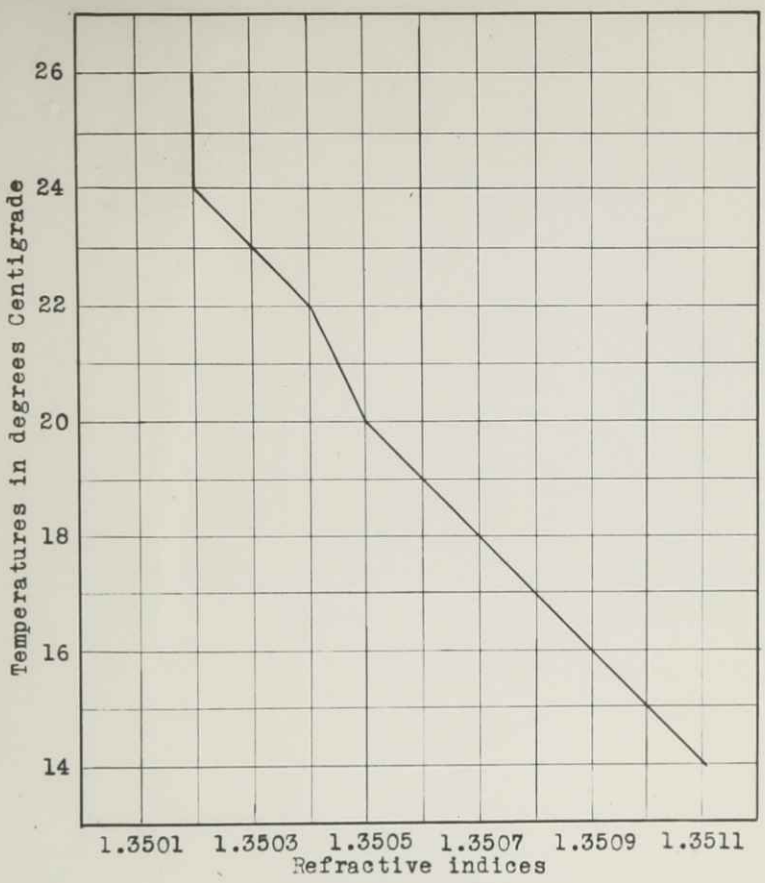

Fig. 1. Curve of temperature corrections for refractive indices of human blood plasma.

EXPERIMENTAL RESULTS

Erythrocyte Enumerations

The average monthly erythrocyte enumerations beginning June 1932 and ending June 1933 are given in Table I.

TABLE I

Erythrocytes in millions per cubic millimeter of blood.

Month	Year	Monthly average of 20 Subjects	Minima	Maxima
June	1932	6.87	5.93	7.88
July	1932	6.57	5.14	8.31
August	1932	6.36	5.02	7.90
September	1932	5.90	4.63	7.05
October	1932	5.91	5.61	6.30
November	1932	6.17	5.56	6.74
December	1932	6.11	5.35	6.73
January	1933	5.38	4.80	6.78
February	1933	5.93	4.80	6.53
March	1933	5.58	5.09	6.23
April	1933	5.69	5.05	6.31
May	1933	5.77	4.98	6.64
Averages		5.97	5.16	6.95

The average erythrocyte count for the summer months of June, July and August of 1932 was 6.6 millions per cubic millimeter or 13.7 per cent higher than the average of 5.8 millions per cubic millimeter for the remaining 9 months and 10.5 per cent higher than the average for the entire

twelve months period. Wintrobe and Landsberg (1933) from experimental results based on blood counts and hemoglobin estimations of 529 Johns Hopkins medical students and male nurses (all male subjects), found the normal erythrocyte count to be 5.4 millions per cubic millimeter with a normal average range of 4.6 to 6.2 millions. These counts were made in the fall after the students had returned to the University from their homes in various parts of the United States (Arizona and New Mexico were not included). The authors found no geographic variation in the normal blood values from various parts of the country. Osgood (1926) and (1927) obtained values very similar to those of Wintrobe and Landsberg.

Altitude has been shown by other workers to have a very pronounced effect upon the number of erythrocytes in human blood. Hurtado (1932), working with 132 normal, male, Indian natives of the Peruvian Andes at an altitude of 14,000 to 15,000 feet, found that the mean value for erythrocyte numbers was 6.6 millions per cubic millimeter at this altitude. Of his subjects, 26 per cent had a count of less than 6 millions per cubic millimeter and 11 per cent had a count less than the normal sea level average; the extreme range was from 4.8 to 10.4 millions per cubic millimeter. Stitt (1927) stated that an altitude of 2,000 feet may increase the red cell count by 200,000 per cubic millimeter and 6,000 feet by 500,000. Applying Stitt's correction factor for altitude, the theoretical average red cell

count for the altitude at which Hurtado worked would be 6.? millions per cubic millimeter. Similarly applying the Stitt factor to the altitude of Tucson, (approximately 2,400 feet) a blood count of 5.7 millions per cubic millimeter would be expected. From Table I it may be seen that the average count for the winter months was 5.8 millions - a rather close check - but not so for the summer months when the average was 6.6 millions of corpuscles per cubic millimeter. Normal ranges for erythrocyte counts are summarized in Table II.

TABLE II

Normal ranges of erythrocyte counts at various altitudes and seasons according to several workers.

Worker	Altitude	Season	Erythrocytes in millions per cu. mm.
Wintrobe Landsberg	sea level	fall	4.6 to 6.2
Hurtado	14,000 ft.	summer	6.3 to 7.0
This work	2,400 ft.	entire year	5.2 to 6.9

Hemoglobin Determinations

The average monthly hemoglobin determinations for the twelve months period of June 1932 to June 1933 are given in Table III.

TABLE III

Hemoglobin in grams per 100 cubic centimeters of blood

Month	Year	Monthly average	Minima	Maxima
June	1932	13.3	12.2	14.0
July	1932	13.5	12.8	15.2
August	1932	12.7	11.8	14.0
September	1932	12.9	12.0	13.8
October	1932	13.1	12.0	13.8
November	1932	13.6	13.1	14.2
December	1932	13.3	12.0	14.0
January	1933	12.8	12.0	14.3
February	1933	13.2	11.0	14.5
March	1933	13.1	11.0	14.0
April	1933	13.2	11.3	14.1
May	1933	13.3	11.0	14.1
Averages		13.16	11.85	14.10

From these data it may be seen that there was no seasonal variation in the hemoglobin content of whole blood throughout the entire twelve months period.

The absence of an accurate, easily handled, standardized method for the determination of hemoglobin tends to make

difficult a comparison of hemoglobin content values as obtained by different types of hemoglobinometers, but does not invalidate a comparison of values obtained with a single instrument when efforts have been made to standardize each step of the procedure. Accordingly, in the present paper, little attempt has been made to compare, value for value, the results obtained with the results of other workers, but rather to compare tendencies and ranges of total data. Wintrobe and Landsberg (1933) give as the normal hemoglobin content value for men, 16.0 grams per 100 cubic centimeters of whole blood. Howell (1933) gives credit to Preyer's statement that the average amount of hemoglobin for the adult male is 14 grams per 100 cubic centimeters of blood. Hurtado (1932), in his work with Peruvian natives found that the normal for his subjects at an altitude of 14,000 feet was 15.93 grams of hemoglobin per 100 cubic centimeters of blood - only 0.07 grams different than the normal sea level average of 16.0 grams which Wintrobe and Landsberg give, and Hurtado's instruments, the Sahli hemoglobinometer and the Newcomer colorimeter had been standardized several times with the oxygen combining power method of Van Slyke and Stadie (1921). The results obtained in the present work check closely with Hurtado's, wherein he found that hemoglobin was a rather constant factor, not subject to a great deal of variation, regardless of altitude.

The hemoglobin content is a relatively stable quantity when the daily results of determinations are studied under

comparable conditions. It is possible that the diurnal variation may equal or even exceed the variations from day to day if the samples are not obtained at the same time each day with the subject under normal dietary and physical conditions. Price-Jones (1931) stressed this stability of the hemoglobin content and also its diurnal variation. There have been other workers in the past who have found hemoglobin to increase in amounts as the altitude increased. Howell (1933) gives a figure from Fitzgerald to show that there is a 30 per cent increase in hemoglobin from the altitude of 10,000 to 16,000 feet, but this work is not accepted by all workers in this field to-day.

Mean Corpuscular Hemoglobin Contents

By calculation, the amount of hemoglobin in one erythrocyte may be determined. The method of Hurtado was used to determine the mean corpuscular hemoglobin content values in these experiments. The measure of the amount of hemoglobin actually contained in one erythrocyte is of importance when studying alterations in either hemoglobin contents or erythrocyte counts, or both, as it is a means of comparing these two determinations in a single figure. Since it has been previously shown in this work that the number of erythrocytes per cubic millimeter increased during the warmer months, an inverse correlation between mean corpuscular hemoglobin content values and erythrocyte counts would be expected. This inverse correlation is shown in Figure 2.

A similar correlation between mean corpuscular hemoglobin content values and temperature and evaporation values is shown in Table IV. There was a 12.9 per cent increase in the mean corpuscular hemoglobin content values during the latter nine months over the months of June, July and August. A comparison of the coldest months, December 1932, January and February 1933, with these summer months shows an increase of 14.2 per cent. The average for the entire twelve months was 22.39 micro micro grams per erythrocyte; the individual extreme range was from 17.0 to 27.7 micro micro grams and the

range of monthly averages was 19.65 (June 1932) to 24.08 (January 1933). Hurtado found a 15 per cent decrease in the mean corpuscular hemoglobin content at 14,000 feet when com-

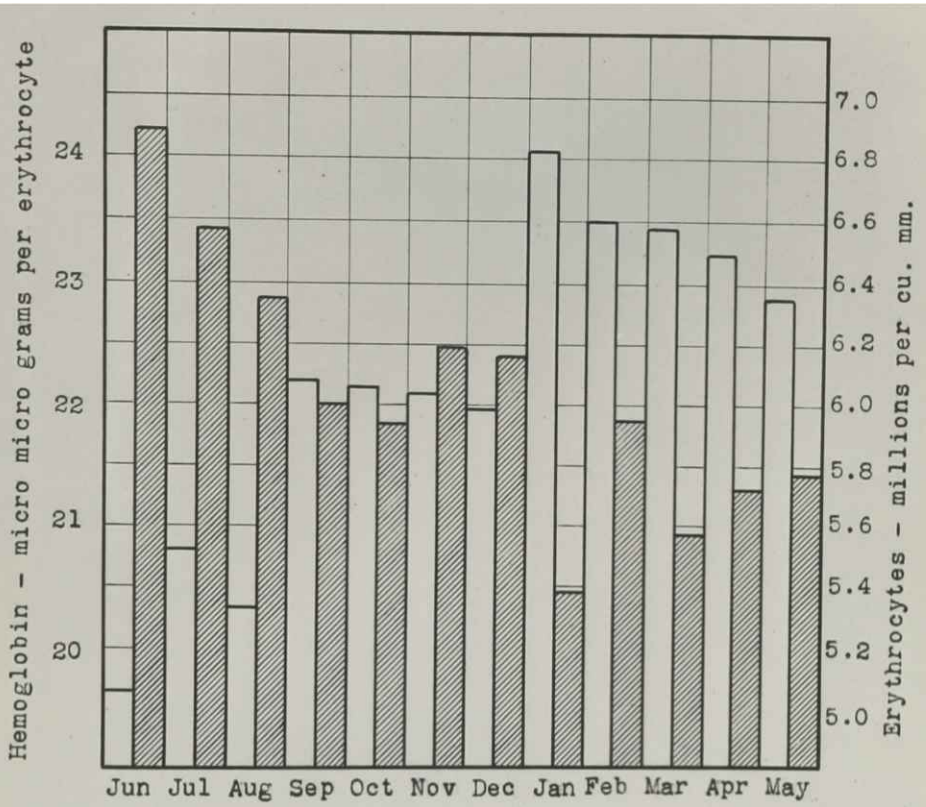

Fig. 2. A comparison of the average monthly erythrocyte counts (on the right ordinate - cross-hatched areas) with mean corpuscular hemoglobin contents (on the left ordinate - blank areas) for the year 1932-33.

pared with sea level values. This decrease would naturally be expected since the erythrocyte values for the high altitudes were greater compared to sea level erythrocyte counts.

TABLE IV

A comparison of the monthly mean corpuscular hemoglobin content averages with mean temperature and evaporation rates.

Month	Year	Monthly mean corp. hemo. contents in micro micro grams per erythrocyte	Average monthly temperature in degrees Fahrenheit	Total monthly evaporation in inches
June	1932	19.65	79.1	13.03
July	1932	20.76	85.2	10.95
August	1932	20.26	85.2	10.15
September	1932	22.15	80.6	10.73
October	1932	22.13	67.8	6.34
November	1932	22.05	60.0	4.95
December	1932	21.93	47.2	2.23
January	1933	24.08	47.7	2.61
February	1933	23.49	47.5	3.37
March	1933	23.45	57.8	6.99
April	1933	23.25	60.0	9.01
May	1933	22.94	67.1	11.48

Refractive Indices of Blood Plasma

The refractive indices of the blood plasma of 14 of these individuals for a period of 6 months, are shown in Table V. The highest monthly average was 1,3517 and the lowest 1.3508. There was no correlation of these figures with the temperature or evaporation rates. The values as a whole are rather constant . This constancy has been observed by some workers, Barnett, Jones and Cohn (1932). They found that normal plasma protein concentration was maintained in spite of repeated protein loss by bleeding. Kerr, Hurwitz, and Whipple (1918), in an earlier work found that normal plasma protein concentration was not maintained and that protein regeneration was a slow process. This work showed little individual variation and only a slight monthly average variation. Neuhausen and Rioch (1923), using the index of refraction of blood sera as a means of calculating the protein content of the sera, found considerable individual variation. The refractive indices of their subjects' sera ranged from 1,3511 to 1,3547, or translated into terms of percentage protein content, 8.2 to 9.96 per cent. Broadly speaking, blood serum is blood plasma minus fibrinogen. Fibrinogen, according to Howell (1933), amounts to .42/7.26 or 5.7 per cent. It may therefore be seen that the refractive indices of sera and plasma should not differ greatly.

Normal blood plasma contains from 6 to 8 per cent protein according to Howell (1933) and investigations have shown that this protein content is maintained with considerable constancy; this would indicate that protein concentration is of extreme importance in the functions of the blood.

TABLE V

Refractive Indices of Blood Plasma

October 1933			
No. of Subject	Refractive index of plasma	Temp. °C	Refractive index corrected to 20°C
1	1.3520	25.5	1.3528
2	1.3505	22.3	1.3506
3	1.3510	23.5	1.3512
4	1.3518	23.5	1.3520
5	1.3517	23.5	1.3519
6	1.3511	23.5	1.3513
7	1.3517	23.5	1.3519
8	1.3514	24.3	1.3517
9	1.3508	24.0	1.3511
10	1.3514	23.3	1.3516
11	1.3517	24.0	1.3520
12	1.3517	23.5	1.3519
13	1.3500	22.0	1.3501
14	1.3509	23.5	1.3511
Average			1.3515

TABLE V (cont)

Refractive Indices of Blood Plasma.

November 1933			
No. of Subject	Refractive index of plasma	Temp. °C	Refractive index corrected to 20°C
1	1.3505	24.0	1.3508
2	1.3504	24.5	1.3507
3	1.3509	26.0	1.3512
4	1.3520	25.0	1.3523
5	1.3507	25.0	1.3510
6	1.3500	24.5	1.3503
7	1.3505	24.5	1.3508
8	1.3507	23.5	1.3509
9	1.3510	24.0	1.3513
10	1.3510	25.0	1.3513
11	1.3520	25.0	1.3523
12	Recovering from operation		
13	1.3505	24.5	1.3508
14	1.3510	24.5	1.3513
Average			1.3512

TABLE V (cont)

Refractive Indices of Blood Plasma.

December 1933			
No. of Subject	Refractive index of plasma	Temp. °C	Refractive index corrected to 20°C
1	1.3518	23.5	1.3520
2	1.3507	22.0	1.3508
3	1.3515	24.0	1.3518
4	1.3517	19.0	1.3517
5	1.3520	18.0	1.3518
6	1.3511	17.0	1.3508
7	1.3522	20.0	1.3522
8	1.3513	24.0	1.3516
9	1.3527	20.0	1.3527
10	1.3515	20.0	1.3515
11	1.3528	18.0	1.3526
12	1.3518	24.0	1.3521
13	1.3508	24.0	1.3511
14	1.3520	23.5	1.3522
Average			1.3517

TABLE V (cont)

Refractive Indices of Blood Plasma

January 1934			
No. of Subject	Refractive index of plasma	Temp. °C	Refractive index corrected to 20°C
1	1.3522	20.0	1.3522
2	1.3519	19.5	1.3519
3	1.3506	22.0	1.3507
4	1.3513	18.5	1.3511
5	Dropped out		
6	1.3489	19.0	1.3488
7	1.3509	21.0	1.3509
8	1.3503	19.0	1.3502
9	1.3527	22.5	1.3528
10	1.3518	21.0	1.3518
11	1.3520	21.0	1.3520
12	1.3511	21.5	1.3512
13	1.3514	22.0	1.3515
14	1.3501	17.0	1.3498
Average			1.3513

TABLE V (cont)

Refractive Indices of Blood Plasma

February 1934			
No. of Subject	Refractive index of plasma	Temp. °C	Refractive index corrected to 20°C
1	1.3506	22.5	1.3507
2	1.3511	22.5	1.3512
3	1.3505	22.0	1.3506
4	1.3514	21.0	1.3514
5	Dropped out		
6	1.3501	21.0	1.3501
7	1.3500	23.0	1.3502
8	1.3513	21.0	1.3513
9	1.3513	24.0	1.3516
10	1.3502	23.0	1.3504
11	1.3500	20.5	1.3500
12	1.3506	24.0	1.3509
13	1.3509	22.5	1.3510
14	1.3508	24.0	1.3511
Average			1.3508

TABLE V (cont)

Refractive Indices of Blood Plasma

March 1934			
No. of Subject	Refractive index of plasma	Temp. °C	Refractive index corrected to 20°C
1	1.3510	23.0	1.3512
2	1.3514	24.5	1.3517
3	1.3511	24.0	1.3514
4	1.3514	22.0	1.3515
5	Dropped out		
6	1.3505	22.5	1.3506
7	1.3513	22.0	1.3514
8	1.3506	24.0	1.3509
9	1.3509	23.0	1.3511
10	1.3503	25.0	1.3506
11	1.3509	24.0	1.3512
12	1.3514	21.0	1.3514
13	1.3501	25.0	1.3504
14	1.3506	24.0	1.3509
Average			1.3511

Temperature and Evaporation Rates

Climatological data were obtained from the University of Arizona Weather Station, Tucson, Arizona, for the months over which this experimental work extended, and a comparison of

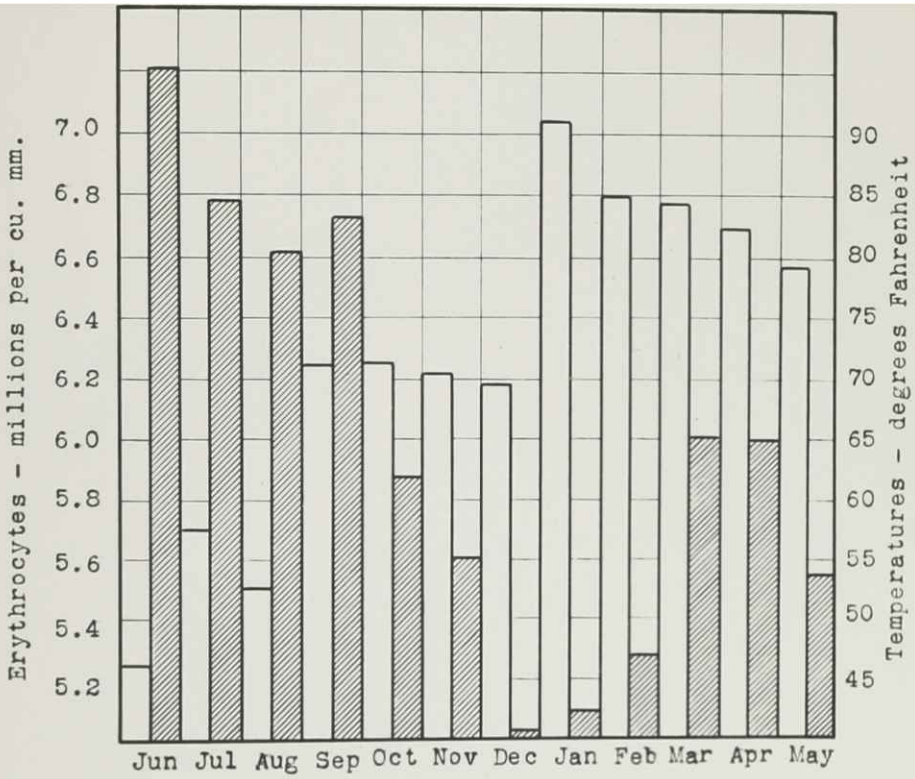

Fig. 3. A comparison of the average monthly temperatures (on the right ordinate - cross-hatched areas) with average monthly erythrocyte counts (on the left ordinate - blank areas) for the year 1932-33.

these data with erythrocyte counts and mean corpuscular hemoglobin content values was made (Table IV).

Average monthly temperatures were compared with average monthly erythrocyte counts (Fig. 3).

A positive correlation between these two factors may be seen. This would indicate that temperature might have something to do with the increase in concentration of erythrocytes.

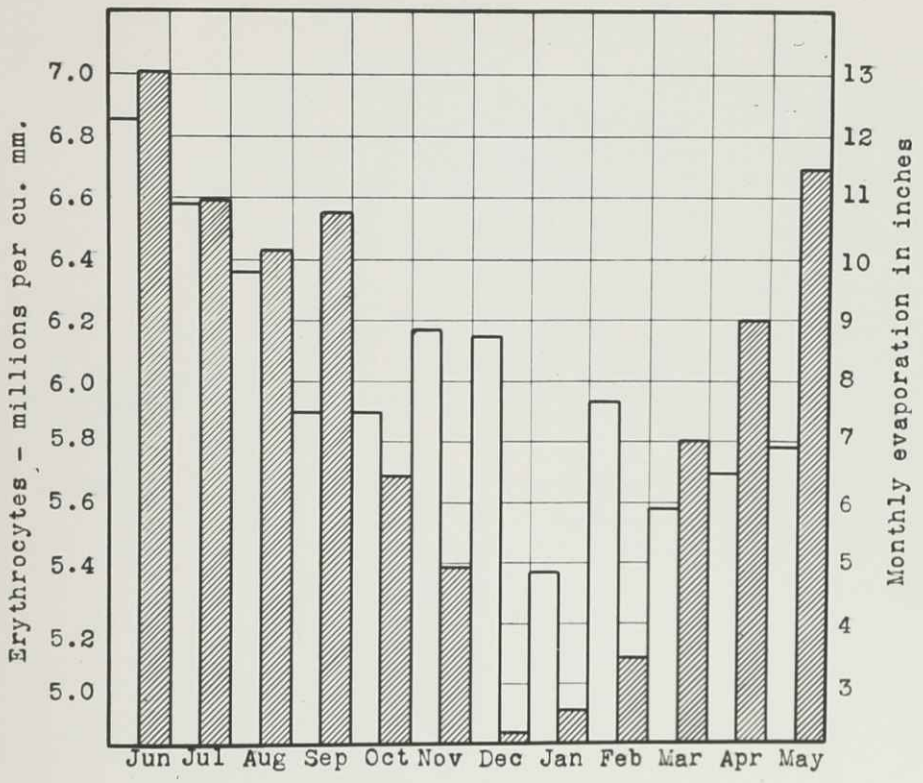

Fig. 4. A comparison of the total monthly evaporation values (on the right ordinate - cross-hatched areas) with average monthly erythrocyte counts (on the left ordinate - blank areas) for the year 1932-33.

A similar positive correlation may be seen between total monthly evaporation values and average monthly erythrocyte counts (Fig. 4). From this comparison it seems that evaporation, too, plays a part in blood concentration.

The amount of precipitation could not be correlated with any of the experimental data, however, the months which experienced the most rainfall were the months of July (2.48 inches), December (2.01 inches), August (1.61 inches), and October (1.62 inches), of 1932. The total amount of rainfall

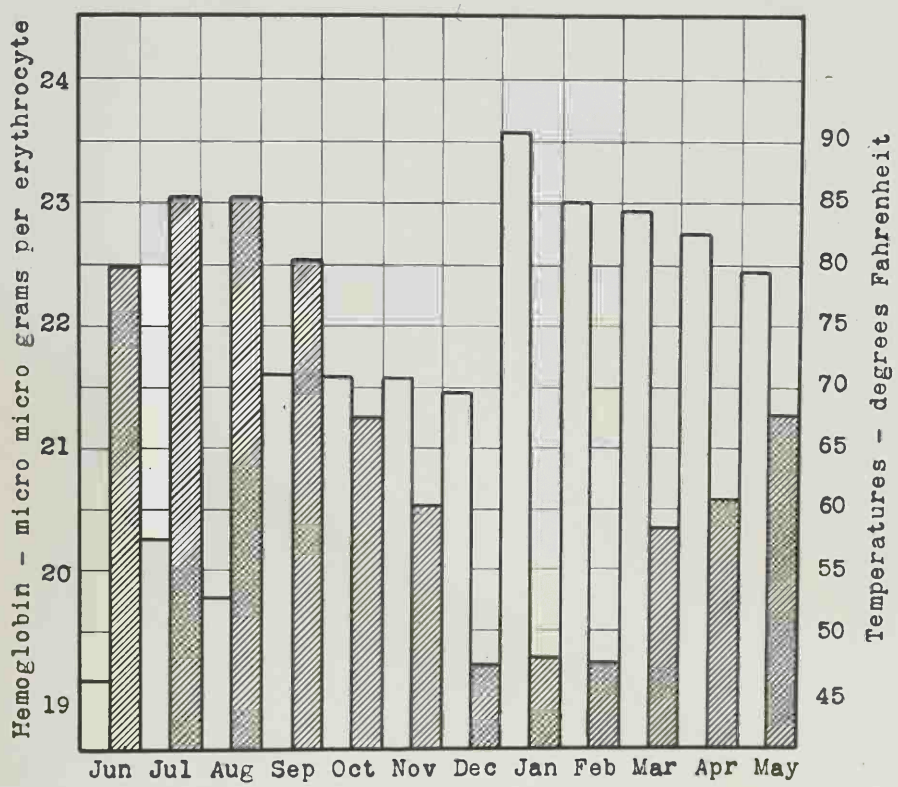

Fig. 5. A comparison of the average monthly temperatures (on the right ordinate- cross-hatched areas) with average monthly mean corpuscular hemoglobin contents (on the left ordinate - blank areas) for the year 1932-33.

for the twelve months period from June 1932 to June 1933 was 9.3 inches.

A comparison of average monthly temperatures with average monthly mean corpuscular hemoglobin content values (Fig. 5), shows a definite inverse correlation between these factors.

Likewise, an inverse correlation exists between average monthly mean corpuscular hemoglobin content values and total monthly evaporation values (Fig. 6).

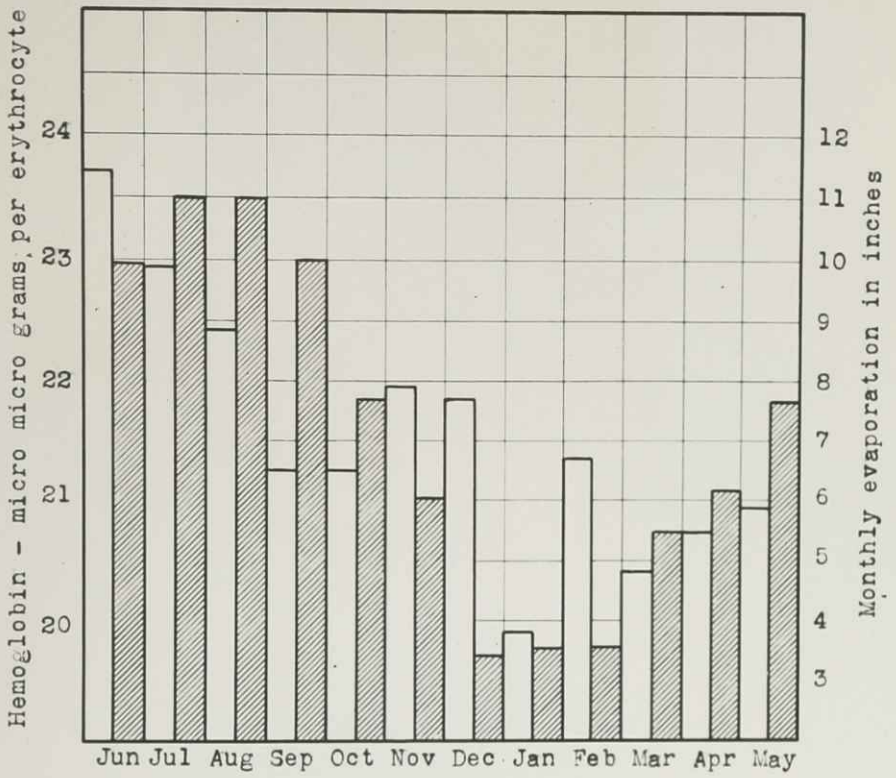

Fig. 6. A comparison of the total monthly evaporation values (on the right ordinate - cross-hatched areas) with average monthly mean corpuscular hemoglobin contents (on the left ordinate - blank areas) for the year 1932-33.

DISCUSSION

A dehydration of blood has been shown to occur in a representative selection of male subjects, living under the conditions which prevail in Tucson, Arizona, with respect to temperature and evaporation. The extent of dehydration was such that an erythrocytosis of 13.7 per cent existed for the months of higher temperature and evaporation rates over the colder seasons.

The effects of dehydration upon the health of the individual and treatment of such dehydrated individuals are of considerable importance. Marriott (1923) pointed out that while dehydration alters the concentration of blood somewhat, the loss of water by this dehydration is far greater in muscle tissue than in blood. He found that approximately 68 per cent of the water withdrawn by desiccation came from muscle tissue although the function of the muscle was not impaired; the alteration of concentration of blood, however, resulted in impairment of circulation and caused secondary functional disturbances to be set up. Not only is circulation impaired by this dehydration, but also metabolic processes and the heat-regulating mechanism are disturbed as Rowntree (1922) brought out. Whenever the amount of water eliminated by the body exceeds the amount taken in, desiccation to some degree must occur. As has been pointed out previously, blood concentra-

tion may be considered as an index to the fluid concentration of the body as a whole, if the fact is kept in mind that the general degree of dehydration throughout the body is probably greater than the concentration increases of the blood would indicate.

Dehydration may be occasioned by either an insufficiency of water intake or an excessive water excretion. In the case of the present work, the dehydration probably resulted from excessive water excretion as caused by the greater evaporation rates and higher temperatures. Marriott (1923) has shown that when the external temperature is equal to or higher than that of normal body temperature (37.5 degrees Centigrade), the only available means for heat dissipation from the body is by means of water evaporation. Below body temperature heat is given off by conduction or radiation.

To compensate for the greater water output as caused by the evaporation, the water intake should be increased. The experiments on the workmen at Hoover Dam, as reported by Zwalenburg (1933) point to the success of this type of treatment of dehydrated individuals. By simply encouraging the workmen to drink more water, and especially a slightly saline water, the number of deaths from heat exhaustion as caused by dehydration was reduced from an extremely high rate to zero. Associated with this report by Zwalenburg is the work of Dragstedt and Ellis (1929) which stressed the importance of the chloride ion in connection with blood concentration and gastric

secretion. All of this indicates that one form of treatment for dehydration as is found in Tucson, Arizona, is the increase in consumption of drinking water with the addition of a little table salt. Also, the advantage of eating foods with a high water content may be seen.

Severe dehydration in cats was followed by increased metabolism, a loss of appetite, concentration of urine, reduced sensory responses, and even coma, as reported by Caldwell (1931). Crisler (1928) noted that dogs deprived of water ate less than normally. Underhill and Kapsinow (1922) found that water deprivation in dogs resulted in an alteration of internal respiration which led eventually to a marked impairment of the vital functions of the cell. It seems very possible that all the metabolic, thermal, respiratory, and other disturbances which occur in dehydrated animals also occur in man when he is subject to desiccation, in proportion to the degree of dehydration.

Where man is active physically and is exposed to the direct rays of sun for relatively long periods of time, special care should be taken in regards to maintenance of water and chloride balance as dehydration under these conditions would be greater. Other causes which tend to reduce the general body fluid content are diarrhea, polyuria, lactation, shock and hemorrhage. Anhydremia and inanition fevers in infants are rather common, according to Harriott (1923); as their water requirement is higher and their water intake

volume depends upon the care of other people, infants are more likely to be desiccated. Careful regulation of the water consumption of new-born babies tends to alleviate the diarrheas resulting from infections to which they are so subject. Special care then should be taken with very young children to see that they receive a sufficient amount of water for their needs.

Still another phase of importance to Tucson, Arizona, as a health center is the problem of possible desiccation in connection with sun baths. Underhill, et al. (1923), in a study of blood concentration changes, as caused by extensive superficial burns, found that the blood concentration was increased in proportion to the extent of the burned skin area. Forcing of fluids in the individual gave very gratifying results as a method of treatment. Blistering caused by sun burn is a very definite burning and a study of individuals' blood concentration before and after a prolonged exposure to sun would be of value. All too often, in a burst of enthusiasm, people expose themselves to the direct rays of the sun for long periods of time without having worked up gradually to this long exposure. Nausea, and a general bodily weakness often result from such indiscretions when the individuals are healthy, and the results upon pulmonary tubercolars are common knowledge.

The effects of dehydration on the refractive indices of blood plasma were very slight as has been demonstrated in

this work. Like hemoglobin values, the refractive indices varied very little in range. Protein concentration should not be appreciably altered during dehydration because of the high degree of impermeability of the capillaries to protein. By virtue of the stabilizing functions of proteins, it would be expected that under the conditions of this work where the dehydration began slowly and gradually increased, the plasma preteins (and therefore the plasma refractive indices) would remain within certain limits a constant facotr. Calculation of the plasma proteins of these experiments from their refractive indices gives as the extreme ranges, 9.1 to 11.3 per cent protein content, and an average content of 10.5 per cent. This is considerably higher than the averages given by Howell (1933) for plasma protein content. The calculation is according to the Reiss method as described by Neuhausen and Rioch (1923). From the corrected refractive index value of the serum or plasma is subtracted the refractive index for distilled water at that same temperature; from this difference is subtracted 0.00277 (which represents the non-protein constituents of plasma such as sodium chloride, buffers, etc.) and this new difference is divided by 0.00172, (the refractive index conversion factor). There are several methods of calculation, but since this compares well with actual chemical analytical methods for determining nitrogen (protein) content, such as the Kjeldahl method, it is most commonly used.

The constancy of normal plasma protein has been further

studied by Barnett, Jones, and Cohn (1932); they found that the daily removal of 25 to 100 cubic centimeters of blood plasma (the erythrocytes were returned to the animal in Locke's solution) occasioned no significant drop in plasma protein content. These results showed a constancy of protein level in agreement with other work cited concerning this factor and demonstrated the adequacy of the mechanism of protein regeneration.

SUMMARY AND CONCLUSIONS

1. These experiments demonstrated a definite dehydration of the blood of normal, adult males, living in a semi-arid region of southwestern United States during the summer months.

2. The erythrocyte counts during the three summer months of June, July and August averaged 13.7 per cent higher than the counts made during the remaining nine months of the twelve months period.

3. Hemoglobin content values did not vary with respect to either temperature or evaporation rates, indicating a constancy of this factor for the conditions of temperature and evaporation as they exist in this region.

4. An inverse correlation was found to exist between temperature and the amount of hemoglobin in each erythrocyte.

5. An inverse correlation was found to exist between evaporation rates and the amount of hemoglobin in each erythrocyte.

6. Refractive indices of blood plasma indicated a relatively narrow range of individual values for six of the winter and spring months.

7. The results suggest the need for greater fluid intake on the part of the twenty subjects during the spring and summer months to compensate for the increased water loss.

LITERATURE CITED

Barcroft, J., 1930. Some effects of emotion on the volume of the spleen. Jour. Physiol., LXVIII, 375-382.

Barnett, C. W., Jones, R. B., and Cohn, R. B., 1932. Maintenance of normal plasma protein concentration in spite of repeated protein loss by bleeding. Jour. Exp. Med., LV, 683-689.

Caldwell, G. T., 1931. Studies in water metabolism of the cat. Physiol. Zoöl., IV, 324-359.

Clough, P. W. 1929. Diseases of the blood. Harper and Brothers.

Crisler, G. 1928, The effect of withdrawal of water on the salivary conditioned reflex induced by morophine. Amer. Jour. of Physiol. LXXXV, 324-331.

Dragstedt, L. R., and Ellis, J. C., 1929. The fatal effects of the total loss of gastric juice. Amer. Jour. Physiol. XC, 331.

Dreyer, G., Bazett, H. C., and Pierce, H. F., 1920. Diurnal variations in the hemoglobin content of the blood. Lancet II, 558-560.

Editorial, 1928, Blood concentration and its treatment. Amer. Med. Assoc., XC, 295-296.

Howell, W. H. and Holt, E. Heparin, 1918. Amer. Jour. Physiol. XLVII, 328-341.

Howell, W. H., 1933. A text-book of physiology. 12th Edition. W. B. Saunders Co.

Hurtado, A., 1932. Blood observations on the Indian natives of the Peruvian Andes. Amer. Jour. Physiol. C, 487-505.

Jordan, H. E., 1931. A text-book of histology. D. Appleton and Co.

Kerr, W. J., Hurwitz, S. H., and Whipple, G. H., 1918. Protein Regeneration. Amer. Jour. Physiol., XLVII, 356-364.

Kolmer, J. A. and Boerner, F. 1931. Aproved laboratory technique. D. Appleton and Company.

Marriott, W. McK., 1923. Anhydremia. Physiol. Rev. II, 275-294.

Neuhausen, B. S. and Rioch, D. M. 1923. The refractometric determination of serum proteins. Jour. Bio. Chem., LV, 353-356.

Newcomer, H. S. 1930. Absorption spectra of acid hematin, oxyhemoglobin, and carbon monoxide hemoglobin. Jour. Bio. Chem., XXXVII, 465-495.

Osgood, E. E. 1926. Normal blood counts. Arch. Int. Med., XXXVII, 685-689.

Osgood, E. E. 1927. Relation between cell count, cell volume, and hemoglobin content of venous blood of normal young women. Arch. Int. Med., XXXIX, 643-655.

Peters, I. and Van Slyke, D. D. 1931. Quantitative clinical chemistry, Vol. I, Williams, and Wilkins.

Price-Jones, C. 1931. The concentration of hemoglobin in normal human blood. Jour. Path. and Bact. XXXIV, 779-787.

Reed, C. I. 1925. Intravascular use of heparin. Amer. Jour. Physiol. LXXIV, 79-82.

Rowntree, L. G. 1922. The water balance of the body. Physiol. Rev., II, 116-169.

Stitt, E. R. 1927. Practical bacteriology, blood work, and animal parisitology. 11th Edition, P. Blakiston's Sons and Co.

Tranter, C. L. and Rowe, A. H., 1915. The refractometric determination of albumin, globulin and non-protein. Jour. Amer. Med. Assoc. LXV, 1433-1435.

Underhill, F. P. and Kapsinow, R. 1922. The influence of water introduction upon blood concentration induced by water deprivation. Jour. Bio. Chem., LIV, 459-464.

Underhill, F. P. et al. 1923. Blood concentration changes in extensive superficial burns and their significance for systematic treatment. Arch. Int. Med., XXXII, 31-49.

Van Slyke, D. D. and Stadie, W. C. 1921. Hemoglobin determinations by oxygen combining power. Jour. Bio. Chem., XLIX, 249-256.

Wintrobe, M. M. and Miller, L. W. 1929. Normal blood determinations in the south. Arch. Int. Med. XLIII, 96-113.

Wintrobe, M. M. and Landsberg, J. W., 1933. Blood of Normal men and women. Bull, Johns Hopkins Hosp., LIII, 118-129.

Zwalenburg, C., 1933. Heat prostration and dehydration. Jour. Amer. Med. Assoc. CI, 1253-1254.

APPENDIX

Table VI

Individual Erythrocyte Counts (average of two counts) and Hemoglobin Determinations for 20 Subjects During the Twelve Months Period from June 1932 to June 1933.

Subject No.	Date	Erythrocytes in millions per cu. mm.	Hemoglobin in gm. per 100 cc. of blood
1	6-32	7.72	13.5
	7-32	6.81	13.7
	9-32	7.05	13.0
	10-32	6.30	13.6
	2-33	5.49	14.5
	3-33	5.40	13.3
	4-33	5.49	13.4
	5-33	5.97	14.1
2	6-32	5.93	13.5
	7-32	6.43	13.3
	9-32	5.63	13.2
	1-33	4.80	13.0
	2-33	5.93	13.2
	3-33	5.58	13.1
	5-33	5.66	13.2
3	6-32	7.88	14.0
	7-32	6.15	13.7
	9-32	6.38	13.6
	11-32	6.06	13.2
	12-32	6.31	12.0
	2-33	5.36	14.1
	3-33	6.23	13.1
	5-33	6.64	13.6
4	6-32	5.97	12.2
	8-32	5.02	12.0
	9-32	4.63	12.0
	2-33	5.02	11.0
	3-33	5.16	11.0
	4-33	5.05	11.3
	5-33	4.98	11.0

Table VI (continued)

Subject No.	Date	Erythrocytes in millions per cu. mm.	Hemoglobin in gm. per 100 cc. of blood
5	7-32	6.58	13.0
	8-32	6.59	12.7
	9-32	6.32	13.3
	11-32	6.30	14.0
	1-33	6.78	14.3
	2-33	6.34	14.2
	3-33	6.11	14.0
	4-33	6.31	13.8
6	7-32	8.31	14.8
	8-32	7.90	14.0
	9-32	5.72	12.0
	11-32	6.31	13.1
	2-33	5.52	undt.
	3-33	5.88	13.4
	4-33	6.12	13.3
	5-33	6.13	13.7
7	7-32	5.14	13.0
	8-32	5.57	12.5
	10-32	5.68	12.0
	12-32	5.35	12.8
	2-33	5.34	12.9
	4-33	5.30	12.7
8	7-32	7.55	14.6
	8-32	6.99	11.8
	9-32	5.59	13.8
	12-32	6.73	14.0
	2-33	5.83	13.9
	3-33	5.60	13.6
	4-33	5.36	13.7
	5-33	5.59	13.3
9	7-32	6.27	13.2
	9-32	5.95	13.0
	12-32	5.83	13.8
	2-33	5.81	13.7
	3-33	5.70	13.6
	4-33	5.72	13.0
	5-33	5.90	14.0

Table VI (continued)

Subject No.	Date	Erythrocytes in millions per cu. mm.	Hemoglobin in gm. per 100 cc. of blood
10	7-32	6.64	13.3
	9-32	5.80	13.1
	2-33	5.93	12.9
	3-33	5.32	13.0
	5-33	5.91	13.4
11	7-32	6.69	13.7
	8.32	6.43	12.3
	10-32	6.06	13.2
	11-32	6.07	13.2
	12-32	6.12	13.6
	2-33	6.08	13.9
	3-33	6.04	13.3
	4-33	5.94	13.4
	5-33	6.24	13.4
12	7-32	6.19	13.0
	8-32	6.53	12.5
	9-32	6.21	12.8
	11-32	6.74	13.8
	2-33	6.53	13.3
	3-33	5.50	12.6
	4-33	5.76	13.0
13	7-32	6.05	13.2
	9-32	5.86	13.0
	11-32	5.56	13.2
	2-33	5.74	13.2
	3-33	5.17	13.0
	5-33	5.37	13.1
14	7.32	6.75	13.8
	8-32	5.85	13.8
	1-33	5.23	12.0
	2-33	5.15	12.1
	3-33	5.54	13.3
	4-33	5.68	13.6
	5-33	6.06	13.6

Table VI (continued)

Subject No.	Date	Erythrocytes in millions per cu. mm.	Hemoglobin in gm. per 100 cc. of blood
15	7-32	6.31	15.2
	10-32	5.84	13.8
	1-33	5.05	12.5
	2-33	5.44	13.2
	3-33	5.39	13.0
	4-33	5.60	14.1
16	7-32	5.66	12.8
	9-32	5.05	12.3
	1-33	5.05	12.5
	2-33	4.80	13.3
	3-33	5.09	13.0
	5-33	5.19	13.2
17	7-32	7.98	13.6
	9-32	6.20	13.0
	12-32	5.83	13.4
	2-33	5.75	13.2
	3-33	5.68	13.1
	4-33	6.17	14.0
18	7-32	7.27	13.1
	10-32	5.61	13.0
	2-33	5.67	12.9
	3-33	5.82	13.1
	5-33	5.83	13.2
19	7-32	6.20	13.2
	10-32	5.96	13.1
	2-33	5.16	12.6
	3-33	5.16	13.0
	4-33	5.49	13.2
	5-33	5.56	13.2
20	7-32	5.80	12.8
	9-32	6.19	13.8
	12-32	6.63	13.8
	2-33	5.72	12.9
	3-33	5.59	12.8
	4-33	5.67	13.0